A SKETCH

OF THE

GEOGRAPHY AND GEOLOGY

OF THE

HIMALAYA MOUNTAINS AND TIBET

BY

COLONEL S. G. BURRARD, R.E., F.R.S.
SUPERINTENDENT, TRIGONOMETRICAL SURVEYS,

AND

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SUPERINTENDENT, GEOLOGICAL SURVEY OF INDIA

Published by order of the Government of India

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PREFACE.

IN 1807 a Survey detachment was deputed by the Surveyor General of Bengal to explore the source of the Ganges: this was the first expedition to the Himalaya undertaken for purely geographical purposes. A hundred years have now elapsed, during which geographical and geological information has been steadily accumulating and we have at length reached a stage where there is a danger of losing our way in a maze of unclassified detail: it is therefore desirable to review our present position, to co-ordinate our varied observations and to see how far we have progressed and what directions appear favourable for future lines of advance.

The present paper originated in a proposal submitted by the Survey of India to the Board of Scientific Advice at the meeting of the latter in May 1906. The proposal was as follows:—"The number of travellers in the Himalaya and Tibet is increasing, "and a wider interest is being evinced by the public in the geography of these regions. "It is therefore proposed to compile a paper summarising the geographical position at "the present time."

Subject to the modification that the scope of the paper should be geological as well as geographical, this proposal has received the sanction of the Government of India and the work has been entrusted to us to carry out. On the understanding that the paper is intended primarily for the use of the public, we have endeavoured to avoid purely technical details and to present our results in a popular manner.

Our subject has fallen naturally into four parts, as follows:—

PART I.—The high peaks of Asia.
PART II.—The principal mountain ranges of Asia.
PART III.—The rivers of the Himalaya and Tibet.
PART IV.—The geology of the Himalaya.

Though the four parts are essentially interdependent, each has been made as far as possible complete in itself and has been published separately. The first three parts are mainly geographical, the fourth part is wholly geological: the parts are subdivided into sections, and against each section in the table of contents is given the name of the author responsible for it.

The endeavour to render each part complete must be our apology for having repeated ourselves in more places than one: the relations, for instance, of a range to a river have been discussed in Part II, when the range was being described, and have been mentioned again in Part III under the account of the river.

As the mountains of Asia become more accurately surveyed, errors will doubtless be found in what we have written and drawn: it is not possible yet to arrive at correct generalisations and we have to be content with first approximations to truth.

Maps, too large for insertion in such a volume as this, are required for a study of the Himalayan mountains: the titles of maps illustrating the text are given in footnotes and are procurable from the Map Issue Office of the Survey of India in Calcutta. Constable's hand atlas of India will be found useful.

We are much indebted to Babus Shiv Nath Saha and Ishan Chandra Dev, B.A., for the care with which they have checked our figures and names, and to Mr. J. H. Nichol for the trouble he has taken to ensure the correctness of the charts. Mr. Eccles and Major Lenox Conyngham have been kind enough to examine all proofs, and to give us the benefit of their advice and suggestions. Mr. Eccles has also supervised the drawing and printing of the charts, and we have profited greatly by the interest he has shown in them.

We have also to express our indebtedness to Messrs. T. D. LaTouche and C. S. Middlemiss for their kind assistance in examining proofs of Part IV.

S. G. Burrard.

H, H. Hayden.

LIST OF CONTENTS.

LIST OF ILLUSTRATIONS.

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PART I

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S. G. BURRARD.

H. H. HAYDEN.

March 1907.

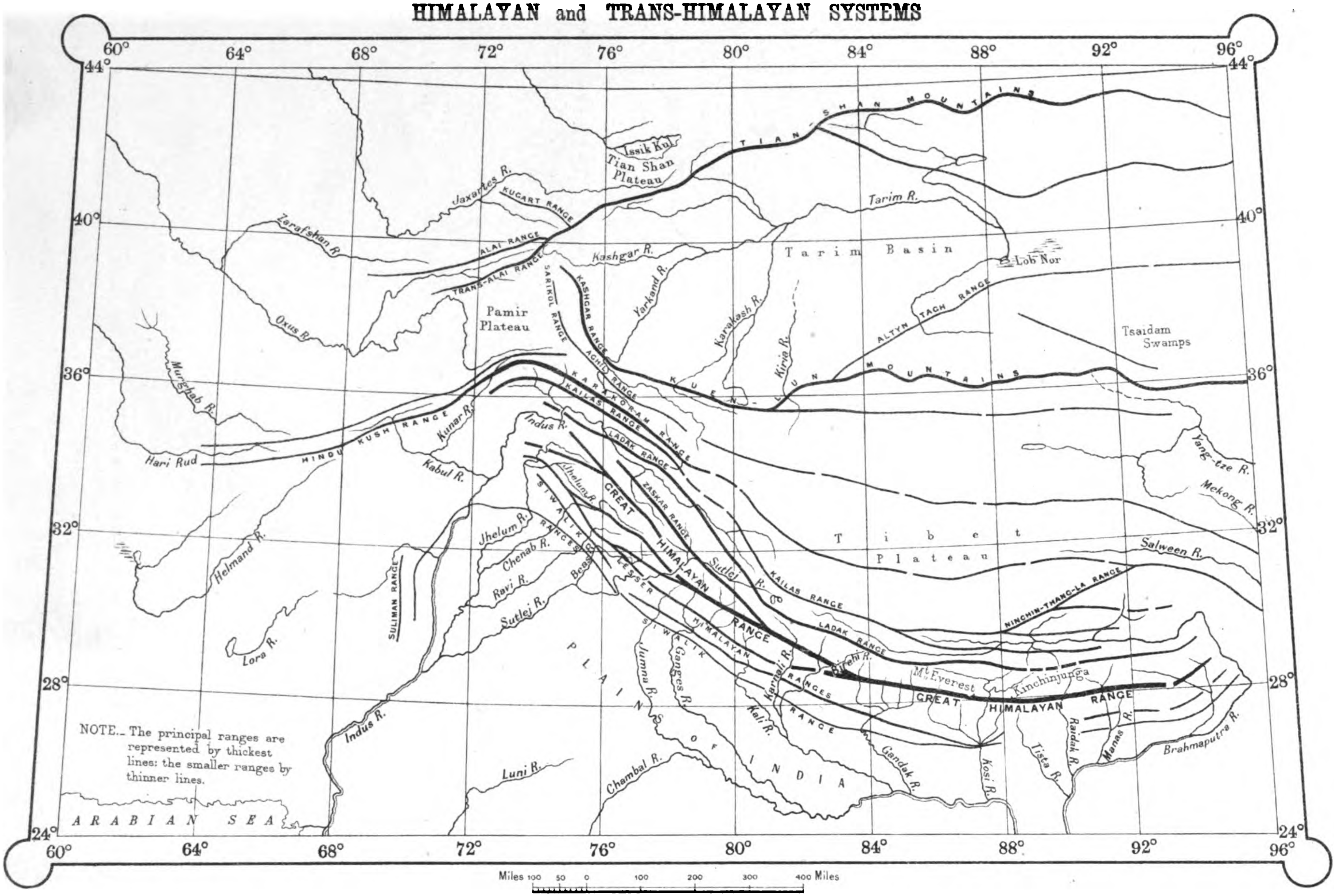
CONTENTS OF PART I

CHARTS AND PLATES.

INDEX.

See PART III.

CHART
to illustrate the TRENDS of the principal Mountain ranges of the HIMALAYAN and TRANS-HIMALAYAN SYSTEMS



THE HIGH PEAKS OF ASIA.

1

THE PRINCIPAL PEAKS AND THEIR ALTITUDES.

IN the earlier stages of geographical investigation the most important features of a mountain mass are the high peaks. They may be, it is true, but slight prominences of lofty ranges and they may possess perhaps no geological significance: but they are conspicuous and definite points; they are the only mountain features that can be observed with accuracy from a distance; and the determination of their positions and heights is the first step of the ladder of geographical knowledge. When this step has been taken, further progress becomes possible; the peaks can be made the basis of subsequent surveys; the courses of rivers and the positions of lakes can be laid down with regard to them; the trends and forms and magnitudes of the ranges can be inferred from the distribution of the peaks.

In the following tables I to V all the peaks of Asia that have been found to exceed 24000 feet in height are catalogued in order of magnitude: their geographical positions are shown in the five corresponding charts, numbered also I to V.*

TABLE I.—Peaks of the first magnitude exceeding 28000 feet in height.

Reference number of Peak.	Name or symbol.	Height.	Number of stations from which the height was observed.	Latitude.	Longitude.†	Mountain range.
		feet		° ′ ″	° ′ ″	
1	Mount Everest ..	29002	6	27 59 16	86 55 40	Nepal Himalaya
2	K^2	28250	9	35 52 55	76 30 51	Karakoram
3	Kinchinjunga I ..	28146	9	27 42 9	88 9 0	Nepal Himalaya

* Those peaks only have been included the heights of which are known with fair accuracy. Peaks the heights of which have been conjectured by explorers to exceed 24000 feet have been omitted.

† The values of longitude are based on the determination of the difference between Greenwich and Madras made in 1894-96, and are not those hitherto accepted by the Survey of India.

Table II.—Peaks of the second magnitude between 27000 and 28000 feet in height.

Reference number of Peak.	Name or symbol.	Height.	Number of stations from which the height was observed.	Latitude.	Longitude.*	Mountain range.
		feet		° ′ ″	° ′ ″	
4	Kinchinjunga II ..	27803	7	27 41 30	88 9 24	Nepal Himalaya
5	Makalu	27790	6	27 53 23	87 5 29	Nepal Himalaya

Table III.—Peaks of the third magnitude between 26000 and 27000 feet in height.

Reference number of Peak.	Name or symbol.	Height.	Number of stations from which the height was observed.	Latitude.	Longitude.*	Mountain range.
		feet		° ′ ″	° ′ ″	
6	T^{45}	26867	3	28 5 32	86 39 51	Nepal Himalaya
7	Dhaulagiri ..	26795	7	28 41 48	83 29 42	Nepal Himalaya
8	XXX	26658	3	28 33 0	84 33 43	Nepal Himalaya
9	Nanga Parbat I ..	26620	8	35 14 21	74 35 24	Punjab Himalaya
10	XXXIX ..	26492	8	28 35 44	83 49 19	Nepal Himalaya
11	K^{5} or Gasherbrum I ..	26470	4	35 43 30	76 41 48	Karakoram
12	K^{4} or Gasherbrum II ..	26360	2	35 45 31	76 39 15	Karakoram
13	Gosainthan ..	26291	2	28 21 7	85 46 55	Nepal Himalaya
14	K^{3a} or Gasherbrum III	26090	2	35 45 36	76 38 33	Karakoram
15	XXXIV	26041	5	28 32 5	84 7 26	Nepal Himalaya
16	K^{3} or Gasherbrum IV	26000	2	35 45 38	76 37 2	Karakoram

* The values of longitude are based on the determination of the difference between Greenwich and Madras made in 1894-96, and are not those hitherto accepted by the Survey of India.

Table IV.—Peaks of the fourth magnitude between 25000 and 26000 feet in height.

Reference number of Peak.	Name or symbol.	Height.	Number of stations from which the height was observed.	Latitude.	Longitude.*	Mountain range.
		feet		° ′ ″	° ′ ″	
17	T^{57} ..	25990	1	28 5 52	86 44 41	Nepal Himalaya
18	B^{782}	25909	1	28 6 24	86 41 15	Nepal Himalaya
19	XXVIII	25801	4	28 26 3	84 38 34	Nepal Himalaya
20	Kambachen ..	25782	4	27 42 59	88 6 47	Nepal Himalaya
21	XXIX	25705	2	28 30 12	84 34 7	Nepal Himalaya
22	Masherbrum East ..	25660	7	35 38 36	76 18 31	Karakoram
23	Nanda Devi ..	25645	9	30 22 32	79 58 22	Kumaun Himalaya
24	Masherbrum West ..	25610	3	35 38 29	76 18 23	Karakoram
25	Nanga Parbat II ..	25572	2	35 15 22	74 35 14	Punjab Himalaya
26	LIX	25563	3	30 22 34	79 58 18	Kumaun Himalaya
27	Rakaposhi ..	25550	3	36 8 39	74 29 22	Kailas
28	Kunjut No. 1 ..	25460	2	36 12 21	75 25 3	Karakoram
29	Kamet	25447	6	30 55 13	79 35 37	Zaskar
30	T^{42}	25433	1	28 6 36	86 37 18	Nepal Himalaya
31	XLIII	25429	5	28 45 45	83 23 25	Nepal Himalaya
32	Tirich Mir I ..	25426	2	36 15 17	71 50 25	Hindu Kush
33	N^{53} ..	25413	2	27 55 47	87 6 44	Nepal Himalaya
34	K^{10}	25400	4	35 24 1	76 50 55	Karakoram
35	Hunza-Kunji I ..	25370	2	36 30 30	74 31 21	Karakoram
36	Gurla Mandhata ..	25355	2	30 26 18	81 17 57	Ladak
37	Jano	25294	9	27 40 56	88 2 47	Nepal Himalaya
38	K^{11}	25280	4	35 24 24	76 50 50	Karakoram
39	XLIV	25271	3	28 45 13	83 22 46	Nepal Himalaya
40	B^{783}	25202	1	28 5 50	86 42 31	Nepal Himalaya
41	Shyok Nubra Watershed No. 5	25170	1	34 52 2	77 45 13	Karakoram
42	Kungur I	25146	2	38 39 23	75 13 5	Kashgar
43	B^{504}	25134	2	28 21 17	85 48 45	Nepal Himalaya
44	Hunza-Kunji II ..	25118	1	36 31 59	74 30 4	Karakoram
45	Karakoram No. 8 ..	25110	4	35 36 44	76 34 23	Karakoram
46	XLVI	25064	7	28 44 7	83 18 53	Nepal Himalaya
47	Hunza-Kunji III ..	25050	2	36 26 32	74 40 53	Karakoram
48	Kungur II ..	25046	2	38 37 4	75 19 39	Kashgar

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TABLE V.—Peaks of the fifth magnitude between 24000 and 25000 feet in height.

Reference number of Peak.	Name or symbol.	Height.	Number of stations from which the height was observed.	Latitude.	Longitude.*	Mountain range.
		feet		° ′ ″	° ′ ″	
49	XLV	24885	5	28 44 3	83 21 51	Nepal Himalaya
50	XXXVI	24750	4	28 35 3	83 59 31	Nepal Himalaya
51	Kulha Kangri I ..	24740	4	28 2 49	90 27 30	Assam Himalaya
52	Karakoram No. 5 ..	24690	1	35 8 54	77 34 41	Karakoram
53	XXXV	24688	4	28 32 11	84 5 5	Nepal Himalaya
54	Kulha Kangri II ..	24660	1	28 4 11	90 26 53	Assam Himalaya
55	Shyok Nubra Watershed No. 3	24650	2	34 48 14	77 48 22	Karakoram
56	Tirich Mir II ..	24611	2	36 25 52	71 50 11	Hindu Kush
57	Shyok Nubra Watershed No. 4	24590	2	34 50 31	77 47 16	Karakoram
58	Kunjut No. 2 ..	24580	1	36 12 45	75 15 12	Karakoram
59†	R^{264}	24496	2	28 13 52	90 37 10	Assam Himalaya
60	Indus-Nagar Watershed No. 2	24470	2	36 0 14	74 52 34	Kailas
61	LVII	24391	3	30 21 58	79 59 54	Kumaun Himalaya
62	Muztagh Ata ..	24388	2	38 16 43	75 7 6	Kashgar
63	K^{13}	24370	4	35 17 46	77 1 23	Karakoram
64	A satellite of Kinchinjunga	24344	5	27 52 40	88 8 35	Nepal Himalaya
65	Tirich Mir III ..	24343	2	36 23 31	71 53 43	Hindu Kush
66	Kuen Lun No. 1 ..	24306	2	35 47 48	81 8 42	Kuen Lun
67	XXVI	24299	1	28 23 30	85 7 45	Nepal Himalaya
68	Haramosh	24270	3	35 50 29	74 53 52	Kailas
69	Sad Ishtragh ..	24171	4	36 32 54	72 6 54	Hindu Kush
70	XLVIII	24150	7	28 43 54	83 12 43	Nepal Himalaya
71	Kunjut No. 3 ..	24090	2	36 19 3	75 2 11	Karakoram
72	A satellite of Kinchinjunga	24089	5	27 47 15	88 11 55	Nepal Himalaya
73	Hunza-Kunji IV ..	24044	1	36 24 10	74 41 43	Karakoram
74	Chamlang ..	24012	2	27 46 31	86 58 56	Nepal Himalaya
75	Kabru	24002	2	27 36 30	88 6 50	Nepal Himalaya

Explanation of the tables.

The names adopted for the peaks are those most commonly employed by geographers. In a later section of this paper is given a list of alternative names and symbols, which have been applied to the high peaks at different times: in the same place are discussed a few geographical names that are giving rise to controversy and confusion.

* The values of longitude are based on the determination of the difference between Greenwich and Madras made in 1894-96, and are not those hitherto accepted by the Survey of India.

† The position of this peak is doubtful.

A column has been included in tables I to V showing the number of stations from which the height of each peak has been observed. For the attainment of accuracy it is more profitable to observe a peak from different places and distances than to multiply observations from any one station; and the number of observing stations is an indication of the trustworthiness of the resulting value of altitude. The accuracy of the adopted values of height is discussed hereafter, and numerical estimates of the magnitudes of the errors that may exist are formed.

The latitude and longitude of each peak have been given in the tables, so that its position on the charts may be ascertained. In the drainage charts XXIV to XXXIV (appended to Part III) these positions have been marked exactly: but in charts I to V the scale is so small that in crowded clusters there has not been always room to mark the precise position of each peak; a few of the symbols overlapped, and had to be slightly displaced in order to make room for others.

It will be noticed that every peak of chart I is shown by a larger and larger circle on each of the successive charts II to V; the reason for this increase is that at the level of 28000 feet Kinchinjunga, for example, is in nature hardly more than a point, but at 27000 feet the contour round Kinchinjunga encloses an *area*; and at 24000 feet a horizontal section taken through the Kinchinjunga pyramid would show that a *considerable* area of the earth's surface had attained that elevation.*

In the last column of each table is given the range on which each peak is situated, the great Himalaya range being divided into four sections:—

(i) the Punjab Himalaya from the Indus to the Sutlej;

(ii) the Kumaun Himalaya from the Sutlej to the Kali;

(iii) the Nepal Himalaya from the Kali to the Tista;

(iv) the Assam Himalaya from the Tista to the Brahmaputra.†

The relative positions of the ranges mentioned in the tables are shown on the range chart which serves as a frontispiece.

Well-known peaks below 24000 feet.

In table VI are given the details of a few well-known peaks, which are *less* than 24000 feet in height. This table unlike the preceding does not contain the names of all peaks above a certain height, and is not therefore a continuation of table V. Peaks have been omitted which exceed in height many of those of table VI; to give complete lists of all known peaks would be to convert this paper into a numerical catalogue.

A great many of the peaks of table VI are visible from Mussooree and Landour, and their outlines are shown in chart VIII.‡ The panorama of chart VIII is continuous from left to right: it has been drawn in three sections that it might be made to fit the size of this paper. The reference letters A and B have been added to indicate continuity.

* On chart V peaks of the fifth magnitude have been drawn as points, those of the fourth magnitude have been given a diameter of 6 miles, those of the third a diameter of 12 miles, those of the second a diameter of 18 miles, and those of the first a diameter of 24 miles.

† The Punjab and Kumaun Himalaya have been for the most part surveyed; the peaks of the Nepal Himalaya have been observed from long distances and the rivers and roads explored: the Assam Himalaya form still a *terra incognita*, although many of the peaks have been well observed from the south.

‡ This chart was copied from the panorama drawn by Col. St. G. C. Gore, C.S.I., R.E., in 1887.

TABLE VI.—Some well-known peaks the heights of which are less than 24000 feet.

Reference number of Peak.	Name in common use.	Height.	Number of stations from which the height was observed.	Latitude.	Longitude.*	Mountain range.
		feet		° ′ ″	° ′ ″	
76	Api	23399	3	30 0 22	80 55 57	Nepal Himalaya
77	Badrinath ..	23190	5	30 44 16	79 16 52	Kumaun Himalaya
78	Bandarpunch ..	20720	5	31 0 12	78 33 17	Kumaun Himalaya
79	Chumalhari ..	23930	2	27 49 39	89 16 15	Assam Himalaya
80	Chumunko ..	17310	4	27 27 31	88 47 12	Nepal Himalaya
81	Dayabhang ..	23750	2	28 15 22	85 31 9	Nepal Himalaya
82	Deotibba ..	20410	5	32 12 51	77 23 54	Punjab Himalaya
83	Dubunni ..	20154	1	35 57 23	74 38 5	Kailas
84	Dunagiri ..	23184	4	30 30 57	79 52 4	Kumaun Himalaya
85	Gangotri † ..	21700	3	30 52 58	78 52 14	Kumaun Himalaya
86	Gardhar ..	21140	1	32 55 7	76 42 48	Punjab Himalaya
87	Gaurisankar ‡ ..	23440	6	27 57 52	86 20 16	Nepal Himalaya
88	Jaonli §	21760	1	30 51 17	78 51 25	Kumaun Himalaya
89	Jibjibia East ¶ ..	21839	2	28 7 41	85 52 16	Nepal Himalaya
90	Jibjibia West ¶ ..	22876	2	28 10 25	85 46 51	Nepal Himalaya
91	Kailas	22028	2	31 4 2	81 18 50	Kailas
92	Kaufmann ..	23000	..	39 18 20	72 50 3	Trans Alai
93	Kedarnath ..	22770	6	30 47 53	79 4 7	Kumaun Himalaya
94	Kharchakund ..	21695	1	30 46 46	79 7 47	Kumaun Himalaya
95	Leo Pargial N. ¶ ..	22210	2	31 54 8	78 44 39	Zaskar
96	Leo Pargial S. ¶ ..	22170	2	31 53 5	78 44 5	Zaskar
97	Lunkho	22641	2	36 46 36	72 26 16	Hindu Kush
98	Mer or Kana ‖ ..	23250	2	34 0 48	76 3 22	Punjab Himalaya
99	Nampa	22162	4	30 0 37	81 0 3	Nepal Himalaya
100	Nandakna ..	20700	2	30 20 56	79 43 9	Kumaun Himalaya
101	Nandakot ..	22510	3	30 16 51	80 4 11	Kumaun Himalaya
102	Narsing	19130	4	27 30 40	88 17 2	Nepal Himalaya
103	Nilakanta ..	21640	3	30 43 52	79 24 28	Kumaun Himalaya
104	Panch Chulhi ..	22650	3	30 12 51	80 25 41	Kumaun Himalaya
105	Pandim	22010	8	27 34 38	88 13 10	Nepal Himalaya
106	Pauhunri ..	23180	2	27 56 56	88 50 39	Nepal Himalaya
107	Sargaroin ..	20370	2	31 6 8	78 30 4	Kumaun Himalaya
108	Ser or Nana ** ..	23410	6	33 58 56	76 1 31	Punjab Himalaya
109	Simvo	22360	2	27 40 44	88 14 38	Nepal Himalaya
110	Srikanta	20120	4	30 57 25	78 48 22	Kumaun Himalaya
111	Tengri Khan ..	23600	..	42 24 10	80 16 43	Tian Shan
112	Tharlasagar ..	22610	2	30 51 41	78 59 45	Kumaun Himalaya
113	Trisul East ..	22320	4	30 16 14	79 52 24	Kumaun Himalaya
114	Trisul West ..	23360	7	30 18 43	79 46 40	Kumaun Himalaya

*The values of longitude are based on the determination of the difference between Greenwich and Madras made in 1894-96, and are not those hitherto accepted by the Survey of India.

† The twin of Jaonli.
‡ Double-peaked.
§ The twin of Gangotri.
¶ Twins.
‖ The twin of Ser.
** The twin of Mer.

2

NOTES ON CERTAIN OF THE GREAT PEAKS.

Mount Everest.

The elevation of Mount Everest was first observed in 1849, but its height was not computed till 1852. Though half a century has elapsed since its discovery and the mountains of Asia have been continually explored in the interval, no second peak of 29000 feet has been found. There is but little probability now of a higher peak than Mount Everest being discovered and even the prospect of finding new peaks of 27000 or 26000 feet is becoming remote.

Some geographers have held that peaks higher than Mount Everest were standing behind it to the north, but their opinion was not founded on trustworthy observations, and when Major Ryder traversed Tibet along the Brahmaputra in 1904 he passed 80 miles north of Mount Everest and found no peak approaching it in height.

Three panoramas showing the outline of Mount Everest are included in chart VI.*

Owing to the objections of the Nepalese Government Mount Everest cannot be approached by surveyors from the side of India within 80 miles, and the trigonometrical observations that have been made of the Everest-Makalu group of peaks have been carried out under great disadvantages. The following description of Mount Everest is taken from a report by Colonel Tanner:†

"The outline of Everest is rather tame than otherwise; it is fairly sharp and has a long snowy "slope on its north-east flank, the south-east being precipitous. Peaks of 22000 feet and thereabouts "encircle its southern base, and below them are seen many outlines of dark mountain masses which "are without snow.

"From due south, near the Kosi river in the Bhagalpur district, Everest is by no means a marked "feature in the landscape; its southern face has but 190 feet of snow, below which the mountain "falls for 4000 to 5000 feet in a series of crags of very dark-coloured rock, only here and there dashed "and streaked with snow, below which are snow fields and broken masses of rock intermingled "with snow and névé. When the atmosphere is not very transparent the sharp tip is seen as a "mere floating white speck, the rock below it being almost exactly of the colour of the sky and there-"fore invisible.

"The southern face of Everest from a near point of view is doubtless wild, and its cliffs must "be very lofty, but the great distance from which it is viewed renders this aspect of the mountain "uninteresting. In fact, from the south, Everest has all the appearance of a very moderate hill, not "in the least imposing and hardly picturesque. It is interesting only because by trigonometrical "operations its summit has been found to rise up further from the general level of the earth's "surface than that of any other point."

* The panoramas from Mahadeo Pokra and Kaulia were drawn by Captain H. Wood, R.E., in 1903: those from Darjeeling and Sandakphu by Captain Harman, R.E., in 1882. Major Ryder's description of Mount Everest as seen from Tibet will be found in the *Geographical Journal*, Vol. XXVI. "It stands alone," he wrote, "in magnificent "solitude." There is no doubt, whatever, that the peak observed by Ryder from Tibet was the same peak as had been fixed by the G. T. Survey from Bengal.

† *General Report, Survey of India*, 1883-84.

PEAK K^2.

The great altitude of peak K^2 was first discovered in 1858 by trigonometrical observations. "It was across the plains of Deosai," wrote Colonel Montgomerie, "from "Haramukh that I took the first observation to peak K^2 at a distance of 137 miles."

K^2 is described by Colonel Godwin-Austen as follows: "K^2 is a conical mass with "sides too steep to allow the snow to rest on them long: it lies therefore only in large "patches and stripes on the fissured surface."

Sir Martin Conway writes that K^2 has a double summit, which he has seen on several occasions. Colonel Godwin-Austen, however, believes it to be single-peaked.*

KINCHINJUNGA.

K^2 has always been supposed to be the second highest mountain on the earth, but its height does not differ much from that of Kinchinjunga, and we cannot yet state with certainty which is the higher of the two.†

The following extract is from Colonel Tanner's report for 1883-84:—

"Kinchinjunga is a better known mountain than any in the Himalaya, and it is perhaps, "with one exception, the grandest in the whole range. It is regarded by the permanent residents "of Darjeeling with admiration that never palls, and although it is constantly, in clear weather, "a prominent object in their front, the beholder is never wearied of studying the great snow slopes "and ice fields which cover its sides.

"The aspect of the mountain has many phases which constantly alter its appearance from day "to day. It is seen to best advantage when its base is veiled in a delicate curtain of clouds, so that "the imagination is allowed to magnify the part which is hidden from view.

"From Darjeeling and from Sandakphu Kabru‡ appears as a straight-topped and "uninteresting ridge of snow, standing slightly away from the central peaks of Kinchinjunga, but at "a distance of 100 miles from points in the Purnea district of Bengal a telescope reveals the fact that "the face of Kabru presented towards Darjeeling is only one side of a huge snow-clad tableland "(24000 feet), quite smooth at the top with a very slight slope down to the westward. Kabru is "connected with the second highest peak of Kinchinjunga (27803 feet) by a ridge, the very lowest "depression of which has an altitude of 22100 feet."

In 1883 Mr. W. W. Graham claimed to have climbed Kabru, but his claim has been disputed by many authorities, though recognised by others. Colonel Tanner thought that Graham had mistaken a lower peak for Kabru.

Although the snow-line in Sikkim is lower than in the Western Himalaya and Karakoram, there are more naked spots on the slopes of Kinchinjunga than at similar altitudes on K^2 and Nanga Parbat.

The outline of Kinchinjunga as seen from Darjeeling is shown in chart VI.

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* *Geographical Journal*, Vol. III, pages 431 and 527.

† *Survey of India, Professional Paper No.* 9, 1905. *Annual Report of the Board of Scientific Advice for India*. 1905-06.

‡ *Vide* table V.

Makalu.

A rock basin filled with glacier-ice is situated near the summit of Makalu and gives a striking appearance to the peak.

In 1853 before trigonometrical observations had been taken Captain Sherwill wrote of Makalu :—

" One mountain in the Nepal range is a most remarkable object, both for its curious shape and " for its immense height : its name none of my party knew, nor have I yet succeeded in obtaining the " name. The peak is a hollow crater-like mountain probably 27000 feet in height with a long table- " mountain attached to it, both covered with glaciers." *

In 1884 Colonel Tanner wrote :—

" With the exception of the Kinchinjunga peak, Makalu is the finest yet fixed in the eastern " Himalaya. It stands apart from the Everest group and exposes a great mass of snow towards the " Sandakphu ridge. From the south, in the plains of Bhagalpur and Purnea, it is the most striking " object in the panorama of snow. It has a remarkable cup or hollow, which extends for about one- " third down its slope, by which it may be recognised. When examined with a high-power telescope " great masses of glacier-ice may be seen finding their way over the edge of the cup. This ice has " been collected round the sides of the amphitheatre-like hollow. The upper half of the mountain is " composed of a very light coloured rock, but the southern spur is dark like the cliffs, which are seen " on the southern face of Everest. The white colour of the rock lends it a softness, which is absent " in the appearance of its higher neighbour. The southern and eastern faces are fully snow-clad, but " on the west are much bare rock and extensive streaks and patches which are too steep to retain " snow on their slopes. No northern spur of this mountain has been seen, but I have traced one " of about 19000 feet elevation towards the east, until it dips into the Arun valley. To the south two " picturesque branches fully clad with snow are thrown off, but I cannot say that I have detected " any saddle or ridge connecting Makalu with Everest."

Makalu is remarkable for its sharp-edged buttresses, one of which is a magnificent specimen of the spiral type. These spiral buttresses conveying the idea of torsion are to be seen in all parts of the Himalaya: Rakaposhi in Hunza has one, Simvo (22360 feet) in Sikkim has one, and to residents of Mussooree the curvature of the eastern buttress of Banog (7433 feet), a small peak in the vicinity, is a permanent object of beauty.

Hermann de Schlagintweit, when observing Makalu from Phallut in 1855, mistook it for Mount Everest, † and the same mistake has been made by other travellers. Sandakphu, situated 38 miles from Darjeeling and on the Singalila ridge, commands a fine view of Makalu: from there the peak is 78 miles distant and is a more striking feature than Mount Everest, which stands 12 miles in rear.

The outlines of Makalu and Everest as seen from Sandakphu are shown in chart VI.

Peak T^{45}.

T^{45} is a high peak of the Nepal Himalaya seventeen miles north-west of Mount Everest. It appears to have been missed by the observers of the Great Trigonometrical Survey in 1850, but was observed by Tanner in 1884 from three different stations. Tanner recorded that it had a rounded top.

* *Journal, Asiatic Society of Bengal*, Vol. XXII, 1853.

† *Vide Nature*, No. 1828, Vol. 71 ; Nov. 10, 1904 ; page 3.

Nanga Parbat.

Nanga Parbat is the most isolated and perhaps the most imposing of all the peaks of Asia. With the exception of subordinate pinnacles rising from its own buttresses, no peak within 60 miles of Nanga Parbat attains an altitude of more than 17000 feet. Throughout a circle of 120 miles diameter Nanga Parbat surpasses all other summits by more than 9000 feet. Its upper 5000 feet are precipitous.

"Perhaps in describing mountains," wrote John Ruskin in *Modern Painters*, "with any effort to give some idea of their sublime forms, no expression comes oftener "to the lips than the word 'peak,' and yet it is curious, how rarely even among the "grandest ranges an instance can be found of a mountain ascertainably peaked in the "true sense of the word,—pointed at the top and sloping steeply on all sides."

A traveller in the Himalaya, who has studied the writings of Ruskin, must constantly be impressed with the accuracy of his observations. How often do we see a high peak towering above us, only to find on ascending that it is but an obtuse angle in the slope of a buttress? How often is a needle discovered to be but the end of a sharp-edged ridge? Many of the peaks of tables I to VI, though they may form good definite points for surveyors, fail to satisfy Ruskin's definition.

But no one can question the claims of Nanga Parbat: its form and its solitude render it a "peak," however we define the word.

"Nanga Parbat's summit," wrote Colonel Tanner, "is 26620 feet above the sea, and its base "stands on the left side of the Indus valley, which at that point is but 3500 feet: it therefore exposes "23120 feet of its side to an observer, who, standing as near as he may dare to the edge of perhaps the "most lofty cliff in the world with the Indus valley 12000 feet below him, may regard at the distance of "less than 40 miles the unparalleled view presented by the vast snow fields, glaciers, and crags of this "King of Mountains. It is a scene that is not grasped or taken in at once, but after a while the "stupendous grandeur of the view is appreciated. It is quite overwhelming in its magnitude; it is "in fact one of the grandest spectacles that nature offers to the gaze of man."

Until the height of Nanga Parbat had been determined by the Great Trigonometrical Survey, it was given on maps as 19000 feet. An error amounting to 7600 feet in defect in the case of a solitary impressive peak shows how worthless are eye-estimations of height.*

Masherbrum or K^1.

The Masherbrum peaks are two well-defined points connected by a saddle: they are 1000 feet apart and differ by 50 feet in altitude.

Rakaposhi.

Of Rakaposhi Colonel Tanner wrote as follows: "The mighty Rakaposhi or devil's "tail of Gilgit, rising from ground which is 7000 or 8000 feet above the "sea, may be viewed from a distance of less than 40 miles by any one bold enough to

* *Annual Report of the Board of Scientific Advice for India,* 1904-05.

"make the journey over the dreadful Saichar pass to Chaprot and thence up to the "grassy downs above that place, and the splendid appearance of Rakaposhi will be a "sufficient reward for his trouble. It is a vast clean-cut brilliant snow needle, abso- "lutely sharp, rising thousands of feet above a mass of broken snows, below which are "the wild precipices and serrated ridges peculiar to the Gilgit mountains."*

Kamet.

Kamet is a conspicuous landmark from all the elevated parts of Nari Khorsam; it is also visible from Almora on the Indian side, "where, however, its appearance is "so modest that, till 1849, it remained unnoticed and unmeasured, though but 250 feet "lower than the King of the western Himalaya, Nanda Devi."†

Kamet stands behind the Great Himalaya range and its height was first determined by Richard Strachey. Its outline as seen from Cheena is shown in chart VII.

Tirich Mir.

Snow forms a thick unbroken covering over Tirich Mir, and gives to the peak a rounded rather than a pointed top. The patches of naked rock, that are to be seen on all the slopes of the great peaks of the Himalaya, are absent from the flanks of Tirich Mir.

Gurla Mandhata.

Dr. T. G. Longstaff made an attempt to climb Gurla Mandhata in 1905, and attained a great height, possibly exceeding 23000 feet, but failed to reach the summit.‡

In 1878 Mr. Ryall wrote of this mountain as follows:—

"Gurla Mandhata, which is 3500 feet higher than Kailas, is held in comparatively "little religious esteem among the Buddhists and Hindus. Owing to its immense "bulk and height—3000 feet above any peak within a radius of 40 miles—it is perhaps "the most impressive sight in the whole of the Himalaya, the celebrated mountain of "Nanga Parbat alone excepted."§

Kungur and Muztagh Ata.

The peaks of Kungur and Muztagh Ata have been mistaken for one another by many travellers. Captain Trotter was the first trigonometrical observer of Kungur, and from the plains of Kashgar he determined its height at 25350 feet; he named the peak "Tagharma."

Muztagh Ata is 26 miles south of Kungur and is not visible from Kashgar. Travellers have frequently thought that they have seen Muztagh Ata from Kashgar: but they have been misled by the natives, who believe Kungur and Muztagh Ata to be one summit. Colonel Wahab called the Muztagh Ata peak "Tagharma."

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* *General Report, Survey of India*, 1883-84.

† *Journal, Royal Geographical Society*, Vol. XXIII, 1853,—Captain H. Strachey *On the Physical Geography of Western Tibet.*

Henry Strachey wrote *before* the height of Nanga Parbat had been ascertained. Montgomerie was right when he said that Nanga Parbat was as much the King of the western Himalaya as Mount Everest was of the eastern. Nanga Devi is the highest point of the Kumaun or central section of the Himalaya, but does not compete with Nanga Parbat.

‡ Charles A. Sherring: *Western Tibet and the British Borderland*; also *Alpine Journal*, August 1906.

§ *General Report, Survey of India*, 1877-78.

The fact that both Kungur and Muztagh Ata were named "Tagharma" by surveyors has tended to increase the confusion. The name Tagharma is given by natives to the peak of Muztagh Ata because it towers above the town of Tagharma in the Sarikol valley, and Wahab was correct in his application of the name. But Trotter made a mistake in adopting the assumption of Kashgarians, that the great snow peak they see to the south-west is the same peak as seen from Tagharma.

There has not only been a confusion of names, but differences of opinion have existed as to which of the two peaks is the higher, Kungur, the northern, or Muztagh Ata, the southern. The values of height entered in tables IV and V are those derived from the data at the disposal of the Survey of India, but it has to be acknowledged that the observations are less reliable than those of the Himalayan and Karakoram peaks. In the case of observations taken to peaks from stations in India the height of the place of observation is accurately known, but the same cannot be said of the points from which Kungur and Muztagh Ata were observed. Though all our information goes to show that Kungur is higher than Muztagh Ata, by about 758 feet, the great weight of Sven Hedin's authority is on the side of Muztagh Ata. "Muztagh Ata," he writes, "the loftiest mountain of the Pamirs and one of the "loftiest mountains in the world, towers up to the height of 25600 feet, and like a "mighty bastion overlooks the barren wastes of Central Asia. It is the culminating point "in a meridional chain. The unchallenged pre-eminence of Muztagh Ata over the peaks "which cluster around it is proved by its name, which means the Father of the Ice "Mountains."*

Sven Hedin made three attempts to climb Muztagh Ata, but was not successful.

Lord Curzon describing the peaks of Kungur and Muztagh Ata wrote: "The "second and southerly peak, which from Sarikol obscures the first, is the real "Muztagh Ata, the height of which is probably a little less than its nameless brother, "being calculated at about 25000 feet, but which is a far finer mountain since it is "conical and comparatively isolated, whereas the more northerly mountain is the "highest crest of an extended ridge."†

Api and Nampa.

The remarkable group of peaks in western Nepal, of which Api and Nampa (table VI) are the principals, has been imperfectly studied. During the observations of the Great Trigonometrical Survey the cluster was continually obscured by haze, and only one peak was observed. A crowded cluster that is seldom visible in winter, except perhaps on certain days for a few minutes at sunrise, and that is completely hidden by clouds in summer, presents great difficulties to the observer.

* Sven Hedin: *Through Asia*, page 221. It is perhaps unfair to give this quotation, for when Sven Hedin wrote he may have been unaware that there was any question at issue. As, however, his book has had a wide circulation, we think it right to point out that our results do not confirm Sven Hedin's opinions.

† *Geographical Journal*, Vol VIII, 1896.

If he succeeds in observing the directions of six peaks from both an eastern and a western station, each of the six rays from his eastern station cuts each of the six from his western, and thirty-six points of intersection are given within a small area. If the peaks have been observed from a third station also, difficulties disappear, but when they have been seen from two only, the true points of intersection have to be determined from a study of the several values of height.

Many map-makers have confused the peaks of Api and Nampa, but their heights differ by 1237 feet. Colonel Tanner's observations show that Api is a double peak, the higher point of which (23399 feet) stands half a mile north-east of the lower (23287 feet).

The observations of Colonel Tanner's assistant Rinzin show another peak called Ningru (23143 feet) rising between the two peaks of Api. It is extremely unlikely that the name of Ningru has been attached by natives to this close companion of Api, and it is more reasonable to assume that Api and Ningru are alternative names employed, perhaps in different localities, for the same snowy mass.

According to the observations of Tanner's assistants Nampa is a double peak also, the two summits being 2 miles apart. The higher Nampa is 4 miles east of the higher Api.

The only peak of this cluster observed by the Great Trigonometrical Survey was peak LIII: its position was fixed, but not its height; its position, which was determined from two stations of observation only, is 1½ miles south-south-west of Api (23399 feet).

The *Encyclopædia Britannica* shows a peak of this cluster as Mount Humla (24702 feet), but, incomplete as the trigonometrical observations of the Api-Nampa group have been, they are sufficient to indicate that no peak exceeding 24000 feet stands in this region.

The outline of Api is shown in chart VII.

"The purity of its unbroken snow and boldness of its outline," wrote Colonel Tanner of the Api peak (23399 feet), "I have nowhere seen equalled. The ridges that connect the highest with the "lower points of Api are perfectly sharp and decided, and for several thousands of feet there is scarcely "a splinter of naked rock to mar the unrivalled whiteness of its slopes. The base and lower spurs of "Api touch the Kali valley and are clothed with variegated masses of birch and pine except in those "places where constantly recurring avalanches admit only of the growth of short grass." *

CHUMALHARI.

The peaks of Chola (17310 feet) and of Chumalhari (23930 feet) appear from Senchal near Darjeeling to be in almost the same direction, the distance of Chumalhari being double that of Chola.†

* *General Report, Survey of India*, 1884-85.

† Chola is called Chumunko in table VI and Gaoring on North-Eastern Trans-Frontier Sheet No. 7 N. W.

A letter written by Dr. Campbell from Darjeeling in 1848 is interesting as showing how mistaken the natives of the mountains may be. His letter runs :—

"When Colonel Waugh left this place in November last, after having satisfied himself of the "position of Chumalhari by observations from Tonglu and Senchal, I took some Lepchas and "Bhotiahs, who had travelled into Tibet by the Phari route, with me to the top of Senchal, to "point out Chumalhari to them, as they were positive in stating their belief that it was not visible from "any part of this neighbourhood. When I said 'There is Chumalhari,' the whole party exclaimed "'No, it is Chola, and not Chumalhari.' I took pains to ascertain the reasons of their dissent, "and afterwards wrote an epitome to Colonel Waugh, who said, as far as I recollect, 'You may rely "upon it, that I shall not finally decide the point until you are satisfied that I am right.' "*

Colonel Waugh eventually proved that the peak observed from Senchal was Chumalhari.

KAILAS.

"It is solely due,'' wrote Mr. E. C. Ryall, "to the circumstance of its shape resem-"bling that of a Hindu temple that Kailas is vested with a sacred character."†

SER AND MER.

Ser and Mer, known also as the Nun Kun peaks, are remarkable twin giants (*vide* table VI), rising from a region of perpetual snow: they are the highest points of the Punjab Himalaya between the Sutlej and Nanga Parbat. Ser is white and Mer is dark, being too precipitous on the side of India to retain much snow.

Ser is 2½ miles south-west of Mer: a third peak (22810 feet) stands 1¾ miles east-north-east of Mer, and there is a fourth peak (22310 feet) two miles east of Mer. The positions and heights of these four peaks were well determined. The account given in the *Geographical Journal* ‡ of the Bullock-Workman expedition refers to a third peak of the group, exceeding 23000 feet. No third peak however of 23000 feet was observed by the Trigonometrical Survey. The peak climbed by Mrs. Bullock-Workman was Mer.

TENGRI KHAN.

Tengri Khan is the highest peak of the Tian Shan and the highest point of Asia north of latitude 39°. In his *Central Tian-Shan Mountains* Merzbacher describes the isolated eminence of Tengri Khan as "without example in mountain systems of like extent." "The mountain,'' he says, "has no rival and overtops the highest "summits of all the neighbouring ranges by over 3000 feet."

* *Journal, Asiatic Society of Bengal,* Vol. XVII.
† *General Report, Survey of India,* 1877-78.
‡ November, 1906.

3

ON THE NAMES OF CERTAIN PEAKS.

Absence of Native names.

It is not often that a surveyor can discover a native name for a peak: natives of the hills do not give names even to remarkable peaks. "To my disappointment," wrote Sir Joseph Hooker, "I "found that neither priest nor people knew the name of a single snowy mountain." *

Of the 75 great peaks included in tables I to V but 19 have native names. If we take into account the lower peaks, we find that there are many thousands of prominent but unnamed summits in Asia, and the problem of nomenclature has to be considered. It would be a mistake to attempt to attach an actual name to every peak. Astronomers do not name the stars: in olden times they grouped them in constellations, and they now number them according to right ascension. Colonel Montgomerie endeavoured to introduce for peaks a method resembling that of constellations, and he named the whole Karakoram region K, and its peaks K^1, K^2, K^3, etc.†

This system would have answered well, but Colonel Tanner and subsequent surveyors have departed from it, and have adopted the plan of designating each peak by the initial letter of the observer: Tanner called, for instance, the peaks he had observed himself T^{45}, T^{57}, etc. The employment of observer's initials has led to confusion; two and more observers have had the same initial, and the same symbol has thus become attached to different peaks. Moreover the designations given under Tanner's system furnish no clue as to the region in which the peaks are situated.

The nomenclature of a mountain region should not be forced: it should grow spontaneously, and we should never invent a name until its absence has become inconvenient. We cannot do better for Tibet and Turkistan than extend the simple system introduced by Montgomerie for the Karakoram: his method of constellations is more suitable for the peaks of Asia than a long series of successive numbers from west to east would be. We need not design constellations to include one whole range, and we need not follow the astronomical plan of drawing animals and heroes; we can have rectangular constellations enclosed by meridians and parallels.

Peaks can be distinguished by their heights.

Peaks however possess in their heights an attribute which stars lack, and there is no more useful means of distinguishing peaks than by their heights. If we are dealing with a complex cluster of peaks, it is simpler to indicate the several members by their heights than to confer on them separate names. In discussions of the peaks of Asia heights must be accepted to a certain extent as substitutes for names.

* *Himalayan Journals*, Vol. 1, page 370.

† A note on the name Karakoram is given in Section 16 of Part II of this paper.

There will be no difficulty in preventing the same value of height being given to two or more peaks. The heights of peaks are not known within 10 feet, and it is thus possible to adjust the height of a newly measured peak by one or two feet, if it happens to have been given the same height as one previously determined.

If the heights of peaks come to be recognised as a means of identification, they should not be altered whenever any trifling improvement in the value is believed possible. The height of Mount Everest was originally determined at 29002 feet, and this value should still be retained: a few years ago its height on maps was reduced to 28995 feet because the stations from which it had been observed were found to be 7 feet lower than had originally been assumed: subsequently for a similar reason the height was altered to 28994 feet. But these alterations were not justifiable, and only tended to produce confusion. It is known that the height 29002 feet is, if anything, too low, but it is not desirable to alter it, because the value 29002 is a clear indication of the particular peak denoted.

We are not proposing now to bind our successors for all time to adhere to the present values of heights: periodical revisions of values can be carried out every twenty or fifty years, if fresh information has been accumulated in the interim. All that is proposed now is that the heights allotted to the peaks in tables I to VI be accepted until proof is forthcoming of serious error, and that no small or frequent changes in value, such as have constantly led to confusion in the past, be made in the future.

In the following table are shown the various names and symbols that have been applied to the several peaks of tables I to VI at different times by surveyors and travellers:—

TABLE VII.—Names and Symbols which have been used by different authorities to denote the peaks of tables I to VI.

No. of Peak.	Name adopted in this paper.	Name employed in the records of the Great Trigonometrical Survey.	Names employed by observers in the field.	Alternative names occasionally used.
1	Mount Everest	XV	. . . . .	See below.
2	K^2	Karakuram No. 13*	K^2 *by Montgomerie*	Mount Godwin-Austen (see below), Dapsang *by Schlagintweit in* 1856.
3	Kinchinjunga I	IX	. . . . .	..
4	Kinchinjunga II	VIII	. . . . .	..
5	Makalu	XIII	. . . . .	..
6	T^{45}	. . . .	T^{45} or T45 *by Tanner*	..
7	Dhaulagiri	XLII	. . . . .	..
8	XXX	XXX	. . . . .	..
9	Nanga Parbat I	Nanga Parbat	. . . . .	Dayamur, Dairmal, Deo Mir.
10	XXXIX	XXXIX	. . . . .	..

* The name *Karakoram* was spelt *Karakuram* by Montgomerie, and is consequently so spelt in many of the records of the Great Trigonometrical Survey. But the form *Karakoram* is now held to be correct.

Table VII.—Names and Symbols which have been used by different authorities to denote the peaks of tables I to VI—*continued.*

No. of Peak.	Name adopted in this paper.	Name employed in the records of the Great Trigonometrical Survey.	Names employed by observers in the field.	Alternative names occasionally used.
11	K^5 or Gasherbrum I	Karakuram No. 9	K^5	..
12	K^4 or Gasherbrum II	Karakuram No. 10 (Gusherbrum)	K^4	..
13	Gosainthan	XXIII		..
14	K^{3a} or Gasherbrum III	Karakuram No. 11	K^{3a}	..
15	XXXIV	XXXIV		..
16	K^3 or Gasherbrum IV	Karakuram No. 12	K^3	..
17	T^{57}		T^{57} *by Tanner*	..
18	B^{782}		B^{782} *by Barckley*	Fishback *by Tanner*
19	XXVIII	XXVIII.		..
20	Kambachen		North of Kanchin *by Robert*, S. E.13 *by Tanner*	..
21	XXIX	XXIX		..
22	Masherbrum East	Masherbrum E.	K^1 East	..
23	Nanda Devi	LVIII		A No. 2 *by Hodgson and Herbert* : XIV *by Webb*
24	Masherbrum West	Masherbrum W.	K^1 West	..
25	Nanga Parbat II		Great Range No. 30	..
26	LIX	LIX		..
27	Rakaposhi	Rakipushi	U^{49}	..
28	Kunjut No. 1	Kunjut No. 1.	Trans-Indus No. 4	..
29	Kamet	LXVII	Kamet *by Richard Strachey*, Kangmen *by Ryder*	Ibi Gamin *by Schlagintweit*
30	T^{42}		T^{42} *by Tanner*	..
31	XLIII	XLIII		..
32	Tirich Mir I		DsEb *by Tanner*	..
33	N^{53}		N^{53} *by Robert*	..
34	K^{10}	Karakuram No. 3	K^{10}	..
35	Hunza-Kunji I	Kunji No. 8	T^{95} *by Tanner*	..
36	Gurla Mandhata		Memonamnyimri *by Ryder*	Nimo Namling *by Tanner*
37	Jano	XI		Jannu
38	K^{11}	Karakuram No. 4	K^{11}	..
39	XLIV	XLIV		..
40	B^{763}		B^{783} *by Barckley*	..
41	Shyok Nubra Watershed No. 5.	Sheok-Nubra Watershed No. 5.	K^{22}	..
42	Kungur I		Peak 2 of Camp 9 *by Ram Singh*	Tagharma *by Trotter*, Mount Dufferin *by Ney Elias*
43	B^{504}		B^{504} *by Barckley*	..
44	Hunza-Kunji II		Highest Peak South *by Holdich*	..
45	Karakoram No. 8	Karakuram No. 8	K^6	Chogolisa *by Norman Collie*

TABLE VII.—Names and Symbols which have been used by different authorities to denote the peaks of tables I to VI—*continued.*

No. of Peak.	Name adopted in this paper.	Name employed in the records of the Great Trigonometrical Survey.	Names employed by observers in the field.	Alternative names occasionally used.
46	XLVI . . .	XLVI . . .	. . . . .	..
47	Hunza-Kunji III . .	Hunza No. 2 . .	U^{51}	..
48	Kungur II . . .	. . .	Peak 3 of Camp 9 *by Ram Singh*	..
49	XLV	XLV . . .	. . . . .	..
50	XXXVI . . .	XXXVI . .	. . . . .	..
51	Kulha Kangri I . .	Bhutan-Tibet range No. 2 Pk	. . . . .	..
52	Karakoram No. 5 .	Karakuram No. 5 .	K^{32}	..
53	XXXV . . .	XXXV . . .	. . . . .	..
54	Kulha Kangri II . .	Bhutan-Tibet range No. 1 Pk	. . . . .	R^{282} *by Ryder*
55	Shyok Nubra Watershed No. 3	Sheok-Nubra Watershed No. 3	K^{24}	..
56	Tirich Mir II . .	. . .	IGmi *by Tanner* . .	Nushau No. 1
57	Shyok Nubra Watershed No. 4	Sheok-Nubra Watershed No. 4	K^{23}	..
58	Kunjut No. 2 . .	Kunjut No. 2 . .	Trans-Indus No. 2 *by Montgomerie*	..
59	R^{264}	. . .	R^{264} or R264 *by Ryder* .	..
60	Indus-Nagar Watershed No. 2	Indus-Nagar Watershed No. 2	U^{57}	..
61	LVII	LVII . . .	. . . . .	..
62	Muztagh Ata . .	. . .	Tagharma *by Wahab* .	..
63	K^{12}	Karakuram No. 4 .	K^{12}	..
64	A satellite of Kinchinjunga	. . .	Centre of great broad peak	..
65	Tirich Mir III . .	. . .	IGmf *by Tanner* . .	..
66	Kuen Lun No. 1 . .	. . .	Peak 9, Camp 58 *by Ram Singh*	..
67	XXVI . . .	XXVI . . .	. . . . .	..
68	Haramosh . . .	Haramosh . .	B^{14} U^{59} . . .	..
69	Sad Ishtragh . .	. . .	Dsb	..
70	XLVIII . . .	XLVIII . .	. . . . .	..
71	Kunjut No. 3 . .	Kunjut No. 3 . .	T^{97} *by Tanner* . .	..
72	A satellite of Kinchinjunga	. . .	Centre of huge mass, North of Kinchinjunga	..
73	Hunza-Kunji IV . .	. . .	CBu . . .	Boyohaghurdonas
74	Chamlang . . .	XIV . . .	. . . . .	..
75	Kabru . . .	X . . .	. . . . .	..
76	Api	. . .	. . . . .	Ningru
77	Badrinath . . .	LXIX . . .	VIII *by Webb* . .	..
78	Bandarpunch . .	LXXVII . .	. . . . .	Jumnootri *by Gerard*
79	Chumalhari . . .	I . . .	. . . . .	..
80	Chumunko . . .	IV . . .	. . . . .	Chola *by Dr. Campbell*
81	Dayabhang . .	XXV . . .	. . . . .	L or Dayabang *by Col. Crawford*

TABLE VII.—Names and Symbols which have been used by different authorities to denote the peaks of tables I to VI—*concluded.*

No. of Peak.	Name adopted in this paper.	Name employed in the records of the Great Trigonometrical Survey.	Names employed by observers in the field.	Alternative names occasionally used.
82	Deotibba	Deotibba	..	..
83	Dubunni	Dubunni	..	..
84	Dunagiri	..	a^{20} *by Carter*	..
85	Gangotri	..	Gangotri α S. P. *by Ryall*	..
86	Gardhar	Gardhar	..	..
87	Gaurisankar	XX	..	..
88	Jaonli	LXXV	..	..
89	Jibjibia East	XXII	..	..
90	Jibjibia West	XXIV	..	..
91	Kailas	Kailas	..	Kangrinpoche
92	Kaufmann	..	..	..
93	Kedarnath	LXXII	III *by Webb*	Bharti Khunta
94	Kharchakund	..	Kharcha Koond No. 2 S.P. *by Ryall*	..
95	Leo Pargial N.	Leo Pargial N.	..	..
96	Leo Pargial S.	Leo Pargial S.	..	..
97	Lunkho	..	IGmp	..
98	Mer	Mer or Kana	..	Kana. Kun. Dam Huy. The Nun Kun peaks are Mer and Ser
99	Nampa	..	..	Namju
100	Nandakna	LXIV	..	..
101	Nandakot	LVI	..	..
102	Narsing	VI	..	..
103	Nilakanta	LXVIII	IX (Nilakanta) *by Webb*	..
104	Panch Chulhi	LIV	XX *by Webb*	..
105	Pandim	VII	..	..
106	Pauhunri	III	Powhunri	Donkia *by Dr. Hooker*
107	Sargaroin	LXXIX	H. Left Peak *by Hodgson and Herbert*	..
108	Ser	Ser or Nana	..	Nana. Nun. Pajah Huy. The Nun Kun peaks are Mer and Ser
109	Simvo	..	S 30	..
110	Srikanta	LXXVI	Bus peak *by Du Vernet*, G or Srikanta *by Hodgson and Herbert*	..
111	Tengri Khan	..	..	..
112	Tharlasagar	LXXIV	M or Mont Moira *by Hodgson and Herbert*, I *by Webb*	..
113	Trisul East	LX	XIII (East Trisool) *by Webb*	..
114	Trisul West	LXII	A No. I *by Hodgson and Herbert*, XII (West Trisool) *by Webb*	..

The name of Mount Everest.

In 1852 the chief computer of the Trigonometrical Survey informed the Superintendent, Sir Andrew Waugh, that a peak designated XV had been found from the computations to be higher than any other hitherto measured in the world. This peak was discovered by the computers to have been observed from six different stations: on no occasion had the observer suspected that he was viewing through his telescope the highest point of the earth.*

The Indian Survey had always adhered to the rule of assigning to every geographical feature its true local or native name, but here was a mountain, the highest in the world, without any local or native name that the surveyors were able to discover. The Surveyor General, Sir Andrew Waugh, decided to name the great snow-peak "Mont Everest" after his former chief, Sir George Everest, the celebrated geodesist.

Waugh wished to introduce the word "Mont" in preference to "Mount," but "Mont" never came into vogue. It seems to have been immediately replaced in common usage by "Mount," and for 50 years "Mount Everest" has been the name generally adopted throughout the world.

When Sir Andrew Waugh announced that the peak was to be named "Mont Everest," Mr. Hodgson, who had been political officer in Nepal, wrote many papers to show that Waugh had been mistaken, and that the mountain had a local name, *viz.*, Devadhunga. But Mr. Hodgson mistook another peak for Mount Everest and it is probable that he never saw Mount Everest at all. All subsequent and recent information goes to show that there is no peak of the Himalaya called Devadhunga.†

In 1855 Hermann de Schlagintweit visited a hill in Nepal called Kaulia near Katmandu, and from it took observations to the snow peaks. He saw the mountain called Devadhunga by Hodgson, and he identified it as Mount Everest; he however repudiated Hodgson's name of Devadhunga and certified that the local native name for the peak was Gaurisankar. Many geographers accepting Schlagintweit's views have continued to this day to call the highest mountain in the world Gaurisankar: the Indian Survey however were unable to reconcile Schlagintweit's results with their own and declined to follow him. There is no doubt now that Schlagintweit was misled in his identification of Mount Everest. In 1903 Captain Wood, R.E., visited Kaulia by order of Lord Curzon: he found that Gaurisankar and Mount Everest were different peaks 36 miles apart, and that the peak called Devadhunga by Hodgson and Gaurisankar by Schlagintweit was a peak long known in the records of the Survey as peak XX (height 23440 feet).‡

In addition to his Kaulia observations, Schlagintweit observed at Phallut on the Singalila ridge, and from there he painted his now well-known picture of Mount

* *Nature*, Nos. 1828 and 1830, Vol. 71; Nov. 10 and 24, 1904.

† This name may possibly be a mythological term applied to the whole snowy range by the natives of a certain part of Nepal.

‡ See Wood's *Report on the Identification and Nomenclature of the Himalayan peaks as seen from Katmandu*, 1904; also his *Narrative Report*, 1903-04.

Everest: but unfortunately he fell again into error, for the mountain he painted is clearly Makalu and not Mount Everest.

Of recent years endeavours have been made to show that the Tibetans have a name for Mount Everest, namely, Jomokangkar or Jhomogangar or Chamokankar, but no reliable evidence has been produced. In 1904 the surveyors attached to the Tibet Frontier Mission made careful enquiries, but found no such name applied to the great Himalayan peak. On the other hand the explorer Kishen Singh found a mountain called Jhomogangar * in the interior of Tibet, 215 miles north-east of Mount Everest. This peak of Jhomogangar has been shown on maps of Tibet since 1872. Kishen Singh in his narrative describes his arrival at Dung Chaka (15700 feet) and then adds, "About 10 miles to the east there is a lofty snowy peak called Jhomogangar, some-"what of the same shape as the Kailas peak near Manasarowar: it is a noted object of "worship, being considered as a female divinity."

After 50 years of controversy no true native name has been produced for Mount Everest: each of those suggested has in turn been shown to be inapplicable, and the evidence that no such name exists is overwhelming. In the meantime the name Mount Everest has been widely adopted, and it would be a mistake to go back upon it now. Personal names for geographical features are doubtless objectionable, but we must accept accomplished facts: geographical progress is retarded by unprofitable changes and by barren controversies over names.†

The name of K^2.

No native name for peak K^2 could be discovered by surveyors, and in 1856 it was designated K^2 by Montgomerie. The designation has been generally accepted, and will now, it is hoped, be retained in perpetuity.

When the final results of the Kashmir Survey were being prepared for publication, the numbering of the peaks of the Karakoram range was altered in order to produce continuity from west to east, and in some publications of the Great Trigonometrical Survey the peak K^2 is shown as Karakoram No. 13. This duplication of designations is now regretted, and the symbol K^2 will alone be used in future.

The height first given by the Survey to K^2 was 28278 feet; the value now accepted is 28250 feet.

Schlagintweit thought that the native name of peak K^2 was Dapsang: Sir Martin Conway gave it as Chiring:‡ and other travellers have reported it to be Chogo Ri.§

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* Latitude 29°50′ N.; Longitude 89°50′ E. *Geographical Journal*, Volume XXV, p. 179.

† In connection with the subject of personal names Lieutenant Wood, R.N., is often quoted as having given the name of Victoria to the Lake of Sir-i-Kul in the Pamirs; it may therefore not be out of place to quote Wood's own words: "As I had the good fortune to be the first European who in later times had succeeded in "reaching the sources of this river, and as, shortly before setting out on my journey, we had received the news of "her gracious Majesty's accession to the throne, I was tempted to apply the name of Victoria to this, if I may so "term it, newly re-discovered lake; but on considering that by thus introducing a new name, however honoured, "into our maps a great confusion in Geography might arise I deemed it better to retain the name of Sir-i-Kul, the "appellation given to it by our guides."

‡ *Proceedings, Royal Geographical Society*, Vol. XIV, p. 857, and *Geographical Journal*, Vol. I, p. 177.

§ Ri merely means "monntain."

None of these names is in common use by the natives, and nothing would be gained by the adoption of any one of them.

Sir M. Conway writes of the Chogo peak as being quite distinct from K^2, and Dr. Hunter Workman attaches the name of Chogo Ri on his map to a different peak from K^2. Professor Norman Collie gives the name Chogolisa to peak No. 45 of table IV.

In 1888 at a meeting of the Royal Geographical Society it was proposed by General Walker to give the name of Godwin-Austen to peak K^2 after the officer who first surveyed the Karakoram range and glaciers; the name Godwin-Austen is now applied to the peak by many map-makers, but it has not been accepted by the Surveyor General of India and has not been entered on the maps of the Government of India.

Of all the designations suggested for the supreme peak of the Karakoram that of K^2 has now the widest vogue, and it will be in the interests of uniformity, if this symbol be adopted henceforth to the exclusion of all others. The permanent adoption of the symbol K^2 will serve to record the interesting facts that a mountain exceeding 28000 feet in height had not been deemed worthy of a name, by the people living under its shadow, and that its pre-eminent altitude was unsuspected until it was brought to light by trigonometrical observations.

The name of Kinchinjunga.

The name Kinchinjunga has been spelt in a variety of ways. Uniformity in spelling is of more importance to geographers than correctness. The correct forms are doubtless Kanchenjunga or Kanchendzonga, but the more familiar form of Kinchinjunga is that adopted by the new Imperial Gazetteer, and this, it is to be hoped, will now come into general use. In north-eastern Nepal Kinchinjunga is known as Kumbhkaran Langur.

Leo Pargial.

The name of Leo Pargial has figured too long upon maps to be abandoned now, but the natives on both sides of the Bashahr-Tibet border call the peak Rio Pórgyúl. Rio is merely a different form of the word Ri, meaning mountain, as in Chumalhari.

4

ON THE ERRORS OF THE ADOPTED VALUES OF HEIGHT

The values of height given in tables I to VI of this paper must be accepted with caution; some are more reliable than others, but none are correct to a foot, and many investigations will have to be completed before altitudes can be determined with a greater degree of accuracy than at present.

Errors of observation.

All observations are liable to error; no telescope is perfect, no level is entirely trustworthy, no instrumental graduations are exact, and no observer is infallible.

In ordinary triangulation the objects to be observed are sharp and specially erected signals, but for the observations of a high peak, the summit, however ill-defined, cannot be furnished with a suitable mark.

If a flat-topped peak be observed from a near station, the surveyor runs the risk of mistaking some lower point for the summit, the latter being obscured from his view by an intervening shoulder.

Errors of measurement however can be greatly reduced and rendered practically negligible, if a peak be observed with a good theodolite on *several* occasions and from *different* stations; observations of Mount Everest, of K^2, of Kinchinjunga, and of others have been repeated so often and from so many different places that the local angles of elevation have been probably determined within one or two seconds of the truth and the errors in the mean values of height *due to faults of observation* are probably less than 10 feet. But in the cases of peaks Nos. 18 and 30 of table IV, and others, which have been observed from one station only and on but few occasions from that, errors due to faults of observation may attain to 100 feet. A single intersection of a peak from a single station deserves no weight whatever: it may give a result hundreds of feet in error.

The adoption of an erroneous height for the observing station.

Heights in the Himalaya that have been measured from one or two stations only may in places be thrown into error to the extent of 10 or 15 feet by the adoption of erroneous altitudes for the stations of observation.

In the case of the Karakoram and Ladak ranges the liability to error on this account is larger and is perhaps 30 feet: the peaks of the Hindu Kush have been observed from less known stations than those of the Karakoram and are possibly 70 feet in error in consequence.

The Kashgar range being still more remote from the triangulation of India, the heights of its peaks are less reliable than those of the Hindu Kush; and the peaks of Kungur and Muztagh Ata may be in error by 300 feet, or even more, on account of the accumulation of error in the assumed altitudes of the stations from which they have been observed.

An element of uncertainty is introduced into heights by the fact that the altitudes of peaks are always varying in nature with the increase and decrease of snow. The discrepancies that obtain between the different determinations of height of the same peak may be partly due to the fact that some observations have been made after the snow has been accumulating, and others after it has been diminished by heat, evaporation, wind, and avalanches. All heights on land have to be measured from the surface of the sea, and as the latter rises and falls with the tides, a mean level of the sea has to be adopted; and so in the case of the great peaks, we shall have eventually to assume the mean level of the snow at their summits as the altitude to be determined.

Variations of snow.

A plumb-line is a string supported at its upper end and stretched by a weight attached to its lower end.* If there were no irregularities of matter near the earth's surface a plumb-line would hang truly normal; but mountains exert a lateral pull, and tend to deflect it towards them. In the same way as plumb-lines are pulled out of the normal, so is the surface of water near mountains pulled out of its spheroidal form. The attraction of the great mass of the Himalaya and Tibet pulls all liquids towards itself, as the moon attracts the ocean, and the surface of water in repose assumes an irregular form at the foot of the Himalaya. If the ocean were to overflow northern India its surface would be deformed by Himalayan attraction. The liquid in levels is similarly affected and theodolites cannot consequently be adjusted: their plates when levelled are still tilted upwards towards the mountains, and angles of elevation as measured are too small by the amount the horizon is inclined to the tangential plane. At Darjeeling the surface of water in repose is inclined about 35″ to this plane, at Kurseong about 51″, at Siliguri about 23″, at Dehra Dun and Mussooree about 37″.

The deviation of gravity from the normal.

No attempt has yet been made to apply corrections to the values of heights on account of Himalayan attraction: the determinations of the deflections of the plumb-

* To render intelligible references to the deviation of gravity it is necessary to define the following words, *vertical*, *horizontal*, *normal*, *level*, *tangential*. If the earth had been at rest, it would under the influence of gravity have assumed the form of a sphere: its rotation round an axis has converted the sphere into a spheroid flattened at the poles. The present figure of the earth is not a perfect spheroid, however, as the surface is disfigured by mountains and valleys, which are rigid enough to withstand the influences of gravity and rotation. Everywhere in fact on land we meet with slopes and cliffs that are obviously inclined to the general surface of the earth. Water, however, whether it be in a basin, or lake or ocean, conforms closely to the spheroidal surface, and it is more exact to say that the figure of the sea is a spheroid, than that the figure of the earth is one. The surface of the sea, however, though more nearly spheroidal than that of the land, suffers from slight irregularities, and water in repose does not conform exactly to the spheroid. Continents and mountains attract water towards themselves, and their attraction disfigures the surfaces of oceans and ponds and levels. If the earth were a homogeneous and perfect spheroid, the direction of gravity would everywhere be perpendicular to its surface, but the earth is irregular, and gravity does not always coincide with the perpendicular to the general surface. Gravity acts in a direction perpendicular to the surface of water. We have then to consider what we mean by a *vertical* line—whether it is the perpendicular to the earth's mean surface or whether it is the direction of gravity. The word *vertical*, we think, should be employed to describe the direction of gravity; the line perpendicular to the mean surface should be called the *normal*. The actual surface of the sea and of water, however disfigured from a spheroid, is the *level* surface, and the word *level* should only be applied to this actual surface. The following definitions will explain the difference between the *horizontal* and *tangential* planes at any point of the earth's surface: the *horizontal* is the plane that is tangential to the local surface of water, however the latter may be deformed: the *tangential* plane is the plane that is tangential to the mean spheroidal surface.

line are at present not sufficiently perfect to justify the results being utilised to correct altitudes.*

We know that all angles of elevation to Himalayan peaks measured from the plains of India and from the outer hills are too small, and consequently all our values of Himalayan heights are too small. Errors of this nature range from 40 to 100 feet.

Of the deflection of gravity from the normal in Tibet or Kashgar or on the Karakoram or Hindu Kush we know as yet nothing.

If a peak be observed from different directions, the deflection of the plumb-line in the plane of the peak will probably be different at every observing station, and the several values of height may consequently appear discordant. Such discordances, however, are unavoidable; their presence implies that the direction of gravity has been varying, and it leads us to hope that the errors due to deflections of the plumb-line are tending to cancel in the mean.

Atmospheric Refraction.

The most serious source of uncertainty affecting values of heights is the refraction of the atmosphere. A ray of light from a peak to an observer's eye does not travel along a straight line, but assumes a curved path concave to the earth. The ray enters the observer's eye in a direction tangential to the curve at that point, and this is the direction in which the observer sees the peak. It makes the peak appear too high. Refraction is greatest in the morning and evening and least in the middle of the day: it is different in summer from what it is in winter. If we observe Dhaulagiri from the plains of Gorakhpur, it appears to fall 500 feet between sunrise and the afternoon, and to rise again 300 feet before sunset. Even in the afternoon, when it appears lowest, it will still be too high by perhaps 700 feet.

In 1853 Sir Andrew Waugh determined the curvature of the path of a ray of light between the outer Himalaya and the low plains of Bengal by means of simultaneous observations taken from both ends of the ray. He then assumed that the path of a ray to a snow peak would be similarly curved, and he reduced the apparent heights of the peaks accordingly. But we believe now that he reduced the heights by too much: his determination of a ray's curvature in the outer Himalaya was correct, but this curvature, we think, is not maintained at higher altitudes. As the rarefaction of the atmosphere increases, the ray assumes a less curved path, and Sir Andrew Waugh's method attributed to refraction a greater effect than it really has. To the Karakoram heights Colonel Montgomerie employed smaller corrections for refraction than Waugh used for the Himalaya.

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* *Philosophical Transactions of the Royal Society of London*: Series A, Volume 205 (1905), pp. 289 to 318.

If we bring together in the following table the different errors to which carefully determined heights of peaks are liable it will help to focus our ideas:—

Summary of errors.

TABLE VIII.—Magnitudes of possible errors.

Source of error.	Great Himalaya range.	Karakoram range.	Kashgar range.
Variations of snow-level from the mean	Unknown	Unknown	Unknown.
Errors of observation	10 feet	20 feet	100 feet.
Adoption of erroneous height for observing station	10 feet	30 feet	300 feet.
Deviation of gravity	60 feet, too small	Unknown	Unknown.
Atmospheric refraction	150 feet, too small	10 to 30 feet	50 feet.

The following table shows how the different values of the height of Mount Everest have been deduced:—

Deduction of the height of Mount Everest.

TABLE IX.—Height of Mount Everest.

Station of observation.	Year of observation.	Height of station of observation.	Distance from Mount Everest.	Values of height, if no correction for refraction be applied.	Resulting height as determined by Waugh with co-efficients of refraction varying from 0·07 to 0·08 from stations in the plains.	Resulting height from computations in 1905 with co-efficient of refraction 0·05 from stations in the hills.	Resulting height with assumed co-efficient of refraction 0·0645 from stations in the plains.
		Feet.	Miles.	Feet.	Feet.	Feet.	Feet.
Jirol	1849	220	118·661	30366	28991·6	..	29141
Mirzapur	1849	245	108·876	30165	29005·3	..	29135
Janjpati	1849	255	108·362	30141	29001·8	..	29117
Ladnia	1849	235	108·861	30171	28998·6	..	29144
Harpur	1849	219	111·523	30221	29026·1	..	29146
Minai	1850	228	113·761	30282	28990·4	..	29160
Suberkum	1881	11641	87·636	29576	..	29141	..
Do.	1883	11641	87·636	29572	..	29137	..
Tiger Hill	1880	8507	107·952	29860	..	29140	..
Sandakphu	1883	11929	89·666	29620	..	29142	..
Phallut	1902	11816	85·553	29589	..	29151	..
Senchal	1902	8599	108·703	29941	..	29134	..
Mean	..	..	..	..	29002	29141	29141
Range of variation in values*	..	..	..	794	Misleading.†	17	43

The 5th column gives the values of height obtained from observation, if no correction for refraction be applied. It will be noticed that all the values of height in this column derived from observations taken at low-lying stations exceed 30000 feet, whereas those derived from observations taken at high altitudes are less than 30000 feet.

The reason of this difference is that refraction tends to elevate a peak to a greater extent when the observation is made through the thick atmosphere of the plains than

* The range of variation is the difference between the largest and smallest values of height in the column above; it is the maximum discordance obtained, and as such it furnishes evidence as to the correctness of the refraction co-efficient adopted.

† The extent of the range of variation affords no useful information unless the same value for refraction has been employed throughout. By using selected values of refraction we can make all values of height identical and have no range of variation at all.

when the line of sight passes only through the rarefied air of hill stations. It will be noticed that when no correction for refraction is applied, the largest of the values in the 5th column differs from the smallest by 794 feet, but that the application of corrections reduces the discrepancies materially.

The height 29141 is still probably too small, as it has yet to be corrected for the effects of deviations of gravity. Though it is a more reliable result than 29002, the latter value is still to be retained in maps and publications of the Survey. We cannot claim to have solved the problems of refraction, nor to have eliminated all uncertainties: our knowledge of the deflections of gravity is still but superficial, and although we may endeavour continually to improve our heights, it would be a mistaken policy to introduce new values at every step of the investigation. Values of heights, as has been explained in a previous section, furnish means of identification and are not to be altered frequently or without good reason. We have discussed the height of Mount Everest to show the degree of uncertainty attaching to it, but we do not propose to substitute 29141 for the long adopted and well-known value 29002.*

It is probable that the accepted height of Kinchinjunga is, like that of Mount Everest, too small: the following table shows how the height of Kinchinjunga has been deduced:—

Deduction of the height of Kinchinjunga.

TABLE X.—Height of Kinchinjunga.

Station of observation.	Year of observation.	Height of station of observation.	Distance from Kinchinjunga.	Values of height, if no correction for refraction be applied.	Resulting height as determined by Waugh with co-efficients of refraction varying from 0·07 to 0·09 from stations in the plains.	Resulting height from computations in 1905 with co-efficient of refraction 0·05 from stations in the hills.	Resulting height with assumed co-efficient of refraction 0·0645 from stations in the plains.
		Feet.	Miles.	Feet.	Feet.	Feet.	Feet
Dumdangi	1847	307	84·951	28856	28137·8	..	28224
Thakurganj	1847	264	88·491	28948	28138·3	..	28266
Bandarjula	1847	238	92·560	29060	28128·6	..	28312
Minai	1850	228	115·174	29494	28162·5	..	28346
Baisi	1850	234	115·631	29483	28152·1	..	28322
Harpur	1849	219	124·694	29651	28133·7	..	28297
Senchal	1847	8599	50·158	28401	28138·8	28231	..
Birch Hill	1847	6874	44·907	28379	28152·3	28239	..
Tonglu	1847	10073	46·369	28370	28169·6	28220	..
Observatory Hill	1884	7162	45·720	28353	..	28212	..
Mean	..	..	..	..	28146	28226	28295
Range of variation in values †	..	..	..	1298	Misleading.‡	14	122

If we examine the results of the 5th column, which have not been corrected for refraction, we find that all the heights derived from observations at low-lying stations exceed 28800 feet, and all those derived from observations made at high altitudes are below 28410. The heavy atmosphere of the plains had greater refracting effects than the rarefied air of the hills and raised the peak to a greater extent.

* *Survey of India, Professional paper No.* 9, 1905.

† The range of variation is the difference between the largest and smallest values of height in the column above; it is the maximum discordance obtained and as such it furnishes evidence as to the correctness of the refraction co-efficient adopted.

‡ The extent of the range of variation affords no useful information unless the same value for refraction has been employed throughout. By using selected values of refraction we can make all values of height identical and have no range of variation at all.

If no correction for refraction be applied, the values of height vary from 28353 to 29651, a discrepancy of 1298 feet: the 7th and 8th columns show how this discrepancy can be reduced by corrections for refraction.

Deduction of the height of Dhaulagiri.

The following table shows how the height of Dhaulagiri was obtained: no observations have been taken to it from stations in the hills:—

TABLE XI.—Height of Dhaulagiri.

Station of observation.	Year of observation.	Height of station of observation.	Distance from Dhaulagiri.	Values of height, if no correction for refraction be applied.	Resulting height as determined by Waugh with co-efficients of refraction varying from 0·07 to 0·09.	Resulting height with assumed co-efficient of refraction 0·0645.
		Feet.	Miles.	Feet.	Feet.	Feet.
Morairi	1848	334	105·975	27974	26791·0	27002
Banarsi	1849	329	95·625	27928	26773·8	27128
Saonbarsa	1849	315	104·043	28093	26830·8	27151
Purena	1849	299	105·800	28011	26813·1	27044
Ghaos	1849	327	95·812	27852	26775·5	27052
Tulsipur	1848	376	104·461	27930	26824·8	26988
Anarkali	1848	434	137·340	28640	26756·6	27002
Mean	..	..	..	..	26795	27052
Range of variation in values *	..	..	..	788	Misleading.†	163

The height 26795 is too low: the reductions made on account of refraction were too great.

The observations in the North-West Himalaya of the great peaks of K^2, Nanga Parbat, etc., were taken not from low dusty hazy plains as those of the Nepalese peaks were, but from high stations, and the rays passed through a rarefied atmosphere.

Deduction of the height of K^2.

The height of K^2 was deduced by Colonel Montgomerie as follows:—

TABLE XII.—Height of K^2.

Station of observation.	Year of observation.	Height of station of observation.	Distance from K^2.	Values of height, if no correction for refraction be applied.	Resulting height as determined by Montgomerie with co-efficients of refraction varying from 0·04 to 0·05.
		Feet.	Miles.	Feet.	Feet.
Shangruti	1859	17531	78·9	28640	28246·6
Biachuthusa	1859	16746	99·0	28846	28218·7
Marshala	1858	16906	58·6	28472	28240·0
Kastor	1858	15983	66·0	28560	28261·4
Thurigo	1858	17246	61·8	28515	28254·1
Haramukh	1856	16001	136·5	29300	28293·9
Kanuri-Nar	1857	15437	114·3	28920	28218·4
Barwai	1857	16304	88·0	28666	28258·5
Thalanka	1857	16830	74·7	28613	28322·7
Mean	..	..	..	..	28253
Range of variation in values *	..	..	..	828	104

* The range of variation is the difference between the largest and smallest values of height in the column above; it is the maximum discordance obtained and as such it furnishes evidence as to the correctness of the refraction co-efficient adopted.

† The extent of the range of variation affords no useful information unless the same value for refraction has been employed throughout. By using selected values of refraction we can make all values of height identical and have no range of variation at all.

The following table shows the height of Nanga Parbat as deduced from the observations using different refraction co-efficients :—

Deduction of the height of Nanga Parbat.

TABLE XIII.—Height of Nanga Parbat.

Station of observation.	Year of observation.	Height of station of observation.	Distance from Nanga Parbat.	Height with refraction co-efficients of										
				0·00	0·01	0·02	0·03	0·04	0·05	0·06	0·07	0·08	0·09	0·10
		Feet.	Miles.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Ahartatopa .	1855	13029	133·744	27885	27646	27407	27168	26929	26689	26449	26210	25970	25734	25494
Pahargarh .	1855	11856	118·751	27680	27492	27304	27116	26923	26739	26551	26362	26174	25988	25800
Gogipatri .	1855	7752	95·055	27332	27211	27090	26969	26848	26726	26604	26485	26363	26243	26124
Haramukh .	1856	16001	59·275	26882	26835	26788	26741	26694	26647	26599	26552	26505	26460	26413
Kajnag .	1856	12111	73·559	27028	26956	26884	26812	26740	26669	26595	26524	26452	26380	26307
Poshkar .	1856	8323	83·491	27219	27125	27031	26937	26843	26749	26654	26562	26468	26376	26282
Ismail-di-dori .	1856	12630	63·805	26947	26892	26837	26782	26727	26671	26617	26563	26508	26454	26400
Safapur .	1856	10296	66·339	26917	26858	26799	26740	26681	26624	26564	26506	26447	26387	26329
Hant .	1856	13479	43·167	26771	26746	26721	26696	26671	26646	26621	26596	26572	26546	26522
Manganwar .	1856	8715	56·510	26854	26811	26768	26725	26682	26638	26596	26553	26510	26467	26425
Marinag . . .	1956	11814	46·342	26780	26751	26722	26693	26664	26636	26606	26579	26549	26520	26492
Mean . . .	..	..	..	27118	27029	26941	26853	26764	26676	26587	26490	26411	26323	26235
Range of variation in values*	..	..	..	1114	900	686	475	265	125	205	386	602	812	1028

It will be noticed that when a co-efficient of 0·10 is used, the height of Nanga Parbat as determined from different places varies between 25494 and 26522, a range of 1028 feet.

This great variation shows that the co-efficient of 0·10 is inapplicable: with a co-efficient of 0·09 the height varies from 25734 to 26546, a range of 812 feet. The range of variation decreases, until with a co-efficient of 0·05 all the values of height fall between 26624 and 26749, a range of 125 feet. If we decrease the co-efficient still further to 0·04, the variations again begin to increase, and the range extends to 265 feet, from 26664 to 26929 : if the co-efficient be decreased to 0·00 the range of variation becomes 1114 feet.

The actual height adopted by Montgomerie for Nanga Parbat was 26620, and we are unable to improve upon his value : it is produced if a general co-efficient of 0·057 be accepted for refraction.

The rise of the Himalaya.

Is the great Himalaya range still rising ? This is a question often asked but which no one has been able to answer. The observations of peaks made between 1850 and 1860 were not sufficiently prolonged at any one station to enable us to rely with certainty on the values of height then obtained. When the absolute height of a peak is being measured, stations of observation have to be multiplied in order to cancel effects of refraction and gravity, but when a slow variation in height is being determined, it is better to carry out long series of observations from one station only. In the latter case differences are being sought, not absolute heights, and all that is necessary is to repeat observations

* The range of variation is the difference between the largest and smallest values of height in the column above ; it is the maximum discordance obtained and as such it furnishes evidence as to the correctness of the refraction co-efficient adopted.

from the same station, on the same days of the year, and under the same conditions. In 1905 a series of observations was commenced from the trigonometrical station of Nojli, and it is proposed to observe the heights of several peaks for some years and at different seasons in each year. If a reliable series of results be once obtained, a similar set of observations can be repeated at a subsequent date and any actual change of height that has occurred in the interim may be discovered.

The Siwalik range was elevated at a more recent date than the Himalaya, and is the most likely of all the ranges to be rising still: a bench-mark has been placed on the crest-line south of Dehra Dun, and its height has been determined by spirit levelling: if the bench-mark is preserved, future changes in altitude should be discoverable.

Slow changes in the level of land, unaccompanied by sudden movements, have been observed to occur along many coasts. At great distances from the sea such changes would take place without being noticed: without the aid of the sea as a datum we do not observe slow gradual movements, and a continuous rise of a foot a year might go on for centuries without attracting the attention of man. If an earthquake occurs and a tract of land suddenly subsides along a line of fracture in the crust, the result is apparent and measurable, but if the elevation of a large area takes place in all directions gradually and without fracture of the crust or any marked upheaval it may be considerable and yet escape observation. In the Dharmsala earthquake of 1905 an immense region may have been elevated or depressed through many feet, but if the change were nowhere sudden we should not without refined trigonometrical observations become aware of its occurrence.

Photogravure — Survey of India Offices Calcutta, December, 1906

NOJLI TOWER.

A STATION OF THE GREAT TRIGONOMETRICAL SURVEY, BUILT IN THE PLAINS OF UPPER INDIA NEAR ROORKEE, AND FROM WHICH THE HIMALAYAN PEAKS OF BADRINATH, KEDARNATH, JAONLI AND BANDARPUNCH HAVE BEEN OBSERVED.

FROM A PHOTO BY C.D. SIMONS.

5

ON THE FREQUENCY WITH WHICH PEAKS OF CERTAIN HEIGHTS TEND TO OCCUR.

Lest this review should degenerate into tables of numerical data we have refrained from continuing the lists of peaks below 24000 feet, but in deducing the continuity of ranges amid a vast mountainous area it is necessary to take into account the lower peaks.

The following table shows the total number of peaks exceeding 20000 feet that have been discovered. The chart forming the frontispiece illustrates the ranges to which the several peaks of the table have been allotted :—

TABLE XIV.—The numbers of peaks of different altitudes which have been discovered in Asia.

Region.	Range.	Between 20000 and 21000 feet.	Between 21000 and 22000 feet.	Between 22000 and 23000 feet.	Between 23000 and 24000 feet.	Peaks of 5th magnitude 24000 to 25000 feet.	Peaks of 4th magnitude 25000 to 26000 feet.	Peaks of 3rd magnitude 26000 to 27000 feet.	Peaks of 2nd magnitude 27000 to 28000 feet.	PEAKS OF FIRST MAGNITUDE. 28000 to 29000 feet.	Above 29000 feet.
Trans-Tibetan.	Tian Shan	..	..	..	1	..	..	..	..	..	..
	Trans Alai	..	1	1	..	..	..	..	..	..	..
	Kashgar	1	..	2	..	1	2	..	..	..	..
	Sarikol	1	..	..	..	..	..	..	..	..	..
North-West Tibet.	Kuen Lun	57	28	10	3	1	..	..	..	..	..
	Aghil	24	2	1	..	..	..	..	..	..	..
	Karakoram	92	71	28	10	7	10	4	..	1	..
	Hindu Kush	49	29	13	9	3	1	..	..	..	..
Southern Tibet.	Kailas, West	9	8	5	..	2	1	..	..	..	..
	Kailas, East	11	12	..	2	..	..	..	..	..	..
	Ladak, West	11	5	1	..	..	..	..	..	..	..
	Ladak, East	11	12	5	..	..	1	..	..	..	..
	Ninchinthangla	5	3	1	1	..	..	..	..	..	..
	Zaskar	20	11	6	2	..	1	..	..	..	..
Himalaya	Great Himalaya range—										
	(In Assam)	9	3	6	6	3	..	..	..	..	..
	(In Nepal)	15	35	33	17	9	13	6	2	1	1
	(In Kumaun)	27	24	32	9	1	2	..	..	..	..
	(In Punjab)	7	6	2	2	..	1	1	..	..	..
Himalaya	Lesser Himalaya range (between Kulu and Lahaul)	5	..	..	..	..	..	..	..	..	..
	Total	354	250	146	62	27	32	11	2	2	1

Russian surveyors probably know of more peaks exceeding 20000 feet than we have been able to allot to the Tian Shan and Trans Alai ranges: but they have only discovered one peak above 23000 feet,—Tengri Khan (*vide* table VI). The highest peak of the Trans Alai range is Kaufmann (table VI).

Twenty-seven peaks exceeding 20000 feet have been allotted in the table to the Aghil range: these peaks when plotted appear to stand between the Karakoram and Kuen Lun ranges, but they are insufficient in number to enable the intervening ranges to be traced: it is possible that some of these peaks belong properly to the Karakoram range and some to the Kuen Lun: no certain distribution can be made at present, and the trend of the Aghil range as shown on the frontispiece chart must be regarded as problematical.

The single peak of the Ladak range that exceeds 25000 feet in height is Gurla Mandhata: the great peak of the Zaskar range is Kamet: the highest peak of the Kailas range is Rakaposhi. The Kailas and Ladak ranges have for convenience been divided into east and west sections at lake Manasarowar.

The effect of snow upon heights.

The totals in table XIV show us that more peaks of the fourth magnitude have been discovered than of the fifth. This phenomenon is so striking that it is necessary to consider whether it can be due in any way to snow-fall,—whether there can exist some critical altitude at which a maximum amount of snow tends to accumulate.

The term "snow-line" is the line through a mountain region along which the quantity of snow that falls annually is equal to the quantity that is melted annually; below this line more snow can be melted in a year than actually falls; above the snow-line more snow falls than can be melted. In the Kumaun Himalaya the snow-line was determined by General Richard Strachey to be 15500 feet on the south side of the great range and 18500 feet on the north side.*

As we ascend above the snow-line, we find the depth of perpetual snow tending to increase, but we do not know at what altitude in any given region the accumulation becomes a maximum. As the altitude increases, less snow is melted in the year, but the amounts removed by wind and evaporation may for what we know to the contrary be greater: the snow-fall moreover itself decreases with height, and at a certain altitude the decrease in fall begins to produce a diminution in the amount annually accumulated.

The problem is complicated too by considerations other than meteorological. A flat-topped summit will accumulate greater masses of snow than a precipitous and pointed peak. Mountains such as K^2, Nanga Parbat, or Rakaposhi are too sharp to allow the snow to lie in quantity; as soon as snow falls upon them it descends in the form of avalanches to lower levels and hardens into glacier-ice. But the great Tirich Mir group of peaks have rounded tops, which have possibly been formed by constant accumulations of snow.

The question is therefore not simply one of the balance of snow-fall and melting, for the shape of a peak is a most important factor. The peaks on which snow has been accumulating for centuries are those possessing flat tops, and as flat tops are not more likely to occur at one altitude than at another, it is not possible to attribute

* *Vide* Section 19, Part II of this paper.

the great number of peaks of the fourth magnitude to excessive accumulations of snow at 25000 feet.

Peaks of 24000 feet are comparatively rare.

In the Himalayan system of ranges the great peaks may be divided into twelve groups: in two the principal peaks exceed 28000 feet, in five the principals lie between 26000 and 27000 feet, in three between 25000 and 26000, and in only two are the principals between 24000 and 25000.*

In the Karakoram system the same paucity of 24000 feet peaks is observed: one group surrounds a principal exceeding 28000 feet; seven groups surround principals of 25000 feet, and in two groups only are the principals of 24000 feet.

In the Himalayan system there are many groups of peaks the principals of which rise to 23000 feet: amongst others table VI shows Api (23399 feet), Badrinath (23190 feet), Chumalhari (23930 feet), Dayabhang (23750 feet), Gaurisankar (23440 feet), Ser or Nana (23410 feet).

So far then as observations have gone, peaks of 24000 feet have been found to be relatively rare, and principals of groups of that height very rare. At the same time the incompleteness of the trigonometrical survey has to be borne in mind; the peaks of Nepal were observed from very distant stations situated on the low-lying plains of India, and some are known to have been hidden from observers by clouds. A trigonometrical surveyor has no fixed observatory in which he can wait with patience for clear days: he has to observe from many stations in the course of a year, and has always to be moving forward. In observing important peaks he may consider it justifiable to delay for days to ensure that no great altitude has been missed, but some of the minor peaks may be lost, if clouds are persistent.

For weeks together the snow-peaks will be visible for a short time after sunrise, and then become obscured for the rest of the day by clouds or dust-haze rising off the plains: the surveyor utilises the few minutes at his disposal in observing carefully the principal peaks in view, but he has not the time to make an exhaustive study of the range. So long as the Nepal peaks have to be observed from distances of 100 miles the trigonometrical survey will remain incomplete.†

In view of the known incompleteness of the survey, as a whole, a discussion of the numbers of peaks of the fourth and fifth magnitudes may be considered superfluous. But though the data are insufficient to justify conclusions being drawn, observed peculiarities are deserving of notice. The surface features of the solid earth do conform generally to the laws of probability: half the whole surface of the lithosphere is situated within 700 feet of sea-level, and the highest heights and the deepest deeps occur very rarely. It was reasonable to expect that we should discover more peaks of 20000 feet than of 21000 feet and more of 23000 feet than of 24000, and this we have done: but

* The actual number of Himalayan groups is ten; Kamet and Gurla Mandhata raise the total to twelve.

† The Kumaun and Punjab Himalaya have however been very closely examined and the absence of peaks of 24000 feet is more marked than in Nepal.

Colonel Tanner, who observed the peaks of Nepal from many different places, with the object of supplementing the previous observations of the Great Trigonometrical Survey, wrote "Very few of the great peaks escaped the observers of "the Trigonometrical Survey."

there is one striking exception to the rule,—*the peaks of the fourth magnitude exceed in number those of the fifth.*

Application of the law of probability.

From present data it is difficult to calculate by the law of probability how many peaks of any particular altitude may be expected to exist in a given region; we have as yet no satisfactory basis. We cannot, for instance, take the peaks of 20000 and 21000 feet as our data and deduce from them the probable numbers of other heights, because we know that many peaks of 20000 and 21000 feet have escaped our surveyors and that our observed numbers are in defect of reality.

We can calculate the probable numbers of peaks upon the hypothesis that all existing peaks above 26000 feet have been discovered, but this hypothesis is not satisfactory as it gives undue weight to the few highest peaks.

Finally, we can take the peaks of 25000 and 26000 feet, and assuming that no others of such heights exist undiscovered, we can deduce the probable number of peaks of all heights. The objection to this hypothesis is that there are reasons for believing that the number of peaks of 25000 feet is larger than the law of probability would give.

In the following table is shown the number of peaks of each altitude that the law of probability would lead us to expect to find:—

TABLE XV.—Comparisons between probable and actual numbers.

Height in feet.	Probable number of peaks on the assumption that there exist eleven between 26000 and 27000 and one peak above 29000 feet.	Actual number of peaks discovered.	Discrepancy between probables and actuals.	Probable number of peaks on the assumption that there exist eleven peaks between 26000 and 27000 and thirty-two between 25000 and 26000 feet.	Actual number of peaks discovered.	Discrepancy between probables and actuals.
Above 29000	1	1	0	1	1	0
Between 28000 and 29000	2	2	0	1	2	+1
„ 27000 and 28000	5	2	−3	4	2	−2
„ 26000 and 27000	11	11	0	11	11	0
„ 25000 and 26000	23	32	+9	32	32	0
„ 24000 and 25000	47	27	−20	84	27	−57
„ 23000 and 24000	93	62	−31	218	62	−156
„ 22000 and 23000	179	146	−33	544	146	−398
„ 21000 and 22000	335	250	−85	1302	250	−1052
„ 20000 and 21000	607	354	−253	2996	354	−2642

In the first half of this table the probable numbers are calculated on the assumption that eleven peaks between 26000 and 27000 feet exist and one peak of 29000 feet. On this assumption the actual number of peaks below 25000 feet is shown throughout to be less than the probable number,—a deficiency that can only be regarded as reasonable seeing that many peaks of these heights are known to be still unobserved. The curious feature of this portion of the table is that the actual number of peaks between 25000 and 26000 feet exceeds the probable number by 9. The meaning of this excess is that *the number of existing peaks between* 25000 *and* 26000 *feet is greater than would be expected from the number known to exist above* 26000 *feet.*

In the second half of the table the probable numbers have been calculated on the assumption that eleven peaks exist between 26000 and 27000 feet and thirty-two between 25000 and 26000 feet. The result of including these thirty-two peaks in the data is to increase greatly the numbers of inferior peaks: the increase becomes enormous if the table is extended down to 16000 feet,* and the numbers of peaks then shown as probably existing are clearly in excess of the actuals. The meaning of this excess is that *the number of existing peaks between* 25000 *and* 26000 *feet is greater than would be expected from the number believed to exist below* 25000 *feet.*

Whilst then we recognise the insufficiency of our data, we think that the results of table xv are not without interest: we find from that table that the number of peaks between 25000 and 26000 feet is unduly great, whether they be compared with those *above* 26000 or with those *below* 25000 feet.

The height of the rock summit of a peak is the resultant effect of two forces,—(i) the force of compression which elevated the range, (ii) the erosive force which is lowering the range. The rock summit is covered by an unknown amount of snow. If we reject the snow-covering as insignificant in effect, we shall have to assume that the combined actions of the compressing and eroding forces have tended to produce in Asia an exceptional number of peaks attaining 25000 feet.

* Probable numbers of peaks:—

Height in feet.	Basis of calculation: one peak above 29000, eleven peaks between 26000 and 27000 feet.	Basis of calculation: eleven peaks between 26000 and 27000, thirty-two peaks between 25000 and 26000 feet.
Between 19000 and 20000	1070	6616
„ 18000 and 19000	1833	14030
„ 17000 and 18000	3048	28566
„ 16000 and 17000	4923	55848

6

ON THE GEOGRAPHICAL DISTRIBUTION OF THE GREAT PEAKS.

One of the difficulties encountered in the classification of mountain-peaks is that absolute altitude is not a true indication of regional importance.

The presence of a peak of 20000 feet that surpasses in height all other surrounding summits furnishes more instructive lessons than one like Jano (25294 feet), which is a mere projection from a buttress of Kinchinjunga.

Peaks may in fact be divided into four classes according to their relative local importance :

(i) There is the *principal* of a group like Everest (29002 feet) or Tirich Mir (25426 feet).

(ii) There is the *twin* of the principal like Kinchinjunga II (27803 feet) or Mer (23250 feet)—situated in close proximity to the principal and rivalling it in altitude.

(iii) There is the *companion* like Makalu or Gasherbrum, which situated in the vicinity of the principal is 1000 or perhaps 2000 feet lower.

(iv) There is the *satellite* like Jano or Kabru, 3000 or 4000 feet lower than the principal.

In the following table the great peaks of the Himalaya are divided into regional groups: those that are twins are marked by an asterisk. The numbers of the peaks are taken from tables I to V of this paper.

TABLE XVI.—An analysis of the great peaks of the Himalayan system.

Groups as numbered from east to west.	Position of the group.	Number of great peaks in the group.	The great peaks.	Height.	Position of each peak in the group.	Notes.
				Feet.		
Group I (Kulha Kangri).	The eastern-most group.	3	No. 51*	24740		
			„ 54*	24660	3000 yards N. N. W. of No. 51.	
			„ 59	24496	15 miles N. E. of No. 51.	
Group II (Kinchinjunga).	140 miles west of group I.	7	No. 3* Kinchinjunga	28146		
			„ 4*	27803	1600 yards S. S. E. of No. 3.	
			„ 20 Kambachen	25782	1 mile N. of No. 3.	
			„ 37 Jano	25294	6 miles W. of No. 3.	
			„ 64	24344	11 miles N. of No. 3.	
			„ 72	24089	6 miles N. N. E. of No. 3.	
			„ 75 Kabru	24002	6 miles S. of No. 3.	
Group III (Everest)	63 miles west of group II.	9	No. 1 Mount Everest	29002	A single pyramid.	If we analyse group III we see that Everest stands alone on the Tibetan side of the crest, that no other great peak is within 10 miles of it, and that 5 peaks are crowded together 15 miles to the W. N. W. It is known that the list of the peaks of the Everest group is incomplete: during the observations by the Great Trigonometrical Survey and subsequently during those by Colonel Tanner, the group was persistently obscured by clouds, and some high peaks to the S.W. of Everest were lost. They were seen several times and observed more than once, but their shapes were not sufficiently distinguished through the hazy atmosphere and amid the distant clouds to admit of their identification from two points.
			„ 5 Makalu	27790	12 miles S. E. of No. 1.	
			„ 6	26867	16 miles W. N. W. of No. 1.	
			„ 17*	25990	13 miles W. N. W. of No. 1 and 5 miles from No. 6.	
			„ 18*	25909	14 miles W. N. W. of No. 1 and 2 miles from No. 6.	
			„ 30	25433	20 miles W. N. W. of No. 1 and 3 miles from No. 6.	
			„ 33	25413	12 miles E. S. E. of No. 1 and 2 miles from No. 5.	
			„ 40	25202	15 miles W. N. W. of No. 1 and 3 miles from No. 6.	
			„ 74 Chamlang	24012	15 miles S. S. E. of No. 1.	

TABLE XVI—*continued.*

Groups as numbered from east to west.	Position of the group.	Number of great peaks in the group.	The great peaks.	Height.	Position of each peak in the group.	Notes.
				Feet.		
Group IV (Gosainthan).	60 miles west of group III.	2	No. 13 Gosainthan .	26291		
			„ 43 . . .	25134	2 miles E. of No. 13.	
Group V .	39 miles west of group IV.	1	No. 67 . . .	24299		
Group VI .	34 miles west of group V.	3	No. 8 . . .	26658		
			„ 19 . . .	25801	10 miles S. E. of No. 8.	
			„ 21 . . .	25705	3 miles S. of No. 8.	
Group VII .	26 miles west of group VI.	4	No. 10 . . .	26492		
			„ 15 . . .	26041	18 miles E. of No. 10.	
			„ 50 . . .	24750	10 miles E. of No. 10.	
			„ 53 . . .	24688	16 miles E. of No. 10.	
Group VIII (Dhaulagiri).	21 miles west of group VII.	6	No. 7 Dhaulagiri .	26795		No. 49 is on the same ridge and in the same alignment as Nos. 31 and 39. No. 39 stands in the centre of the ridge, with No. 31 at a distance of 0·90 mile N. E. and with No. 49 at a distance of 2·51 miles S. W. This ridge is a rare example of a linear summit surmounted by 3 great peaks of almost the same altitude.
			„ 31* . . .	25429	7 miles W. N. W. of No. 7.	
			„ 39* . . .	25271	8 miles W. N. W. of No. 7.	
			„ 46 . . .	25064	11 miles W. N. W. of No. 7.	
			„ 49 . . .	24885	9 miles W. N. W. of No. 7.	
			„ 70 . . .	24150	17 miles W. N. W. of No. 7.	
Group IX Kumaun).	250 miles west of group VIII.	3	No. 23* Nanda Devi .	25645		No. 61 stands in the prolongation of the ridge connecting the Nanda Devi twins. This is an example of a three-peaked linear summit.
			„ 26* . . .	25563	Within 100 yards of No. 23.	
			„ 61 . . .	24391	$1\frac{1}{2}$ miles E. S. E. of No. 23.	
Distant outliers of the Kumaun group.		2	No. 29 Kamet . .	25447	40 miles N. N. W. of No. 23.	These peaks are in Tibet and are not situated on the Great Himalaya range itself: their presence indicates that the Tibetan ranges beyond the Himalaya have been exceptionally elevated north of Kumaun.
			„ 36 Gurla Mandhata	25355	80 miles E. of No. 23.	
Group X (Kashmir).	458 miles west of group IX.	2	No. 9 Nanga Parbat .	26620		Throughout the great distance of 458 miles separating groups IX and X no known peak exists exceeding 4000 feet in height.
			„ 25 . . .	25572	1 mile N. N. W. of No. 9.	

Photogravure

NANGA PARBAT

AS SEEN FROM A DISTANCE OF 80 MILES

Survey of India Offices Calcutta, December 1906

BANDAR PUNCH

AS SEEN FROM A DISTANCE OF 45 MILES

Out of the 75 peaks of Asia that are known to exceed 24000 feet in height, 42 have been distributed amongst the ten groups above and may be regarded as belonging to the Himalayan system.

TABLE XVII.—Summary of Himalayan peaks.

No. of group.	Name of group.	No. of great peaks exceeding 24000 feet.
I	Kulha Kangri	3
II	Kinchinjunga	7
III	Everest	9
IV	Gosainthan	2
V	. . . .	1
VI	. . . .	3
VII	. . . .	4
VIII	Dhaulagiri	6
IX	Kumaun	3
X	Kashmir	2
	Total number of great peaks on Himalayan range	40
	Total number of Trans-Himalayan great peaks north of Kumaun group.	2
	Total	42

We described on page 10 how few peaks were really peaked in the true sense of the word; and of true peaks there is hardly one that can be accurately described as solitary. Nanga Parbat (26620 feet) is the most famous example of a solitary cone, but even Nanga Parbat has a companion (25572 feet) standing at a distance of a mile and a satellite (23170 feet) within 3 miles.

Gurla Mandhata is often described as a solitary peak, but it has two satellites : one of these, 22846 feet in height, stands 2 miles N. of its principal ; the other is 22673 feet and 3 miles E.N.E.

Kamet appears on the charts to be standing alone on the border of Tibet, but the peak of Mana (23862 feet) is within 3 miles of it.

The accompanying plate contains two drawings by Colonel George Strahan, R.E. That of Nanga Parbat furnishes a fine example of a solitary peak. The other shows the twin peaks of Bandarpunch with their connecting ridge resembling a suspended chain; these twin peaks are 3000 yards apart and 20720 and 20017 feet in height respectively.

Of the great peaks of Asia the thirty-three that stand north of the Indus may be considered as belonging to the Karakoram system.† In the following table they are divided into regional groups. Throughout this system twin peaks are a common form of summit; they are marked with an asterisk in the table. The distinguishing numbers of the several peaks are taken from tables I to V of this paper.

TABLE XVIII.—An analysis of the great peaks of the Karakoram system.

Groups as numbered from east to west.	Position of the group.	Number of great peaks in the group.	The great peaks.	Height.	Position of each peak in the group.	Notes.
				Feet.		
Group XI (Shyok Nubra).	Between Shyok and Nubra rivers.	3	No. 41 . . .	25170		
			„ 55* . . .	24650	5 miles S. E. of No. 41.	
			„ 57* . . .	24590	3 miles S. E. of No. 41.	
Group XII .	20 miles west of group XI.	1	No. 52 . . .	24690		
Group XIII .	35 miles from No. 52.	3	No. 34* K^{10} . .	25400	Within ½ a mile of one another.	
			„ 38* K^{11} . .	25280		
			„ 63 K^{12} . .	24370	13 miles S. E. of No. 34.	
Group XIV (Karakoram).	22 miles west of group XIII.	8	No. 2 K^2 . .	28250		Gasherbrum furnishes the only instance amongst the great peaks of so many as 4 of equal altitude being situated on one ridge. Two of the peaks Nos. 12 and 14 are within 1200 yards of one another, a third No. 16 lies in the alignment 2 miles to the east, and a fourth No. 11 lies two miles to the west.
			„ 11* K^5 Gasherbrum	26470	The Gasherbrum quadruplet comprising 4 great peaks standing on a crescentic line 5 miles long is situated some 11 or 12 miles to the S. E. of K^2.	
			„ 12* . . .	26360		
			„ 14* . . .	26090		
			„ 16* . . .	26000		
			„ 22* Masherbrum	25660	18 miles S. W. of K^2.	Peaks Nos. 22, 24 and 45 are situated in the prolongation of the alignment in which the groups XI, XII and XIII are ranged, but K^2 and the four Gasherbrum peaks are situated on a parallel alignment some 15 or 16 miles to the N.E. It is possible that the summit of the range is corrugated, and that there are two distinct folds, the Gasherbrum peaks standing on the one, the Masherbrum on the other. The Karakoram group is very complicated: its seven peaks lie on the perimeter of an oblong area, which extends for 15 miles, in the direction of the range and for 18 miles astride the range. K^2 is at the northern corner of the oblong, Masherbrum is at the western corner and Gasherbrum at the eastern corner. No great peak has been discovered inside this area.
			„ 24* . . .	25610		
			„ 45 . . .	25110	18 miles S. of K^2. 11 miles S. S. W. of Gasherbrum. 16 miles E. S. E. of Masherbrum.	

† For name "Karakoram" see Section 16 of Part II.

Table XVIII—*continued*.

Groups as numbered from east to west.	Position of the group.	Number of great peaks in the group.	The great peaks.	Height.	Position of each peak in the group.	Notes.
				Feet.		
Group XV (Kunjut).	60 miles west of group XIV.	3	No. 28 . . . . „ 58 . . . . „ 71	25460 24580 24090	 10 miles W. of No. 28. 24 miles W. N. W. of No. 28.	
Group XVI (Hunza Kunji).	22 miles west of group XV.	4	No. 35 . . . . „ 44 . . . . „ 47 . . . . „ 73 Hunza-Kunji.	25370 25118 25050 24044	 2 miles N. N. W. of No. 35. 11 miles E. S. E. of No. 35. 13 miles E. S. E. of No. 35.	There are many peaks of 22000 and 23000 feet in this group. A curvilinear alignment of peaks exceeding 20000 feet can be traced westwards from the Hunza-Kunji group for 80 miles: it is then broken by the Kunar river, but the continuation of the alignment can be traced for a further 60 miles as far as the great group of Tirich Mir.
Group XVII (Tirich Mir).	140 miles west of group XVI.	4	No. 32 Tirich Mir . „ 56 * . . . . „ 65 * . . . . „ 69 Sad Ishtragh .	25426 24611 24343 24171	 10 miles N. of No. 32. 9 miles N. N. E. of No. 32. 26 miles N. E. of No. 32.	To the westward of Tirich Mir no great peaks have been discovered.
Group XVIII	Between the Indus river and the Karakoram range.	3	No. 27 Rakaposhi . „ 60 . . . . „ 68 Haramosh .	25550 24470 24270	 25 miles E. S. E. of No. 27. 32 miles S. E. of No. 27.	This group stands north of the Indus, but south of the Karakoram range: its peaks are separated by so great distances that they can hardly be described as composing one group: they are however all situated on the same range, and are the only great peaks of that range: they can therefore be conveniently classed together. On the frontispiece chart this range has been designated the Kailas range.
Group XIX (Kashgar).	East of the Pamir plateau.	3	No. 42 Kungur . . „ 48 . . . . „ 62 Muztagh Ata .	25146 25046 24388	 7 miles E. S. E. of No. 42. 28 miles S. S. W. of No. 42.	These three peaks are on the Kashgar range (see frontispiece chart); they are isolated, being 140 miles from the nearest group.
Group XX (Kuen Lun).	North-West Tibet	1	No. 66 Kuen Lun .	24306		The only peak of the Kuen Lun range that has been found to exceed 24000 feet in height.

The ten groups of the Karakoram system may now be summarised :—

TABLE XIX.—Summary of Karakoram peaks.

No. of group.	Name of group.	No. of great peaks exceeding 24000 feet.
XI	Shyok Nubra	3
XII	. . . .	1
XIII	. . . .	3
XIV	Karakoram	8
XV	Kunjut	3
XVI	Hunza-Kunji	4
XVII	Tirich Mir	4
	Total number of great peaks on the Karakoram range . .	26
XVIII	Great peaks between the Indus river and the Karakoram range	3
XIX & XX	Great peaks north of the Karakoram range	4
	Total number of great peaks in the Karakoram system . .	33

Colonel Tanner has pointed out that the imposing appearance of a peak depends not on absolute height but on the amount of its slope exposed to view, and he gave the following table of peaks which he had observed, to show the superiority in appearance of Nanga Parbat.

TABLE XX.

Name of peak.	As seen from	Distance.	Height of slope exposed to view.
		Miles.	Feet.
Mount Everest . .	Purnea, Bengal	118	8000
Mount Everest .	Sandakphu on Singalila ridge	90	12000
Makalu . . .	Purnea, Bengal	120	8000
Makalu . . .	Sandakphu	79	9000
Nanga Parbat .	From the right bank of the Indus	40	23000
Tirich Mir . .	On the road from Gilgit to Chitral	40	18000
Rakaposhi . .	Chaprot	40	18000
Kinchinjunga. .	Darjeeling	46	16000

7

THE GEOLOGY OF THE GREAT PEAKS.

In dealing with the great peaks the geologist is at no small disadvantage as compared with the surveyor, whose instruments enable him to work from a distance and to fix with accuracy the position and height of the object of his observation. The geologist, on the other hand, must toil arduously up the mountain sides, examining at close quarters such outcrops of rocks as he can find clear of snow, and, where further progress is barred, must depend for his information on fallen fragments, splintered from the cliffs above and brought down by avalanches and glaciers to form moraines and talus heaps. Thus the composition of the highest peaks is rarely known in any detail, but the general character of the rocks can be ascertained, with a fair approximation to certainty, from observation of the material on their flanks, and from a distant view of the weathering characters and apparent structure of the peaks themselves: it has thus been found that almost all those of 25000 feet or more in height are composed of granite, gneiss, and associated crystalline rocks.

Of the granite there are at least two varieties, a foliated rock composed essentially of quartz, felspar, and biotite (black mica), and a younger non-foliated form containing, in addition to quartz and felspar, white mica (muscovite), black tourmaline, beryl, and various accessory minerals. The former variety was long regarded as a sedimentary rock which had been converted by heat and pressure into gneiss, but its truly intrusive nature was recognised by the late Lieutenant-General C. A. McMahon,* who proved conclusively that the great central gneissose rock of the Himalaya was in reality a granite crushed and foliated by pressure. This rock is frequently pierced by veins of the second or non-foliated variety, and where these run parallel to the foliation planes, they lend to the series a deceptive appearance of bedding and cause it, when seen from a distance, to be mistaken for a mass of stratified deposits. This is a common characteristic of the higher peaks and may be noticed in many of the granitic masses of the great Himalayan range.

Although our experience leads us to assume that all the highest peaks are composed largely of granite, many more observations must be made before this can be positively asserted to be the case. Thus the most important mass of all, the Everest group, is still a blank on our geological maps, and so also is Kulha Kangri in Bhutan. Between these two, however, we know that all the most important peaks are formed of granite. Thus Chumalhari (23930 feet) is composed of foliated (gneissose) granite penetrated by veins of the non-foliated variety, and flanked by the altered representatives of slates and limestones metamorphosed by the granite which has been forced up through them from below. Further to the west, the Kinchinjunga group is also formed of granite,† flanked by metamorphic rocks certainly in part derived from pre-existing

* *Records, Geological Survey of India*, Vol. XV (1882), p. 44. Vol. XVI (1883), p. 129, and *Geological Magazine*, Dec. III, Volume 4 (1887), p. 215.

† E. J. Garwood in D. W. Freshfield's *Round Kangchenjunga* (1903).

sediments but re-arranged and recrystallised by heat and pressure and converted into various forms of gneiss and schist. Owing to the rigid exclusion of British travellers from Nepal, we know little or nothing of the geological characters of the highest mountain in the world, since practically the whole country is still unsurveyed. It is probable, however, that, like Kinchinjunga, the Everest group is composed chiefly of granite and gneiss.

To the west of Nepal we are on surer ground, since both Kumaun and Garhwal have been geologically surveyed. Here again the high peaks, such as Nanda Devi, the Kedarnath group, and Kamet,* are all composed of granite and gneiss with gneiss and schist on their flanks. The same may be said of most of the high peaks of Kashmir, including Nanga Parbat, Rakaposhi, and K2,† while granite is also probably the prevailing rock on Muztagh Ata and the other high peaks of the Kashgar range.

This correspondence between the great elevation and the geological structure of the high peaks appears to be too constant to be attributable to mere coincidence, and we are forced to the conclusion that their exceptional height is due to the presence of granite. This may be explained on two separate grounds, either (*a*) that the superior power of the granite to resist the atmospheric forces tending to their degradation has caused them to stand as isolated masses above surrounding areas of more easily eroded rocks, or (*b*) that they are areas of special elevation.

If now we examine the relationships of the peaks to one another, we find that along certain definite lines the intervening areas are also frequently composed of the same granite as the peaks themselves, and if we follow these definite lines we further find that they constitute the axes of the great mountain ranges. Thus the great eaks lie on more or less continuous and elevated zones composed of granite and crystalline rocks, and since the lower portions of the zones are of the same composition as the peaks themselves, it is difficult to regard the latter merely as relics of a once continuous zone of uniform height, and it seems probable that special elevating forces have been at work to raise certain parts of the zone above the general level of the whole; when once such elevation has been brought about, the disparity between the higher peaks and the intervening less elevated areas would undoubtedly be intensified by the destructive forces at work; the mantle of snow and ice, while slowly carrying on its own work of abrasion, will serve as a protection for the peaks against the disintegrating forces of the atmosphere, whilst the lower unprotected areas will be more rapidly eroded.

By the assumption that the higher peaks are due to special elevatory forces, it is not intended to imply that each peak is the result of an independent movement, for it has already been shown in a previous section of this paper that the peaks occur in well-marked clusters, any one of which may cover an area of many hundred square miles: when, therefore, during the development of the Himalaya as a mighty mountain range vast masses of granite welled up from below, forcing their way through and lifting up

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* C. L. Griesbach, *Memoirs, Geological Survey of India*, Vol. XXIII (1891).

† R. Lydekker, *Memoirs, Geological Survey of India*, Vol. XXII (1883).

the pre-existing rocks above, it is probable that owing to dissimilarity of composition and structural weaknesses in certain portions of the earth's crust, movement was more intense at some points than at others, and that the granite was locally raised into more or less dome-like masses standing above the general level of the growing range: these masses were subsequently carved by the process of erosion into clusters of peaks. Whether the elevatory movement is still in progress it is not at present possible to say, but many phenomena observable throughout the Himalaya and Tibet lead us to infer that local elevation has until quite recently been operative, and the numerous earthquakes still occurring with such violence and frequency forcibly remind us that the Himalaya have by no means reached a period of even comparative rest.

G. I. C. P. O.—No. 96 D. G. S.—14-4-1908.—1,000—E. A.

CHART I

PEAKS OF THE FIRST MAGNITUDE

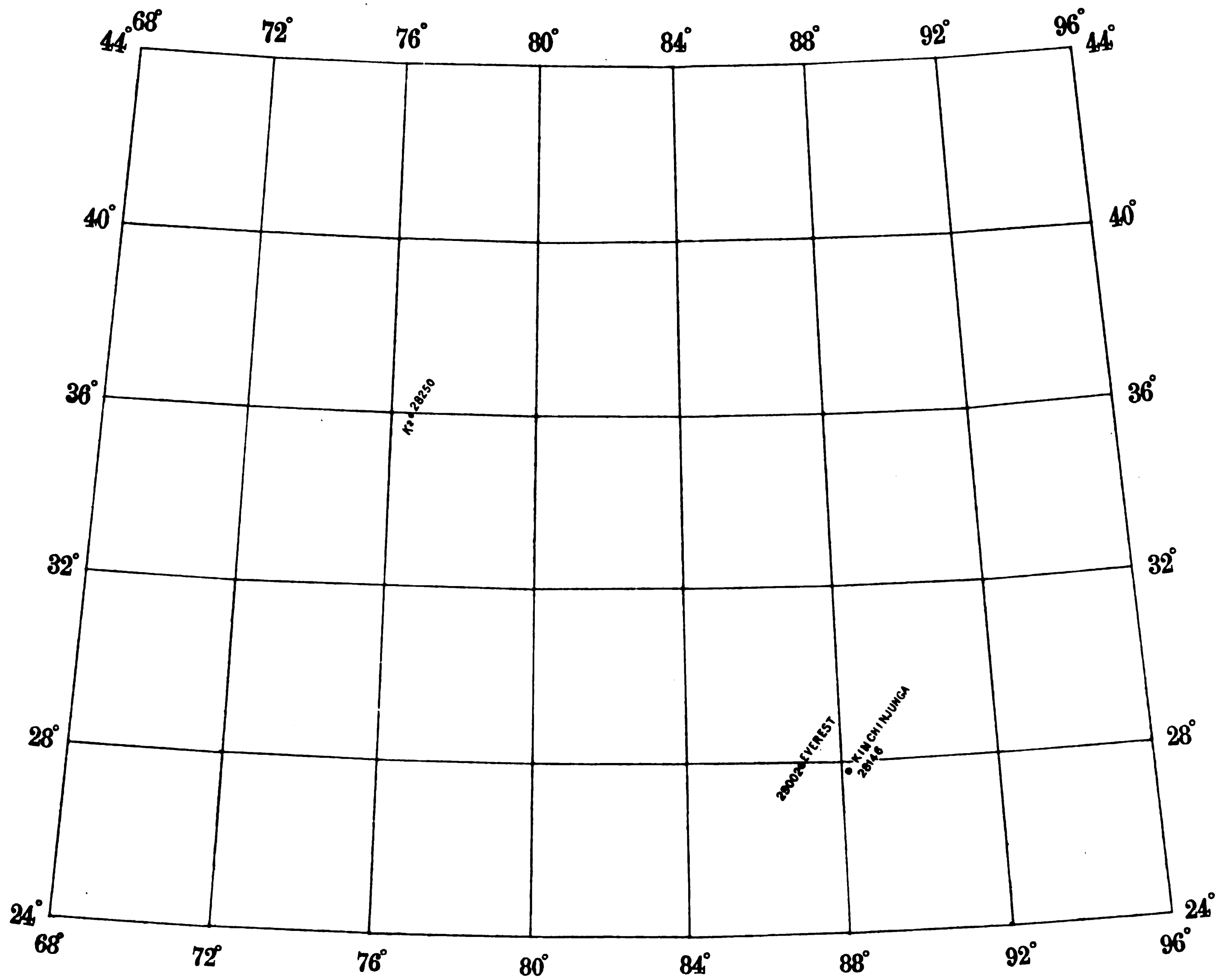


CHART II

PEAKS OF THE SECOND AND FIRST MAGNITUDE

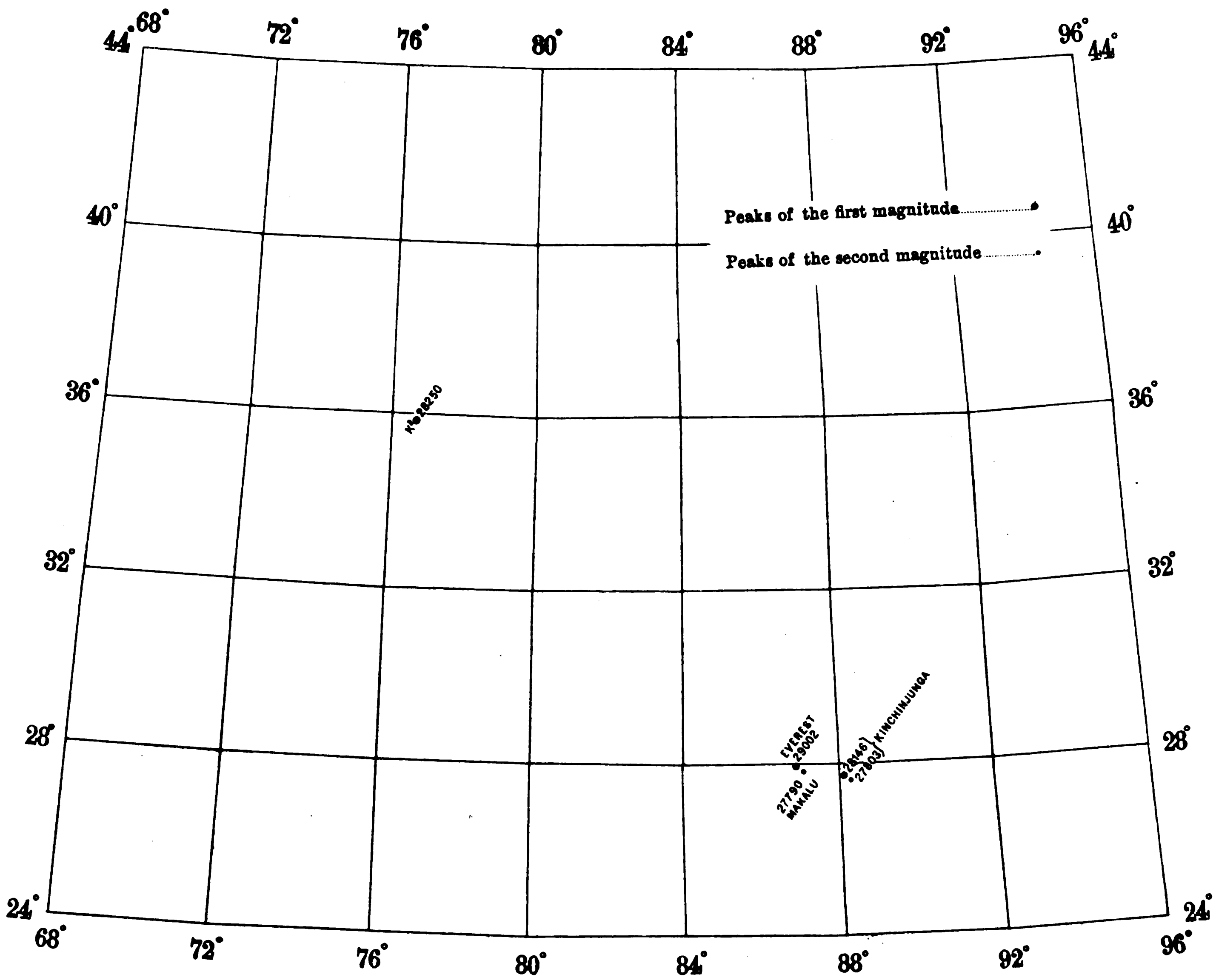


CHART III

PEAKS OF THE THIRD AND HIGHER MAGNITUDES

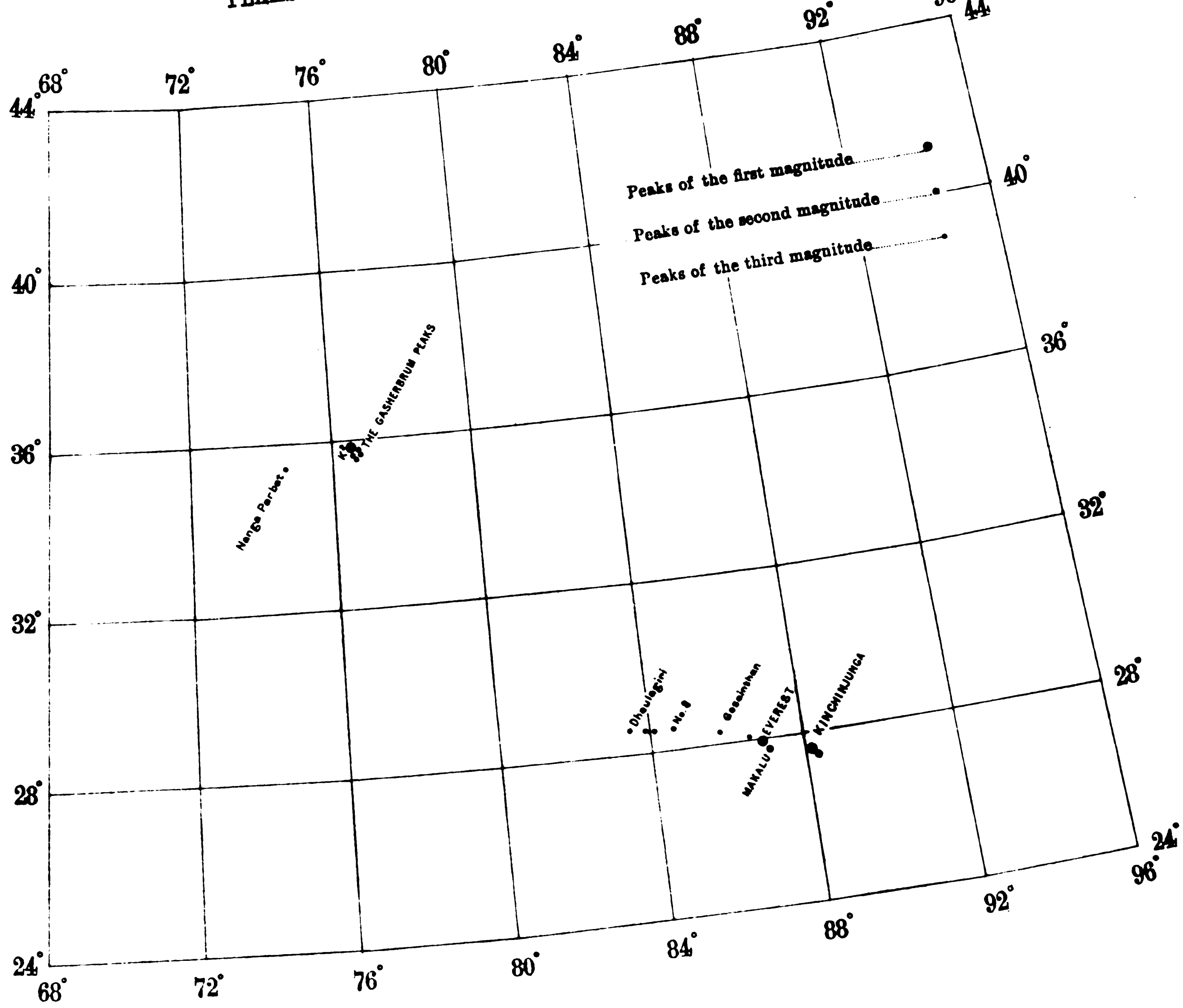


CHART IV

PEAKS OF THE FOURTH AND HIGHER MAGNITUDES

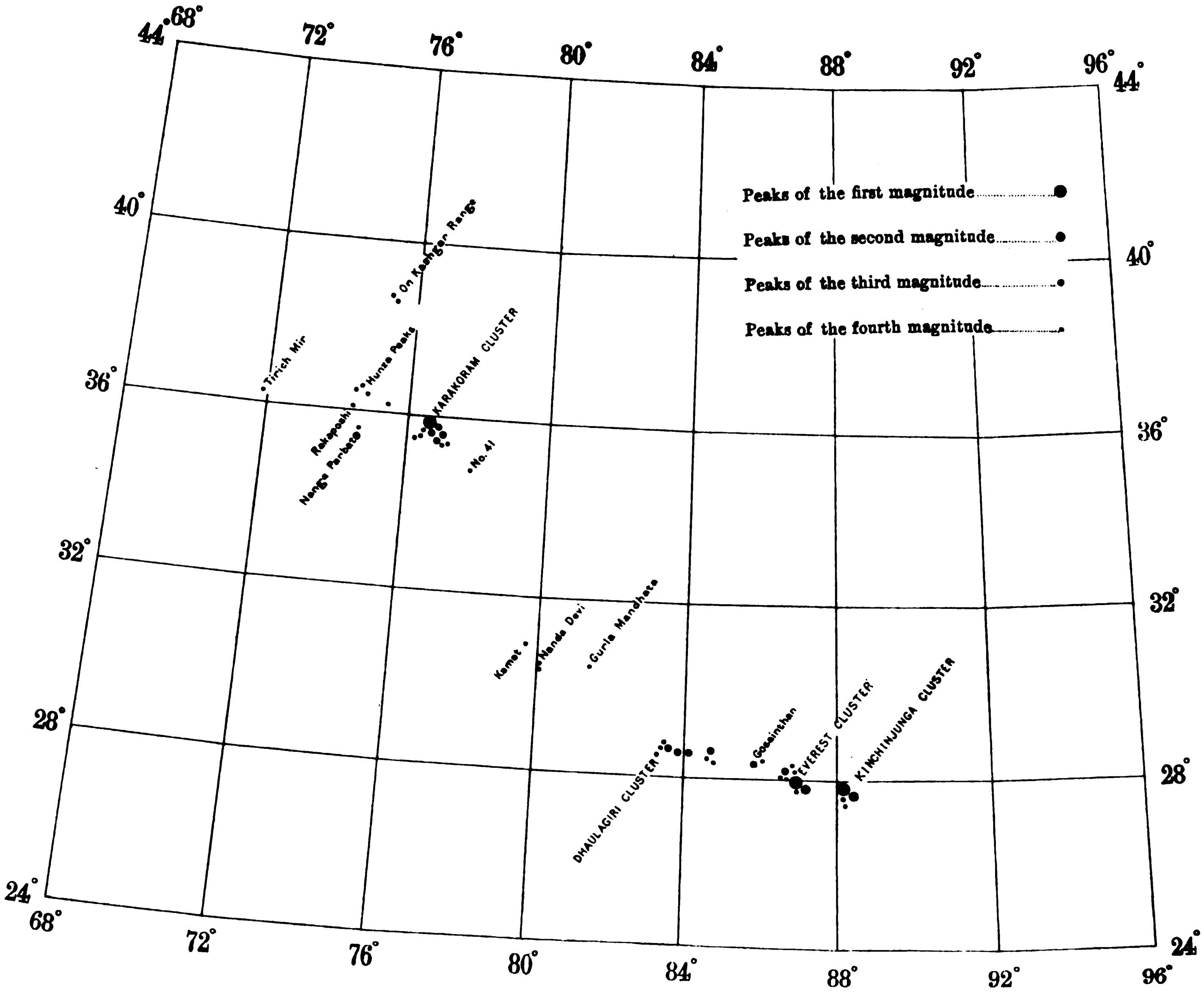


CHART V

PEAKS OF THE FIFTH AND HIGHER MAGNITUDES.

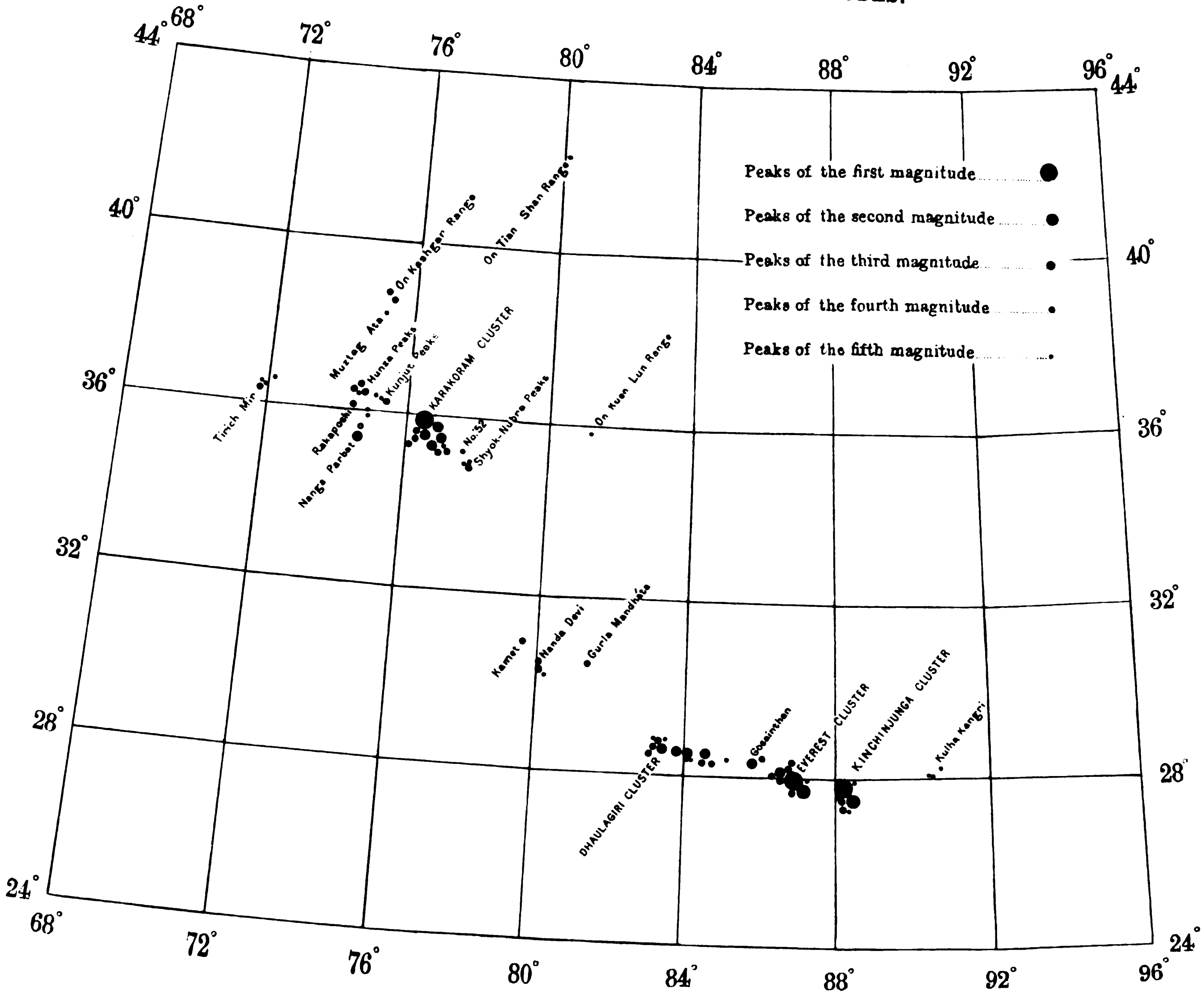


CHART V

PEAKS OF THE FIFTH AND HIGHER MAGNITUDES.

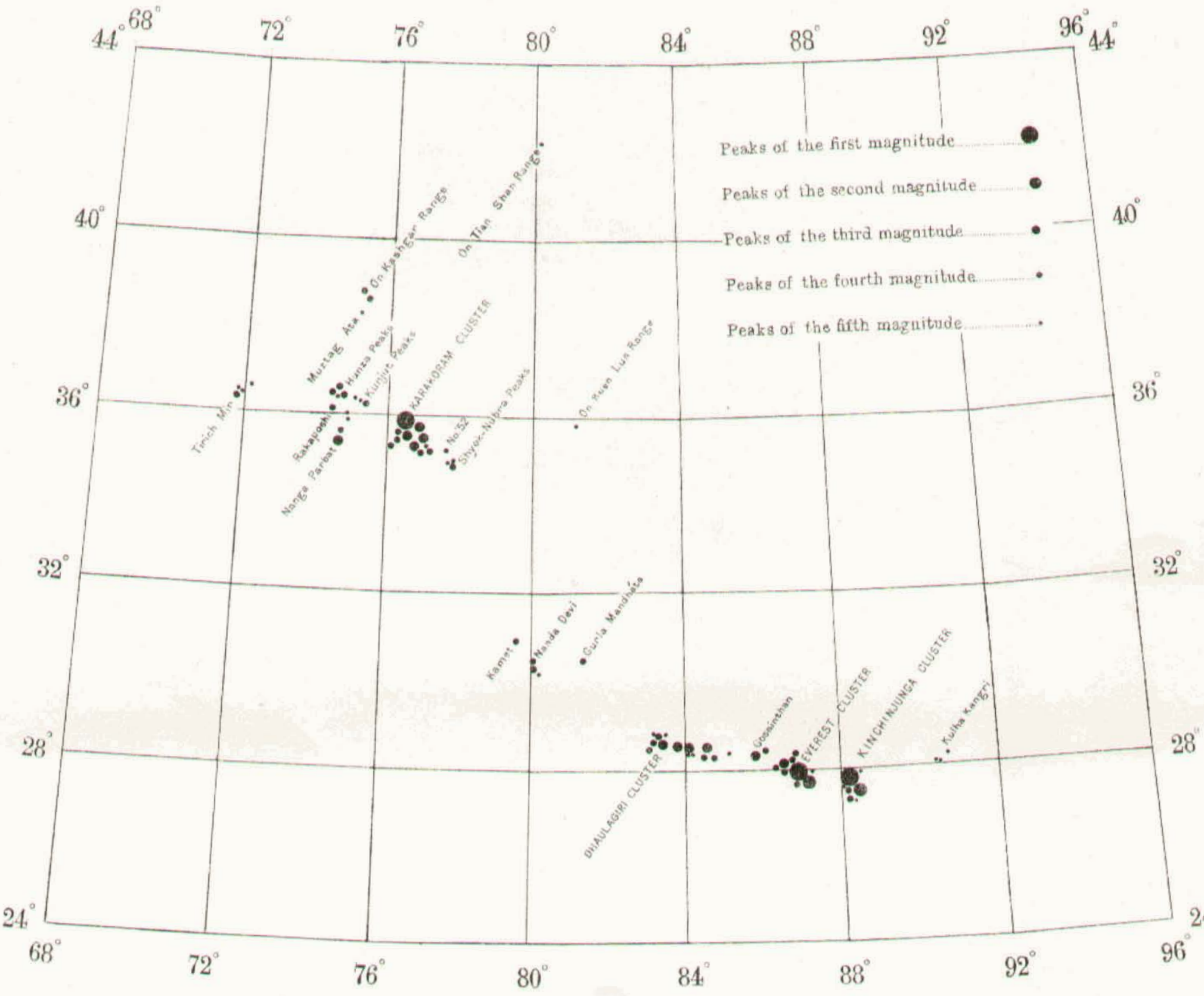
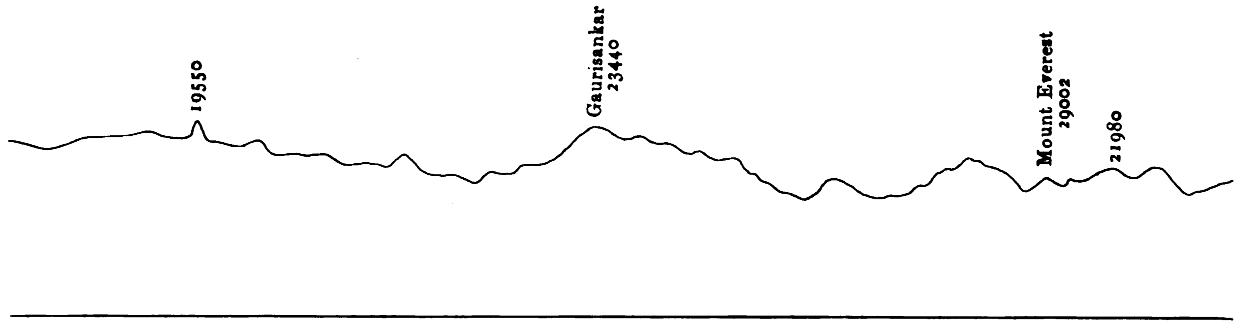
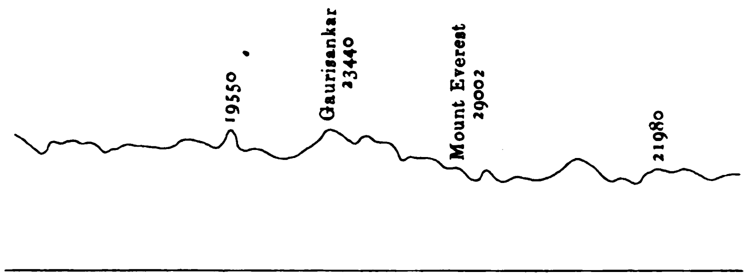


CHART VI

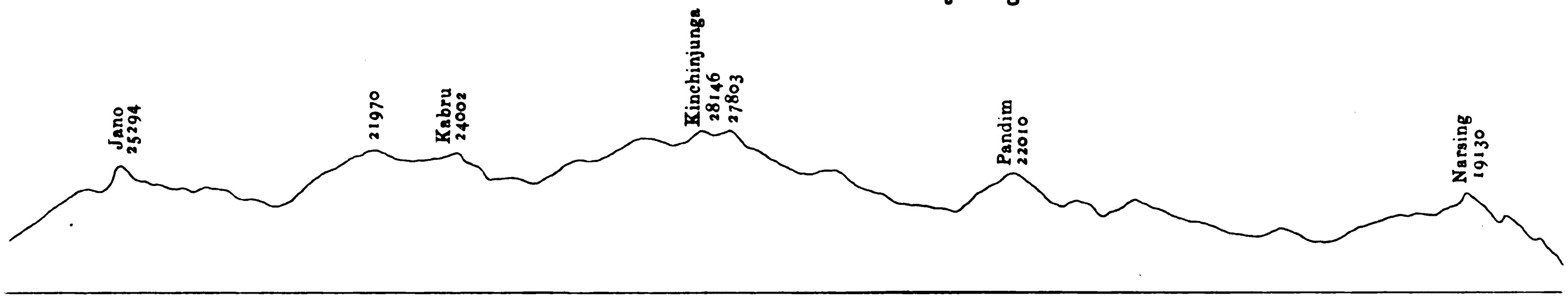
GAURISANKAR and EVEREST as seen from Mahadeo Pokra in Nepal



GAURISANKAR and EVEREST as seen from Kaulia in Nepal



KINCHINJUNGA as seen from Darjeeling



MAKALU and EVEREST as seen from Sandakphu

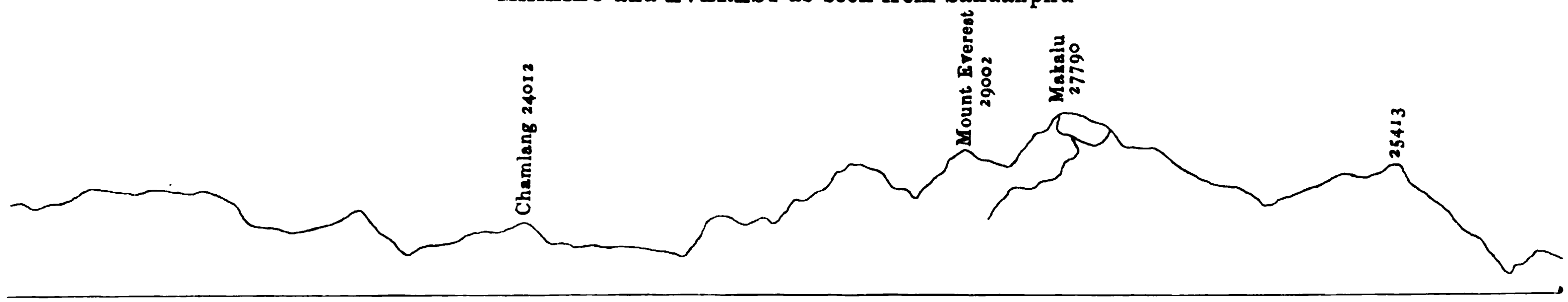
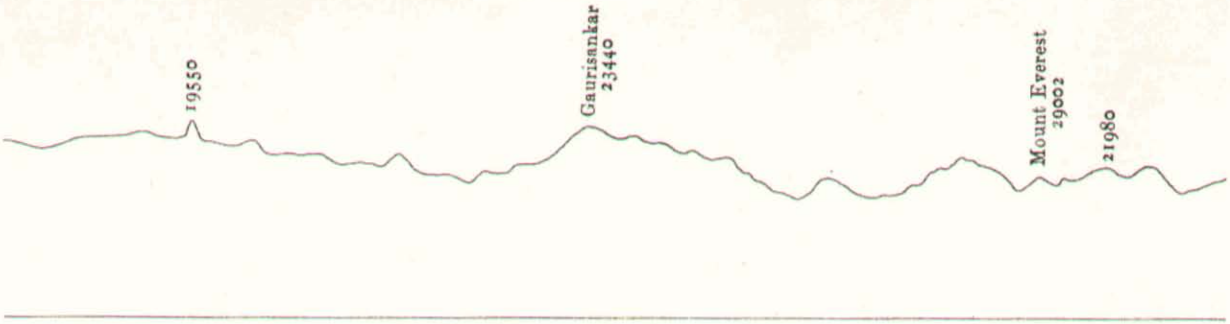
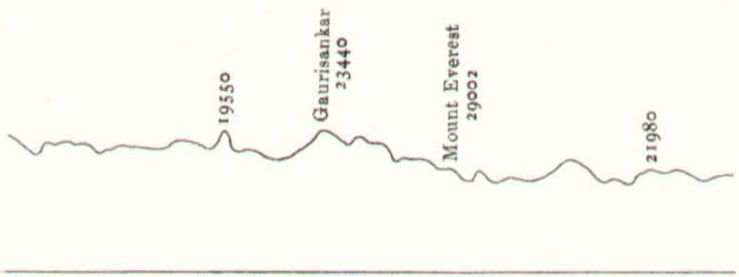


CHART VI

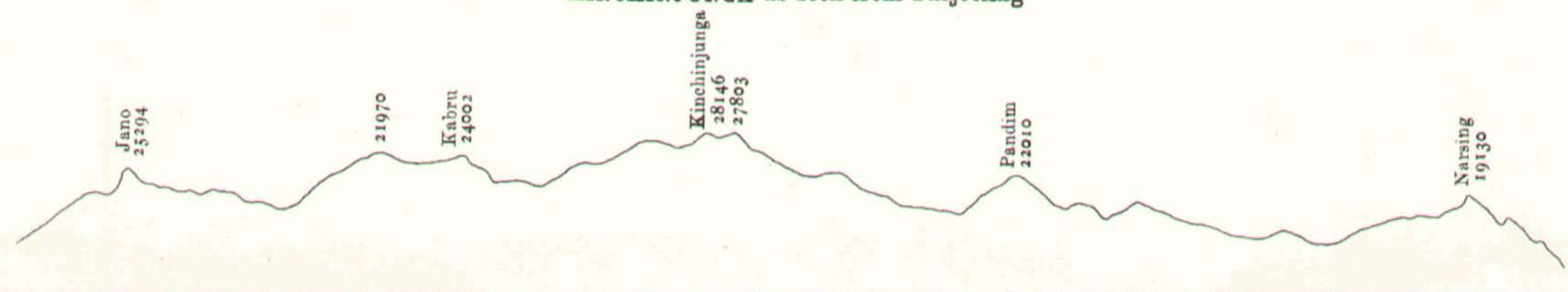
GAURISANKAR and EVEREST as seen from Mahadeo Pokra in Nepal



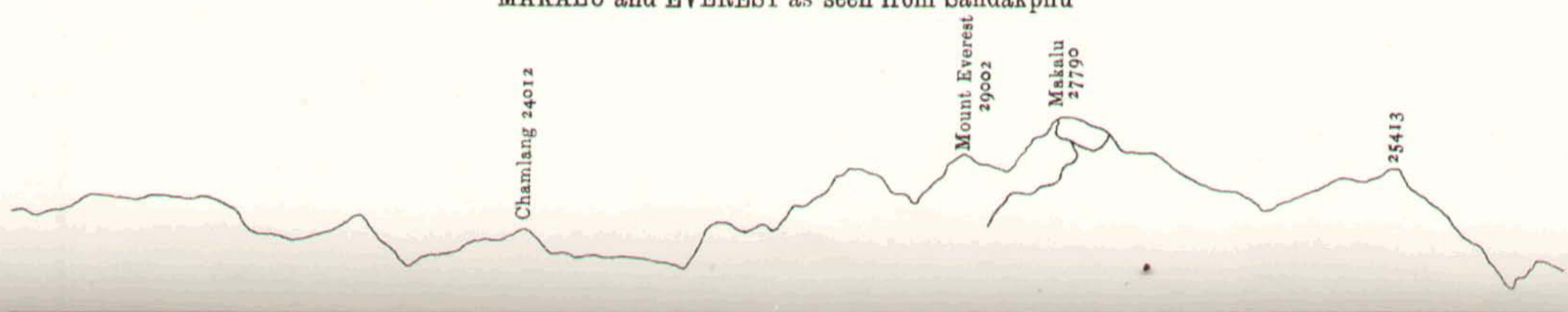
GAURISANKAR and EVEREST as seen from Kaulia in Nepal



KINCHINJUNGA as seen from Darjeeling

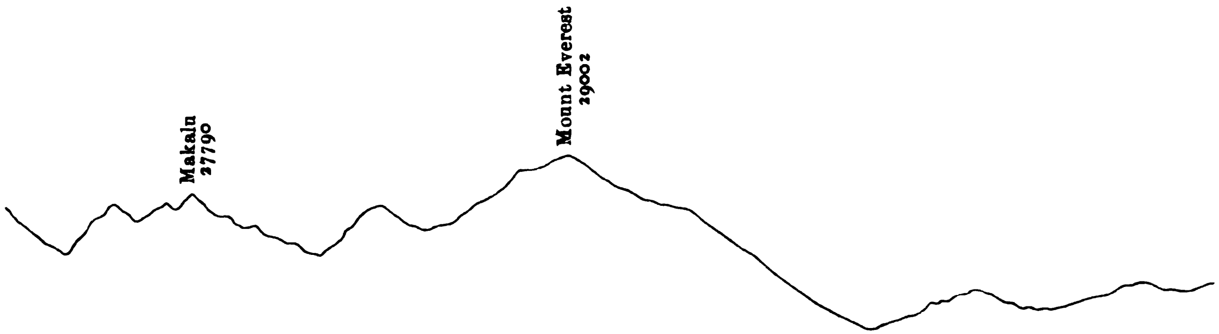


MAKALU and EVEREST as seen from Sandakphu



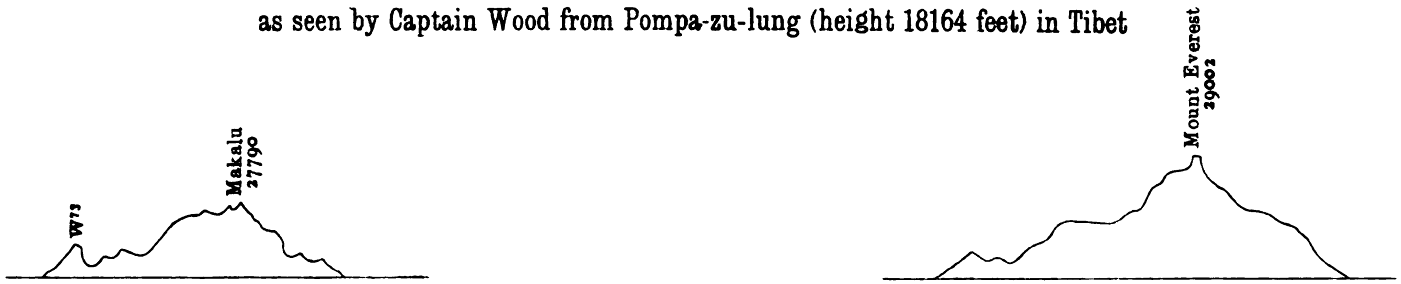
Continuation of **CHART VI**

MAKALU and MOUNT EVEREST as seen from Kam-pa Dzong in Tibet

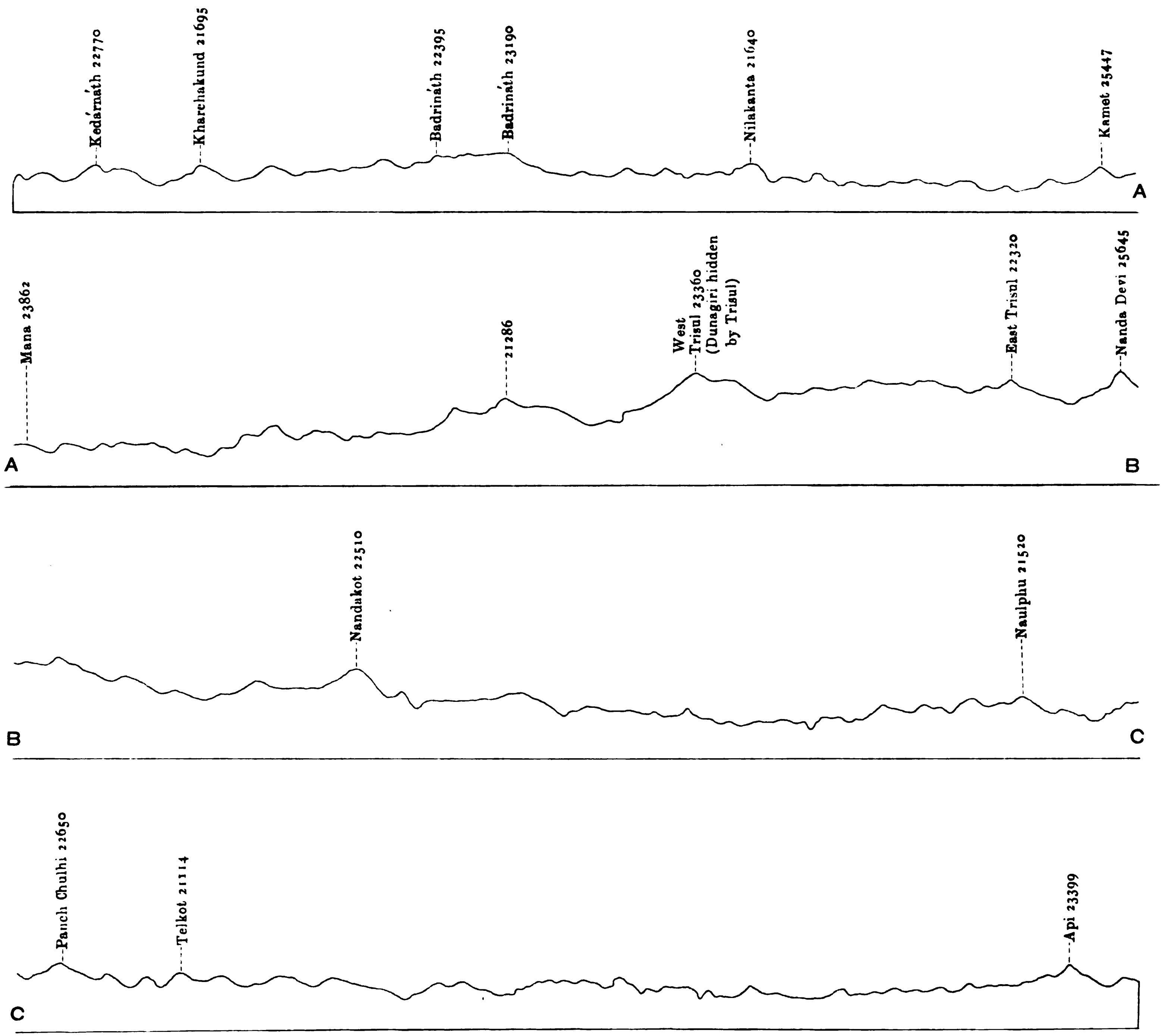


The azimuths and elevations of Mount Everest and Makalu were observed from Kam-pa Dzong by Major Ryder in Season 1903-04

MAKALU and MOUNT EVEREST
as seen by Captain Wood from Pompa-zu-lung (height 18164 feet) in Tibet



OUTLINE of the SNOWY RANGE as seen from Cheena (near Naini Tal)



OUTLINE of the SNOWY RANGE as seen from Cheena (near Naini Tal)

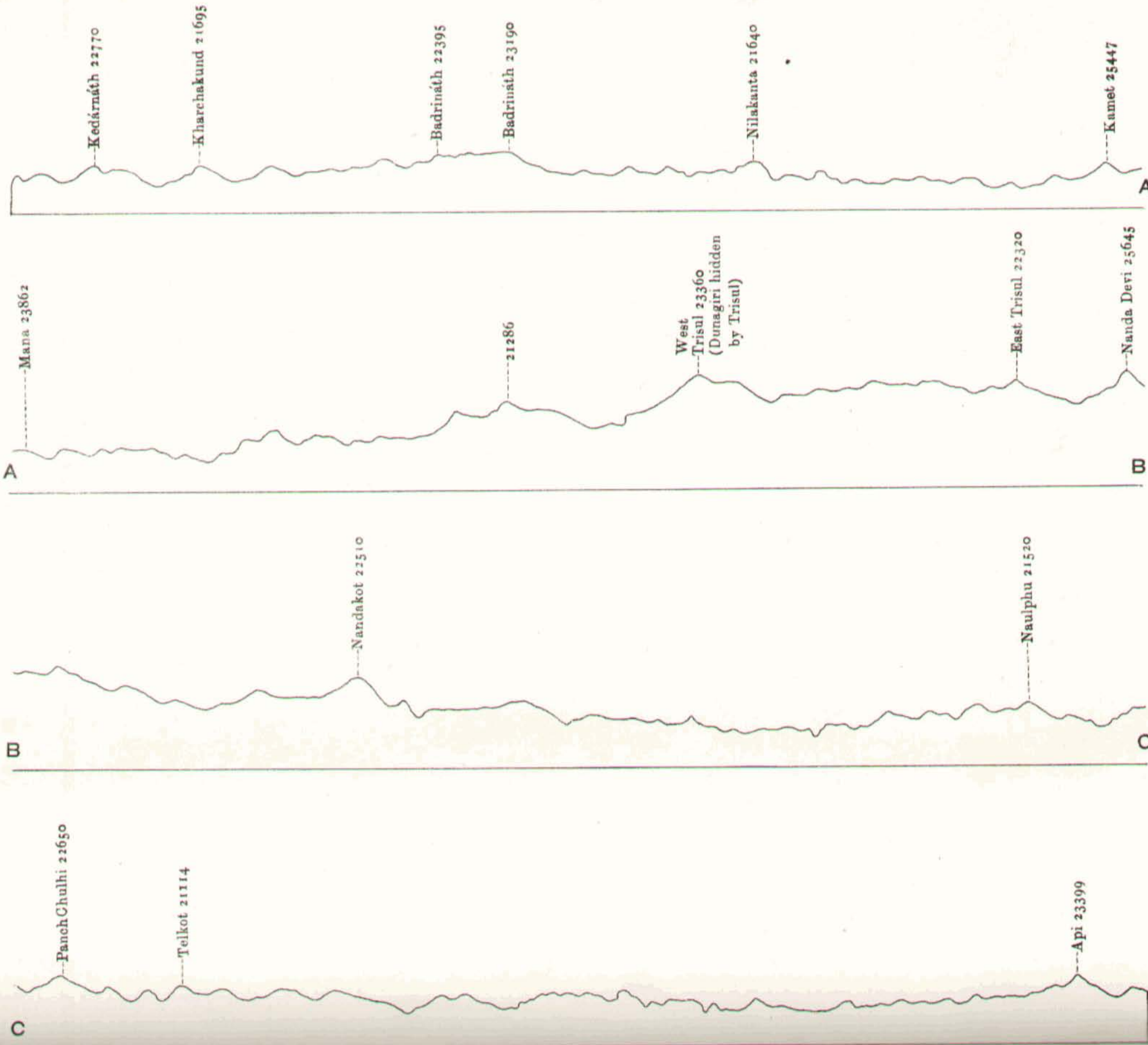


CHART VIII

OUTLINE of the SNOWY RANGE as seen from Landour

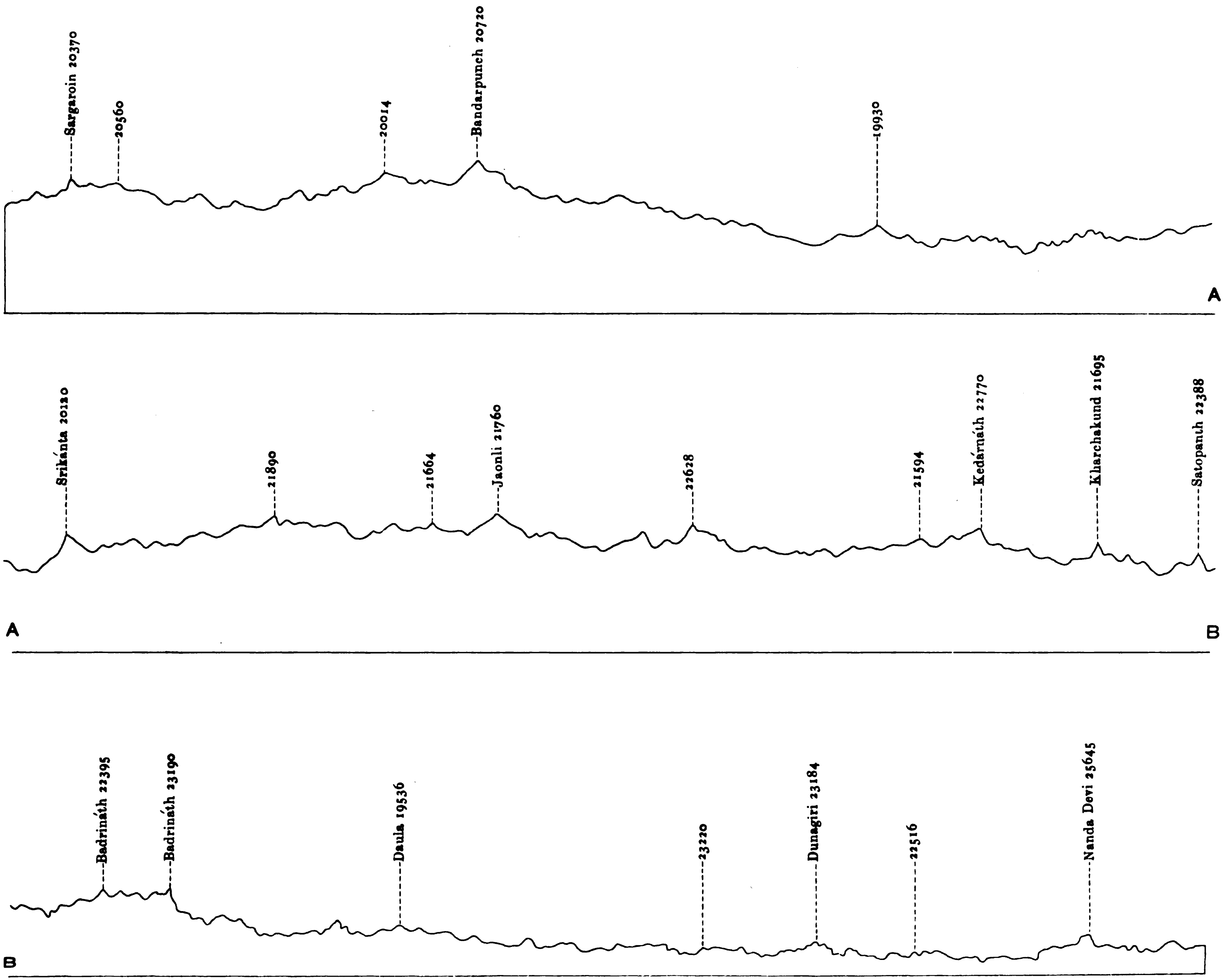
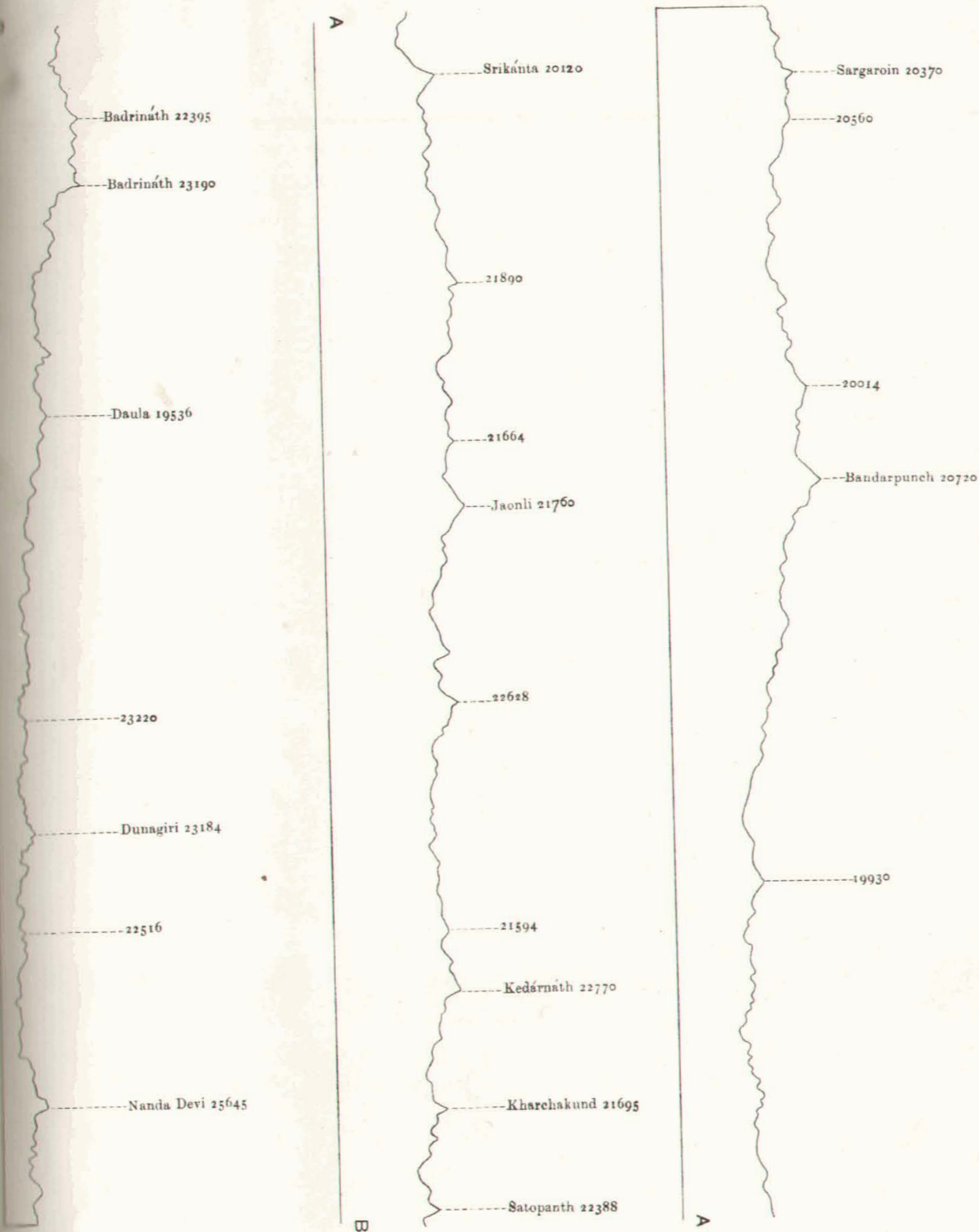


CHART VIII

OUTLINE of the SNOWY RANGE as seen from Landour



A SKETCH

OF THE

GEOGRAPHY AND GEOLOGY

OF THE

HIMALAYA MOUNTAINS AND TIBET

BY

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PART II
THE PRINCIPAL MOUNTAIN RANGES OF ASIA

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PREFACE

IN 1807 a Survey detachment was deputed by the Surveyor General of Bengal to explore the source of the Ganges: this was the first expedition to the Himalaya undertaken for purely geographical purposes. A hundred years have now elapsed, during which geographical and geological information has been steadily accumulating and we have at length reached a stage where there is danger of losing our way in a maze of unclassified detail: it is therefore desirable to review our present position, to co-ordinate our varied observations and to see how far we have progressed and what directions appear favourable for future lines of advance.

The present paper originated in a proposal submitted by the Survey of India to the Board of Scientific Advice at the meeting of the latter in May 1906. The proposal was as follows:—"The number of travellers in the Himalaya and Tibet is "increasing, and a wider interest is being evinced by the public in the geography of "these regions. It is therefore proposed to compile a paper summarising the geographi-"cal position at the present time."

Subject to the modification that the scope of the paper should be geological as well as geographical, this proposal has received the sanction of the Government of India and the work has been entrusted to us to carry out. On the understanding that the paper is intended primarily for the use of the public, we have endeavoured to avoid purely technical details and to present our results in a popular manner.

Our subject has fallen naturally into four parts, as follows:—

PART I.—The high peaks of Asia.

PART II.—The principal mountain ranges of Asia.

PART III.—The rivers of the Himalaya and Tibet.

PART IV.—The geology of the Himalaya.

Though the four parts are essentially interdependent, each has been made as far as possible complete in itself and will be published separately. The first three parts are mainly geographical, the fourth part is wholly geological: the parts are subdivided into sections, and against each section in the table of contents is given the name of the author responsible for it.

PREFACE

The endeavour to render each part complete must be our apology for having repeated ourselves in more places than one: the relations, for instance, of a range to a river have been discussed in Part II, when the range was being described, and have been mentioned again in Part III under the account of the river.

As the mountains of Asia become more accurately surveyed, errors will doubtless be found in what we have written and drawn: it is not possible yet to arrive at correct generalisations and we have to be content with first approximations to truth.

Maps, too large for insertion in such a volume as this, are required for a study of the Himalayan mountains: the titles of maps illustrating the text are given in footnotes and are procurable from the Map Issue Office of the Survey of India in Calcutta. Constable's hand-atlas of India will be found useful.

We are much indebted to Babus Shiv Nath Saha and Ishan Chandra Dev, B.A., for the care with which they have checked our figures and names, and to Mr. J. H. Nichol for the trouble he has taken to ensure the correctness of the charts. Mr. Eccles and Major Lenox Conyngham have been kind enough to examine all proofs, and to give us the benefit of their advice and suggestions. Mr. Eccles has also supervised the drawing and printing of the charts, and we have profited greatly by the interest he has shown in them.

S. G. BURRARD.

H. H. HAYDEN.

March 1907.

CONTENTS OF PART II.

CHARTS OF PART II.

INDEX.

See PART III.

THE PRINCIPAL MOUNTAIN RANGES OF ASIA.

8

ON THE ORIGIN OF MOUNTAIN RANGES.

The floor of a former Tibetan sea has been raised and wrinkled.

THE surface of Central Asia appears to consist of two primary elevations of the crust, separated by a trough-like depression; the southern elevation is the plateau of Tibet, the northern is the Tian Shan chain, the intervening depression is the Tarim basin (see frontispiece, Part I). A second trough is to be seen south of the Tibet plateau, separating that plateau from the ancient Vindhya mountains; it is now filled with alluvium and constitutes the plains of Northern India.

These two wide elevations of the crust and their complementary depressions form the basis of the mountains of Asia.

Until a comparatively recent date in the geological time-scale—the middle tertiary epoch—all the northern part of what is now the Himalaya, and probably the whole of Tibet were covered by a great sea,* in which deposition of sediment had continued for a vast period. At length, owing to forces, the origin of which we can at present only conjecture, a period of crust-movement set in and the floor of the Tibetan sea began gradually to rise and to be thrown into a series of long parallel wave-like folds.

As the crests of the earth-waves rose from the waters of the sea, they were eroded by rain and weather, and the rising land became broken and irregular : drainage basins were carved out of its flanks and a river system, composed of "transverse" valleys, was gradually developed. As elevation continued, the troughs of the folds emerged and a series of "longitudinal" valleys was established at right angles to the transverse valleys and parallel to the longitudinal axes of the folds. From a combination of the concurrent processes of elevation and erosion, the existing mountain systems of the Himalaya and Tibet have been slowly evolved. As denudation has proceeded, deeper and deeper parts of the crust have been laid bare, but the forms of many folds can still be traced and the trends of their longitudinal axes followed for long distances. The folds, although analogous to waves, more nearly resemble the breakers on a beach than the swell of the open sea; the form of their surface is rarely that of a simple arch and trough; fold has been superimposed on fold, arches have been overturned until they are almost horizontal, and whole areas have been so distorted and crumpled, that the details of structure can only be unravelled with difficulty. Where the stress has exceeded the breaking-strain of rock, the structure has been com-

* This old sea of a previous geological age once covered much of Europe as well as Central Asia and has been named by Suess the "Tethys," *Natural Science*, Vol. II (1893), p. 183.

plicated by fracture; parts of the crust have in some cases subsided, and in others been moved horizontally. Nor are these the only causes of complexity, for along many of the planes of weakness and fracture molten material has been forced up from below, and has partly absorbed the original sediments.

The forces that raised the mountains.

Though the origin and nature of the forces which produced the Himalayan mountain system are not subjects which fall within the scope of this paper, it may not be out of place to allude briefly to the more important theories that have been put forward to explain the cause of folding.

The great series of parallel plications in Asia are supposed to have been caused by a horizontal thrust from the north: the sediments of the Eurasian sea were forced against the northern coast of the once continuous Indo-African continental mass which stood like a buttress in the path of the advancing earth-waves. The following hypotheses among others have been advanced to account for the origin of such a thrust:—

(*a*) Contraction of the earth.
(*b*) Disturbance of isostasy.
(*c*) Change in the rate of the earth's rotation.

(*a*) *Contraction of the earth.*—This hypothesis is based on the assumption that the earth as a whole is contracting in volume, owing to loss of heat or other causes, and that the rate of contraction of the inner nucleus is greater than that of the crust; the latter is thus left unsupported and becomes wrinkled, when adapting itself to its reduced core. Although this theory has met with wide acceptance, it has been adversely criticised by many authorities chiefly on the ground of the inadequacy of any known cause—whether it be gravitation or loss of heat—to produce contraction on a sufficiently large scale to account for the observed folding.*

The extent to which the surface of the earth has been contracted by folding appears to be considerable; it has, for instance, been calculated that the folds of the Alps represent a contraction of 74 miles, and it has been roughly estimated, that the original surface of Asia has been shortened by wrinkling between Siberia and India by at least 100 miles, and by possibly as much as 400.† Estimates of the contraction of the surface of the earth from the observation of folds are, however, of doubtful value. Even in areas of which the structure is known in greatest detail, the problem cannot be solved by simple measurements, for folds of strata have, in certain cases, been found to indicate stretching rather than contraction, and it is impossible to tell how far the one effect has balanced the other.‡

(*b*) *Disturbance of isostasy.*—This hypothesis was put forward by Captain C. E. Dutton in the year 1889.§ The term "isostasy" may be most suitably explained in

* *Vide* Rev. O. Fisher's *Physics of the Earth's Crust.*

† In the Sub-Himalaya C. S. Middlemiss found a contraction of 8 miles in 19. *Memoirs, Geological Survey of India*, Vol. XXIV, Part 2, p. 77.

‡ In the Henry Mts., G. K. Gilbert found that a bed of sandstone had been stretched by 300 feet in a distance of three miles. *Report on the Geology of the Henry Mts., U. S. Department of the Interior*, 2nd Edition (1880), p. 75.

§ *Bull. Phil. Soc., Washington*, Vol. XI (1892), pp. 51-64.

Dutton's own words: "If the earth were composed of homogeneous matter its normal "figure of equilibrium without strain would be a true spheroid of revolution; but if hetero-"geneous, if some parts were denser or lighter than others, its normal figure would "no longer be spheroidal. Where the lighter matter was accumulated there would "be a tendency to bulge, and where the denser matter existed there would be a tendency "to flatten or depress the surface. For this condition of equilibrium of figure, to which "gravitation tends to reduce a planetary body, irrespective of whether it be homo-"geneous or not, I propose the name *isostasy*. We may also use the corresponding "adjective *isostatic*. An isostatic earth, composed of homogeneous matter and without "rotation, would be truly spherical. But if the earth be not homogeneous, if some "portions near the surface be lighter than others, then the isostatic figure is no longer "a sphere or spheroid of revolution, but a deformed figure bulged where the matter is "light and depressed where it is heavy."

The presence in mountain ranges of masses of shallow-water deposits, having a vertical thickness of many thousand feet, without break of continuity, proves that during vast periods of time deposition of sediment took place in seas of which the depth remained constant; this could only occur if the sea-floor continued to sink *pari passu* with the deposition of sediment. Observations have also shown that the adjacent land surfaces, from which the sedimentary material was being taken, were gradually rising and Captain Dutton was led to conclude * that "these subsidences of accumulated "deposits and these progressive upward movements of eroded mountain platforms "are, in the main, results of gravitation restoring the isostasy, which has been disturbed "by denudation on the one hand and by sedimentation on the other"; that is to say, the eroded portion becomes lighter and rises while the loaded area becomes heavier and sinks, isostatic equilibrium of the crust of the earth being analogous to hydrostatic equilibrium in a fluid. A cause has thus been suggested for the sinking of the sea-floor on the one hand and the rising of the land on the other; but in order to explain the folding of the deposits laid down, it is necessary to take a step further and assume, as Dutton has done, that as sediment accumulates, the lower layers, owing to the pressure of the overlying material, acquire a certain amount of plasticity, and that there is produced "a true viscous flow of the loaded littoral inward upon the unloaded "continent"; such a process might tend to form long parallel plications following the trend of the coast-line. The theory of isostasy however does not account for the rise of the sea-floor and its conversion into a continental mass; in fact, as enunciated by Dutton, it tends rather in the opposite direction, and its author expressly stated that "the theory of isostasy offers no explanation of these permanent changes of level."

So far as the Himalaya are concerned there are grounds for believing that isostasy is operative and has been an important factor in mountain-building at least during the later stages of growth of the Siwalik range,† but the hypothesis in its present form

* *Op. Cit.*, p. 56.

† Rev. O. Fisher: *Physics of the Earth's Crust* (1889), and
C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, Part 2 (1889).

undoubtedly seems inadequate to account for the uplift of the northern ranges and of the Tibet plateau.

(c) *Change in the rate of the earth's rotation.*—The rate of the earth's rotation was formerly greater than it is now and, as the figure of a rotating body depends on its rate of rotation, any change in the latter will be accompanied by a change in the former. Retardation of the rate of rotation produces a more perfect sphericity, and tends to reduce both the excess of matter at the equator as well as the deficiency at the poles. The strains thus set up might produce a wrinkling of the crust, but can hardly be held to account for the general plication of the surface of the earth.

Other theories have been propounded to explain the origin of mountain ranges, but all are open to objections. Theories, that attribute surface-folds to changes in the position of the earth's axis, cannot be given any weight, for although such changes are known to take place, they have so far been found to be very small.* The theory ascribing the elevation of the sea-floor to the expansion, which it undergoes from heat when it becomes buried under layers of sediment, has been fully discussed and discarded by Middlemiss.†

* Prof. Albrecht: *Astron. Nach*, No. 3619, abstracted in *Nature*, Vol. 58 (1898), p. 42.

† C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, Part 2 (1890).

9

OBSERVATIONS OF THE PLUMB-LINE AND PENDULUM.

Observations of height cannot be trusted to show the original axial alignment of a mountain range. In the case of a recent range like the Siwalik, the highest peaks do perhaps overlie the axis of elevation, but in the course of years rain and rivers disfigure the original form to such an extent, that when ranges are old, their highest points afford no clue as to the original configuration. Geologists have often found from examinations of the lie of rocks, that a row of peaks, which appears to trigonometrical observers to be a range, marks the line of a former valley, and that the original hills on either side have all been washed away.

Just as geological studies of rocks have upset conclusions derived from surface measurements, so have observations of the plumb-line and pendulum shown that the structure of mountains is more complex and deep-rooted than investigations of surface rocks would lead us to suppose.

A plumb-line, as is explained in Part I, is a string hanging under the influence of gravity. A cord stretched by a hanging weight is forced to assume a vertical position by the attraction of the earth upon the weight, but if a mountain is situated on one side, and a flat plain or deep sea on the other, the plumb-line does not coincide with the normal to the spheroidal surface of the earth but is deflected towards the excess of mass. If the crust of the earth were homogeneous, and if no mountains nor hollows existed at the surface, the plumb-line would everywhere coincide with the normal.*

The earth is so large compared with mountains, that attractions exercised by the latter have but slight influence upon hanging weights, and deflections of the plumb-line are always small. Nevertheless deflections do exist, and by studying them we are able to calculate the excesses and deficiencies of mass hidden in the crust.

In many places in Southern India the plumb-line undoubtedly coincides with the normal, but deflections of 3″ and 4″ are also common. Near Bangalore a deflection of the plumb-line of 7″ towards the south has been discovered; at Deesa one of 8″ towards the north, and at Bombay one of 10″ towards the north. At none of these places are there mountains sufficiently high or near to cause so large deflections of gravity, and the sources of disturbance must be subterranean.†

Between 1830 and 1840, when the trigonometrical survey was first extending its operations across the plains of Northern India, Sir George Everest found that the attraction of the Himalaya mountains was not appreciable, even when they were actually in view. Everest's station of Kaliana near Muzaffarnagar is 40 miles from the outer

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* For definitions of the words *normal* and *vertical* see Part I, footnote to page 24.

† Deflections of the plumb-line are determined from astronomical observations, and are relative to some assumed datum. The values given in this paper are taken from *The intensity and direction of the force of gravity in India, Philosophical Transactions of the Royal Society*, Series A, Vol. 205 (1905).

hills and 120 miles from the line of great peaks, and at this point the plumb-line is only deflected 7″ towards the Himalaya.

In 1852 Archdeacon Pratt of Calcutta calculated what the effect of Himalayan attraction should be at Kaliana according to the laws of gravitation, and he found that the plumb-line there ought to be deflected 27″ towards the north. Seeing how large a deflection was indicated from theory, and how small the actual deflection proved to be, Pratt devised his famous hypothesis of "mountain compensation". He explained the difference between the theoretical and the actual deflection by assuming the mountains to be "compensated". In all parts of the earth's crust, he said, the amount of matter is the same. "In the land portions of the earth's surface," to quote his own words, "there is a deficiency of matter below the sea-level approximately "equal to the amount of matter above it : below ocean beds there is an excess of "matter approximately equal to the deficiency of matter in the ocean as compared "with rocks." Pratt's theory, like the modern theory of isostasy, assumed that mountains were being supported not by the rigidity of the crust but by the buoyancy of light matter floating in a denser medium.

As the operations of the trigonometrical survey have come to be extended to the foot of the Himalaya, it has become increasingly evident, that these mountains are not compensated—at any rate not completely—by underlying deficiencies of density. At the *foot* of the hills north of Kaliana great deflections of the plumb-line have been observed—at Nojli 13″, at Dehra Dun 37″, at Rajpur 47″: at Siliguri in Bengal the deflection is 23″. Throughout the *outer* Himalaya themselves large deflections prevail,—at Kurseong 51″, at Tonglu 42″, at Birond 44″, at Mussooree 37″. These deflections all go to show that the Himalaya mountains must be exercising a more powerful attraction than the observations at Kaliana and other similarly situated places had led Pratt to believe.

The problem that confronted Pratt was,—*Why do the Himalaya exercise no attraction at Kaliana?* The problem that has confronted his successors has been,—*How can the Himalaya exercise a powerful attraction at Dehra Dun, and yet cause but a small deflection at Kaliana, only* 55 *miles south of Dehra Dun?*

If the attraction of the Himalaya is capable of producing a deflection of 37″ at Dehra Dun, it will produce a deflection of 18″ at Kaliana, and one of 1·5″ at Cape Comorin, the southernmost point of India.* The attraction of a great mountain mass must decrease with distance in accordance with the laws of gravitation, and cannot die suddenly away.

It was suggested by General Walker that the deficiencies of matter underlying the Himalaya were situated so many miles below the surface, that their effect on a plumb-line at Dehra Dun was small and at Kaliana great—that their presence compensated the visible Himalaya when observed from the distance of Kaliana, but not when observed from a near station like Dehra Dun. But this hypothesis did not satisfy mathematical tests; the actual effects of compensating deficiencies were calculated for a great

* *Monthly Notices, Royal Astronomical Society*, January 1902.

many assumed depths, and no depth could be found, at which the deficiency would be compensating for Kaliana and not for Dehra Dun.*

The explanation of the observed phenomena, that is now accepted, is that an invisible chain of excessive density, parallel with the Himalaya, is underlying the plains of northern India: this buried chain is 150 miles distant from the foot of the mountains; at stations like Kaliana the southerly attraction of this chain is counteracting the northerly attraction of the Himalaya; at Dehra Dun, where the Himalaya are near and the buried chain is distant, the effect of the latter is not very apparent, but as we move southwards, the attraction of the visible mountains to the north decreases, and that of the invisible mass to the south increases. The suddenness with which deflections of the plumb-line decrease as we recede from the Himalaya is due to the presence of a southern and subterranean source of opposite attraction.

Observations of the Pendulum.

In 1903 pendulum observations were commenced in India in order to test the correctness of the conclusions that had been drawn from observations of the plumb-line.† The plumb-line shows the direction in which gravity is acting, the pendulum shows the strength with which it pulls. Deflections of the plumb-line are due to the *horizontal* attractions of surrounding masses: observed differences in the strength of gravity are due to variations in the *vertical* attraction of underlying masses.

When a pendulum is being observed, the time in which it makes one vibration has to be measured: if this time is shorter than the normal time, gravity is strong in that locality; if the time is longer than the normal time, it is a proof that gravity is weak. If the force of gravity is found to possess exceptional strength, there must exist an excess of matter in the crust underneath the pendulum station: and if gravity is exceptionally weak there must be subterranean deficiencies of density. Thus the pendulum indicates to what extent the local crust differs from the normal crust in density.

The following tables show the results obtained from pendulum observations during the last three years‡:—

TABLE XXI—Stations in the Himalaya.

Pendulum station.	Height of station = visible excess of rock.	Invisible deficiency of rock as revealed by the pendulum.	Resultant excess of rock in the crust.
	Feet.	Feet.	Feet.
Kurseong	4915	—3700	+ 1215
Darjeeling	6966	—4070	+ 2896
Sandakphu	11766	—4180	+ 7586
Mussooree (Camel's Back)	6924	—3100	+ 3824
Mussooree (Dunseverick)	7131	—3270	+ 3861
Simla	7043	—3380	+ 3663

* *Monthly Notices, Royal Astronomical Society*, January 1902, page 183, and *Survey of India, Professional paper No. 5*, 1901.

† *Philosophical Transactions of the Royal Society*, Series A, Vol. 205 (1905).

‡ See Major Lenox Conyngham's reports on the pendulum operations in India, 1903 to 1906.

It will be noticed in the third column that a *deficiency* of rock, averaging 3600 feet, underlies each of the Himalayan stations. The compensation is, however, not complete, and the last column shows the heights at which the stations would be situated, if the crust were everywhere of the same density.

TABLE XXII—Stations near the foot of the Himalaya.

Pendulum station.	Height of station = visible excess of rock.	Invisible deficiency of rock as revealed by the pendulum.	Resultant deficiency of rock in the crust.
	Feet.	Feet.	Feet.
Siliguri	387	—3840	—3453
Dehra Dun	2241	—3440	—1199
Kalka	2202	—2386	— 184
Pathankot	1088	—5055	—3967

The hidden deficiencies underlying these four submontane stations average about 3600 feet; the last column shows, that in every case the subterranean deficiency more than compensates the excess above sea-level, and that on a homogeneous crust the whole submontane region would be situated below sea-level.

TABLE XXIII—Stations between 20 and 30 miles from the Himalaya.

Pendulum station.	Height of station = visible excess of rock.	Invisible deficiency of rock as revealed by the pendulum.	Resultant deficiency of rock in the crust.
	Feet.	Feet.	Feet.
Jalpaiguri	268	—2700	—2432
Ludhiana	833	—1306	— 473

Jalpaiguri of table XXIII is in the plains of Bengal, and 25 miles from Siliguri of table XXII: the underlying deficiency of matter has decreased by 1140 feet in those 25 miles.

Ludhiana of table XXIII is in the plains of the Punjab and is more distant from the Himalaya than Pathankot or Kalka of table XXII by 25 miles: the deficiency under Ludhiana is 1080 feet less than under Kalka, and 3749 feet less than under Pathankot.

TABLE XXIV—Stations between 80 and 120 miles from the Himalaya.

Pendulum station.	Height of station= visible excess of rock.	Invisible excess of rock as revealed by the pendulum.	Resultant excess of rock in the crust.
	Feet.	Feet.	Feet.
Kisnapur	113	+ 1000	+ 1113
Mian Mir	708	+ 170	+ 878
Ferozepore	647	+ 227	+ 874

Kisnapur is in Bengal, Mian Mir and Ferozepore in the Punjab. Below these stations the crust is of excessive density. If the crust were made homogeneous, the stations of table XXIV would all stand higher above sea-level than they do at present.

The pendulum has therefore corroborated the conclusions which were drawn from observations of the plumb-line. In Northern India there are three variations in the crust, where the eye-observer notices but two forms of surface. The eye-observer sees a hilly region on the north and flat plains to the south: the pendulum observer finds three parallel zones—the zone of mountains on the north, the zone of deficiency in the centre, the zone of excess to the south.

From determinations of horizontal attractions the observer of the plumb-line was led to the conclusion that a great chain of density lay buried underneath the plains of northern India, and now the pendulum observer has arrived at the same result from an investigation of vertical attractions.

If when observing near the foot of the Himalaya, we rely upon our eyes or upon our levels, we become aware of mountains on the one side of us but none on the other: but if we disregard the evidence of eye and of level, and believe our pendulums and plumb-lines, we are led to imagine that we are standing between *two* mountain ranges, one of which visible to the north rises abruptly out of the plains, whilst the other invisible to the south slowly gains in elevation for one or two hundreds of miles.

It is not possible to explain how these variations of density in the crust have come about or to what they are due: the parallelism to the Himalaya of the buried chain of density seems to indicate unity of origin, but whether the zones of excess and deficiency are caused by the weight of the Himalaya and of Tibet pressing vertically upon the yielding crust of the earth, or whether by the horizontal thrust of the Himalayan arches against a subterranean abutment, we cannot venture an opinion. It may be that the Himalaya mountains are more due to the buried chain, than the chain is to the Himalaya, and it may be that both mountains and chain have been caused by one and the same movement in the crust.

In reports on geodetic work it is customary to call the outer shell of the earth the *crust*, and in the descriptions given above we have repeatedly referred to the *crust*; but we possess no evidence that a *crust* exists sharply separated from an interior *core*. It would indeed be more reasonable to assume that the so-called crust and core merge imperceptibly into one another. If, however, the crust of the earth does differ in density from the core, and if the transition from the one to the other is sudden and not gradual, the hidden excesses and deficiencies of mass revealed by the plumb-line and pendulum may be due to variations in the depth, at which the surface of the heavy core lies below the surface of the light crust; the core may be approaching nearer to the surface of the earth in some places than in others.

Our observations are at present insufficient to admit of the *depth* of the hidden variations of mass being determined, but there are reasons for believing that the excesses and deficiencies, which have been discovered. are between 20 and 70 miles deep.

10

THE HIMALAYA AS REPRESENTED UPON MAPS.

Methods of hill-shading.

There is no portion of the earth's surface so difficult to represent upon maps as the high mountains of Asia. The complexity of their configuration tries the skill of the most experienced surveyors; and the immensity of their area obliges draftsmen to keep a reserve of power in hand, lest they should reach the utmost possibilities of hill-shading before they have depicted the regions of boldest relief.

In all discussions upon the drawing of mountains the fundamental fact to be recognised is that draftsmen have at their disposal an inadequate means of representation. Hill-shading by strokes of a pen is a feeble method of indicating great variations of slope and height, and the artistic reforms that have been introduced at intervals are evidence of the dissatisfaction of map-makers.

Three different systems of shading by pen strokes have been devised for the representation of mountains on paper, but no one of them can be held to be adequate. Under the first an appearance of relief was given to a map by making eastern and southern slopes dark, western and northern light. Under the second the strongest darks were used for emphasising the greatest altitudes and the commanding points. Under the third depth of shade was made proportional to steepness of slope. In many maps the first and second systems have been combined, in many others the second and third, and in some few there are traces of all three to be found.

In the *General Report of the Survey of India* for 1904-05, the Surveyor General, Colonel Longe, writes: "I believe that no system has yet been evolved by any country "which deals satisfactorily from a systematic and artistic point of view with this "question. If any light can be thrown on this question by any student of the subject "his conclusions would be most gratefully welcomed."

Methods of generalisation.

If we examine large scale maps of the Himalaya we become bewildered by the ramifications of ridges and spurs, and we fail to discover any evidence of structural law underlying the chaos. If we turn to small scale maps, we find that the mountains have been generalised and are now represented in a simple form. But these generalisations have been carried out by draftsmen, who were unaware of the scientific problems involved, and they are nothing more than conventions.

A draftsman can no more draw mountains without a knowledge of their structure than a landscape artist can draw a village scene without perspective, or than a figure painter can draw men and animals without studying their anatomy. If we attempt to cover many square yards of paper with hill-shading, without having a knowledge of the governing lines of structure, we only succeed in presenting a chaotic mass of incoherent details.

Ruskin says that it is always wrong to draw what we do not see. No one will oppose Ruskin's maxim, but the difficulty in mountains is *to see*, and long experience is necessary to give the power of doing so. The untrained eye will see details readily enough, but it will miss the governing lines. In small scale representations we require the governing lines, not the details.*

In many cases the surveys incorporated in maps have necessarily been executed by eye-sketching from great distances and the mountain features have been roughly delineated. But even when large scale maps do show the hills with accuracy the general effect is apt to be uninteresting and monotonous, and the draftsman, who has to construct from them maps on a smaller scale, is utterly at a loss to know what to retain and what to omit.

Those who realise the difficulties attending generalisation in any branch of science will sympathise with the draftsman who has to discover the governing lines of a mountain mass. A surveyor can map the visible ridges and rivers, but he can never obtain a bird's-eye view of the whole, and in his generalisation he is apt to attach an exaggerated importance to the rivers.

Undue emphasis is given to water-partings.

On almost all maps the water-partings are made the most conspicuous ranges: draftsmen see two streams and create a ridge between them: we thus have ridges running in all directions, the more important the water-parting the darker the ridge. This system has rendered small scale maps useless for scientific investigation. There will be no progress in Himalayan mapping, until the water-parting ridges are subordinated to the ranges of original elevation. The lines of water-parting, though emphasised on maps, have rarely any structural importance, and have but little interest for the geographer or geologist. What, for example, can be more misleading than to show Mount Everest rising from a southern spur of a Tibetan range, because the latter happens to be a water-parting? Yet this was done in the map illustrating the Imperial Gazetteer of India.†

On a map a river is a sharp line, that admits of no modification; a range is indefinite, and can be squeezed at will. On all maps the draftsmen begin by drawing as many rivers as the scale allows, and they adjust the hills afterwards to the rivers.

In nature the mountains determine the directions of rivers: in maps the rivers determine the directions of mountains.

The principal Himalayan rivers tend to flow down *perpendicular* to the great range: this important fact could hardly be illustrated on a large scale map, the details of which would be too intricate; but it should be clearly visible on small scales. When, however, in practice a map comes to be reduced from a large to smaller scales, the

* The following is extracted from a memorandum on the Survey of Kashmir by Sir Henry Thuillier, Surveyor General of India, who was an expert draftsman: "The difficulty of sketching ground of such a character may be imagined. To do so with any degree of faithfulness requires a peculiar talent and is a gift as much as copying the human face. Stevenson, the civil engineer, in his evidence before parliament on the Ordnance Survey of England stated his belief, that there were not above eight persons in England who understood how to pourtray ground. If difficult therefore in England, it must be still more so, where the relative commands are so immense."—*Journal, Asiatic Society of Bengal*, Vol. XXIX, 1860.

† Dated 1881.

great rivers become nearer together on the paper, and less space is left for the hill-shading between them; in the course of reduction, though numerous ridges have to be eliminated, the great parallel rivers are retained as though they were the governing lines of the topography. Finally on the smallest scale the draftsman fills up the space between two rivers with a long ridge running *parallel* to them.

Representations of the Kumaun Himalaya.

Chart x illustrates our meaning: here we have a portion of the Himalaya as represented on the 1 inch = 32 miles map of India, and the representation has been obtained by generalisation from maps on a larger scale.* Three rivers, the Sutlej, the Bhagirathi, and the Alaknanda, rise behind the great Himalayan range and cut across it. These rivers have been allowed to determine the form of the hill-shading on the map, whereas in nature it was the great range that gave to the rivers their falls and determined their directions.

In the first drawing on chart XI the same area is shown as represented on the 1 inch = 64 miles map of India; the influence of the three rivers upon the hill-shading is very marked. In the second drawing on chart XI an endeavour has been made to show how the hills should be shaded: the ranges have not been drawn following the rivers, but at right angles to them: the long spurs between the rivers have been eliminated, and the parallelism and continuity of the ranges have been emphasised.

Until the Himalaya have been surveyed by geologists, we shall be limited to drawing conclusions from the forms of the surface. In studying surface features we must admit as evidence only actual measurements of height and position; the artistic conventions entered upon maps must be excluded from consideration. In the drawing of maps on small scales each range must be traced by its peaks, not by its rivers.

If we plot on a chart all the highest points of a region, we find that they align themselves in narrow zones. This is how the frontispiece of Part I was prepared. The points of maximum altitude were plotted, and lines drawn through them, the higher the points the thicker the lines were made. Until geologists prove our assumptions to be wrong, the lines of this frontispiece will be taken to represent the axes of ranges.

* Kumaun and British Garhwal Survey, Scale 1 inch = 1 mile.

11

THE HODGSONIAN CONTROVERSY.

Hodgson's views.

In 1849 Brian Hodgson, the celebrated naturalist, who was then the political resident in Nepal, advanced a theory, which has had great influence upon map-makers, and which is illustrated in chart XII. The great Himalayan peaks, he maintained, did not stand on a range of mountains, but on spurs projecting from the Tibetan range behind. Mr. Hodgson devised his theory to account for two phenomena, *viz.*, (*i*) that the great peaks are not standing on a main water-parting between India and Tibet, (*ii*) that the Himalayan rivers tend to converge inside the hills instead of flowing at right angles to the high mountains in a great number of parallel courses.

"We are led irresistibly to enquire," wrote Mr. Hodgson,* "why the numerous "large feeders of the rivers, instead of urging their impetuous way from the snows to "the plains by independent courses, are brought together upon or near the verge of the "plains: how unity is effected among them despite the interminable maze of ridges they "traverse, and despite the straight downward impulse given them at their sources. "I answer, it is because of the superior elevation of the lateral barriers of these river-"basins, between which there are synclinal slopes of such decided preponderance, that "they overrule the effect of all other inequalities of surface, how vast soever the latter "may sometimes be."

"It will be seen by the map (chart XII) that these lateral barriers of the river-basins "are crowned by the pre-eminent Himalayan peaks, that the peaks themselves have a "forward position in respect to the *ghât* line or great longitudinal watershed between "Tibet and India, and that from these stupendous peaks, ridges are sent forth "southwards proportionally immense."

Mr. Hodgson's views were supported by Sir Joseph Hooker. "The snowy "mountains seen from the southward," wrote the latter,† "are not on the axis of a "mountain chain, and do not even indicate its position, but they are lofty "meridional spurs projecting southwards."

"I have always said," again wrote Sir Joseph Hooker, "that the Sikkim Hima-"laya (I mean the snowed mountains) do not form a continuous snowed chain running "east and west, but that they are meridional ridges running north and south, separated "by waters that flow southerly between them."‡

Mr. Hodgson's arguments can be answered as follows:—the great Himalayan peaks are not connected by spurs with the Tibetan range, but are separated from it by troughs;

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* *Journal, Asiatic Society of Bengal*, Vol. XVIII, 1849.

† *Himalayan Journals*, Vol. II, page 298.

‡ *Journal, Royal Geographical Society*, Vol. XX, 1851.

the great peaks are not limited to the ridges between river-basins as drawn by Mr. Hodgson, but stand in a long line which intersects the basins; the Himalayan rivers have not been forced to converge by lofty lateral spurs, but by the recent upheavals of the outer parallel ranges, which have barred the paths of rivers and forced them to combine within the hills.

Undue importance attributed to water-partings.

Mr. Hodgson made the mistake of assuming that the main line of water-parting between India and Tibet must be the main range; in Part III of this paper it will be shown that no single range forms this water-parting and that in parts of Tibet the latter even crosses flat plains.

The great Himalayan range has been cut through in places by rivers rising behind it; the rivers were regarded by Hodgson as the fundamental features of the topography and the isolated blocks, into which they had cut the great range, were incorrectly assumed to be spurs of the range behind.

The highest peaks of the Himalaya stand not on spurs but in the crest-zone of a great range; this is the primary fact of structure. The range resembles a crocodile's back; it is a wide flat arch, with relatively slight prominences, called peaks, and it has no sharply edged crest-line. The highest peaks all fall within a narrow zone running throughout the length of the crocodile. Glaciers have cut back between the peaks, and created a serpentine water-parting line along the zone. Many of the great peaks stand actually on the water-parting and many stand off it on either side: but whether they are on the water-parting line or not, they are all situated in the crest-zone of the range.

The great Himalayan range is not the water-parting *between India and Tibet:* streams that flow down the northern slopes of Mount Everest eventually find a passage through a gorge in the range, and join the streams that have their sources on the southern slopes: though this fact prevents the great range from being a continental water-parting, it does not prevent it from being a regional water-parting.

The range which stands behind the great Himalaya, and which was regarded by Hodgson as the Indo-Tibet water-parting, is only a regional water-parting: it separates the streams which flow into the Ganges of Bengal from those which flow into the Brahmaputra of Tibet. But the Brahmaputra and Ganges eventually unite in India, and the water-parting between their upper feeders is no more entitled to be called the water-parting between India and Tibet than the great Himalayan range is.

A range is a wrinkle of the Earth's crust, a water-parting is a line carved by rivers, and though the two coincide during the youth of mountains, they begin to separate when rivers cut the mountains to pieces.

Sir Clements Markham wrote: "A range of mountains is a ridge of elevated land "running in one general direction, and the fact of its being cut through by one or more "rivers does not alter its character and convert it into a series of spurs."*

* Clements R. Markham *on the Himalayan System* in *the Geographical Magazine*, Volume IV, 1877.

Longitudinal troughs separate the Himalayan and Tibetan ranges; and the great peaks of Everest, Makalu, Gosainthan and Dhaulagiri are not connected by cross-ridges with the range behind them; but Kinchinjunga is. Kinchinjunga stands at a point where the Himalayan range assumes an exceptional form, and Kinchinjunga being near to Darjeeling is the peak that Mr. Hodgson knew best,—perhaps the only great peak he had closely observed.

Hodgson generalised from an exceptional case.

A ridge, well known from the *Himalayan Journals* of Hooker as the Singalila ridge, runs from Tibet through Kinchinjunga southwards to the plains of India, and at right angles to the great range.* This ridge is an extraordinary feature of Himalayan topography; its crest follows a straight line from Tibet to Bengal; the descent from the snows to the plains is almost continuous. In Southern Sikkim this ridge is a more marked feature than any continuous snowy range. It is probable that Mr. Hodgson generalised from the Singalila ridge and from Kinchinjunga, and in so doing he generalised from exceptions.†

Mr. Hodgson's theory of Himalayan configuration still finds supporters, and it has been even applied by subsequent writers to other ranges than the Himalaya. Almost all existing small scale maps of Tibet continue to represent the great peaks of the Himalaya as standing on spurs of a hinder range, and it is common to read in geographical works that the highest altitudes of the Karakoram and of the Hindu Kush are to be found not on main ranges but on lateral spurs.‡

Extensions of Hodgson's theory.

The Himalaya have been compared to the Alps, and it has been said that in neither region do the highest peaks stand on the water-parting line. But we doubt whether any such comparison is possible. Though many of the high peaks of the Alps may not stand upon what is called the main chain, yet they are all situated within the crest-zone of the range.

Comparison with the Alps.

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* See North-Eastern Trans-frontier sheet, No. 7 N.W., Scale 1 inch=4 miles. It has been argued that the name Singalila was coined by Hooker, and that no such native name exists. The name has, however, been widely used by geographers following Hooker, and it cannot be abandoned now.

† The transverse ridge of Singalila, separating the basins of the Tista and Kosi, is not a *solitary* exception, for the Narkanda ridge separating the basins of the Sutlej and Jumna, and the Chola ridge, separating the Tista and Raidak, though smaller, are similar. Singalila and Chola are perpendicular to the great range, but Narkanda is oblique. No such continuous ridge separates the basins of the Ganges and Kali, or those of the Ganges and Jumna : the river-basins of the Punjab Himalaya are separated by oblique ranges.

‡ The following is an extract from the narrative of the Survey of Kumaun, vide *General Report of the Survey of India*, 1877-78 :—

"The features of the Nilang valley correspond with the general physical geography of this belt of the Himalaya as observed in other valleys : the main watershed being as a rule lower and the slopes about it easier than the southern and more interrupted range, on which the highest groups of snowy peaks occur. The snowy range is, properly speaking, not a continuous range but a series of enormous spurs which everywhere dominate the parent ridge, the Indian watershed."

The following extract is taken from *Among the Himalayas* by Colonel L. A. Waddell, C.B., C.I.E., 1900 :—

"It was now evident that the Everest range like that of Kinchinjunga seemed off the main axis of the Himalaya and the margin of the great Tibetan plateau, and appeared as a spur and at right angles to that axis."

The following extract is taken from the *Sand-buried ruins of Khotan* by Dr. M. A. Stein, 1904 :—

"The great peak was entirely separated," (from the Kuen Lun), "an interesting observation fully in accord with the orography of the Karakoram and Hindu Kush. There it has long ago been remarked, that the points of greatest elevation are not to be found on the actual watershed but on secondary spurs detached from it."

The case of Mount Everest is quite different: here there are two parallel ranges sixty miles apart, separated by a deep trough; Mount Everest stands on the one, whilst the water-parting is situated on the other. The Alpine peaks and the Alpine water-parting are at any rate upon the same range, but the Himalayan peaks and Himalayan water-parting are not.

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12

THE HIGH PLATEAUX OF ASIA.

The horse-shoe.

The frontispiece of Part I illustrates the position and dimensions of the three high plateaux of Asia. The plateau of Tibet with an average height of 15000 feet is joined at its north-western corner to the Pamir plateau, height 12000 feet, and this again is connected by mountains with the Tian Shan plateau, height 11000 feet. The three plateaux together assume roughly the shape of a horse-shoe.

The want of parallelism between the Tian Shan and Tibet ranges has been supposed to indicate a difference of origin, of age and of elevating force. But no such conclusion is justified from the scanty existing data, and we must for the present regard the three plateaux as one mass. It is not safe to draw too positive conclusions from the directions of ranges, or to assume that a compressing force must have acted in a direction exactly at right angles to the range it has raised; the heterogeneity of the crust may have had an important influence in determining the course of a range. If a portion of the crust, advancing under pressure, meets with hard resistant subterranean masses, the course of the wrinkle will be deflected. Such a mass underlying the Punjab seems to have barred the southward advance of the Himalayan ranges on the west, to have forced the Tibet ranges to converge and to have caused the Karakoram-Hindu Kush range to take the form of a bow.* On the extreme west the Hindu Kush range does assume a significant parallelism with the Tian Shan.

Chart IX has been drawn to illustrate the extraordinary parallelism that exists between the southern border of the Himalaya-Hindu Kush system of mountains on the one side, and the northern border of the ancient mass of rock forming Peninsular India on the other.

The interior of the horse-shoe formed by the plateaux is an inland desert basin (*vide* chart XXII) drained by the Tarim river and its feeders;† the sand of this basin is annually accumulating, and Sven Hedin found towns buried beneath it. The lowest part is the lagoon of Lob Nor (height 2200 feet), and though there is no mountain range closing it on the east, its mouth here is narrow and the desert of Gobi beyond has a superior elevation of nearly 2000 feet. On the north and west and south it is bounded by decomposing mountains, and no other portion of the earth has so gloomy a future. Unless geological changes ensue, the sand will continue to accumulate, until the lagoon of Lob Nor and the rivers of Tarim are choked.

We believe that the plateaux of Asia have been elevated by a horizontal pressure in the crust, and that this has continued to act in a meridional direction through long periods down to the present time. The wrinkling of the crust has taken many forms.

* The pendulum observations have revealed the presence of a mass of great density underlying the plains of the Punjab.

† Royal Geographical Society's map in Holdich's *Tibet the Mysterious*.

Firstly, there are the great plateaux themselves; secondly, the surfaces of the plateaux have been wrinkled into ranges; and thirdly, the surfaces of the ranges have been corrugated into smaller folds.

The ranges are composed of consolidated rock, but the flat portions of the plateaux,—the only portions in fact which can be described as table-lands,*— are troughs between ranges, which have now become filled up with loose débris and boulders, gravel, sand and mud washed down from the mountains and arranged in level layers by water. Ranges vary in breadth, in places bulging towards one another, in places receding from one another, and the intervening troughs and flat plains become alternately narrower and wider.

The flat portions of the plateaux.

"The immense extent of the existing alluvium," wrote Henry Strachey,† "and "the uniformity of its maximum elevation lead me to infer that it must have been "deposited under a general sea covering the whole country, and not by lakes, much "less by rivers."

Henry Strachey thought that the alluvium had been deposited at the bottom of an ocean and afterwards upheaved to its present height without the horizontality of its layers being disturbed.

From fossil bones found at a height of 17000 feet in Tibet, Colonel Godwin-Austen drew the conclusion that in recent times the climate which is now arctic must have been sufficiently warm to enable the rhinoceros and other tropical animals to live. "The only rational solution," he wrote, "which science could suggest, was that "within a comparatively modern period, closely trenching upon the time when man "made his appearance upon the face of the earth, the Himalaya has been thrown up "by an increment approaching 8000 or 10000 feet."

It is possible that the action of wind has helped to fill up the high-level basins of the plateaux with loess: this was the suggestion of Baron Von Richthofen. Those of us who have lived in the plains of northern India can testify to the enormous amount of dust carried annually by wind into the mountains. The finer particles of dust are lifted to very high altitudes and are probably transported for hundreds of miles.

Wind may also help to distribute the dust that arises from the decomposing rocks of the plateaux themselves. These rocks are exposed by day to great heat from the direct rays of the sun, and by night to arctic temperatures; and their surfaces rapidly disintegrate under the influence of these changes.

The presence of boulders and gravel proves that the alluvium cannot be wholly attributed to the action of wind, and Sir Martin Conway thinks that mud avalanches have filled up the valleys. "Mud avalanches, I maintain, have done all this work "of filling up the valleys, and done it too with great rapidity."‡

* Valleys filled to a high level with débris are however not strictly speaking "table-lands."

† *Journal, Royal Geographical Society,* Volume XXIII, 1853.

‡ *Exploration in the Mustagh Mountains,* by W. M. Conway in *the Geographical Journal,* Vol. II, 1893.

The Tibet plateau.

The mountainous area of Tibet extends from the foot of the Siwalik range on the south to the foot of the Kuen Lun range on the north: the alluvial deposits have been washed by rivers out of the greater number of troughs south of the Ladak range and north of the Kuen Lun range, and the principal Tibetan table-lands lie between these two ranges (see frontispiece to Part I). There are however rock basins on the Indian side of the Ladak range that are still filled with alluvium, of which the plains of Nari Khorsam and the valleys of Kashmir, Nepal and Dingri and the several "duns", enclosed by the Siwalik range, are the principal. The extensive plateau of Tsaidam lies north of the Kuen Lun.*

From west to east the Tibet plateau extends from the Karakoram mountains to the Kansu and Ssuchuan provinces of China. Southern Tibet consists of troughs drained by the rivers of India,—the Sutlej, the Brahmaputra, the Arun and others. Western Tibet has been compressed between north and south, and its central range, the Karakoram, is the highest. Northern, north-eastern and central Tibet form a table-land which contains vast numbers of lakes. South-eastern Tibet is a rugged mountainous country, and not a table-land: its elevated mass has been cut up by the rivers of China and Burma and is intersected by deep ravines. Tibet is wooded in its south-eastern portion only.

On all sides of the Tibet plateau rivers are cutting back into it by head erosion and the high level alluvial plains are only found intact in those portions which have not as yet been reached by feeders of the oceans. On the north and south and west the great rivers are confined to a few thoroughly drained troughs, and they can only expand their drainage areas now, if their upper feeders succeed in cutting back through the ranges of solid rock bounding the troughs. But on the east the rivers of China rise in the wide troughs of central Tibet and have before them the comparatively easy task of cutting back westwards into the soft alluvium, and of capturing for their basins long zones of the undrained portions of the plateau.

The unexplored portions of Tibet.

The portions of Tibet drained by the Brahmaputra, the Sutlej, the Indus and the Yarkand rivers are fairly well-known, and chart XXII shows that explorers have crossed the plateau in all directions. Nevertheless large areas are still *terræ incognitæ.* Sven Hedin has given us maps of northern Tibet, Prejevalsky of north-eastern, and Deasy of north-western; but we do not as yet know the positions and heights of the ranges and lakes in the centre of the plateau, nor the westernmost limits of the drainage basins of the Yangtze, Mekong and Salween (frontispiece to Part I).

The narratives of explorers have led us to believe that the interior of Tibet consists of alternate ranges and troughs running east and west, the troughs being partly filled up with alluvium, and containing long series of lakes.

* Royal Geographical Society's map published in Holdich's *Tibet the Mysterious.*

In western Tibet the lakes are mostly dry, and flat plains occupy the spaces between the mountains. Of these lofty plains the following are the best known:—

The plains of western Tibet.

	Area in square miles.	Height in feet.
Nari Khorsam	800	15000
Lingzi Thang	1000	17000
Aksai Chin	1200	16500
Dapsang	500	17500
Deosai	600	12500

These plains hold no water now; Nari Khorsam has long been dry, and having become part of the basin of the Sutlej is now intersected by the deep canyon of that river.*

The plains of Tsaidam consist of salt-wastes and swamps, and form the surface of the great high-level area, which projects from north-eastern Tibet, and separates the Tarim basin from the desert of Gobi (frontispiece to Part I). They are situated north of the Kuen Lun range and are consequently not always regarded as part of the Tibet plateau itself. They however belong to the Tibet mountain system, and their exclusion from the plateau is a mere question of definition.

The plains of Tsaidam.

According to Prejevalsky their surface is 1700 feet lower than the level of the water in Koko Nor (height 10700 feet), the principal lake of north-eastern Tibet. The mean height of Tsaidam is consequently about 6000 feet less than that of Tibet.

Prejevalsky described the Tsaidam country as a salt marsh covered with high reeds. Its morasses, he said, were so thickly impregnated with salt as to be encrusted with a layer in some places half an inch to an inch in thickness. The plains of Tsaidam, he thought, were in recent geological times the bed of a large lake.†

Sven Hedin writes that the streams of Tsaidam die away in the sand and that the central parts of the basin are occupied by extensive marshes.‡

The mountains of China are the eastern terminations of the Tibet plateau, and belong to the same system of ranges as the Himalaya, the Kuen Lun, and the Karakoram. The provinces of China, that embrace the mountainous area, are Kansu on the north and Ssuchuan on the south. Kansu is in the basin of the Hoang Ho, Ssuchuan in that of the Yangtze, the water-parting between the two being of great altitude. The aridity of Tibet gives place in Kansu and Ssuchuan to a damp climate, and Prejevalsky found that a great increase of moisture occurs in north-east Tibet immediately east of Koko Nor.§

Eastern limits of Tibet.

* Nari Khorsam was described in Henry Strachey's paper—*Journal, Royal Geographical Society*, Volume XXIII, 1853: also in *Memoirs, Geological Survey of India*, Volume XXIII, 1891.

† N. Prejevalsky: *Mongolia*, Volume II, 1876.

‡ Sven Hedin: *Through Asia*.

§ The word *Nor* means *Lake*; if then we speak of '*Lake Koko Nor*' either the word *Lake* or the word *Nor* is redundant, for both have the same meaning. On the other hand the description '*Lake Koko*' would not suffice, and '*Koko Nor*' would be defective in a popular account. We are therefore of opinion that at the present stage of Tibetan Geography it is desirable to accept the form '*Lake Koko Nor.*' In the same way we cannot avoid speaking of the '*Lake of Sir-i-Kul*' though *Kul* means *Lake*: the '*Lake of Sir*' would be insufficient. In England we have the case of Winder-mere and Derwent-water which are frequently spoken of as Lake Winder-mere and Lake Derwent-water. Geographical names, which include both a native word and its English equivalent, such as Lake Koko Nor or Lake Sir-i-Kul, should never be used *upon maps*: in cases, where the native word for lake, or river or pass, has come to be an essential part of the native geographical name, as in Koko Nor and Sir-i-Kul, it is advisable *in the preparation of maps* to adopt the native name without any modification or addition.

*The Tian Shan plateau.**

The Tian Shan consists of several ranges crowning a plateau, with alluvial plains in the intervening troughs. The main mass of the plateau south of Issik Kul is 150 miles wide, and 11000 feet high; the ranges separating the alluvial basins rise to 16000 feet.

The essential difference between the plateaux of Tian Shan and Tibet is that the ranges of the former tend to run in two directions at right angles to one another, whilst those of the latter take but one direction and are generally parallel. "The two "main directions of mountains in the Tian Shan," writes Prince Kropotkin," are south-"west to north-east (that is, parallel to the fringe of the great plateau of East Asia) and "south-east to north-west which direction is taken by several ranges shooting off the "Tian Shan. The former is the oldest; the mountains following it have been lifted "up during the palæozoic period, while the other line of upheavals was relatively mod-"ern and attained its greatest force during the tertiary and post-tertiary periods."†

The Pamir plateau.

The Pamir mass (see frontispiece to Part I) is enclosed in the rectangle formed by the Hindu Kush, the Kashgar and Trans Alai ranges; it is the water-parting between two inland systems of drainage,‡ one of which ends in the sea of Aral, the other in the lagoons of Lob Nor. Its elevated plains, like those of Tibet and Tian Shan, consist of horizontal accumulations of gravel deposited in rocky troughs.

The structure of the Pamir plateau.

The ranges enclosing the alluvial troughs of Tibet are parallel to one another, and those of the Tian Shan are according to Kropotkin mutually perpendicular; the directions of the Pamir ranges have not yet been determined. We do not know how the Kashgar and Sarikol ranges connect with the Tian Shan (see frontispiece to Part I), nor how the crustal folds of the Pamir plateau trend west of the Sarikol range. We can form some idea as to the direction of the force which elevated Tibet and the Tian Shan into wrinkles, but the Pamir presents a more difficult problem, which cannot be solved from existing data.

Humboldt's conception of the Pamir was a great meridional range connecting the Tibetan and Tian Shan systems, and this view was supported subsequently by Hayward: but Severtsoff and Fedchenko contended that the fundamental mass of the Pamir plateau was a series of parallel ranges running from east to west. From the plains of Kashgar Hayward saw a snowy range on the east of the Pamir running north and south: Fedchenko argued that this so-called range consisted only of the ends of the parallel ranges which were running east and west.

* See *The Central Tian-Shan Mountains*, 1905, by Merzbacher. An excellent account of the Tian Shan plateau was given by Ellsworth Huntington in the *Geographical Journal* for January 1905.

† *Geographical Journal*, Vol. XXIII, 1904.

‡ Northern Trans-frontier Sheet No. 2: scale 1 inch=8 miles.

We know now that two ranges, the Kashgar and the Sarikol, separated by a high level trough, do trend not exactly meridionally but from north-west to south-east, and these ranges form the eastern portion of the Pamir mass.

The frontispiece to Part I shows these ranges to be connected with the north-western ranges of Tibet. That the Kashgar range is a continuation of the Kuen Lun is considered certain, but the connection of the Sarikol range on the chart with the Aghil is nothing more than conjecture. We cannot even conjecture how the Kashgar and Sarikol ranges are connected with the Tian Shan.

As to the structure of the Pamir mass west of the Sarikol range, there undoubtedly exists a series of parallel valleys running east and west and separated by mountain chains. But we do not know whether these east and west chains are real original ranges wrinkled at right angles to the Sarikol and Kashgar ranges, or whether they are long spurs of the Sarikol range carved by water. If the latter view is correct then the whole Pamir plateau is a broad fold of the crust sloping steeply on the east, gently on the west, and running north and south. Whatever may have been the direction in which the principal force of upheaval acted, complicated cross-pressures from different sides have probably contributed to form the elevated mass that is now standing at the conjunction of the Tibetan and Tian Shan systems.

The configuration of the Pamir plateau.

The average elevation of the Pamir alluvial plains is 12000 feet, and that of the mountains dividing them 17000 feet.

"Pamir," wrote Stoliczka, "is not a plateau at all: it is a congregation of chains."*

"We may say," wrote Sven Hedin, "that the Pamir may be grouped into two sharply "contrasted divisions, an eastern half which is principally a plateau land such as I have "described, and a western half consisting of latitudinal mountain chains disposed parallel "to each other. There can be no doubt that at one period the entire region was strictly a "plateau and that it is being rapidly broken down by the agency of erosion."†

"The meridional range," wrote Colonel Wahab, "forms the eastern boundary of the "Pamir plateau; that range and the Hindu Kush are the dominating features of the "region; the trend of the several ranges which are being carved out of the original plateau "is parallel to the Hindu Kush. There is nothing on the west that can be called a "meridional chain, though the course of the Oxus is deflected in that direction by a great "spur thrown out from the Hindu Kush north of Tirich Mir."‡

"Beyond the fact," wrote Lord Curzon, "that the general elevation of the Pamir "valleys is from 12000 to 14000 feet, and that they are consequently at a higher level than "the surrounding countries, there is nothing in their superficial character in the least "degree calculated to suggest a table-land or plateau, which I take to mean a broad "stretch of flat and elevated land, surrounded, may be, and even interspersed, but not "positively broken up, with mountain masses. Nor can anything less like a down or a

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* Suess: *Das antlitz der Erde.*

† Sven Hedin: *Through Asia,* page 185.

‡ Extract from a letter.

"steppe be conceived than the troughs or valleys, of no great width, shelving down-"wards to a river-bed or lake, and uniformly framed on either hand by mountains, "whose heads are perpetually covered with snow, which anybody who has been to the "Pamirs will at once recognize as a fair description of those regions. In reality, over "the entire region embraced by the title, it has been calculated that the plains or valleys "constitute less than one-tenth of the total area. Correctly described, a Pamir in theory, "and each Pamir in fact, is therefore neither a plain, nor a down, nor a steppe, nor a "plateau, but a mountain valley of glacial formation, differing only from the adjacent or "other mountain valleys in its superior altitude, and in the greater degree to which its "trough has been filled up by glacial detritus and alluvium, and has thereby "approximated in appearance to a plain owing to the inability of the central stream to "scour for itself a deeper channel."*

Lord Curzon enumerates eight Pamirs or alluvial plains :—

(i) The Taghdumbash Pamir lies in the basin of the Tarim, and north-east of the Kilik pass; it is 60 miles long and from one to five miles broad; it is drained by the Tashkurgan, a feeder of the Yarkand river.

(ii) The Wakhan Pamir extends for 20 miles along the northern bank of the Wakhan affluent of the Oxus.

(iii) The Little Pamir encloses lake Chakmaktin and follows the Aksu affluent of the Oxus for 60 miles. It is a long grassy plain varying from one to four miles in breadth.

(iv) The Great Pamir encloses the lake of Sir-i-Kul; it is 80 miles long and varies in width from one to six miles; it is in the basin of the Oxus.

(v) The Alichur Pamir lies north of the Great Pamir and is in the basin of the Oxus. It contains the lake of Yeshil Kul.

(vi) The Sarez Pamir is north of the Alichur Pamir and in the basin of the Oxus.

(vii) The Rang Kul Pamir containing the lake of that name lies north-east of the Sarez Pamir; it possesses no drainage outlet.

(viii) The Khargosh Pamir is north of the Sarez Pamir and encloses the great Kara Kul lake; it possesses no drainage outlet.

* *Geographical Journal*, Vol. VIII, 1896.

13

THE PRINCIPAL MOUNTAIN RANGES OF ASIA.

The plateaux have been wrinkled into ranges, and the intervening troughs have been filled with débris and their surfaces levelled by the action of water: one of the first tasks now confronting geographers and geologists is the investigation of the ranges,—the determination of their positions, heights and trends.

Although large portions of the earth's surface have been surveyed and examined, the origin of mountains is not as yet understood; various explanations have been offered but none has been generally accepted. Geologists and physicists and mathematicians differ in their views, and the problems arising from the wrinkling of the earth's surface must still be regarded as unsolved. Complete surveys of the Himalaya will afford valuable data, provided we realise at the outset the questions involved. We must not confuse *ranges* and *ridges*; *ranges*, however modified by denudation, are features of original structure; *ridges* are the results of erosion only. *Ranges*, as their name denotes, must possess length, and an elevated ring or dome or compact mass could not be called a *range*. But though length is an essential feature of a true *range*, a long line of mountains is not necessarily a *range*, for it may have been carved by rain and rivers out of an older and larger mass.

Surveyors and geologists will have to determine in the field how the several Tibetan ranges run, and whether they are connected by cross-ranges or not; they will have to discover to what extent the form and structure of the Himalaya resemble those of the Andes and Alps; they will have to enter upon the investigation with open minds, and endeavour to learn, without preconception or bias, how the Tibetan and Himalayan ranges have been upraised.

The ranges of Central Asia appear all to belong to one great system, and to have no separate existence apart from that system, and no investigations are likely to be profitable that leave out of account the relations of the ranges to one another. "The "physical unity," wrote Richard Strachey, "of the great mass of Tibet with the "Himalaya range seems to me very strongly shown by the general geological "structure." The parallelism of the Kailas, the Ladak, the Great and Lesser Himalaya and the Siwalik ranges, all of which change direction together, is evidence of inter-connection.

The high ranges of Asia—those that are known to us—may be classified as follows:—

I. Ranges of the first magnitude, carrying many peaks above 25000 *feet*—

(1) The Great Himalaya in Nepal.

(2) The Karakoram.

II. Ranges of the second magnitude, carrying many peaks above 22000 feet—

(1) The Great Himalaya in Kumaun.
(2) The Hindu Kush.
(3) The Kuen Lun.
(4) The Kashgar range.

III. Ranges of the third magnitude, carrying many peaks above 19000 feet—

(1) The Great Himalaya in Assam.
(2) The Great Himalaya in the Punjab.
(3) The Ladak range.
(4) The Kailas range.
(5) The Tian Shan.
(6) The Trans Alai range.
(7) The Zaskar range.
(8) The Aghil range.
(9) The Ninchinthangla range.

IV. Ranges of the fourth magnitude, carrying many peaks above 15000 feet—

(1) The Sarikol range.
(2) The Alai range.
(3) Eastern portion of the Pir Panjal range of the Lesser Himalaya.
(4) Eastern portion of the Dhauladhar range of the Lesser Himalaya.

V. Ranges of the fifth magnitude, carrying many peaks above 11000 feet—

(1) Western portion of the Pir Panjal range of the Lesser Himalaya.
(2) The North Kashmir range of the Lesser Himalaya.

VI. Ranges of the sixth magnitude, carrying peaks above 7000 feet—

(1) Western portion of the Dhauladhar range of the Lesser Himalaya.
(2) The Nag Tibba range of the Lesser Himalaya.
(3) The Mussooree range of the Lesser Himalaya.
(4) The Mahabarat range of the Lesser Himalaya.
(5) The Rattan Pir range of the Lesser Himalaya.

VII. Range of the seventh magnitude, carrying peaks above 3000 feet—

(1) The Siwalik range.

It has been argued that the Great Himalaya range is the border range of the plateau of Tibet, and comparisons have been drawn with other mountainous regions in which the highest range forms the border. But the frontispiece to Part I shows that the real "border range" on the south of the mountains of Asia is not the Great Himalaya but the low Siwalik.

Geographical knowledge incomplete.

Our geographical knowledge is not at present sufficiently complete to enable us to show on a map all the principal ranges of High Asia, and breaks in the lines of the frontispiece chart have been introduced where information is altogether wanting. British surveyors have observed the high peaks of the Himalaya, of the Karakoram, of the Hindu Kush, of the Ladak and of the Kailas ranges. Russian surveyors have fixed the principal points of the Tian Shan. But observations of the Kuen Lun have been limited to their western end; those of the Sarikol and Kashgar ranges are deficient in accuracy and completeness, and our knowledge of the Aghil range and of all the ranges of central and eastern Tibet is at present based not on trigonometrical determinations but on the reports of travellers.

It is possible that many of our present ideas of ranges will be found in the future to be incorrect: geographical science when it is not advanced by sound and systematic surveys, but is dependent on the information acquired from the itineraries of explorers, has to make its way by zig-zags of approach, often overshooting the mark to which it is directed, sometimes perhaps going wrong altogether, but yet always endeavouring to reach its goal by successive approximations.* Until all data, that are based upon the writings of travellers and upon the cross-examinations of natives, have been superseded by the results of a rigorous survey, the geography of central, of northern and of eastern Tibet will have to be regarded as a preliminary approximation, which is liable to be largely corrected in future.

We do not as yet know the number of great ranges that cross Tibet from west to east: one explorer follows a trough between two ranges and another does the same along a parallel line to the south, but without trigonometrical determinations of the positions of peaks we cannot tell if the range seen to the south by the northern traveller is identical with that seen to the north by the southern traveller.

We do not know whether the Karakoram range ramifies in its eastern extension over central Tibet, nor how the Tibetan ranges merge into the oblique and diverging chains of Ssuchuan and Burma, nor how the Kuen Lun range breaks up at its eastern extremity into the complicated network of minor ranges, described by Prejevalsky and Sven Hedin.

It is certain that great parallel ranges do traverse Tibet from west to east and that after being compressed between Peshawar and Yarkand they tend to diverge as they progress eastwards. In northern Tibet Sven Hedin followed a trough running east and west between two ranges for 400 miles, Wellby explored a similar trough and Nain Singh traversed one of great length in central Tibet.

Continuity of ranges.

It is open to question whether we are justified in drawing the Kailas, the Ladak, the Great Himalaya and the Siwalik ranges, on the frontispiece of Part I, continuous throughout their whole lengths. By giving them an uninterrupted continuity we imply that each range is a separate wrinkle of the crust, raised throughout its length, not necessarily at the same time, but by the same series of movements. It is possible that these ranges will be found in places to cease and to consist in reality of two or more shorter ranges, differing perhaps

* See General Walker's notes on his map of Turkistan, which he compiled in the office of the Trigonometrical Survey at Dehra Dun in 1873.

slightly in alignment and overlapping each other at their extremities. Observations of peaks, however, lead us to believe that the ranges are continuous and are not broken by overlaps.

In the Great Himalayan range continuity of alignment has been almost established throughout. It is difficult certainly to trace the prolongation of the Kumaun Himalaya into the Punjab, the Sutlej having cut through and destroyed all signs of the original connection (figure 4, chart XVI), but the evidence available tends to indicate that the Kumaun and Punjab Himalaya were once a continuous range, and there are no signs of the existence of any original overlap. The only overlap that we know of is one on the Siwalik range illustrated in figure 2 of chart XIX, and this occupies such a narrow area, that if the range ever grows into a broad high fold, the overlap will be lifted up and become a mere surface feature of the crest.

The chart of ranges in Part I.

From what has been said, it will be readily understood that no complete representation of the principal ranges of Asia can at present be prepared. Between perfect knowledge and entire ignorance there lies a wide field of uncertain information derived from inferences and speculations; it is not possible to omit all unverified information; were we to do so, our chart would be almost a blank. For the aid of future investigators we must include theories and ideas which may be confirmed or may be disproved hereafter. In the descriptions of individual ranges, however, care has been taken to distinguish between what is known and what is inferred.

Though the range-chart of Part I may be found in the future to contain errors, it summarises the present position of Himalayan geography. No attempt has been made to show the spans of the ranges nor the numberless subsidiary ridges into which the ranges have been carved by water; we have merely indicated the trends of the original axes of elevation, and, in order to give some idea of the relative magnitudes of the ranges, we have thickened the alignments that carry the highest peaks, and drawn those of low elevation finely.

14

THE RANGES OF THE HIMALAYA.

The ranges of the Himalaya may be classified as follows (*vide* frontispiece of Part I):—

(I) The Great Himalaya, a single range rising above the limits of perpetual snow.

(II) The Lesser Himalaya, a series of ranges closely related to the great range.

(III) The Siwalik ranges, which intervene between the Lesser Himalaya and the plains.

The Great Himalaya range.

The Himalaya is the name applied to the intricate and complex system of mountains that forms the northern boundary of India from Afghanistan to Burma. Some writers have limited the name *Himalaya* to the mountain ranges included between the Indus and the Brahmaputra, but any such limitation conveys an erroneous idea of the physical unity of the mass. The Indus and the Brahmaputra, like the Sutlej and the Ganges, cut across the Himalaya through gorges, which they themselves have carved, and one of the problems now confronting geographers and geologists is the determination of the trans-Indus and trans-Brahmaputra courses of the Himalayan ranges. We shall not therefore be in a position to define the limits of the Himalaya, until the geology of their extremities has been studied.

The Himalayan area divided into five parallel zones.

The Great and Lesser Himalaya and the Siwalik ranges are so closely related that it may perhaps be desirable to commence with a general description of the area they cover. The outer zone of mountains, which is contiguous to the plains of India and which contains the small Siwalik range and the valleys in rear of it, was elevated more recently than the Himalaya: the width of this zone varies from five to thirty miles, being narrow in those places where the Siwalik range is jammed against the Lesser Himalaya, and wide where open valleys intervene.

The second zone is 40 or 50 miles broad, and is covered with mountains, that assume in the Punjab and Nepal the form of longitudinal ranges running generally parallel to the great range. In Kumaun the form is more intricate: here the peaks of the second zone do not appear to follow distinct alignments of maximum elevation, but to be scattered throughout the region and to possess everywhere a remarkable uniformity of height between 6000 and 10000 feet.

The third zone is 10 miles broad, and is occupied by spurs projecting southwards from the great range; a few peaks of this zone exceed 15000 feet in height.

The fourth zone is 15 miles broad, and contains the great line of snowy peaks, the average height of which exceeds 20000 feet. With the exception of the low ravines cut by rivers, the whole of this zone is situated above the limits of perpetual snow. To an observer on the outer hills the Lesser Himalaya appear to vary but slightly in altitude throughout a great area, but the Great Himalaya range to the north seems to rise suddenly like a wall of snow.

The fifth zone is about 25 miles broad, and contains the troughs of rivers rising behind the Great Himalaya. The average height of the beds of the troughs is 14000 feet and of the mountains intersecting them 19000 feet; the average height of the zone is considerably less than that of the snowy zone.

The ranges covered with perpetual snow and the highest altitudes of the Himalaya occur about 90 miles from the southern limit of the mountains.

In the charts XIV and XV eight cross-sections are shown; they have been drawn through the Himalaya at different points but always at right angles to the great range.

The age of the Himalaya.

The rocks of the Siwalik range are stratified and date from the latter half of the tertiary period; those of the outer Himalaya are stratified also but are very much older.

The central axis of the Great Himalayan range is composed of granite and gneiss; on either side of it are to be seen immense depths of sedimentary strata, which show that thousands of feet of rock have been removed from the crest-line. The granite solidified and cooled while below the surface of the earth, and its original covering has been worn away by the subsequent action of seas and rivers.

The Great Himalaya rose to be a mountain range in the same geological age as the mountains of Afghanistan and Baluchistan on the west and as those of Arakan and Manipur on the east.* The immense depression of northern India, now filled with the alluvium of the Ganges and Indus, dates from the same period as the elevation of the Himalaya; as the latter was pressed upwards into an arch, the former was pressed downwards into a trough.

Though the whole length of the Great Himalaya range belongs to one geological age, yet the Punjab Himalaya are supposed to have risen at a somewhat later date than the Nepal Himalaya. The presence at elevations of 16000 feet in the Punjab Himalaya of nummulites indicates that this portion of the range did not emerge from the sea till comparatively recently.

Bifurcations.

The direction of the Great Himalaya range does not bend with an uniform curvature, but follows different alignments. As it bends from west to north-west it frequently bifurcates and throws off minor ranges on the convex side of the bends. At each bifurcation the minor range tends at first to continue in the alignment which the great range is forsaking; it gradually, however, turns and finally runs parallel to the new alignment of the great range.

The total length of the Himalaya divided into four sections.

For purposes of description it is convenient to divide the great range into four parts,—the Assam Himalaya, the Nepal Himalaya, the Kumaun Himalaya, and the Punjab Himalaya. Whilst

* *A Manual of the Geology of India, 2nd Edition, page 494.*

in all four parts the great range rises like a wall and the outer ranges tend to run parallel to it, no one portion of the Himalaya resembles another. In Sikkim the lesser and outer ranges are absent; in Kashmir they are conspicuous; in Kumaun they exist, but being oblique in their trend are not clearly marked. Sikkim is a transverse basin, Kashmir is a longitudinal basin, Kumaun is an intricate region of mountains.

In Nepal we find numerous rivers cutting across the Great Himalaya range; in the Punjab between the Sutlej and the Indus we do not find one. In Nepal the great peaks stand in clusters and rows; the great peak of the Punjab stands in solitude. The differences between different Himalayan regions show how impossible it is to deduce general laws from the study of one area.

The Assam Himalaya.

The Assam Himalaya extend from the Brahmaputra to the Tista. Their highest peaks are Kulha Kangri (table v, Part I). The axis of the range appears to trend from east to slightly south of west; it meets the Nepal section of the range in Sikkim, and at the conjunction a change of alignment takes place, the great range in Nepal trending from east to north of west.

At the point where the change occurs, a remarkable sinuosity in the main range is observable; the lower and outer ranges moreover disappear and two long spurs stretch southwards to the plains,—the Singalila ridge from Kinchinjunga and the Chola ridge from Padhunri.* It is conceivable that the change of alignment, the sinuosity of axis, the disappearance of the outer ranges and the two great ridges are all effects of an easterly pressure from the direction of Burma along the range.

The Nepal Himalaya.

The Nepal Himalaya stretch from the Tista to the Kali, and carry the peaks of Everest, Kinchinjunga, Makalu and Dhaulagiri. The great range bends and bifurcates near Dhaulagiri (see figure 1, chart XVI). West of Dhaulagiri (26795 feet) the height of the range diminishes and throughout the wide basin of the Karnali the highest peaks do not rise above 22000 feet; near the western edge of the basin there is the Api-Nampa cluster of peaks.

Not far from Nampa there is a second bifurcation of the great range (figure 2, chart XVI). At all the other Himalayan bifurcations the more northerly branch has been regarded as the continuation of the great range, but from Nampa the southerly branch, carrying Nanda Devi (25645 feet) and Badrinath (23190 feet) has been assumed to be the Great Himalaya, and the northerly branch carrying Kamet (25447 feet) and Leo Pargial (22210 feet) to be the Zaskar range.† After the Nampa bifurcation the southern branch is so large and carries such high peaks, that the northern is obscured from view from the side of India: but at all other bifurcations the northern branch remains the more important, and the more remarkable to Indian observers. *Himalaya was the name given by the Hindus to the snowy range visible from India.*

* North-East Transfrontier sheet No. 7 N. W., 1 inch=4 miles.

† Kamet is seventeen miles in rear of Badrinath, the Vishnuganga flowing between. Atlas Sheets 65 and 66, Scale 1 inch=4 miles.

The Kumaun Himalaya.

The Kumaun Himalaya stretch from the Kali to the Sutlej; the highest peak is Nanda Devi (25645 feet). There are bifurcations at Badrinath and at the Sutlej (see chart XVI).

After the bifurcation at Nampa the width of the great range becomes less and its altitude greater; after the bifurcation at Badrinath (see figure 3, chart XVI) the width becomes greater and the altitude less.

The upper surface of the Kumaun Himalaya appears to be corrugated. The Gangotri glacier, for example, at the source of the Bhagirathi flows for 16 miles along a trough in the crest-zone of the great range (see chart XXIV, Part III). The mean altitude of its surface is 14000 feet, and there are peaks of 22000 feet on either side within 2 miles of it; its trough is parallel to the axis of the great range. * Similar corrugations exist in the Nepal Himalaya behind Mount Everest.† The parallelism of the corrugations leads us to think that they are the results of a superficial compression of the crust. The view of the Great Himalaya, that is obtainable from the plains of India or from the outer hills, conveys the impression that the snowy range possesses a narrow and sharply-edged crest-line, but this idea is incorrect: the summit of the range is several miles broad, and the great peaks stand in a wide zone. To a distant observer the snowy range east of the Sutlej appears to resemble the edge of a saw, but its crest-zone measures 30 miles in breadth.

The Punjab Himalaya.

The Kumaun and the Punjab Himalaya do not follow the same alignment, and originally met at an angle; they are now separated by the defile of the Sutlej, which cuts across the range exactly at the angle. An important bifurcation occurs here (figure 4, chart XVI). After the bifurcation at Dhaulagiri the elevation of the range diminishes, and a similar diminution occurs after the bifurcation at the Sutlej. East of Dhaulagiri there are peaks exceeding 26000 feet, west of it but few peaks rise to 22000 feet. East of the Sutlej the Kedarnath, Jaonli and Badrinath peaks stand above 22000 feet, but west of the Sutlej few peaks exceed 20000 feet. We have already seen that as a range bends, it bifurcates, and now we see that it changes its form after bifurcation.

The characteristics of the great range are so different on the two sides of the Sutlej that doubts as to its original continuity have been expressed: our maps show one range meeting the Sutlej from the east, and two, if not three, smaller ranges leaving it on the west.

The difficulty of determining he original lines of structure is increased by the presence of the extraordinary Narkanda-Mahasu ridge that runs diagonally across the Himalaya from the high snows to the low plains :‡ this ridge is not cut across by any river, and its unbroken uniformity of descent is only equalled by that of Singalila. It forms the southern boundary of the basin of the Sutlej, and it was

* Atlas Sheet No. 65: 1 inch = 4 miles.
† Map of Nepal, 1 inch = 16 miles.
‡ See Atlas Sheet No. 47, scale 1 inch = 4 miles, and Sheets of the Punjab Survey, Nos. 310 S.-E. and 311 N.-E., Scale 1 inch = half-a-mile.

regarded by Mr. Fraser in 1820, by Captain Herbert in 1821, and by Captain Gerard in 1822 as the real termination of the great Himalaya of Kumaun and Nepal.

The bifurcating branch at Badrinath becomes the Dhauladhar range of the lesser Himalaya, that at the Sutlej becomes the Pir Panjal range of Kashmir. The Dhauladhar, the Pir Panjal, the Punjab Himalaya and the Zaskar ranges are all secondary undulations superposed on one flat broad arch, the span of which reaches from the plains of the Punjab to the Indus in Tibet.

Near the centre of the Punjab Himalaya the range culminates in the Nun Kun peaks* (23410 and 23250 feet) which stand 3000 feet above the crest.

The water-parting of the Punjab Himalaya follows an exceptionally straight line from the Sutlej to the Nun Kun peaks, and again from those peaks onwards, but at the peaks themselves it exhibits a double sinuosity, which is illustrated on chart XXXIV of Part III, and which is possibly a feature of original structure. North-west of the Nun Kun peaks the crest-zone is in places corrugated.

The northern and southern slopes of the Punjab Himalaya are very different in form and character; the northern are bare and stony, but contain lakes and high plains, the southern are forest-clad but are seldom level.

In the Nepal and Kumaun Himalaya there are many river gorges piercing the granite range, but no river crosses the Punjab Himalaya. The Zoji pass, however, is a remarkable feature of the latter. This pass across the great range is only 11300 feet high, and is consequently below the level of the troughs that lie in rear of the Nepal Himalaya. "Such a depression elsewhere would have been sufficiently deep to open "a passage for the drainage of the table-land, but the great depth of the valley further "north, in which the Indus flows, here gives the waters a more favourable escape in that "direction."†

Though the Zoji defile was probably carved out of the range by a pre-historic river, it is now a true pass, that is to say, it crosses a water-parting line, and from its summit streams descend in opposite directions. The descent from the Zoji is very steep on the side of Kashmir, but is gentle on the side of Ladak: the pass itself is grassy and so level for half a mile that the exact water-parting line is difficult to discover. Peaks rise immediately on both flanks of the pass to 14000 feet, and then gradually to 16000 and 17000 feet.

Western termination of the Great Himalaya.

To the casual observer the Punjab Himalaya appear to terminate suddenly at the Indus in the gigantic cone of Nanga Parbat: and even trigonometrical observations have failed to indicate the course of the great range beyond the Indus (see chart XVII).

Schlagintweit considered that on the western side of the Indus the Himalaya and Karakoram (see frontispiece to Part I) could not be separated into chains: "they "form," he wrote, " one mountain mass, the elevation of which decreases very 'rapidly to the westward."‡

* Ser and Mer, *vide* table VI of Part I. For an exploration of the Nun Kun group see Hunter Workman's address, *Geographical Journal*, Vol. XXXI.

† Sir Richard Strachey's *Himalaya : Encyclopædia Britannica*, Vol. XI.

‡ *Journal, Asiatic Society of Bengal*, Vol. XXVI, 1857.

Colonel Tanner wrote as follows of the country between the Indus and the Kunar (see frontispiece to Part I):—

"The central backbone may be described as a huge broken table-land running up into "wave-like ridges, which rise but a few hundred feet above the general level of the range. "The ridges and peaks on the central backbone are all of nearly the same height, and are "very similar to each other in appearance, and consequently not easy to identify from "points more than a few miles apart. For this reason neither my surveyors nor myself "have been able to fix with accuracy any points on the watershed, nor the passes which "lead over the range, though several have been determined approximately. It is not I "only who have experienced a difficulty here, for the Great Trigonometrical Surveyors, "when prosecuting the Kashmir triangulation, though they have fixed peaks far away "even in the very heart of Kafiristan, have failed to determine more than two or three "points on the entire watershed, a distance of nearly 150 miles. From the beginning of "September the great ocean-like expanse of wavy ridges was snowed up."*

At a subsequent date Colonel Tanner referred again to the same region. "We have "now obtained," he wrote,† "nearly all the topography of that remarkable region, which "is situated on the northern slope of its ill-defined watershed, and to the eastward a small "portion of the southern slope as well. It is an immense tangle of exceedingly sharp "ridges, which zigzag about in the most perplexing manner. There are hundreds of peaks "of nearly the same height and so like each other that after moving a few miles they cannot "be recognised. One very marked feature in this range is the extraordinary number "of mountain lakes or tarns, which are found as many as three or four together at the "sources of all the small feeders."

Mr. Lydekker has also referred to the uniformity of elevation which prevails in the region north-west of the Indus. "A remarkable feature," he wrote, "along the Indus "valley in Darel, for the notice of which the writer is indebted to Lieutenant-Colonel "Tanner, is that all the peaks over a considerable area reach to a nearly uniform height "of about 21000 feet; thus apparently leading to the conclusion that this level indicates "an old plain of marine denudation, originally bordered by higher ground of which "the peaks of Nanga Parbat and Rakaposhi reaching to over 26000 and 25000 feet "are remnants."‡

Trigonometrical surveyors have thus not been able to trace by means of heights the continuation of the Great Himalayan axis beyond the Indus, and the problem will not be solved without a geological survey. It is possible that the range curves in

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* *General Report, Survey of India*, 1878-79.

† *General Report, Survey of India*, 1879-80.

The following extract is also from Colonel Tanner's Report for 1879-80: "When I say that I have fixed 145 hill peaks, "I do not wish it to be understood that the points have the accuracy of those hitherto accepted by the Great Trigonometri- "cal Survey. The apexes of some of my triangles are so acute that an error of one minute at either of the ends of the base "would make an error of ten miles in the position of the point. I hope however at some future time to be able to improve "the shape of the triangles, so that my points shall be true to a tenth of a mile."

‡ *Memoirs, Geological Survey of India*, Vol. XXII, 1883.

parallelism to the Karakoram and Kailas ranges, and that the Indus has cut through it at its bend. If the bend is accompanied by a bifurcation, the same difficulty of identifying continuity will occur here as has occurred at the Sutlej.

The country to the west of the Indus has not as yet been geologically surveyed, and we know nothing of the trend of folds between the Indus and the Kunar. We know, however, that in Chitral the prevailing strike of the stratified rocks as observed by Sir Henry McMahon is approximately from north-east to south-west,* whilst a similar trend has been observed by Mr. Middlemiss in all the sedimentary series of Hazara,† and it is therefore highly probable that a corresponding change of alignment occurs in the ranges of the intervening area.

Eastern termination of the Great Himalaya.

Though trigonometrical observations failed to determine the trans-Indus extension of the great range, they revealed the general surface form of the region, but east of the Brahmaputra no observations have been taken; and nothing is known at all of this extremity of the Himalaya, beyond the meridian of 93°.‡

The southerly extension of the Ninchinthangla range shown on chart XVII is purely conjectural.

The Arakan ranges running in directions parallel to one another and perpendicular to the Great Himalaya appear on maps to be compressed unduly close together opposite the extreme point of the latter range; north and south of this point they seem to diverge to a certain extent from one another. If we were to accept the maps as reliable, we might be led to infer that the wrinkles of the Arakan crust had been squeezed together by the resistance offered to them by the point of the perpendicular range: but the country has never been surveyed and the maps cannot be accepted; the apparent crowding of the Arakan ranges against the Himalayan point must have originated in the imagination of a draftsman.

Prince Kropotkin thinks that the Great Himalaya continues as a considerable range through Arakan into China, and that it is cut across by the Salween, the Mekong and the Yangtze. "The great Khingan," he writes, "which is the eastern border range "of the great plateau of east Asia, joins the Himalaya, and consequently in the region "(29° N., 117° E.) where we have on our maps fan-like chains of mountains radiating "between the Salween, the Mekong and the Blue river, there are simply narrow gorges "through which these rivers descend from the plateau."§

There are, however, reasons why we are unable to accept Prince Kropotkin's theory: it is improbable that three extraordinary rivers, possessing long Tibetan courses, should develop very close parallel troughs between Tibet and Burma: we believe that

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* *Geological Magazine*, Dec. IV, Vol. 9 (1902), p. 5.

† *Memoirs, Geological Survey of India*, Vol. XXVI (1896).

‡ General Walker thought there were no peaks higher than 16700 feet east of longitnde 93°. *Proceedings, Royal Geographical Society*, 1887.

§ *Geographical Journal*, Vol. XXIII, 1904.

the troughs in which they flow must be features of original structure: if the three rivers had had to force a passage through the Great Himalaya, they would have probably united before doing so (chart XVII).

It may be found that near longitude 98° the Great Himalaya changes direction to the south-east. On the other hand it is possible that no continuous extension will be discovered, and that the range will be shown to end between the meridians of 96° and 98°.

If we consider the great difficulty of tracing the Himalayan connection across the Sutlej through a tract that is comparatively well-known, we shall realise the futility of theorising upon the unexplored region east of the Brahmaputra. Were a range to maintain similarity of form and uniformity of height on the two sides of a river gorge, no difficulty of identification would arise; but rivers frequently cut across ranges at the very points where the ranges are undergoing change in shape, and destroy the ranges at the places where the differences originate.

Chart XVII illustrates the similarities between the eastern and western terminations of the Great Himalaya. We have as yet no proof that the Ninchinthangla sweeps round on the east as the Karakoram does on the west, but the courses of the rivers in the two regions are very similar. On the north-west we have a number of rivers flowing parallel to the Hindu Kush and crossing the Himalayan alignment at right angles: there are the Indus, the Kishanganga, the Swat, the Kunar, the Panjshir and the Oxus. On the east we observe the same phenomenon: the Brahmaputra, the Salween, the Mekong and the Yangtze all cross the Himalayan alignment at right angles.

On the north-west the several parallel rivers flow into the Kabul river, which flows from the Hindu Kush on a course parallel to the Himalaya: on the east the Zayul river is to the Brahmaputra what the Kabul river is to the Indus. The Raga tributary of the Brahmaputra in Tibet has its counterpart in the Shyok tributary of the Indus (charts XXX and XXXIV of Part III).

The variations in the height of the crest of the Great Himalaya.

We have now to trace the crest-zone of the Great Himalaya and to observe its variations in height. From the ten Himalayan groups of peaks described in Part I and tabulated on pages 37 and 38, we can determine the lengths of the Himalayan axis carrying peaks of 24000 feet and higher, and the lengths of axis on which no such peaks occur.

In chart XIII a longitudinal section along the crest-line of the Great Himalaya range, from the Indus to the Tista, has been drawn to illustrate the principal gaps in the line of great peaks.* In the following table are given, *firstly*, the several lengths

* We have not sufficient information to justify us extending the section from the Tista to the Brahmaputra.

of crest-line which have been observed to carry peaks exceeding 24000 feet, and, *secondly*, those lengths on which no peaks of 24000 feet have been discovered :—

TABLE XXV.

The clevated portions of the range.	The depressions of the range.	Length of continuous crest-zone carrying peaks exceeding 24000 feet.	Length of depressions in crest-zone where no peaks of 24000 feet occur.
		Miles.	Miles.
Kinchinjunga group of peaks	....	7	....
....	Passage of the Arun Kosi .	....	63
Everest group of peaks . .	....	35	....
....	Passage of the Bhotia Kosi .	....	60
Gosainthan group of peaks .	....	2	....
....	Passage of the Trisuli Gandak	....	39
Group V *	....	1	....
....	Passage of the Buria Gandak .	....	34
Group VI*	....	10	....
....	Depression of range . .	....	26
Group VII * . . .	....	18	....
....	Passage of the Kali Gandak.	....	21
Dhaulagiri group . . .	....	17	....
....	Depression of range .	....	223
Nanda Devi	....	1	....
....	Depression of range .	....	470
Nanga Parbat . . .	....	2	....
Aggregate length of crest carrying great peaks . . .		93	....
Aggregate length of gaps and depressions . . .		....	936

Ninety miles of the crest-zone of the Nepal Himalaya carry peaks exceeding 24000 feet : the twin peaks of Nanda Devi are the only points of the Kumaun Himalaya that rise above 24000 feet, and the peaks of Nanga Parbat the only points of the Punjab Himalaya.

If complete maps existed of the Himalaya, the whole area would be found to be dotted with passes: the number of passes runs into thousands, and no attempt has been made in this paper to compile a catalogue.

Passes over the Great Himalaya.

Passes do not as a rule possess any scientific interest; they are mostly situated on the crests of spurs and minor ridges, and are seldom found upon the axes of the great ranges. We will take the cases of a few well-known passes to illustrate our meaning. The Tipta (15600 feet), for example, is a much-frequented pass

* *Vide* page 38 of Part I.

of eastern Nepal, but it has no geographical significance; it is situated on the crest of a southern spur of the Great Himalaya,—a spur that has been carved altogether by water,—and it allows travellers to cross from the valley of the Tambar Kosi to that of the sister-river the Arun. The Rohtang pass (13000 feet, chart XXXII) and the Hamta (14000 feet) cross the eastern section of the Pir Panjal range between Kulu and Lahaul and are on the water-parting between the Beas and Chenab. The Buran ghati* (15121 feet) and the Shatul (15555 feet) cross the eastern section of the Dhauladhar range south of the Baspa. The Kamri (13250 feet) and the Burzil (13500 feet) cross weather-worn ridges north of Kashmir. Even the Manirang (18600 feet), south of the Spiti basin, and the Baralacha (16047 feet), north of Lahaul, cannot be regarded as crossing the Great Himalaya.

In the Nepal and Kumaun Himalaya travellers pass from India into Tibet along the channels of the great rivers: these channels, difficult though they are, furnish readier means of access than mountain paths above the snow, and passes over the range are consequently not necessary. The defile of a river is sometimes regarded as a "pass," but when entered upon a map, the word "pass" almost always denotes the highest point of a path, with an ascent to it from one side and a descent from it on the other.†

The Bhotia Kosi and Dudh Kosi rivers (chart XXVIII) rise in the Great Himalaya range but north of its axis, the former at the Thanglang pass (18460 feet), the latter at the Pangula (20000 feet). These passes are the highest points of routes connecting Nepal and Tibet, but they are not situated on the axis of the great range, being 30 or 40 miles in rear of it. The rivers have cut down the axis and the passes cross only the northern flank of the range. Similarly the passes into Tibet from the Tista basin, the Koru (16900 feet), the Naku (18186 feet), the Donkia (18100 feet), are over the northern flank of the great range but not over the axis; the Tista has carved a bay out of the range behind the axis and the passes lead over the northern edge of the bay. The Tang pass (15200 feet), however, near Chumalhari, at the head of the Chumbi valley, is a pass over the axis of the great range itself.

The Punjab Himalaya, not having been pierced by rivers, furnishes more examples of passes crossing the axis than the mountains of Nepal and Kumaun. A notch in a range does not become a "pass," until it is frequented by travellers, and though notches in Nepal are probably as plentiful as in the Punjab, they are not used as passes. In the Punjab the absence of river-gorges through the range obliges men to cross the crest-line, if they wish to enter Tibet, and several passes, of which the Zoji (11300 feet) is the best known, do traverse the axis of the great range.

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* The "Boorendo" of Gerard, 1821.

† The English word "pass" denotes any narrow passage. The Afghan word "Kotal" and the Tibetan word "La" denote the highest point of a mountain path, with an ascent to it on one side and a descent from it on the other. The topographical *symbol* for "pass" is only applied on maps to *Kotals* or *La-s*, but the *word* "pass" has been applied also to long river beds like the Khyber and Bolan

The Siwalik range.

Its age and continuity.

The Siwalik range separates the Himalaya mountains from the plains of India and is the southern border range of the Tibet mountain system. Though its upheaval was accompanied by movements of the Himalayan mountains themselves, and probably by increases in the latter's elevation, yet the Siwalik range is of more recent formation, and is, perhaps, the most recently formed range of similar magnitude on the earth. It is still in the first stage of growth, and it may be expected in the future to rise in altitude and to expand in width.

With the exception of a short distance of 50 miles, opposite to the basins of the Tista and the Raidak, the Siwalik range has been shown by geologists to skirt the Himalaya throughout their length with remarkable uniformity for 1600 miles, from the Brahmaputra to the Indus and even to the west of the Punjab.

At the passage of the Sutlej there is a break—not a bend—in the alignment and the two lengths of range appear to overlap. Figure 2 of chart XIX shows how the range north of the Sutlej is not a direct prolongation of the one to the south.* If the elevation of the Siwalik range continues now to increase, and at a rate sufficient to dam the Sutlej, the present overlap will be converted into a sinuosity of the crest-line and water-parting, such as is often seen on great ranges, and the present defile of the Sutlej will become a "pass."

Its "duns."

In places the Siwalik range is pressed against the outer Himalayan ranges, and its existence would be overlooked by the casual observer: in other places, it is separated from the Himalaya for distances of 20 or 50 miles and encloses canoe-shaped longitudinal valleys called "duns."† The best known of these is the Dehra Dun, that stretches from the Ganges to the Jumna: deposits of rounded stones, gravel and sand have been brought down to the Dehra Dun from the Himalaya and have raised its surface 1000 feet above the level of the plains beyond the Siwaliks. Other duns near Kumaun are the Kotah, Patli, Kothri, Chgumbi, and the Kyarda, and many exist in Nepal; but they are not found north of the Ravi.

A bifurcation.

The Siwalik range is strongly developed opposite the Dehra Dun with steep southern slopes and gentle northern: near the centre of this dun the range bends through an angle of 40 degrees, a similar bend being observable in the outer Himalayan range, 15 miles to the north. On the convex side of its bend, following the example of its great Himalayan neighbour, the Siwalik range threw off a branch range, remains of which are still visible in the hill of Nagsidh (see figure 3 of chart XIX). As is a common occurrence in the great Himalaya, the Siwalik range is crossed by a defile at the very point of its bend.‡ Figure 1 of chart XIX illustrates another bifurcation in the Siwalik range.

* Atlas sheet No. 47, Scale 1 inch=4 miles.

† Vide *Physical Geology of the Sub-Himalaya of Garhwal and Kumaun*, by C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, 1890.

‡ The defile is the Mohan pass, see Atlas sheet 48 N. E.; also see sheets of the Dehra Dun and Siwalik Survey.

The Ganges bounds the Dehra Dun on the east, and east of the Ganges the Siwalik range is compressed against the outer Himalaya : it is deserving of note that the Ganges cuts through the two ranges near their point of conjunction.

Its rocks.

The Siwalik range is composed of the same material, hardly consolidated, that forms the deposits of the level plains of northern India. The Siwalik zone was formerly the northernmost belt of the flat alluvial region : it has been compressed by lateral forces into a long fold or range. The folding of the Siwalik strata shows that the whole Himalaya must have advanced southwards.* The thickness of the strata in the Siwaliks exceeds 15000 feet ; these immense deposits were all brought down by the Himalayan rivers and upheaved in recent times. The rocks of the Siwaliks are entirely of fresh-water origin and prove that the sea has not washed the base of the Himalaya since the eocene period.†

Its configuration.

The Siwalik range is of so recent a growth that its features are for the most part the direct results of crustal deformation, and are consequently very different from those of the outer Himalaya which have been mainly modelled by river erosion.

The Siwalik range is cut across by the great rivers of the Himalaya, but no open mountain valleys have been developed by its own streams : the latter are mere torrents, and are enclosed by precipitous walls. Its ridges and spurs are narrower, more sharply edged and more inaccessible than those of the outer Himalaya.

The Siwalik range is of importance because of its proximity to populated tracts, its wonderful continuity, and its geological interest, but from the point of view of magnitude it cannot be compared with any other range of the frontispiece to Part I ; the smallest ranges of the chart are the Lesser Himalaya and the Siwalik, and of these two the former is immensely larger than the latter.‡

The Lesser Himalaya ranges.

The Great Himalaya and the Siwalik ranges are two long parallel folds of the earth's crust,—about 90 miles apart from axis to axis (charts XIV and XV). The region enclosed between them is occupied by the intricate system of ranges we have called the Lesser Himalaya and which we have briefly mentioned on page 75. If we allow for the widths of the Great Himalayan and Siwalik ranges themselves, the zone occupied by the Lesser Himalaya averages perhaps 50 miles in width.

The contortions of the strata show that the Lesser Himalaya region has everywhere been compressed horizontally. These mountains are however the result not

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* *A Manual of the Geology of India.*

† Presidential address by Colonel Godwin-Austen to the Geographical Section of the British Association for the Advancement of Science, 1883.

‡ Objection may be taken to the occasional use that has been made of the plural form *Siwaliks*. We have ourselves no liking for it, but find it difficult to avoid. The plural form is undoubtedly in general use by residents. Similar plural forms are applied to many mountains, such as the *Alps, Appenines, Pyrenees.* We have however avoided employing the form *Himalayas* in this paper.

of one but of many movements of the crust and their history is more complex than that of the Siwaliks: ranges have been uplifted, and have been afterwards forced to change direction: the whole region has been subjected to successive compressions, and the general wrinkling process is probably still continuing.

In Kashmir and parts of Nepal, where outer ranges are distinct, flat alluvial valleys are enclosed behind the Lesser Himalaya, like the " duns " of the Siwalik and like the plains of Tibet, but in Kumaun, though rivers may run for miles parallel to the mountain axes, the longitudinal and high level alluvial valleys are absent.

Cunningham in his work on Ladak writes: " The inferior mountains of the eastern "chain generally run at right angles to its axis, whereas those of the western chain "are mostly disposed in subordinate parallel ranges." We do not think that this view is correct. Cunningham was probably borrowing his ideas of the Nepal Himalaya from the writings of Brian Hodgson. Though the inferior mountains of Kumaun and of parts of Nepal do not run so clearly parallel to the axis of the great chain, as those of the Punjab, yet throughout the Lesser Himalaya the governing lines are parallel and the most striking characteristic is parallelism.

If we attempt to analyse the Lesser Himalayan ranges, we find that they can be divided into two classes: (*a*) those that branch from the Great Himalaya, (*b*) those that are separate folds. The branch ranges of the first class run obliquely across the mountain area; the separate folds of the second class follow curvilinear alignments parallel to the great range.

The great range bifurcates generally at the points where it is changing its alignment, and each successive branch range adopts the alignment, which the trunk range is forsaking. Having traversed the mountain area obliquely the branches slowly alter their direction and finally run parallel to the great range.

We may classify the seven known ranges of the Lesser Himalaya as follows:—

the Nag Tibba,
the Dhauladhar,
the Pir Panjal,
the North Kashmir.

These four ranges are oblique and are separate branches of the great range.

The three outer ranges, which may or may not be different sections of one long range, are—

the Mahabarat,
the Mussooree,
the Rattan Pir.

The Nag Tibba range.

The most easterly oblique range, that is known to us, branches from the Great

Himalaya near Dhaulagiri (figure 1, chart XVI) and runs at first in prolongation of the great range's alignment. It continues in a straight line strongly developed across the basin of the Karnali; it passes through Almora, Nag Tibba and the Chur,* and conjoins with the Dhauladhar range near the Bara Bangahal (chart XVIII). For over 100 miles in Kumaun this range is without a break, and it compels the Alaknanda, the Pindar and the Sarju to flow parallel to it along its northern flank: the Alaknanda and Pindar rivers combine to pierce it north of Hardwar, and the Sarju combines with the Kali to pierce it near the western border of Nepal.

Twenty-four miles west of Dhaulagiri (26795 feet) the highest peak of the Nag Tibba range is 23750 feet: at 52 miles the highest peak is 19875 feet, at 70 miles 15000 feet, at 96 miles 12000 feet;† south of the Pindar river its peaks are 9000 feet. These figures indicate how the branch declines in height on separating from the trunk range.‡

The Dhauladhar range.

The second oblique range branches from the great range near Badrinath, and runs south of the Baspa tributary of the Sutlej. It is cut in two by the Sutlej at Rampur and by the Beas at Larji; and it is crossed by the Ravi south-west of Chamba. The northern flank of the Dhauladhar range impinges against the southern flank of the Pir Panjal range at the mountain knot of Bara Bangahal.§ The bifurcation near Badrinath is illustrated in figure 3, chart XVI, and the conjunction of flanks at the source of the Ravi in chart XVIII.

The Pir Panjal range.

The third oblique range leaves the great range at the Sutlej (figure 4, chart XVI), and forms the water-parting between the Chenab on one side and the Beas and the Ravi on the other. It bends towards the Dhauladhar range near the source of the Ravi, and the clash between their flanks has created the mountain knot of Bara Bangahal (chart XVIII). The Pir Panjal is the largest of all the Lesser Himalayan ranges, and even at its extremity in Kashmir it carries many peaks exceeding 15000 feet.|| South of Lahaul a considerable area rises above the snow line and numerous glaciers exist: south of Kashmir there are no glaciers, but in places snow lies throughout the year.

The North Kashmir range.

The fourth oblique range branches from the great Himalaya near the Zoji pass: it constitutes the water-parting between the Jhelum and Kishanganga, the latter river draining the angle formed by the bifurcation. Its height is greatest near the point of

* The Chur is a remarkable double peak (11966 feet) twenty-five miles south-east of Simla. It is composed of granite and is supported by seven buttresses. It exceeds in height by 1500 feet all points within thirty miles of it. Though so prominent it is less high than the peaks of the Pir Panjal range. In 1816 Captain Hodgson and Lieutenant Herbert determined the difference of height between the two peaks of the Chur as 460 feet; the higher peak they found to be 1½ miles north of the lower. Atlas Sheet No. 47.

† Between latitude 29° 10′ and 29° 20′, and longitude 82° and 81° 30.′

‡ It is 17776 feet in longitude 82° 30′, 15000 in 82° 10′, 12000 in 81° 30′, and 9000 in 80° 45.′

§ Map of Kangra, 1 inch = 2 miles; Atlas Sheet No. 47.

|| Map of Kashmir, 1 inch = 2 miles.

bifurcation, one of its peaks, Haramukh* (16890 feet), reaching above the snow-line, but westwards it ramifies and declines. For the first 100 miles of its length it is without a gorge: its width exceeds 30 miles.

The Mahabarat range.

West of the Singalila ridge an outer parallel range, known as Mahabarat, traverses the basins of the Kosi and Gandak; it is strongly marked and continues through western Nepal.† Immediately to the east of Singalila, however, no such range is visible, all the lesser ranges having disappeared from the basin of the Tista. Further to the east in Bhutan trigonometrical observations have disclosed the existence of an outer range in latitude $27\frac{1}{2}°$.

The peaks of the Mahabarat range vary from 6000 to 8000 feet, dwindling near the left bank of the Kosi to 5000 feet; throughout its length this range, though serrated like the edge of a saw, offers but few recognisable points to trigonometrical surveyors.

The Mussooree range.

Between the Ganges and Sutlej there is an outer alignment of hills, of which Sirkanda (9080 feet), Landour (7464 feet), Banog (7433 feet), Badraj (7320 feet), and Kasauli (6322 feet) form prominent points: whether this is a remnant of a more southern range, now almost extinct, or whether it originally formed a flank of the Nag Tibba range, 10 miles to the north, we are unable even to conjecture: nor can we tell at present, whether this so-called Mussooree range is a continuation or not of the Mahabarat range of Nepal.

The line of mountains we have called the Mussooree range has barred the exit of the Ganges from the mountains and has forced the Bhagirathi, the Alaknanda, and the Navar affluents to unite in rear of it: the junction of the Tons and the Jumna is also due to its presence.

The Rattan Pir.

South of Kashmir the outermost range is known as the Rattan Pir. This range may be the western extremity of a long outer range, pressed near Kashmir against the Pir Panjal range, or it may be an old flank of the Pir Panjal range itself and not a separate fold. It is separated from the Pir Panjal by the river Punch.

If the Lesser Himalaya had consisted of the oblique ranges only, the mountains might have terminated in the plains of India as diverging and diminishing chains—increasing in number and decreasing in magnitude—like the Hindu Kush in Afghanistan and the Kuen Lun in China. But one or more outer ranges seem to have been upheaved parallel to the great range and these appear to have pressed back the oblique ranges and to have formed a curvilinear wall stretching almost unbroken for 1600 miles from the Brahmaputra to the Indus. If the sea were now to flow over the Indo-Gangetic plains, the Himalayan coast would be a long wall without capes or islands.

* The trigonometrical station of Haramukh is 16001 feet high and one mile north-west of the peak.

† We can trace it from longitude 86°, latitude $27\frac{1}{4}°$, through 85°, $27\frac{3}{4}°$ and 83°, 28° to $80\frac{1}{2}°$, $29\frac{1}{2}°$.

A great transverse spur protrudes from the Zaskar range at Kamet into the upper basin of the Alaknanda. For a length of 20 miles its peaks exceed 20000 feet; its altitude then diminishes to 14000 feet in 6 miles, and it is not visible south of the Dhauli at Joshimath.* It is this extraordinary buttress of Kamet that separates the basins of the Vishnuganga and Dhauli behind the great Himalayan range (chart XXIV, Part III). Its magnitude and continuity suggest the idea that it is a structural fold due to cross pressure.

Transverse ridges.

The western boundary of the Spiti basin seems also to be a transverse range branching at right angles from both sides of the Zaskar range.

The Zaskar range, being the water-parting between the Kumaun Himalaya and Tibet, is crossed by a great number of well-known passes: the Lipu Lekh (16750 feet) is south of the Upper Karnali basin, and near the conjunction of the Zaskar and Great Himalayan ranges. The Manghang, Lankpya and Dharma passes are about 18000 feet, the Untadhura is slightly below 17500: these passes lead to Tibet out of the basin of the Kali. The Kingri Bingri (18300 feet), the Balchha (17500 feet), the Shalshal (16200 feet), the Silikank (18000 feet) and the Niti (16500 feet) are all passes across the water-parting between the Dhauli affluent of the Alaknanda and Tibet, and they by no means constitute a complete list. The Mana pass (18000 feet), called also the Dhungri or Chirbitya, is at the head of the Saraswati affluent of the Alaknanda.† The Muling pass (height unknown) crosses the water-parting between the Bhagirathi and Tibet. The Gumrang and Sholarung passes are further west and connect the Himalayan basin of the Sutlej with its basin in Tibet.

Passes over the Zaskar range.

The Ladak range.

The western portion of this range was called by Sir Alexander Cunningham the Kailas range, on the supposition that the peaks of Kailas rose from its easterly continuation. But the Kailas peaks stand north of the Manasarowar lakes, and the continuation of Cunningham's Kailas range has been found to pass south of Manasarowar (figure 1 of chart XXI, and frontispiece to Part I). Many writers have followed Cunningham, but Drew adopted the name "Leh" range. Godwin-Austen called it the "Ladak" range, because it was the principal feature of Ladak. We have accepted the name Ladak, and have applied it to the whole range from Assam to Baltistan. We are not, however, in a position to certify that a continuous range stretches in rear of the Great Himalayan range throughout the whole length of the latter from east to west.

In rear of the Assam Himalaya the Ladak range is strongly developed, and forms the water-parting between the Brahmaputra of Tibet and the Brahmaputra of Assam.

The southern water-parting of the Brahmaputra of Tibet.

North of the Chumalhari peak of the Great Himalaya, the Nyang river has cut through the Ladak range, and drains northwards into the Brahmaputra.‡ Westwards

* Kumaun and Garhwal Survey, 1 inch=1 mile. Atlas Sheet, No. 65, 1 inch=4 miles.

† The Saraswati is a feeder of the Vishnuganga. The names of passes are spelt in various ways, and much uncertainty prevails.

‡ North-eastern Frontier Sheets, 6 N. W. and 6 S. W., 1 inch = 4 miles.

from the Nyang basin, as far as Lake Manasarowar, the Ladak range is the water-parting of the Brahmaputra, and the drainage of its southern slopes passes across the Great Himalaya into India. The bend in the water-parting at Chumalhari, as drawn on charts XXIII and XXXV, is therefore due to the Nyang river: at this one point the Great Himalaya becomes the water-parting, and the trough to the north of it drains into the Brahmaputra of Tibet.

Westwards from the Nyang basin for a distance of 200 miles, the Ladak range and the Great Himalaya run parallel and enclose between them the long trough of the Arun river, the plains of Dingri, and of Digur Thanka and the lake of Palgu.*

In rear of the bifurcation of the Great Himalayan range at Dhaulagiri the Ladak range increases in elevation, and the trough separating it from the Great Himalaya becomes less distinct.

Continuity of the range.

Behind the Karnali basin the range is strongly developed; it culminates south of Manasarowar in Gurla Mandhata. Immediately west of this great peak the continuation of the range is not distinct.† The gap here is more difficult to explain than the gorge cut by the Nyang, and it is this break in continuity that mainly prevents us from stating definitely that the Ladak fold is continuous. To give a single name to one long range is advantageous, in that the name indicates the position maintained by the range with regard to other ranges. But identity of name implies identity of origin, and whether one long fold extends through Gurla Mandhata from the east of Tibet to the west, is a question that has not been finally decided. The apparent break near Gurla may have been a feature of original structure; the range east of Gurla may be overlapping that from the west; or a portion west of Gurla may have subsided, or have been deflected by recent pressures; or the Ladak range and the range to the north may have expanded sympathetically at Manasarowar, and their flanks have been merged by pressure (figure 1, chart XXI).‡ From information at present available it appears more correct to give one name to the whole range and thereby to imply continuity, than to give different names to different lengths and thereby to imply independence.

When we consider what small accidents of heterogeneity or of resistance in the crust are sufficient to break the uniformity and continuity of a long fold, our wonder is that the ranges of southern Tibet, subjected as they have been to ever varying cross pressures, are as continuous and as uniform as they are.

Intersections of the Ladak range by the Indus.

East of Manasarowar the Ladak range runs south of the Brahmaputra, and, except at Chumalhari, forms the water-parting: west of Manasarowar the range follows the Indus, and its relations to this river are extraordinary.§ The frontispiece to

* Map of Nepal, 1 inch=16 miles.

† Northern Frontier Sheet, 14 S.-W., 1 inch = 4 miles. Ryder's map of southern Tibet, *Geographical Journal*, Vol. XXVI.

‡ On chart XXI this contact between the ranges is called a conjunction: it is however a clash of flanks only and not a conjunction of axes: the thick lines on the chart show only the axes of the ranges and give no idea of their spans.

§ Sheets 5 and 6, Punjab map, 1 inch=8 miles.

Part I shows how the Indus and the Ladak range are intertwined: for the first 180 miles from its source the Indus flows along the trough north of the Ladak range and parallel to the range: near Thangra, north of Hanle, it bends at right angles, cuts across the range, and forsakes the trough it has been occupying. It now flows for 300 miles along the south flank of the Ladak range, and then, shortly before its junction with the Shyok, passes back across the range to its original side. It remains on the north side for 100 miles and then cuts across the range for the third time.*

At the intersection near Hanle the range is strongly developed, and that it is cut through there can be little doubt. On both sides of the river-gorge the core of the range is found to be of granite, and the alignment is found to be the same.

The troughs on either side of the Ladak range in Ladak are comparatively open and contain but small impediments to the flow of the mighty river: the behaviour of the latter in cutting constant gorges through a granite range in preference to pursuing a straight and simple course is most eccentric. As a geographical feature it is unique.† We can only suppose that the Ladak range has grown, since the Indus began to flow, and that like a tree trunk embraced by a creeper, it has in its expansions had grooves cut across it by the river.

But little is known of the Ladak range between the Sutlej and its intersection by the Indus near Hanle; nothing is known of it east of longitude 91°, or west of longitude 74°.

A great number of passes cross the Ladak range: on its north-western section south of the Indus are situated the Harpo (16785 feet), the Burgi (15697 feet), the Bunnuk. Behind Leh are the Lasirmou (16900 feet), and the Laowchi or Khardung (17600 feet).

Passes over the Ladak range.

Between Leh and the intersection of the Ladak range near Thangra by the Indus the principal pass is the Kay (18250 feet). Between Hanle and Manasarowar are the Medosi (17700 feet), the Boga (19200 feet) and the Ayi (18700 feet): south of the lake Rakas Tal are two passes over the Ladak range, height 17100 and 18200 feet: north of Nepal there are the Photu (15080 feet), the No (16600 feet), the Taku, the Sheru (17600 feet), the Kura (17900 feet) and others.‡

The Marsemik, Dumche, and Chang passes are on the Kailas and not on the Ladak range.

The Kailas range.

The Kailas range runs parallel to the Ladak range fifty miles in rear of it (figure 1, chart XXI). Near Manasarowar it contains a crowded cluster of peaks, several of which exceed 20000 feet, and the highest of which is Kailas (22028 feet). Opposite to

* In the frontispiece of Part I the third intersection of the range by the river is drawn at Bunji near the great knee-bend of the Indus: the continuity of the range has, however, not been proved. It is clear that the Indus must pass somewhere in this region across the range to the south, but it is not certain where it does so. The return passage may occur a little west of longitude 76°: if that be the case, the range should have been drawn on the chart nearer to the Kailas range, and the Zaskar range should have been produced across the Indus at the point on the chart where the Ladak range crosses it.

† Compare, however, the intersections of the Zaskar range by the Spiti river. On chart XXXI of Part III the course of the Zaskar range can be traced from its peaks of Shilla, Leo Pargial, and Kamet.

‡ The names of passes are spelt in different ways, and it is not possible to say which are the correct forms. The Khardung pass is described in the *Marches of Hindustan* by David Fraser. Ryder crossed the Kura Pass in 1904, *vide Geographical Journal*, Vol. XXVI, p. 383.

the culmination of the range in the Kailas peak, the Ladak range culminates in Gurla Mandhata; both ranges expand at this point and their flanks come into conjunction.

East of Manasarowar the Kailas range forms generally the northern rim of the Brahmaputra's trough: it cannot, however, be called the water-parting, as it is cut through in places by rivers from the north.

A branch from the Kailas range.

East of longitude 85° the Kailas range bifurcates* (frontispiece to Part I), and for nearly 150 miles the river Raga (chart xxx) flows along the trough between the two branches.

Immediately after bifurcation the branch range is crowned by a cluster of peaks, many of which were found by Captain Wood to exceed 20000 feet; peaks of 18000 feet have been found upon it as far east as its intersection, in longitude 87° 45′, by the main stream of the Brahmaputra: its height diminishes near its intersection by the Nyang but increases again to 18000 feet further east.

The branch range appears to conjoin with the Ladak range near Lake Yamdrok: this section of it was called by Ryder the Karo La range.†

Continuity of the Kailas range.

After throwing off its branch the main Kailas range runs eastwards with peaks of 20000 feet. Trigonometrical observations show that it joins with a range of Tibet, known as the Ninchinthangla, in longitude 88°. After this conjunction the Kailas range itself continues to trend in its former alignment as far as longitude 92° and possibly further. Nothing is known of the Kailas range east of 92°.

Near Manasarowar the Kailas range is strongly developed and the ranges to the south of it expand here in sympathy. Within one region are to be found the culminating peaks of four different ranges,—Kailas, Gurla Mandhata, Kamet and Nanda Devi.

From Manasarowar the Kailas range can be traced along the north bank of the Indus as far as the Pangong lakes. In longitude 80° it is intersected by the Singhgi, the eastern branch of the Indus.

A break in the continuity.

On reaching the Pangong lakes it appears to end in the peak of Sajum (20018 feet), but further west it can be traced again, and then forms the water-parting between the Shyok on the south and the Nubra on the north: the alignment from Sajum to the junction of the Nubra and Shyok has not been determined, and the range has been broken on the frontispiece to Part I to denote uncertainty.‡ It is possible that the Kailas range has clashed with the Ladak west of Sajum peak, and that for a short length the two ranges are

* The Ladak range appears to bend sympathetically opposite to the bifurcation. Sheets 22 N. W. and 22 N. E., Northern Frontier, 1 inch = 4 miles. This part of Tibet was surveyed by Ryder in 1904, *vide Report on survey operations on the journey from Gyangtse to Simla viâ Gartok.*

† North-Eastern Frontier Sheet 6 N. E., 1 inch = 4 miles.

‡ North of Leh the Kailas range is clearly marked. Sheet No. 5, Punjab map. 1 inch=8 miles. For Sajum peak, see map of Turkistan, 1 inch=32 miles.

here welded together. It is also possible that vertical subsidences have destroyed the continuity of the Kailas near Pangong.

West of the junction of the Nubra and Shyok the Kailas range runs parallel to its northern neighbour the Karakoram; the long troughs occupied by the Biafo, Hispar and Chogo Lungma glaciers lie between the Kailas and Karakoram ranges.

Culmination and termination.

Opposite the kneebend of the Indus near Bunji the Kailas range is crowned by the peak of Haramosh (24270 feet).* Within nine miles of its intersection by the Hunza river stands Rakaposhi, its highest peak, and it is near this point—the point of intersection and of supreme altitude—that the range begins to change its direction. After a long course from south-east to north-west it bends through a wide curve, and then runs from north-east to south-west, declining in height as it bends. West of Rakaposhi, however, its alignment is very difficult to trace; in this region the range has been so cut to pieces by feeders of the Gilgit and Kunar rivers, that its present appearance resembles a line of detached pyramids (chart XXXIV).

In figure 2, chart XXI, the Kailas range has been extended across the Kunar river at Chitral: but this prolongation is only suggested, and has not been entered upon the frontispiece of Part I.

* Atlas Sheet 27 S. E., 1 inch = 4 miles. Northern Transfrontier Sheet 3 N. E., 1 inch = 4 miles. Map to illustrate Captain Younghusband's explorations, 1 inch = 16 miles.

16

THE KARAKORAM AND THE HINDU KUSH.

The Karakoram.

The nomenclature of the mountain ranges of Asia has been the source of many difficulties. The applications of names by natives are vague and indefinite; and a mountain chain may even be designated differently in neighbouring villages. In the study of geography the employment of names is a means to an end, and we should therefore endeavour to introduce as simple a nomenclature as possible. It is not necessary to retain several names for a single range; nor is it advisable to abandon a name, after it has been for many years in common use upon maps, because faults come to be found with it.

Moorcroft was the first western geographer to apply the name Karakoram to the great range of mountains, which separates the Indus and Tarim basins. Moorcroft was a careful observer, and he learnt the name from natives in Tibet. For 60 years the name Karakoram was employed by geographers, and throughout the surveys of Kashmir and Baltistan no objections to it were raised by surveyors.

Some 20 or 30 years ago the alternative name, Muztagh, was introduced and an endeavour was made to displace the name Karakoram. There was nothing to be gained by the change, and it has only resulted in confusion. By some writers and map-makers the name Karakoram has been retained, by others the name Muztagh has been accepted, and by others the two names are now given together.

The objection raised to the old name "Karakoram" was that it meant "black "gravel," whereas "Muztagh" means "ice mountain." The original meaning of a name has nothing to do with its suitability: black gravel is found on the slopes of the Karakoram, and Moorcroft relying on native information named the range "black "gravel."

The confusion caused by the introduction of the name Muztagh should be a warning to geographers to accept accomplished facts. Now that the name Muztagh has come to be applied on modern maps to the Karakoram range, explorers are discovering that it is attached to every snow mountain in Chinese Turkistan. The peak Muztagh Ata is not on the Karakoram but on the Kashgar range: Sven Hedin writes of the Kashgar range as the Muztagh range:* on the authority of a village headman Dr. Stein gives the name Muztagh to a peak of the Kuen Lun;† Semenoff called the western portion of the Tian Shan "the Muztagh."

Muztagh, meaning "ice mountain," is in fact a description, not a name. Colonel Wahab writes, "Muztaghs are as common all over Central Asia as Safed Kohs on our "north-western frontier. The name Karakoram is quite established now for the moun- "tain range separating the Indus and Zarafshan, and is the most suitable."

We are of opinion that the name Muztagh should be used for the peak Muztagh Ata, but not as an alternative for the name Karakoram; the latter alone should in future be applied to the mountain range, of which K^2 is the highest summit.

* Sven Hedin: *Through Asia,* page 670.
† M. A. Stein: *Sand-buried ruins of Khotan.*

The earth-fold. The Karakoram and Hindu Kush ranges of mountains are different sections of the same crustal fold. The fold traverses western Tibet from south-east to north-west, curves round through Hunza and Gilgit, passes north of Chitral, and enters Afghanistan in a direction from north-east to south-west.* The eastern portion of the fold is known as the Karakoram range, the western portion as the Hindu Kush.

The range does not change its name at any particular natural feature; but, as the limits of application of the two names require to be settled for the convenience of geographers, it will perhaps be well, if we call the mountain chain in Tibet and Hunza the "Karakoram," and in Gilgit, Chitral and Afghanistan the "Hindu Kush." The water-parting between the Hunza and Gilgit rivers (charts xx and xxxiv) situated some ten miles east of the meridian of 74° will then form the dividing line.†

Gaps in the Karakoram range. In chart xx a longitudinal section of the Karakoram has been drawn to explain graphically the causes of the gaps in the range. This section has been made to follow the curved alignment of the Karakoram and Hindu Kush ranges. A comparison of the section against the groups of peaks, described in Part I, will show how the range is divided into blocks: the following table gives both the continuous lengths of range that carry peaks higher than 24000 feet, and the intervening gaps, where no such peaks exist:—

TABLE XXVI.

The elevated portions of the range, carrying peaks of 24000 feet and higher.	The depressions of the range.	Length of continuous crest-zone carrying peaks exceeding 24000 feet.	Length of depressions in crest-zone, where no peaks of 24000 feet occur.
No peaks of 24000 feet have been discovered on the Karakoram east of the Shyok river.			
		Miles.	Miles.
Shyok Nubra group of peaks .	. . . .	5	....
....	Passage of the Nubra river .	....	12
Group XII‡	. . . .	1	....
....	Crest-zone carries no great peaks.	....	35
Group XIII‡.	. . . .	13	....
....	Crest-zone carries no great peaks.	....	22
Karakoram group	. . . .	18	....
....	Crest-zone carries no great peaks.	....	60
Kunjut group	. . . .	25	....
....	Passage of the Hunza river .	....	22
Hunza-Kunji group . . .	. . . .	16	....
....	Long depression of range containing the gorges of the Gilgit and Kunar rivers .	....	140
Tirich Mir group . . .	. . . .	26	....
	There are no peaks of 24000 feet west of the Tirich Mir group.		
Aggregate length of crest carrying great peaks		104	....
Aggregate length of gaps and depressions		....	291

* The curvature of its course is sharper than that of the great Himalaya.

† Northern Transfrontier, Sheet No. 2 : 1 inch=8 miles. As a dividing line across a range, a river would be more distinct than a water-parting. But water-partings form the divisions between tribes and dialects more often than rivers, and are therefore perhaps the more suitable divisions in nomenclature.

‡ *Vide* page 40 of Part I.

The Shyok, Hunza, Gilgit and Kunar rivers drain the trough *behind* the Karakoram range; the Nubra river rises *in* the Karakoram, the glacier at its source having cut a notch in the crest-zone.

Though the number of great peaks is less on the Karakoram than on the Great Himalaya, there is a greater length of high range, on which great peaks stand without deep intervening depressions. A length of 104 miles of the Karakoram crest carries great peaks against one of 93 miles of the Great Himalaya. The Karakoram rises as it leaves Tibet, culminates in K^2, and then slowly declines: its crest does not show the surgings of the Great Himalaya.

Eastern extension of the Karakoram.

The western termination of the Karakoram is the Hindu Kush, but of its eastern termination we know nothing.* The peak of Aling Kangri, which stands in Tibet near the eastern source of the Indus, has been supposed to mark the continuation of the Karakoram fold, but chart xx illustrates our inability to draw the eastern section of the range. At Pangong and Rudok, between the known eastern extremity of the Karakoram and its supposed continuation at Aling Kangri, no range appears to exist,† but our geographical knowledge of this region is very imperfect.

As we said of the Kailas range when referring to this same region, a portion of the Karakoram may have subsided vertically: on the other hand, the normal height of the Karakoram at this spot may not be above 17000 or 18000 feet, in which case it would be now projecting only 1000 or 2000 feet above the surface of the high level alluvial plains of Tibet and be attracting no particular attention from explorers.

East of Aling Kangri a great range was observed by the explorer Nain Singh. He left Leh in July 1874, and travelled due east from Rudok for a distance of more than 800 miles; an almost continuous range of snow mountains, he said, trended eastwards from Aling Kangri (longitude 81°) to the Ninchinthangla peaks (longitude 90° 30′) (see frontispiece to Part I).‡

The possible existence of a second Karakoram range.

Another question that cannot yet be answered is—Are there two Karakoram ranges parallel to one another? There are, we shall show hereafter, two Hindu Kush ranges (frontispiece to Part I), and we have not been able to discover where the northern Hindu Kush range terminates towards the east.

North-west and south-east of the peak K^2 we see in rear of the Karakoram range, and at a constant distance from it, a very marked water-parting shown on maps, which curves back from the Karakoram axis in two places (see areas C and H of chart xxxv). It is crossed by numerous passes, the Shimshal (14719 feet), the Khunjerab (15420 feet), the Mintaka (15430 feet), the Kilik (15600 feet), the Karakoram (18550 feet).§

What is this water-parting? Is it a fold of the Earth's crust? Is it an easterly continuation of the northern Hindu Kush fold, and has it been welded by pressure

* Map of Hundes or Nari Khorsam, 1 inch = 8 miles.

† Access to Tibet from the west is easy at this point, *vide* Sir Thomas Holdich's *India*.

‡ *General Report, G. T. Survey of India*, 1874-75.

§ The two Muztagh passes, the western of which was crossed by Younghusband, are on the great Karakoram range. Height of western Muztagh pass 19029 feet, Ferber's aneroid value, *Geographical Journal*, Vol. XXX, Dec. 1907, p. 639.

into the Karakoram at K^2? These are questions we are quite unable to answer. No second Karakoram range has been shown upon the frontispiece to Part I; its existence as a separate crustal fold is conjectural, and it would be unsafe to draw conclusions as to structure from observations of drainage. It is possible that the Karakoram range has thrown off bifurcations, and that these have complicated the orography.

Even the great Karakoram peaks themselves seem to follow two alignments. The Masherbrum peaks and peak 63 (table v of Part I) surmount a ridge parallel to that on which the peaks of K^2 and Gasherbrum stand, and at a distance of ten miles from it. Of the Karakoram peaks north-east of K^2 we have no knowledge, and there is no more likely spot than this for great undiscovered peake to be existing.

Comparisons with the Alps.

Colonel Montgomerie gave the following account of the mountains of western Tibet, of which the Karakoram is the backbone: "From "any point in the Punjab at the foot of the Himalaya "it takes a man assisted by a pony sixty-six days to cross the mountains; and I think "that even if a man tried his utmost he could not well do it under fifty-five days; during "that distance the road is for twenty-five marches never under an elevation of 15000 "feet, and during forty-five marches never descends below 9000 feet."

"The Alps, I suppose, would take, at the outside, three days for a man to cross, "and I believe that a good walker can cross from a village on one side to a village on "the other in one summer's day. The Munshi took twenty-five days to march from "the last village south of the Karakoram to the first village north of the Karakoram."

"In no parts of the Alps," writes Sir Martin Conway, "is there anything like the "amount of rock ruin, even in proportion to the size of the mountains, that one finds "in these dry districts of the Karakoram."*

The Karakoram is a more arid and less wooded region than the Himalaya; its topographical features are consequently different. Rain-water runs off more rapidly, less sinks below the surface, and the rocks are not protected to the same extent against variations of temperature by a mantle of verdure.

The Hindu Kush.

Humboldt believed that the Hindu Kush range was a continuation of the Kuen Lun,† and an examination of the frontispiece to Part I shows how natural such a supposition was. Even now we cannot draw the crustal folds of the Pamir plateau or of the region to its south-east.

Trigonometrical observations and topographical surveys have shown that the Hindu Kush consists of two distinct parallel ranges.‡ The highest peaks and the deepest gorges are found on the southern range, and smaller variations of relief on the northern.

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* W. M. Conway: *Climbing in the Himalayas*, 1894.

† A. Von Humboldt: *Cosmos*, Vol. II, page 154.

‡ Holdich's *India*, page 84.

Drainage of the Hindu Kush trough.

The northern Hindu Kush range bears the same relation to the southern, as the Ladak range does to the Great Himalaya in Nepal: that is to say, the northern is the primary water-parting, and its drainage escapes through the gorges of the loftier southern range.

The Hunza river rises beyond the southern range and cuts through it. Similarly the Gilgit river drains the trough between the two Hindu Kush ranges for 40 miles and escapes through the southern range; the crests of the two ranges are 13 miles apart in the basin of the Gilgit. The Kunar river drains the interior of the trough for over 50 miles and pierces the southern Hindu Kush range at the Ishpirin defile.* The Panjshir river drains a great length of the trough and passes through the southern range to the Indus.†

West of the peaks of Tirich Mir a portion of the trough appears to belong to the system of the Oxus, and still further west is a second and similar alternation of the drainage.† (Chart xx: figure 2 of chart xxi: chart xxxv.)

Continuity of the Hindu Kush.

The frontispiece of Part I and the section in chart xx show that the southern Hindu Kush range is a western extension of the Karakoram fold,‡ and on page 98 we decided to assume the water-parting between the Hunza and Gilgit rivers as the boundary mark between the two names.

For a distance of 140 miles, from the Hunza-Gilgit water-parting to the peaks of Tirich Mir, the Hindu Kush rises to no great altitude, and the original alignment can in places be only traced by the presence of huge pyramidal masses 20000 feet high, which have been carved out of the range.

The Tirich Mir buttress.

North from Tirich Mir a perpendicular buttress projects from the Hindu Kush and deflects the Oxus to the north: it resembles the buttress of Kamet (page 92), and in the same way as the latter issues from the culminating point of the Zaskar range, so does the former protrude from the Hindu Kush at the place of its greatest vertical expansion. The association of a giant peak surpassing all its neighbours with a perpendicular ridge seems to indicate that the crust of the region has been subjected to extraordinary cross-pressures.

The clash of ranges at Tirich Mir.

It will be seen that the drawing in figure 2 of chart xxi does not reproduce the representations of the frontispiece to Part I; the divergence helps to illustrate the uncertainties surrounding the orographical problem. In the frontispiece of Part I we have shown the two parallel Hindu Kush ranges extending westwards from longitude 74° and forming the basins of the Panjshir and of the Hari Rud: the range pierced by the Kunar river at Chitral is, in this chart, the southern Hindu Kush. In figure 2 of chart xxi we have suggested an alternative solution, and have made

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* Northern Transfrontier Sheet No. 2, 1 inch = 8 miles.

† North-west Transfrontier Sheets Nos. 26, 27, 1 inch = 8 miles.

‡ Chart xx illustrates the southern range only. On this chart the Kunar river has been wrongly called the Yarkhun, which is a local name for one section of the river.

the two Hindu Kush ranges conjoin near the mass of Tirich Mir, and continue thereafter as one range. According to chart XXI the range pierced by the Kunar river near Chitral and the range forming the southern limit of the long trough drained by the Panjshir river are extensions of the great Kailas fold, a further extension of which then becomes the southern rim of the basin of the Hari Rud.*

Westwards from Tirich Mir the Hindu Kush continually throws off minor branches and declines in height: in longitude 68½° its peaks rise above 16000 feet, in 66° they rise to 12000, in 63° they hardly reach 10000.

It is not known whether the water-parting between the Indus and the Helmand (longitude 68½°) is a structural bifurcation from the Hindu Kush or whether it is a ridge carved by rain: its elevation rapidly diminishes as it extends southwards from the Hindu Kush.

Passes over the Hindu Kush.

The beds of the great rivers that pierce the southern Hindu Kush range, provide thoroughfares, and the number of well-known passes over this range is consequently not large. The Darkot (15000 feet) is perhaps the most important; it crosses the range opposite to the Baroghil (12460 feet) and Shawitakh (12560 feet) passes of the northern Hindu Kush.

The northern Hindu Kush is pierced by a few torrential streams, but by no great river. It is crossed by an extraordinary number of passes: west of longitude 67° there are the Sharak Kushta, the Barkak and several others between 10000 and 11000 feet. Further east there are the Irak (13500 feet), the Chahardar (13900 feet), crossed by the Afghan Boundary Commission in 1886, the Kaoshan (14340 feet), crossed by Alexander the Great, and the Khawak (11640 feet), a great trade route.† In the Tirich Mir region there are the Dorah (14800 feet), the Agram (16630 feet), the Nuksan (16050 feet), the Khatinza (17500 feet) and the Sad Ishtragh (17450 feet). Between the last named and the Kilik pass, near the trijunction of the basins of the Indus, Oxus and Tarim, there are numerous passes which average in height about 16000 feet, two of them however being low, namely, the Baroghil (12460 feet) and the Shawitakh (12560 feet). These lists do not pretend to be complete; a few names only have been mentioned to indicate the general elevation of the lowest notches in the Hindu Kush.

* Map of Afghanistan, 1 inch = 16 miles.

† Holdich's *India*, page 85.

17

THE RANGES OF NORTHERN TIBET AND TURKISTAN.

The Aghil, the Kuen Lun and the Altyn Tagh.

The Aghil range.

But little is known of the Aghil range; it was discovered by Sir Francis Younghusband, and a few of its peaks have been observed by surveyors; but its length and direction have not been determined. The position given to it on the frontispiece to Part I and its junction with the Sarikol range are conjectural. The peaks observed between the Kuen Lun and Karakoram ranges along the upper courses of the Yarkand river appear to be scattered rather than aligned, and the region seems to resemble in complexity that between the Indus and Kunar rivers.

It may be that the Kuen Lun, Aghil and Karakoram folds have been pressed against one another; all the ranges of Tibet tend to converge at the north-western corner of the plateau, as though they were trying to escape through the neck of a bottle; once having passed the neck they separate again, but during the passage they appear to suffer from extreme compression.

The Kuen Lun.

The Kuen Lun range runs in an east and west direction through northern Tibet (*vide* frontispiece to Part I); as far as we know, there are in the Kuen Lun no outer and lower parallel ranges as there are in the Himalaya, and from longitude 76° to 83° the Kuen Lun may be described as the northern border range of the Tibet mass. It is, however, only west of longitude 83° that the Kuen Lun faces the Tarim desert: east of this its branch, the Altyn Tagh, becomes the border range.*

The absence of outer and lower ranges has an effect upon the drainage: there are in the Kuen Lun no long valleys like the Dehra Dun, and rivers instead of converging, like those of the Himalaya, inside the mountains flow more directly down from the snows, and enter upon the plains in greater numbers and with smaller volumes. South of Khotan and Kiria the rivers issue from the Kuen Lun at intervals of 20 miles; on the Himalayan side the average interval exceeds 50 miles.

From the snows to the plains of India the Himalaya are 80 or 90 miles broad; from their crest to the plains of Tarim the Kuen Lun are 40 or 50 miles broad.

The portions of the Kuen Lun drained by the Yarkand and Karakash rivers are known as the western Kuen Lun, the remaining lengths as the eastern. Many trigonometrical observations of peaks have been made in the western Kuen Lun, but our knowledge of the eastern range is confined to that gained by explorers, among whom Prejevalsky and Sven Hedin are pre-eminent.* East of longitude 86° the Kuen Lun is known as the Arka Tagh.

* For map, see Holdich's *Tibet the Mysterious*. In the frontispiece chart of Part I the axis of the central Kuen Lun has been drawn too far north. In longitude 84° the axis should have been placed in latitude 36.° Chart XXXV repeats this mistake. Chart XXIII is correct.

The Altyn Tagh.

The north-eastern portion of Tibet consists of the high level plains and basin of Tsaidam, which are bounded on the south by the Kuen Lun, on the north-west by the Altyn Tagh, and on the north-east by the Koko Nor range. The Altyn Tagh was discovered by Prejevalsky; it is a precipitous range, and portions of it rise above the line of perpetual snow. The easterly prolongation of the Altyn Tagh is the great range of Nanshan, considerable lengths of which rise also above the snow-line. The principal peaks of the Altyn Tagh are Anambarula, Amuninoku, and Koukye, all of which probably surpass 19000 feet in height. Both the Altyn Tagh and its continuation the Nanshan appear to be wide folds with minor corrugations superposed. The Koko Nor range of Tsaidam is parallel to the Nanshan, and the trough between them is over 300 miles long, the lake of Koko Nor being situated at its eastern extremity.

Easterly termination of the Kuen Lun.

As the Kuen Lun passes from Tibet eastwards into China, it loses the form ot a great continuous fold and breaks up into minor ramifications, as the Hindu Kush does in Afghanistan. There is however this difference, that whereas the Hindu Kush does not split up into secondary folds, until it has emerged from the high plateau and descended to lower levels, the Kuen Lun begins to throw off its branches before it has left Tibet. Eastern Tibet is very intricate, no surveys have been made, and it is not possible at present to analyse the mountains from existing data, or to determine the relations of the Kuen Lun to the numerous ranges that traverse western China between the Hoang Ho and Yangtze rivers.

From Prejevalsky's descriptions the Kuen Lun appears to bifurcate at its eastern extremity into two ranges, the Burkhan Buddha and the Shuga.*

"The Burkhan Buddha," he wrote, "is a distinct range more particularly on the "north, where it rises boldly from the perfectly level plains of Tsaidam: it has no very "conspicuous peaks, but extends in one unbroken chain."

"The ground gradually rises to another range the Shuga, lying parallel with the "Burkhan Buddha and terminating as abruptly on the west, where it abuts on the "Tsaidam plains.† About 70 miles to the south of the Shuga range rises a third "chain of mountains called by the Mongols Baian Kara Ula: they are situated on the "left bank of the head waters of the Blue river, called by the Mongols Murui-ussu, and "form the watershed between its basin and that of the sources of the Hoang Ho."

"Between the Shuga and Baian Kara Ula chains lies a terrible desert 14500 feet "above the level of the sea."‡

The Baian Kara Ula range is an eastern extension of the Kokoshili range of Tibet, which will be described subsequently.

The Kuen Lun does not form the water-parting between the Hoang Ho and Yangtze. The most westerly source of the Hoang Ho is in the interior of Tibet and *south* of the

* N. Prejevalsky: *Mongolia*, Vol. II, page 175.

† *Idem*, page 178.

‡ *Idem*, page 180.

Kuen Lun; a feeder of the Yangtze drains the southern slopes of the Kuen Lun west of the Hoang Ho's source.*

The Kashgar and Sarikol ranges.

The Kashgar and Sarikol ranges are two parallel mountain chains that form the eastern flank of the Pamir plateau, and that trend from south-south-east to north-north-west (frontispiece to Part I). The more easterly of the two is the Kashgar range, called by Humboldt the Bolor and by Hayward the Kizil-Art. It rises like a wall from the Tarim deserts, and is surmounted by glaciers and snow-clad peaks.

The Kashgar range.

The Kashgar range is shown on the chart as a direct continuation of the Kuen Lun on the high authority of Stoliczka, but its connection with the Tian Shan is not understood (chart XVII).

North of the Kungur peaks (table IV, Part I), the Kashgar range appears to bend towards the north-west; at its bend it bifurcates, and throws out a branch range on the convex side of the bend. The Gaz river cuts through the range at the bifurcation a few miles north of Kungur. From its crest to its easternmost flank, where its further continuation is buried under sand, the Kashgar range is 60 miles wide.†

The Sarikol range.

The Sarikol range, running parallel to the Kashgar on the west and at a distance of 30 or 40 miles from the latter, is the lower range of the two, and its peaks do not reach 20000 feet. Nevertheless it is a primary water-parting of Asia, its western slopes draining into the Oxus and sea of Aral, its eastern into the Tarim river and lagoons of Lob Nor. The Sarikol range separates the Taghdumbash Pamir from the Little Pamir, and is crossed by the Nezatash (14915 feet), the Uzbel (15200 feet), and other passes.

The connection between the Sarikol and Aghil ranges is conjectural (frontispiece to Part I).

The trough enclosed between the Kashgar and Sarikol ranges is known as the Sarikol valley; it extends from the Taghdumbash Pamir to the little Kara Kul lake. "The valley of Sarikol," writes Sven Hedin, "is a gigantic trench piercing to the "heart of the stupendous Pamir plateau." The plains of the Taghdumbash Pamir form a southern continuation of the Sarikol valley; and the plains of Tashkurgan and of Tagharma are in the valley itself.

The Tashkurgan river drains the Taghdumbash Pamir and the northern slopes of the Hindu Kush, and passes into the Sarikol valley: in the valley it bends at right angles and piercing the Kashgar range escapes through a precipitous gorge to the plains of Tarim. The northern portion of the trough between the Sarikol and Kashgar ranges is drained by the Ulu-Art and Ikebel-su rivers, which unite and force a passage through the Kashgar range at the Gaz defile.

The Kashgar and Sarikol ranges thus constitute a system similar to that of the Hindu Kush and to that of the Great Himalaya. The Great Himalaya is higher than

* On chart XVII the name of the Chinese river was spelt Huang; the new edition of the Imperial Gazetteer spells it Hoang Ho.

† Map to illustrate Younghusband's explorations, 1 inch = 16 miles.

the Ladak range, but the latter is the water-parting, and its drainage cuts across the former through deep gorges. The same phenomenon is witnessed in the Hindu Kush; the southern range is the higher but the northern is as a rule the water-parting. Now again we see the Kashgar range higher than the Sarikol and yet pierced by the drainage of the latter.

The northern termination of the Kashgar range.

The chart XVII was drawn primarily to illustrate the apparent clash of the Great Himalayan alignment with the Hindu Kush on the north-west and with the Arakan ranges on the east, but it has been made to include the clash of the Kashgar and Tian Shan ranges. East of the Brahmaputra we find the Great Himalaya trending perpendicularly to the Arakan chains; at the Indus we see the same giant range advancing at right angles to the Hindu Kush. And now to the north we have the Kashgar range running perpendicular to the Tian Shan. Just as we ask ourselves what has become of the Himalaya beyond the Brahmaputra and the Indus, so are we unable in Turkistan to decide how the Kashgar range has ended. The forces, that create ranges, are so powerful compared with those that are available for our experiments, that we cannot calculate the probable results of their action even under given conditions. What would now be the effect on the Himalaya if the earth's crust were compressed between Afghanistan and China, and if wrinkles like the Hindu Kush and the Arakan mountains began to advance from the west and the east against the ends of the established range? Would the axis of the latter be crumpled in plan into horizontal sinuosities, or would it be forced into an uniform curve, or would its ends be bent and crushed? These are questions we are unable to answer.

*The Tian Shan ranges.**

The Tian Shan mountains are a complex system of ranges. They appear to be a broad crustal fold, the surface of which has been wrinkled into minor folds by forces acting from different directions. Severtsoff writes of the Tian Shan as "a system of "intersectional ranges:" the predominant ranges, he thinks, trend from east-north-east to west-south-west.†

Prince Kropotkin writes, that the two main directions of mountains in the Tian Shan are, firstly, from south-west to north-east, and, secondly, from south-east to north-west.‡

The axial line of the Karakoram range has been shown to trend from south-east to north-west and to bend round into the Hindu Kush, which runs from north-east to south-west. A remarkable parallelism, therefore, exists between ranges situated north and south of the mountain knot, known in geography as the Pamir plateau.

Of the Tian Shan ranges that run from south-east to north-west the Kugart range is perhaps the best known: of the ranges that run from south-west to north-east there are

* *Vide* Tian Shan plateau, page 68 of this paper.

† *Journal, Royal Geographical Society*, Vol. XL, 1870.

‡ *Geographical Journal*, Vol. XXIII, 1904.

the Alai and the Trans Alai, as shown on the frontispiece to Part I, and then south of Issik Kul there are the Terek range on the north, the Koktan in the centre, and the Artush bordering the Kashgar plains. The great lake of Issik Kul (height 5300 feet) lies north of the Terek range and is itself bounded on the north by the two granite ranges of Alatau.

At one time it was believed that no sedimentary rocks existed in the Tian Shan, but Semenoff showed that this idea was incorrect, and now Merzbacher writes, that the most elevated region of the Tian Shan is built up exclusively of sedimentary rocks.

The great peak of the Tian Shan is Tengri Khan (23600 feet, *vide* table VI of Part I); the height of its summit surpasses all other peaks of the region by 3000 feet.* Many of the crests of the Tian Shan are above the line of perpetual snow, and it is probable that several peaks of 20000 feet exist on the central ranges. The outer ranges do not carry peaks above 16000 feet.

The " duns."

The outer ranges of the Himalaya enclose longitudinal valleys known as "duns," but such valleys are not found in the Kuen Lun. On the southern flank of the Tian Shan they occur in places. "A "peculiar feature," wrote Stoliczka, "in this part of these hills consists in the occurrence "of extensive plains, to which the name 'jilga' is generally applied. It means origi- "nally, I think, merely a water-course, and on a large scale these plains may be looked "upon as water-courses of former water-sheets. They occur at the base of the "high range, and in some respects resemble the 'duns' of the southern slopes of the "Himalaya. North of Tangitar one of these large plains occurs within the lime-stone "rocks, being surrounded by them on all sides. It must be about 30 miles long from "east to west, and about 16 from north to south."†

Professor Ellsworth Huntington writes: "Apparently the Kashgar basin has long "been growing smaller by a process of continuous folding along the edges."‡

In his *Central Tian-Shan Mountains*, however, Merzbacher gives a different description of the outer hills: the latter he describes as "subsiding gradually in ranges of "transverse spurs, whose cape-like ends project far into the desert." "Much of the "outermost skirting range," he says, "lies buried in the enormous rubbish heaps of "the high plain. The hitherto prevailing conception of the wall-like descent of the "range must be given up."

At their eastern extremity the Tian Shan are separated from the Altai mountains of Mongolia by the remarkable depression known as the Zungarian strait, 2300 feet high; on the west they end in the Alai and Trans Alai ranges.

The Trans Alai.

The Trans Alai range is the snow-clad chain, which borders the Pamir plateau on the north: it is a very important range and surpasses in height all the mountains that intersect the Pamir plateau itself. Kaufmann (23000 feet) is its highest peak; the pass of Kizil-Art crosses it at a height of 14260 feet.

* Merzbacher: *Central Tian-Shan Mountains*, 1905.

† T. D. Forsyth: *Report of a Mission to Yarkand*, 1873, page 472.

‡ Compare this, however, with our preceding note on the Kuen Lun in which we come to the conclusion that outer ranges are absent.

The Alai.

The Alai range is north of the Trans Alai and lower; its average elevation does not exceed 16000 feet, and its highest peaks rise only to 19000 feet. There are several passes crossing it at 12000 feet.

The trough between the two ranges is known as the Alai valley; it is crossed by the water-parting between the Aral and Tarim basins, the drainage of its eastern portion flowing one way, that of its western the other. The height of the trough at the water-parting is 11000 feet; the surface of the trough has gentle slopes, and the actual water-parting is not a marked feature. The two rivers flowing eastwards and westwards from the water-parting of the Alai valley are both named Kizil-su.

18

THE RANGES OF THE INTERIOR OF TIBET.

A complete history of the exploration of Tibet will be found in Sir Thomas Holdich's *Tibet the Mysterious.* Chart XXII of this paper illustrates the tracks of explorers over the interior of Tibet.

Many parallel mountain ranges have been found to exist, but their number and positions and heights are not at present known.

Between the Kailas and Kuen Lun ranges there are probably at least five primary ranges, and of these the prolongation of the Karakoram fold is probably one. We have observed the continuity of the Great Himalaya, and of the Kailas and Ladak ranges in Southern Tibet; and explorers have traced the Kuen Lun on the north of Tibet from west to east. It is probable, then, that the central folds will also be found continuous; they may bend in places, and subside in others; they may bifurcate and conjoin; and different lengths may appear to overlap; but the primary folds probably do continue from Afghanistan to China.

Many explorers have emphasised the fact, that the interior ranges of Tibet and their intermediate troughs trend from west to east.* Nain Singh followed a long west and east trough containing a continuous series of lakes: Bower followed another, and Sven Hedin a third. The large rivers of central Tibet appear to flow in west and east directions.

"Like all the previous lakes," wrote Sven Hedin in northern Tibet, "lake No. 18 "had an east and west direction, and was one of the largest we encountered; we travel-"led beside it the whole of the day (sixteen and three-quarter miles)."

The explorer Kishen Singh traversed Tibet from south to north, from Lhasa to Saichu, and crossed over several ranges: the following are extracts from the narrative of his journey in the interior of Tibet:—†

(*i*) "We reached the Lani La pass by an easy ascent of 2¼ miles. The Lani La "range comes from the east, and far off in that direction are some high "peaks covered with perpetual snow."

(*ii*) "Tangla is a long range of mountains running from the west and possess-"ing several snowy peaks and spurs."

(*iii*) "The Dungbura Khuthul pass has an easy ascent. The general direc-"tion of the long range bearing this name is from east to west."

(*iv*) "We crossed the Kokoshili Khuthul pass which has an easy ascent. "The general direction of the range is from east to west."

(*v*) "A steep ascent of 1½ miles then brought us to the Angirtakshia Khuthu "pass. The Angirtakshia, a long range, lies east and west."‡

* Littledale's evidence does not support this view; he marched southwards from the Kuen Lun (latitude 36° 5′) to Tengri Nor (latitude 30° 40′). "We never," he wrote, "saw a single continuous mountain range, till we came to the Ninchin-"thangla."

† J. B. N. Hennessey: *Report on the explorations in Great Tibet and Mongolia made by A-K in* 1879-1882.

‡ Angirtakshia is a local name for an easterly extension of the Kuen Lun.

The Ninchinthangla range, however, trends from north-east to south-west and forms a very striking exception to the east and west rule (frontispiece to Part I).

If we examine the frontispiece to Part I we see that the meridian of 92° crosses four ranges in Tibet; of these that situated north of latitude 30° is the Lani, that north of 31° is the Ninchinthangla. The Tangla is near latitude 33° and the Kokoshili is north of 35°. Kishen Singh's Dungbura range, which has not been shown on the chart, runs north of 34° between the Tangla and the Kokoshili.

On the west of Tibet we find between the Kailas and the Kuen Lun ranges two primary ranges, the Karakoram and the Aghil: on the east we find five, the Lani, the Ninchinthangla, the Tangla, the Dungbura and the Kokoshili. Two ranges are thus known to enter the interior of Tibet from the west, five have been observed to issue from it on the east. How the two become five, or whether there are not more than five we do not know.

The Kokoshili.

When Wellby travelled in 1896 from west to east through northern Tibet he marched south of the Kokoshili range for a long distance. Sven Hedin explored the long trough to the north between the Kokoshili and Kuen Lun. In longitude 94° 20′ the Kokoshili is cut through by a northern affluent of the Yangtze, but east of the gorge it becomes, under the name of Baian Kara Ula, the water-parting between the Hoang Ho and Yangtze.

Wellby's "Abrupt" peak and the "King Oscar" peak of Sven Hedin rise from this range.

The Tangla.

The Tangla range forms the water-parting in Tibet between the Yangtze and Salween, and Prejevalsky traced an affluent of the former almost to its source in the Tangla at a height of 16400 feet.

The Ninchinthangla.

The Ninchinthangla range forms the water-parting between the Brahmaputra and the closed basin of Tibet. Mr. and Mrs. Littledale crossed this range by the Goring pass (19587 feet), and the explorer Nain Singh crossed it by the Khalamba pass (17200 feet). Littledale described the Ninchinthangla as "a magnificent range—a succession of snow-clad "peaks and glaciers." "Above all," he wrote, "towered with cliffs of appalling "steepness the great peak of Charemaru, 24153 feet. From this point of view it was "perhaps one of the most impressive mountains I had ever seen.*" Colonel Montgomerie wrote: "To the south the lake is bounded by a splendid range of snowy peaks flanked "with large glaciers, culminating in the magnificent peak Jang Ninchinthangla which "is probably more than 25000 feet above the sea. The range was traced for nearly "150 miles running in a north-easterly direction."†

In a table below we give a list of all the highest peaks of Tibet, the positions of which are known: we are unable to identify either Montgomerie's peak Jang Ninchinthangla or Littledale's Charemaru: the two were possibly the same peak.‡ In 1904

* *Geographical Journal*, Vol. VII, 1896.
† Colonel Montgomerie's Memorandum on the exploration of the Nam Tso or Tengri Nor Lake, 1873-74.
‡ For Ryder's note on Bonvalot's peaks see *Report on Survey operations with the Tibet Frontier Commission*, 1904

Major Ryder fixed several peaks of the Ninchinthangla range from the neighbourhood of Lhasa. R^{217} was the highest peak he observed, and its altitude was 23255 feet. It is unlikely that Montgomerie's or Littledale's peaks are higher than this.

The Lani range is an easterly branch of the Ninchinthangla.

Nothing is known of the Dungbura range beyond the fact that Kishen Singh crossed it.

Prolongation of the Karakoram in Tibet.

The prolongation on the frontispiece to Part I of the Karakoram range and its conjunction in longitude 92° with the Ninchinthangla are hypothetical. We do not yet know that the Karakoram range does continue eastwards through Tibet, and even if it be proved to do so, it may be found to connect with the Tangla range north of latitude 32°, and not with the Ninchinthangla. Observers of the Himalaya, the Ladak and the Kailas ranges have been impressed with their apparent continuity, and it is perhaps natural that we should seek for the prolongation of the gigantic Karakoram: the prolongation, however, as entered on the chart, is intended to suggest only the *possibility* of continuity, and must not be accepted as fact.

The following extracts show the evidence upon which the drawing of the Karakoram range in the chart has been based:—

"A number of lofty snowy peaks were determined from various stations of the "route survey, the most remarkable being the Aling Kangri group north of the Indus, "which, judging from the great mass of snow seen on its southern face during August "and September, must be upwards of 23000 feet above the sea, possibly as much as "24000 feet. The line of perpetual snow on the southern slopes of the Ladak "Mountains approximates to 20000 feet in the same latitude, and it would require "several thousand feet of snow above that line in order to be very imposing at 80 "miles, at which distance the Pandit first saw it. The Aling Kangri group had never, "as far as I am aware, been heard of before. They appear to be a continuation of "the range between the Indus and the Pangong lake."*

"The Pandit Nain Singh left Leh in July 1874, and succeeded in crossing the "Tibetan frontier in the disguise of a Lama or Buddhist priest. Passing about 15 "miles to the north of Rudok, he travelled nearly due east for a distance of more than "800 miles over a new line of country, separated from the valley of the Sangpo "(Brahmaputra) by an almost continuous range of snow mountains, which trends east'wards, from the Aling Kangri peaks in longitude 81°, up to the Ninchinthangla peaks "in longitude 90½°."†

In central Tibet the line of perpetual snow does not lie much below 20000 feet, and the fact that Nain Singh saw snow extending almost continuously from longitude 81° to 90½° is evidence of the existence of a great range.

* Colonel Montgomerie's *Report on Trans-Himalayan Explorations*, 1867. The range between the Indus and ths Pangong lake is the Ladak range: possibly the Kailas range also passes between. The Aling Kangri peaks are now believed to stand considerably north of the Kailas and Ladak ranges, and to mark perhaps the continuation of the Karakoram.

† An account of Trans-Himalayan expiorations by General J. T. Walker, R.E., F.R.S. *General Report, Great Trigonometrical Survey of India*, 1874-75, page 20.

The question may be asked whether the snowy range seen by Nain Singh to the south may not have been the Kailas range: the answer is that the snow peaks fixed by Nain Singh stand 120 miles north of the Brahmaputra and many miles north of any known peaks of the Kailas range. Thus the Aling Kangri peaks east of longitude 81° are a hundred miles north of the sacred peaks of Kailas. In longitude 85° the two ranges are one hundred miles apart and in 86° eighty miles. The interval in fact between Nain Singh's range of peaks and the Kailas range is greater than between the Kailas and Ladak ranges, and if we have regard to the spans of the known ranges of the Himalaya and Karakoram, we find it more reasonable to assume that an intermediate trough separates Nain Singh's range from the Kailas than that the two apparent chains of mountains are the respective flanks of one broad range.

The following extract from Captain Trotter's report on the Trans-Himalayan explorations of 1873-74-75 gives further details of Nain Singh's journey:—

Four hundred miles east of Aling Kangri "the Pandit encountered a lofty "range of mountains, which was crossed by a high but easy pass called Kilong, 18170 " feet above sea-level. This range runs southwards and culminates in some enormous "peaks known by the name of Targot, from which extends eastwards a snowy range, "numerous peaks of which were fixed by the Pandit along a length of 180 miles "up to where the range terminates in a mass of peaks called Gyakharma, which also " lie to the south of and very near the Pandit's road. The highest of these Gyakharma "peaks was ascertained by measurement to be 22800 feet above sea-level, and the " Pandit *estimates* that the highest of the Targot peaks, which lay too far off the road for "vertical measurement with a sextant, is at least 2500 feet higher".*

" This range is probably not the watershed between the basin of the Brahma- "putra and the lake country of Tibet, for the Pandit was informed that to the south " of the range, running parallel to it, is a large river, the Dumpho or Hota Sangpo " which ultimately changes its course and flows northwards into the Kyaring lake."

"Thus far on his journey," continues Captain Trotter, "the Pandit states that " a cart might be driven all the way from Noh without any repairs being made to "the road, but in crossing the range the path was steep and difficult. There is an " alternative road, however, lying to the north, by which it is said a cart might " easily travel to the Nam Tso lake without meeting a single obstacle *en route*."

" The height of the plateau traversed appears to vary but little between 15000 " and 16000 feet above the sea-level. The plain is as a rule confined between moun- "tains which run parallel to the direction of the road, but a few transverse ridges " of considerable elevation are crossed *en route*."

The following table gives a list of the high peaks of Tibet, as known to us, and shows the ranges on which they stand. A few of the heights such as those of Leo Pargial, Kamet, Kailas and Gurla Mandhata have been well determined and may be ranked as values of the first class in accuracy : many heights, however, which have been

* Estimates of heights of snow peaks have so often proved to be in error by 5000 or 6000 feet, that no weight whatever is now attached to them.

measured trigonometrically from stations in Tibet, can only be regarded as belonging to the second class of accuracy, owing to the uncertainty attaching to the altitudes of the points from which the observations were taken. The sextant observations of Nain Singh furnish heights of the third class of accuracy, whilst his numerical estimates of Aling Kangri, Targot Yap, and Samdankang Jang can only be accepted as indications of imposing height. The explorer Kishen Singh contented himself with recording against Jhomogangar "very high", and refrained from numerical estimation.

TABLE XXVII.—The high peaks of Tibet.

NOTE.—Peaks of the Himalaya, Karakoram and Kuen Lun ranges have been excluded, as this list is intended to show peaks that stand in the interior of Tibet.

Range.	Name.	Height in feet.	Latitude. ° ′ ″	Longitude.* ° ′ ″	Authority.
Zaskar	Leo Pargial S.	22170	31 53 5	78 44 5	Great Trigonometrical Survey.
	Leo Pargial N.	22210	31 54 8	78 44 39	
	Kamet	25447	30 55 13	79 35 37	
Ladak	Gurla Mandhata	25355	30 26 18	81 17 57	G. T. Survey.
	W167	20751	30 13 46	82 8 5	Wood.
	W168	21007	30 14 25	82 8 38	
	W156	21431	30 17 8	82 8 53	
	W166	21383	30 9 37	82 9 41	
	W144	22032	30 7 26	82 11 17	
	W145	21568	30 12 35	82 11 28	
	W164	20467	30 1 50	82 19 36	
	W143	20168	30 0 44	82 21 51	
	W155	21754	29 51 0	82 42 16	
	W162	20684	29 47 57	82 43 23	
	W154	22492	29 45 29	82 45 0	
	W153	21477	29 40 32	83 0 3	
	W161	20000	29 36 11	83 13 21	
	W159	20244	29 30 57	83 21 53	
	W124	20560	29 33 51	83 39 5	
	W89	20727	28 45 34	85 32 27	
	W90	21248	28 46 37	85 32 57	
	W77	21169	28 56 58	86 5 12	
	W48	21263	28 57 58	87 16 51	
	R119 or Nojinkang Sang	23600	28 57 2	90 11 1	Ryder.
	R121	21852	28 51 13	90 12 43	
	R122	21424	28 50 18	90 13 26	
	R123	20456	28 48 25	90 13 33	
	R289	21660	28 46 33	91 59 20	
	R289 (*a*) (Yala Shimbo *of Nain Singh*)	21768	28 47 46	91 59 20	

* The values of longitude are based on the determination of the difference between Greenwich and Madras made in 1894-96, and are not those hitherto accepted by the Survey of India.

TABLE XXVII.—The high peaks of Tibet—*continued.*

Range.	Name.	Height in feet.	Latitude. ° ′ ″	Longitude.* ° ′ ″	Authority.
Kailas	W^{215}	20437	31 5 18	81 13 57	Wood.
	Kailas	22028	31 4 2	81 18 50	G. T. Survey.
	W^{135}	21600	29 55 16	84 33 33	Wood.
	W^{134}	23150	29 50 4	84 36 39	
	W^{133}	21300	29 48 49	84 38 8	
	W^{122}	20628	29 43 16	85 10 11	
	Harkiang	...	29 32 0	85 14 0	Nain Singh.
	W^{117}	20616	29 26 45	85 21 44	Wood.
	W^{100} or Cho-ur-dzong	21300	29 27 43	85 23 8	
	W^{86}	20752	29 26 37	85 23 18	
	W^{88}	21097	29 29 25	85 24 52	
	W^{87}	21227	29 28 30	85 24 53	
	W^{60}	20000	29 33 25	87 8 38	
	R^{273}	21439	29 20 56	91 45 42	Ryder.
These peaks stand on a range in Tibet that may possibly prove to be the continuation of the Karakoram.	Aling Kangri	24000	32 46	81 2	Nain Singh.
	Ning Kangri	..	32 15	83 0	
	Shyalchikang Jang	Very high	31 45	84 45	
	Targot Yap	25000	30 40	86 15	
	Gyakharma	22800	30 50	88 30	
Ninchinthangla	Jhomogangar	Very high	29 50 0	89 50 0	Explorer A-K.
	R^{210}	22950	29 54 7	90 2 3	Ryder.
	R^{291}	20207	29 51 26	90 13 25	
	R^{216}	21694	30 18 9	90 29 7	
	R^{212}	20456	29 57 7	90 32 46	
	R^{217}	23255	30 22 17	90 35 19	
	R^{219}	20366	30 27 37	90 41 41	
	R^{222} or Samden Khansa of A-K	20576	30 47 55	91 25 54	
	R^{223}	21543	30 50 38	91 29 40	
	†Samdankang Jang	24000	30 50 0	91 30 0	Nain Singh.
	Potamolam	...	30 30 0	91 49 0	
	R^{224}	20130	30 30 33	91 52 9	Ryder.
Central Tibet	Kangdigar	20600	31 20 0	86 45 0	Nain Singh.
	Munza Kangri	...	32 20 0	87 15 0	
North-Eastern Tibet	Caroline	18000	35 20 0	97 30 0	Rockhill.

* The values of longitude are based on the determination of the difference between Greenwich and Madras made in 1894-96, and are not those hitherto accepted by the Survey of India.

† The *Samdankang Jang* of Nain Singh is probably identical with R^{223}: possibly the *Samden Khansa* of A-K is the same peak also, and not R^{222} as shown. The *Potamolam* of Nain Singh is probably identical with R^{224}. Nain Singh's value for the height of *Samdankang Jang* has been shown by Ryder to be over 2000 feet too great.

TABLE XXVII.—The high peaks of Tibet—*concluded.*

Range.	Name.	Height in feet.	Latitude.	Longitude.*	Authority.
			° ′ ″	° ′ ″	
Northern Tibet	Abrupt peak .	...	35 30 0	82 30 0	Wellby.
	Ullug Muztagh	24000	36 30 0	87 20 0	Sven Hedin.
	King Oscar peak	...	35 30 0	87 40 0	
Western Tibet	Camp 74 peak 273 .	20010	33 58 3	79 40 28	Deasy.
	,, 51 ,, 170 .	20980	32 47 58	81 8 58	
	,, 51 ,, 169 .	20730	32 47 10	81 12 40	
	,, 57 ,, 185 .	20100	33 40 37	81 18 2	
	,, 109 ,, 84 .	20370	34 32 49	81 33 9	
	,, 57 ,, 179 .	20200	33 42 15	81 39 25	
	,, 51 ,, 142 .	21020	33 26 56	81 42 31	
	,, 49 ,, 144 .	20550	33 35 49	81 55 41	
	,, 51 ,, 165 .	20180	33 26 30	82 12 57	
	,, 32 ,, 116 .	20970	33 27 54	82 15 30	
	,, 29 ,, 94 .	20100	33 58 45	82 17 6	
	,, 110 ,, 103 .	20260	34 40 19	82 19 19	
	Peak 95 .	20350	33 49 4	82 19 32	Ram Singh.
	Camp 57 peak 162 .	20650	33 48 55	82 19 41	Deasy.
	,, 110 ,, 93 .	20750	34 44 20	82 20 49	
	,, 110 ,, 94 .	20490	34 43 53	82 21 4	
	,, 51 ,, 163 .	20820	33 46 38	82 21 11	
	Peak 89 .	20310	33 48 7	82 22 19	Ram Singh.
	Camp 110 peak 92 .	20640	34 46 33	82 22 42	Deasy.
	,, 32 ,, 89 .	20690	33 40 53	82 30 21	
	Snow Peak 34 .	20010	34 25 4	83 1 13	Ram Singh.
	Camp 32 peak 110 .	20480	33 16 24	83 5 18	Deasy.
	,, 32 ,, 109 .	20910	33 11 2	83 24 45	
	,, 32 ,, 108 .	20120	33 15 33	83 29 9	

* The values of longitude are based on the determination of the difference between Greenwich and Madras made in 1894-96, and are not those hitherto accepted by the Survey of India.

19

THE LIMIT OF PERPETUAL SNOW.

The "snow-line" is the lower limit of perpetual snow—the line above which the snow resists the heat of summer, and below which it all disappears for a certain time every year. Snow will remain unmelted in deep ravines long after it has disappeared from neighbouring summits, but in determining the snow-line we have to consider not sheltered snow but snow exposed to the rays of the sun.

The snow-line is dependent upon temperature and snow-fall, and to a lesser degree upon wind. A light snow-fall renders the line high; the temperature of air at the snow-line is always below the freezing point of water in regions of scanty snow-fall.

If snow-fall were everywhere uniform, the height of the snow-line would vary with temperature, and would consequently tend to decrease from the equator to the poles, as the latitude increased. It would, however, under such conditions, be slightly lower (north of the equator) on northern slopes than on southern, owing to the difference between the angles at which the sun's rays are inclined to the mountain surface.

On the southern slopes of the Great Himalayan range the snow-line is 3000 feet lower than on the northern: this large difference is mainly due to the southern slopes being exposed to damp winds from the Indian ocean, which drop their moisture before they cross the range. Tibet and the Tian Shan are extraordinarily dry, and their snow-lines are consequently higher than those of mountains situated in the same latitudes but in other continents. In western China and in the extreme east of Tibet a quantity of rain and snow falls, and the snow-line is low.

TABLE XXVIII.—Height of the snow-line in Central Asia.

Range.	Aspect.	Latitude.	Height of snow-line in feet.	Authority.
Nepal Himalaya	South	28°	14700	Hooker: *Journal, R. G. S.*, XX, 1851.
South-East Tibet	...	29°	13000	Gill: *Journal, R. G. S.*, XLVIII, 1878.
Kumaun Himalaya	South	30° 30′	15500	Richard Strachey: *Journal, A. S. B.*, XVIII, 1849.
Kumaun Himalaya	North	30° 30′	18500	
Punjab Himalaya	South	34°	17000	Montgomerie: *G. T. Survey Syn.*, *Vol.* VII.
Punjab Himalaya	North	34°	19000	Cunningham's *Ladak*.
Zaskar	South	34°	20000	
Zaskar	North	34°	19500	
Ladak range near Leh.	North	34°	18500	Drew: *Jummoo and Kashmir territories.*
Ladak range near Leh.	South	34°	19000	
Kailas	South	31°	19500	Richard Strachey: *Journal, A. S. B.*, XVIII, 1849.

TABLE XXVIII.—Height of the snow-line in Central Asia—*continued.*

Range.	Aspect.	Latitude.	Height of snow-line in feet.	Authority.
Western Tibet . .	...	34°	20000	Richard Strachey : *Encyclopædia Britannica, article Himalaya.* Drew : *Jummoo and Kashmir territories.* Deasy : *In Tibet and Chinese Turkistan.*
Karakoram . .	South	36°	18500	Cunningham's *Ladak.*
Karakoram . .	North	36°	18500	Hayward : *Journal, R. G. S.*, XL, 1870.
Karakoram . .	North	36°	18000	Cunningham's *Ladak.*
Tian Shan . .	...	42°	11000	Semenoff: *Journal, R.G.S.*, XXXV, 1865.
Alai . . .	...	40°	14000	Delmar Morgan : *R. G. S., Supplementary Papers*, 1886.
The snow-line in Europe and Western Asia.				
Pyrenees. . .	...	43°	8500	
Caucasus. . .	...	43°	10000	
Alps . . .	...	46°	8500	

Twenty thousand feet is the highest elevation to which the snow-line has been observed to recede, and it is probable that it will be nowhere found higher: the snow-lines on the Kuen Lun and in central Tibet have never yet been determined, but they are estimated to lie lower than that of western Tibet, which is one of the driest regions of the earth.

We do not know at present to what extent the rainfall or snow-fall varies with height, nor have we been able to determine the elevation of maximum precipitation. Sir Joseph Hooker doubted whether the winds from the Indian Ocean ever reached the summit of Kinchinjunga, and he thought that very little snow fell at that great height.*

The outer Himalayan ranges everywhere intercept a large part of the rainfall from the Indian Ocean; the Pir Panjal range, for example, prevents the moisture-laden winds from reaching the valley of Kashmir. But the snow covering the Great Himalaya shows that there are damp currents at high altitudes, which are prevented by the range from entering Tibet.

The water in the lakes of western Tibet is due not to rain falling on the high plains but to snow accumulating on the ranges and descending in glaciers.

"The height," wrote Richard Strachey, "at which it is certain that snow will fall "every year in this region (Kumaun) of the Himalaya, is about 6500 feet, and at an "elevation of 5000 feet it will not fail more than one year out of ten. The least height "to which sporadic falls of snow are known to extend is about 2500 feet, and of such "falls there are only two authentic instances on record, since the British took possession "of Kumaun, *viz.*, in 1817 and 1847."†

Snow was observed to be falling on one occasion, at 10 o'clock at night, in February, 1906, in Dehra Dun, at a height of 2400 feet.

* *Himalayan Journals*, Vol. II, page 390.
† *Journal, Asiatic Society of Bengal*, Vol. XVIII, 1849.

CHART IX

Chart
illustrating the PARALLELISM
between the borders of
the old Peninsular Table-land and
the Central Asian Highlands

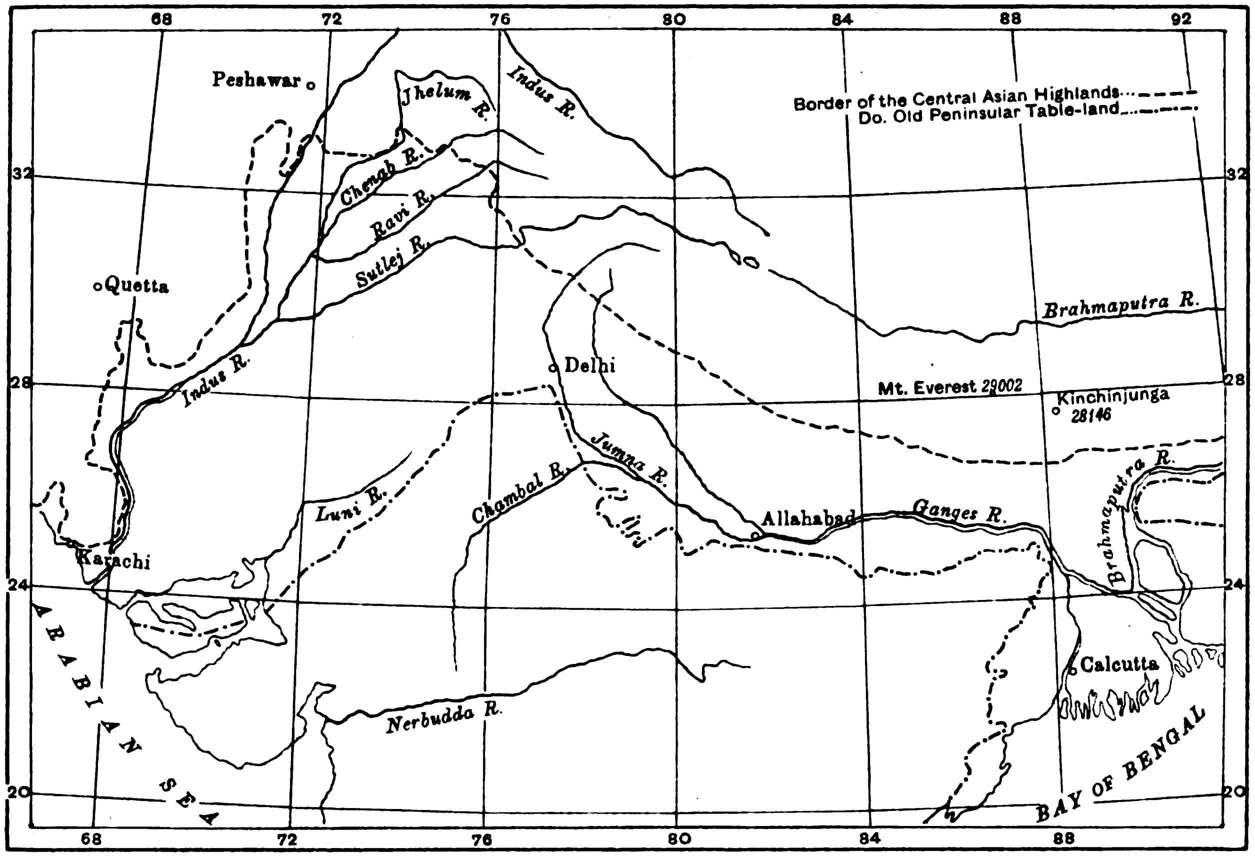
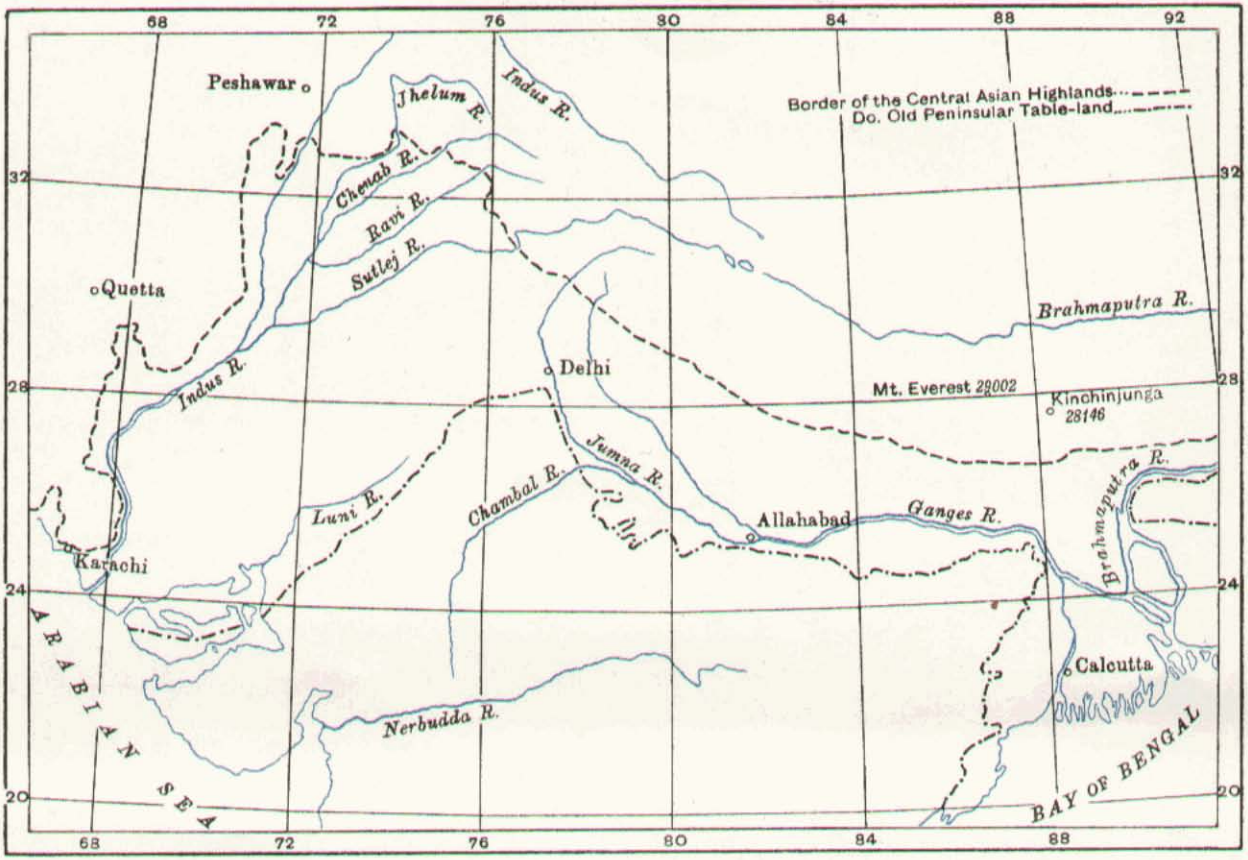


CHART IX

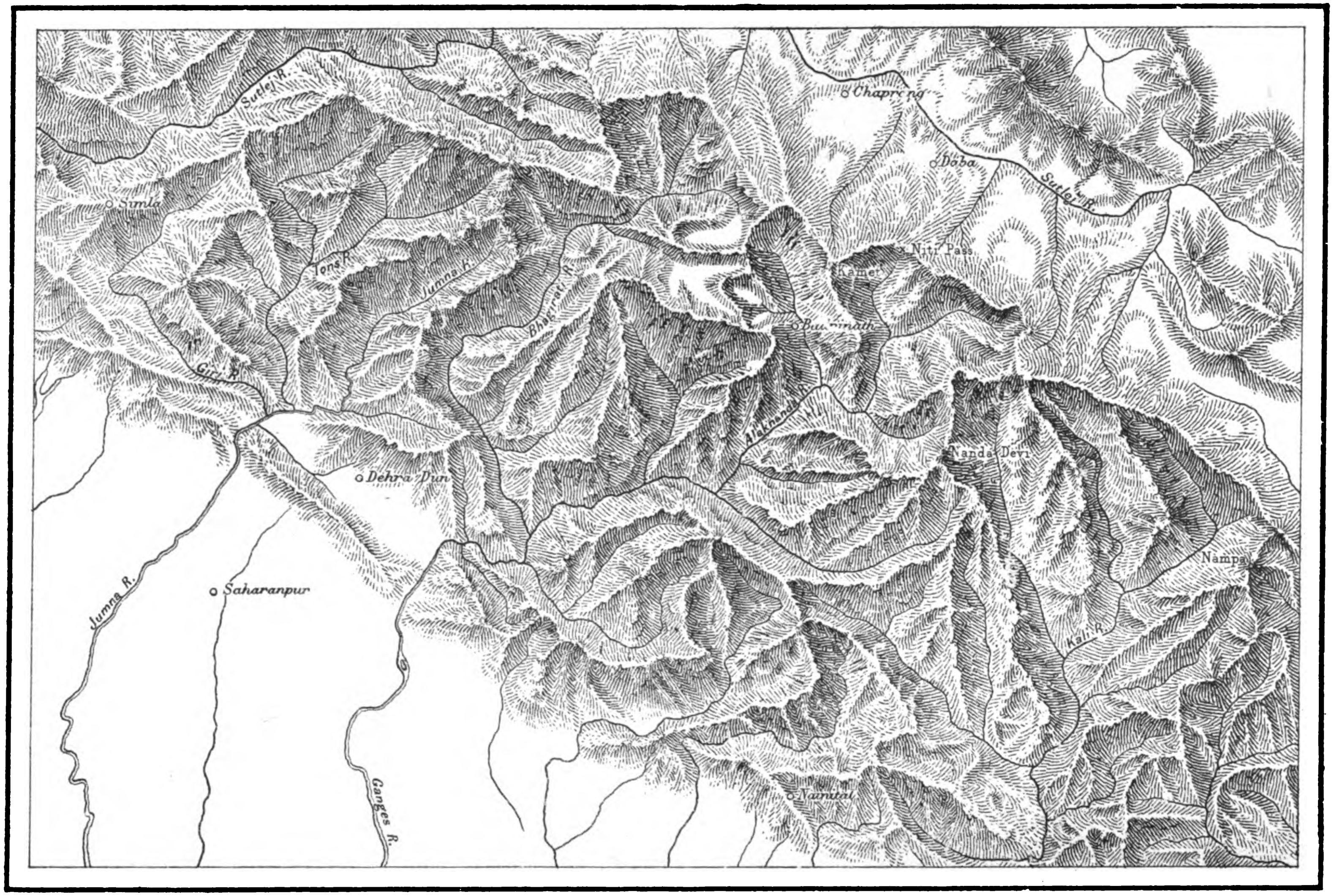
Chart
illustrating the PARALLELISM
between the borders of
the old Peninsular Table-land and
the Central Asian Highlands



THE

KUMAUN HIMALAYA

AS REPRESENTED ON THE 32 MILE MAP OF INDIA. CHART X

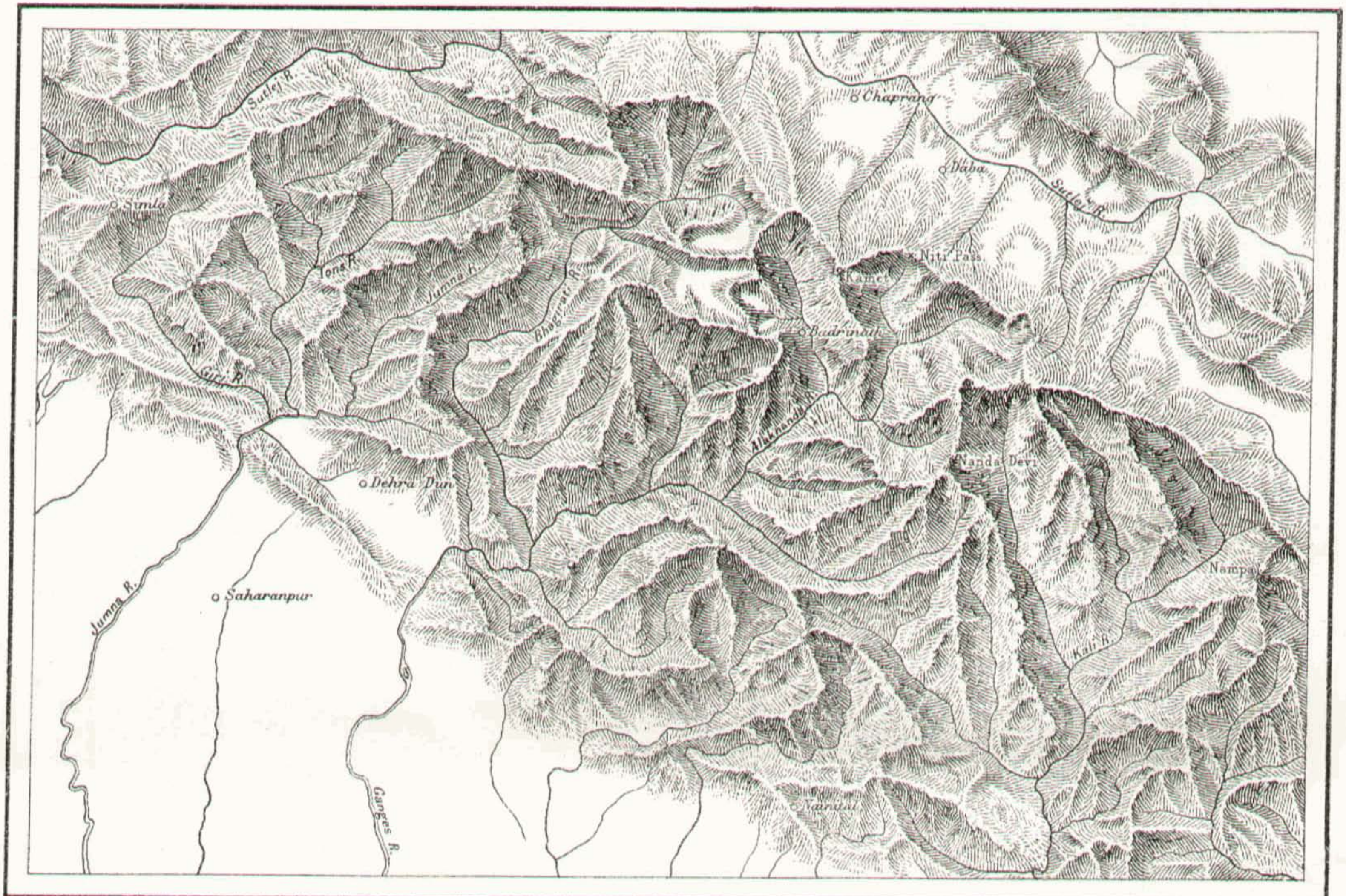


THE

KUMAUN HIMALAYA

AS REPRESENTED ON THE 32 MILE MAP OF INDIA.

CHART X

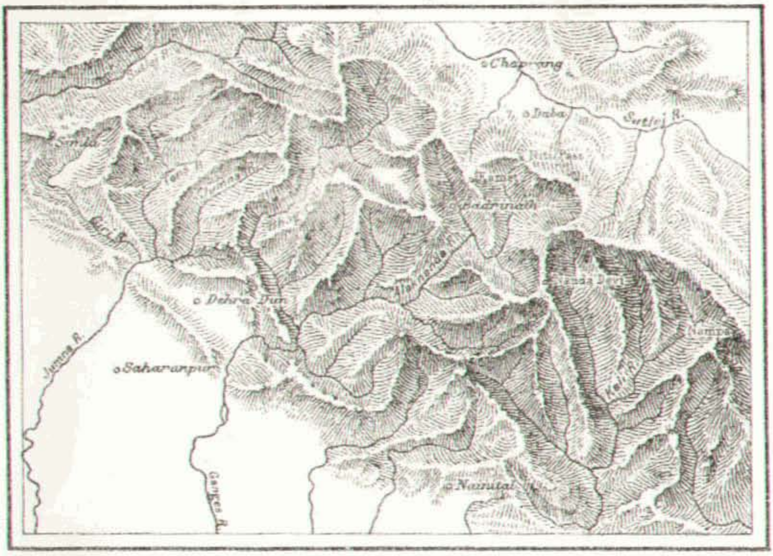


THE

KUMAUN HIMALAYA

CHART XI

AS REPRESENTED ON THE 64 MILE MAP OF INDIA.



THE KUMAUN HIMALAYA

DRAWN ON THE 64 MILE SCALE IN ACCORDANCE WITH THE GENERALIZATIONS OF THIS PAPER.

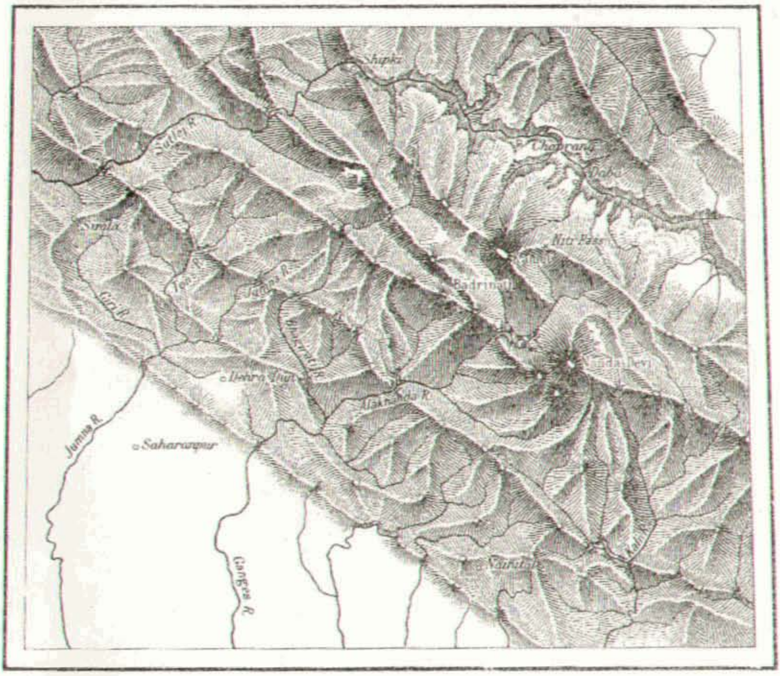
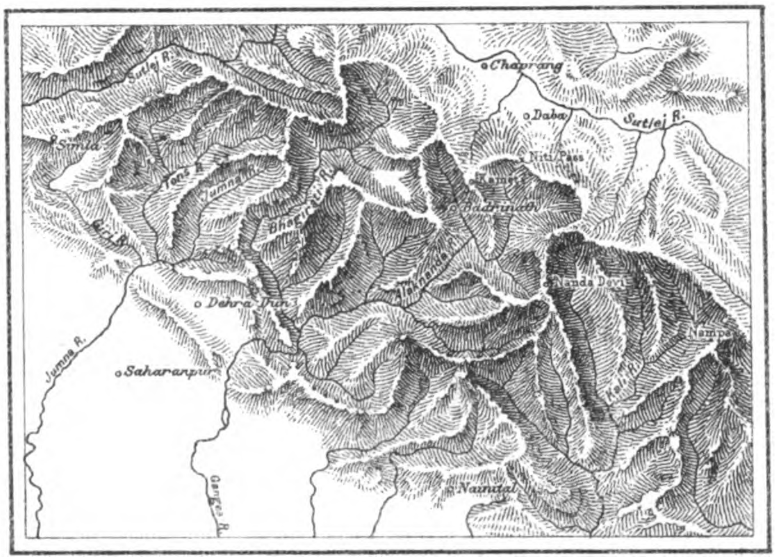


CHART XI

THE
KUMAUN HIMALAYA

AS REPRESENTED ON THE 64 MILE MAP OF INDIA.



THE KUMAUN HIMALAYA

DRAWN ON THE 64 MILE SCALE IN ACCORDANCE WITH THE GENERALIZATIONS OF THIS PAPER.

CHART XII

Diagram to illustrate
Brian Hodgson's theory of
HIMALAYAN CONFIGURATION
1848

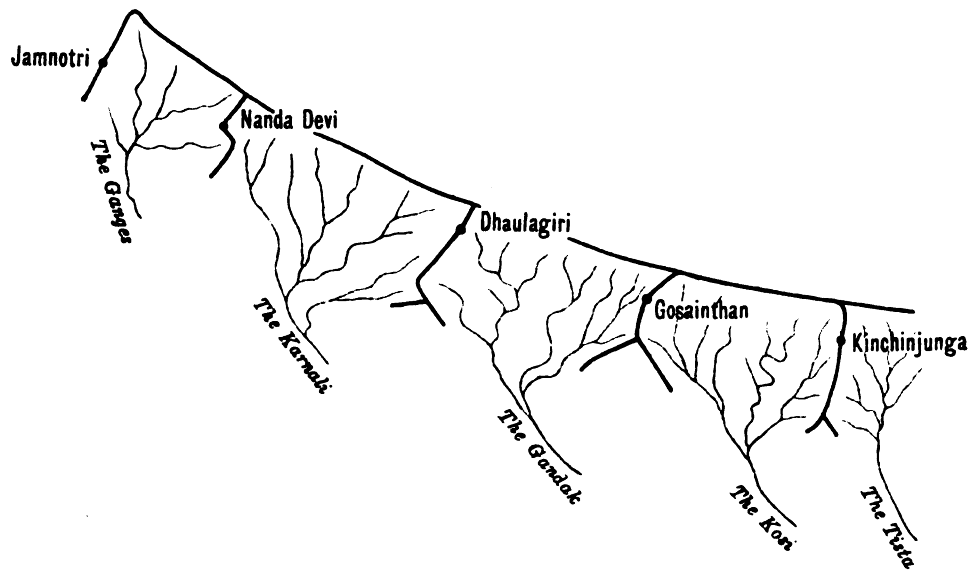


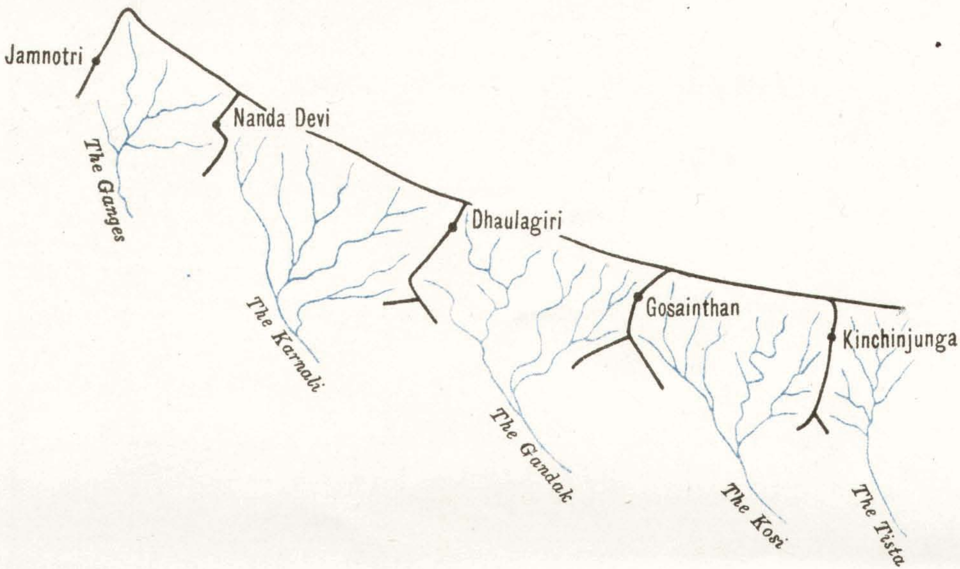
Diagram to illustrate

Brian Hodgson's theory of

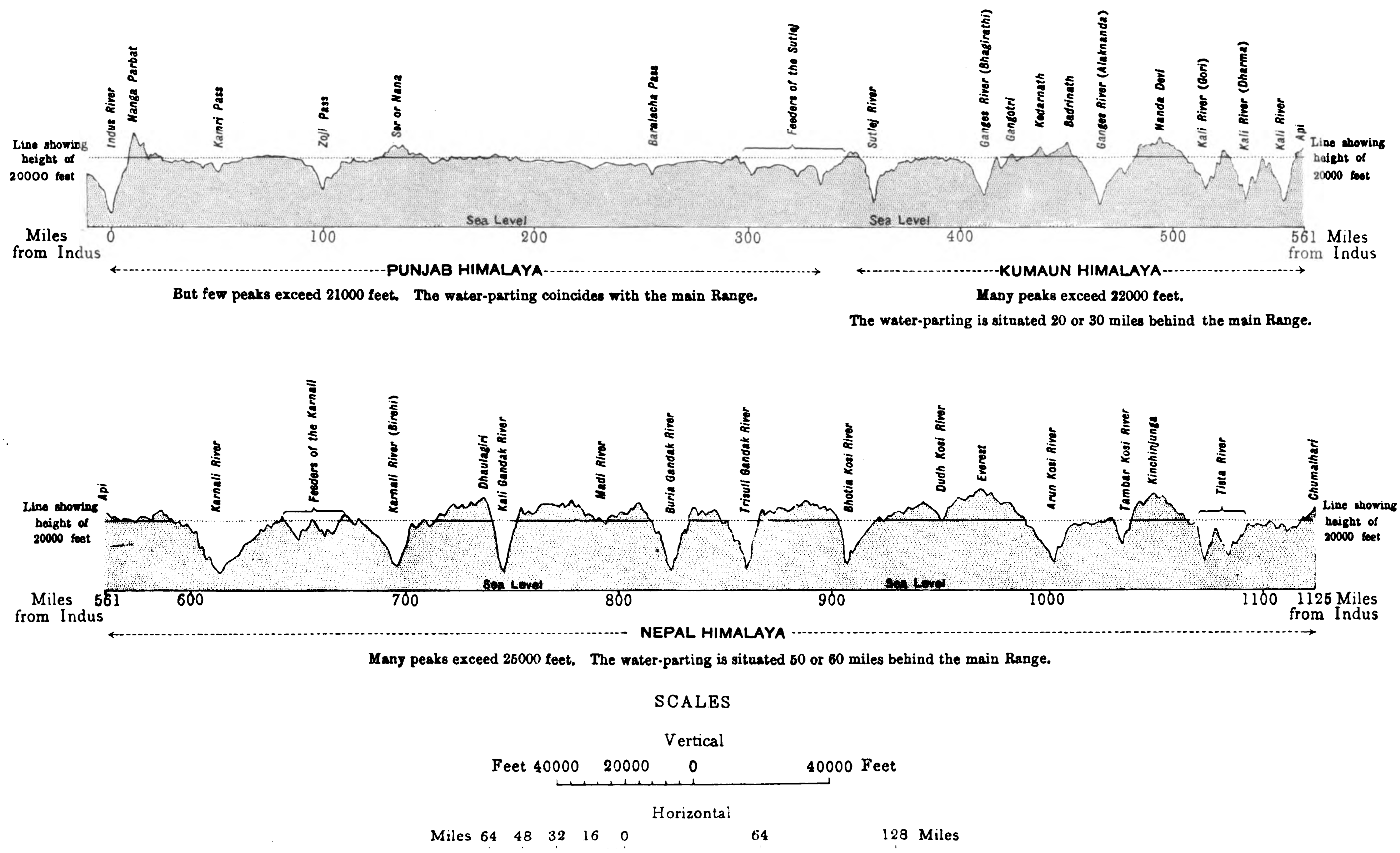
HIMALAYAN CONFIGURATION

1848

CHART XII



SECTION
along the GREAT RANGE of the HIMALAYA from the INDUS to the TISTA showing how it is being cut by the rivers into isolated blocks



SECTION
along the GREAT RANGE of the HIMALAYA
from the INDUS to the TISTA
showing how it is being cut
by the rivers into isolated blocks

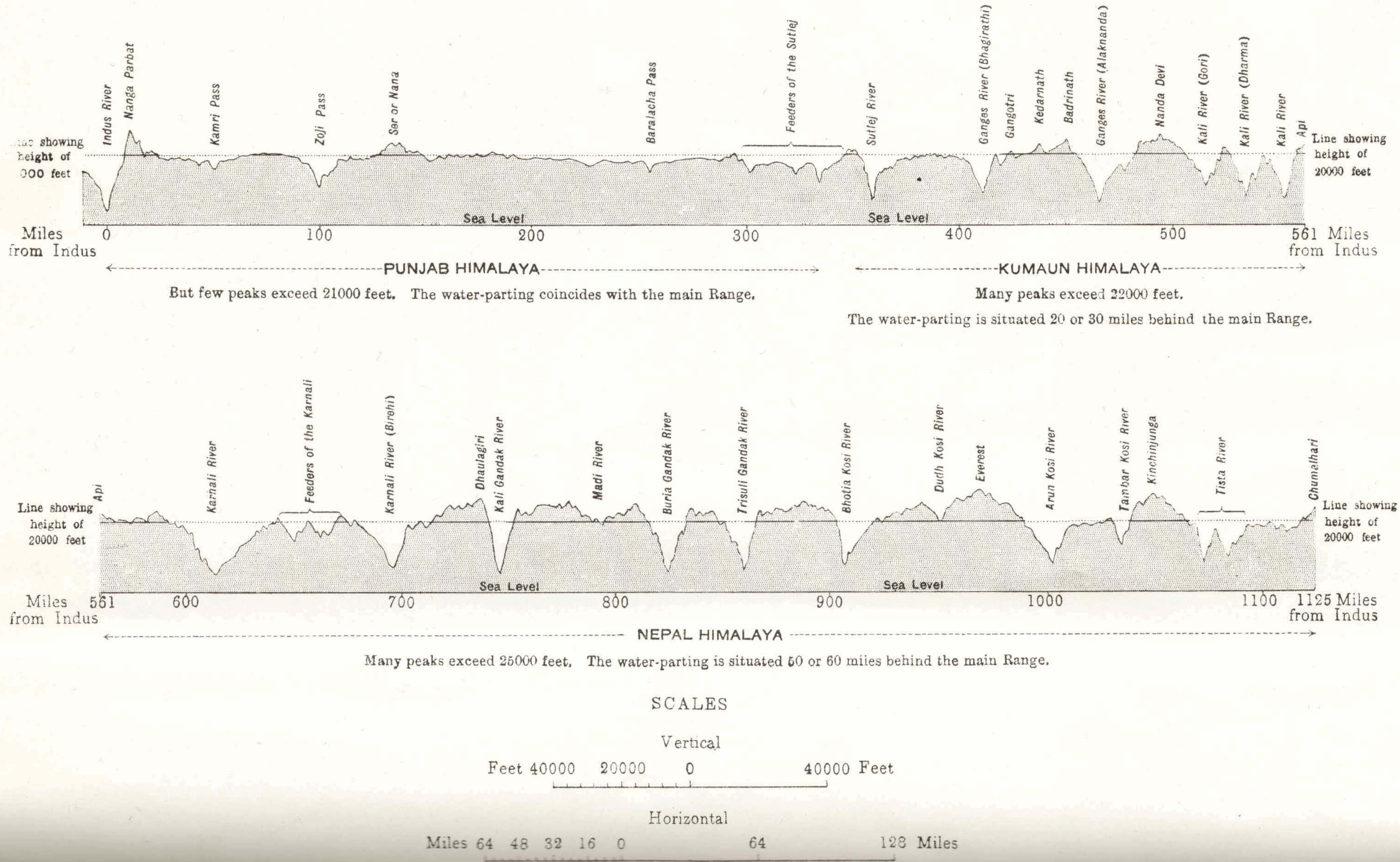
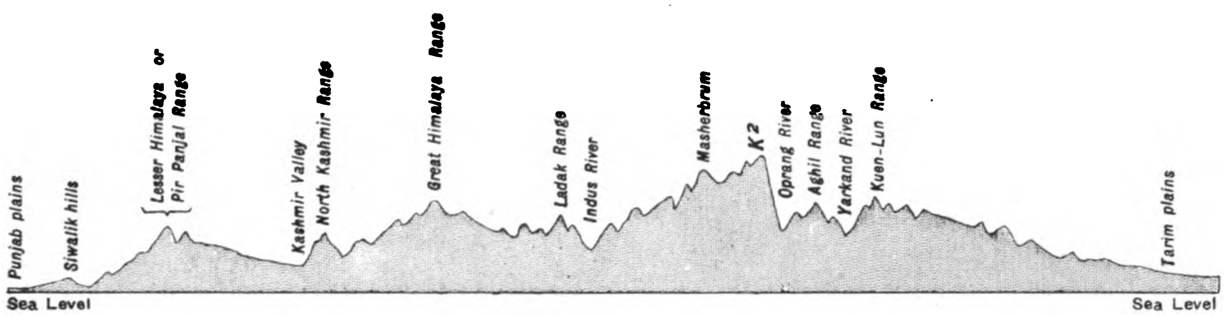


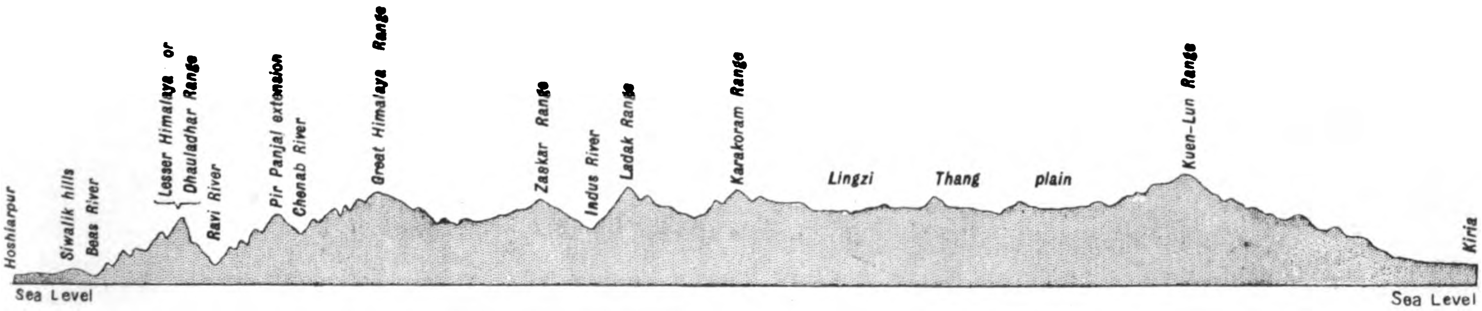
CHART XIV

EIGHT CROSS SECTIONS of the HIMALAYA
drawn at right angles to the Great Range
Cross-Sections 1 to 4.

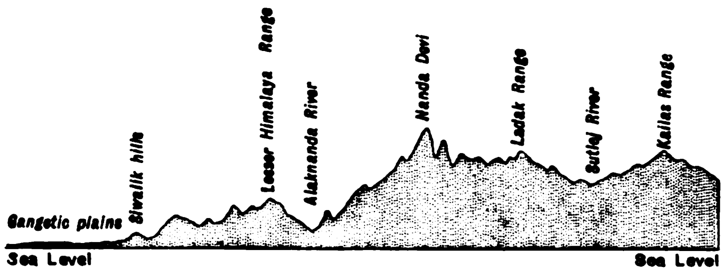
No. 1 THROUGH KASHMIR AND K².



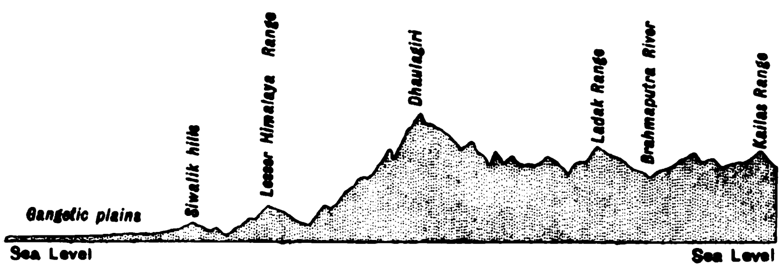
No. 2 THROUGH KANGRA AND WESTERN TIBET.



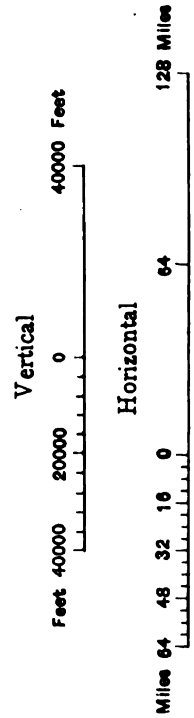
No. 3 THROUGH NANDA DEVI.



No. 4 THROUGH DHAULAGIRI.



SCALES



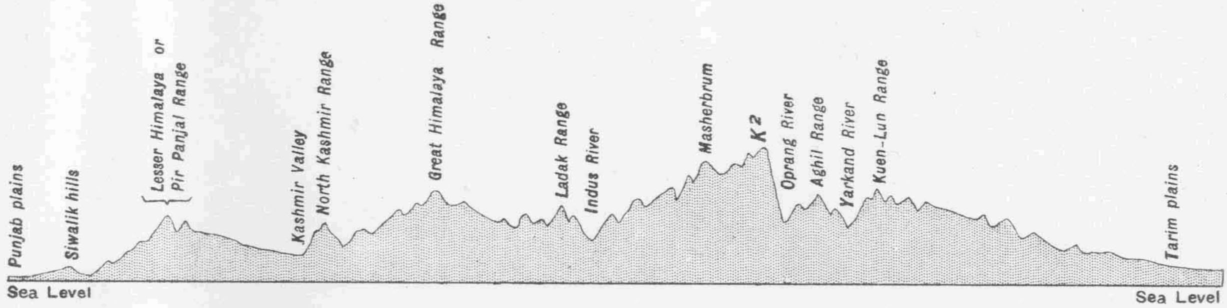
EIGHT CROSS SECTIONS of the HIMALAYA

CHART XIV

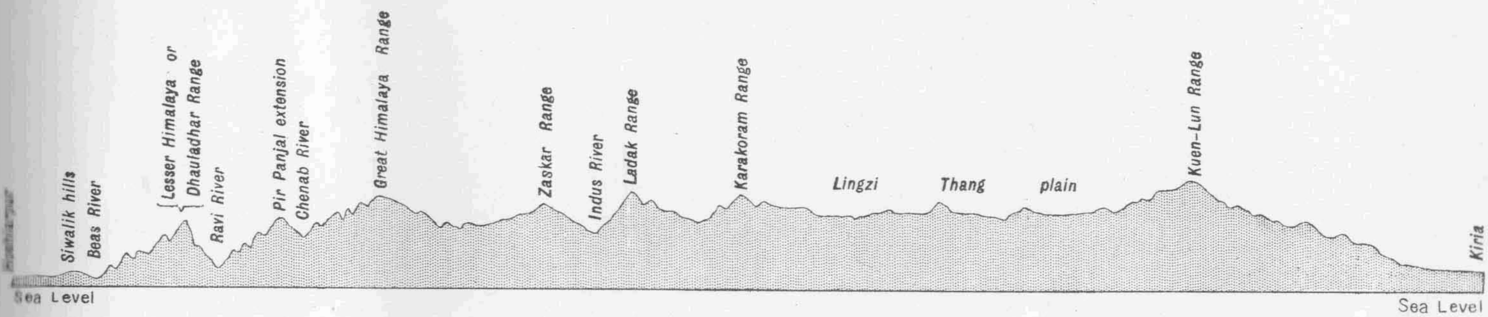
drawn at right angles to the Great Range

Cross-Sections 1 to 4.

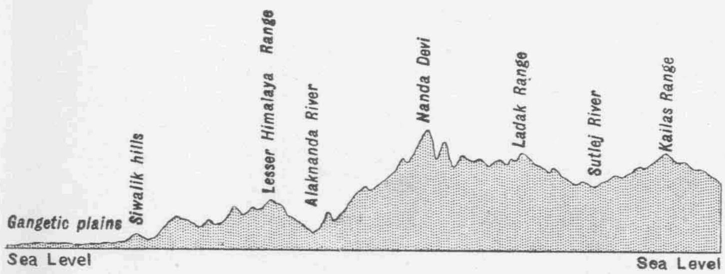
No. 1 THROUGH KASHMIR AND K².

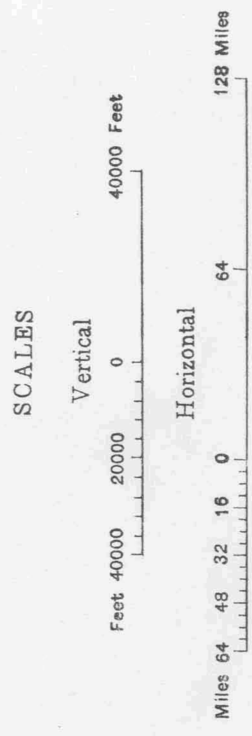


No. 2 THROUGH KANGRA AND WESTERN TIBET.

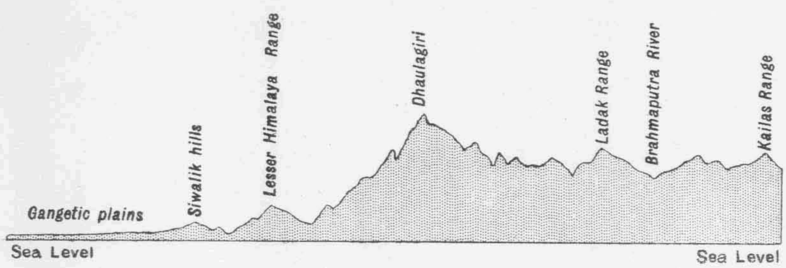


No. 3 THROUGH NANDA DEVI.





No. 4 THROUGH DHAULAGIRI.

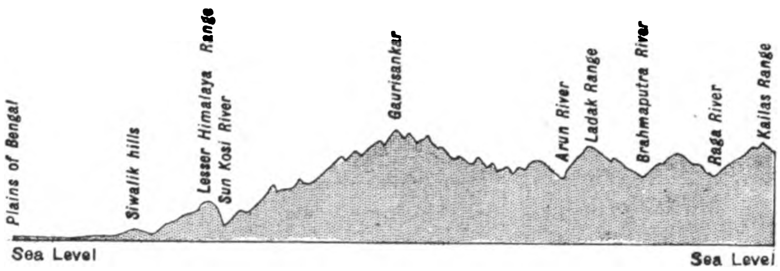


EIGHT CROSS SECTIONS of the HIMALAYA drawn at right angles to the Great Range

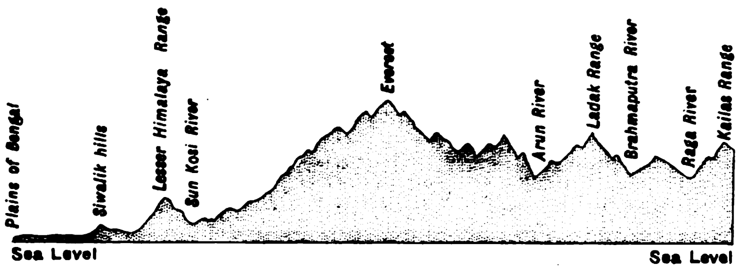
CHART XV

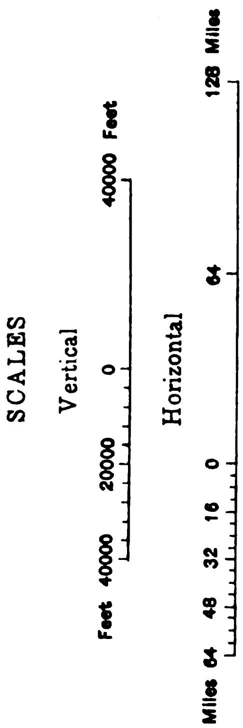
Cross-Sections 5 to 8.

No. 5 THROUGH GAURISANKAR.

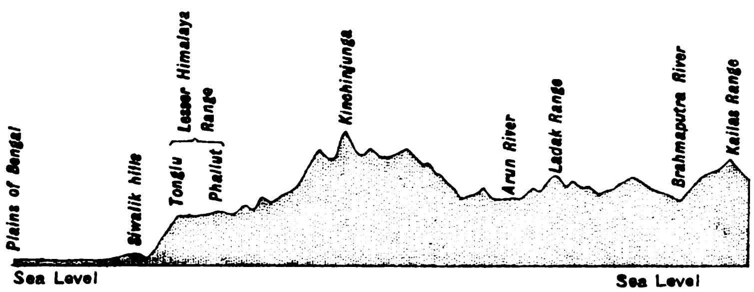


No. 6 THROUGH MOUNT EVEREST.

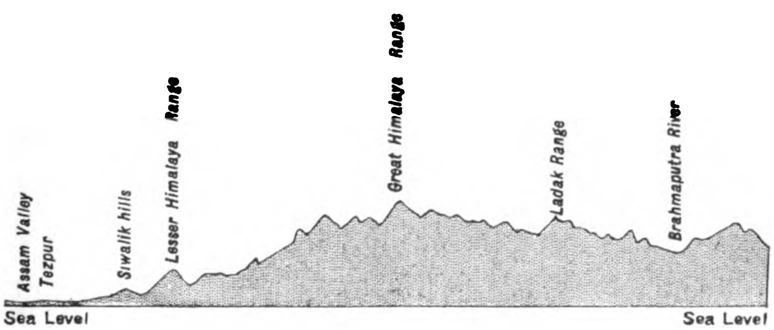




No. 7 THROUGH KINCHINJUNGA.



No. 8 THROUGH THE ASSAM HIMALAYA.



EIGHT CROSS SECTIONS of the HIMALAYA drawn at right angles to the Great Range

CHART XV

Cross-Sections 5 to 8.

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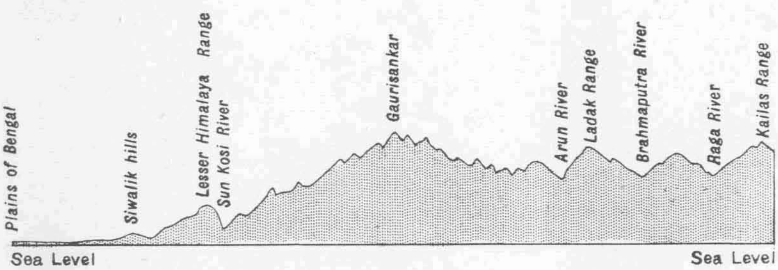

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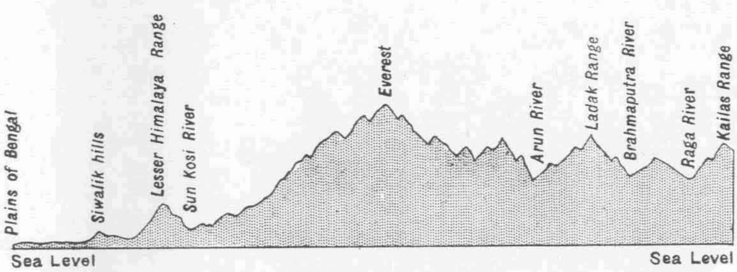

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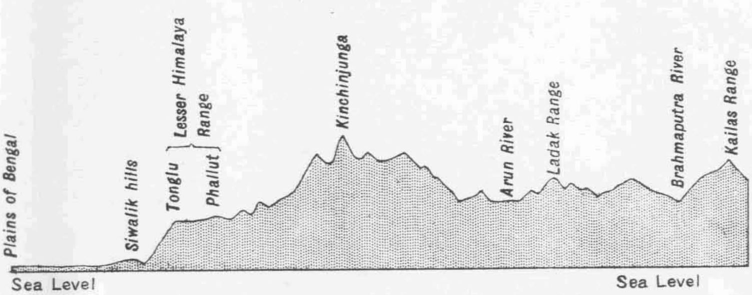
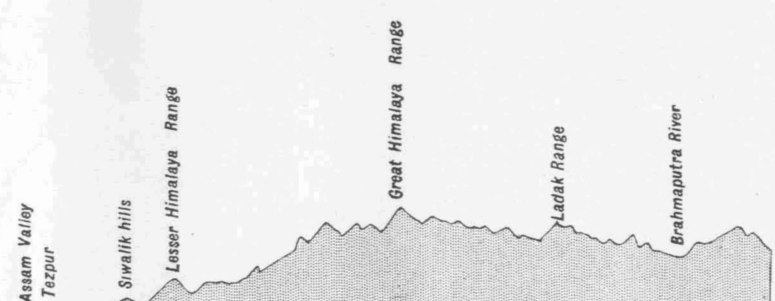


No. 8 THROUGH THE ASSAM HIMALAYA.



SCALES

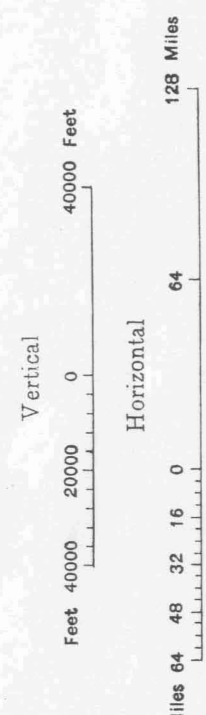
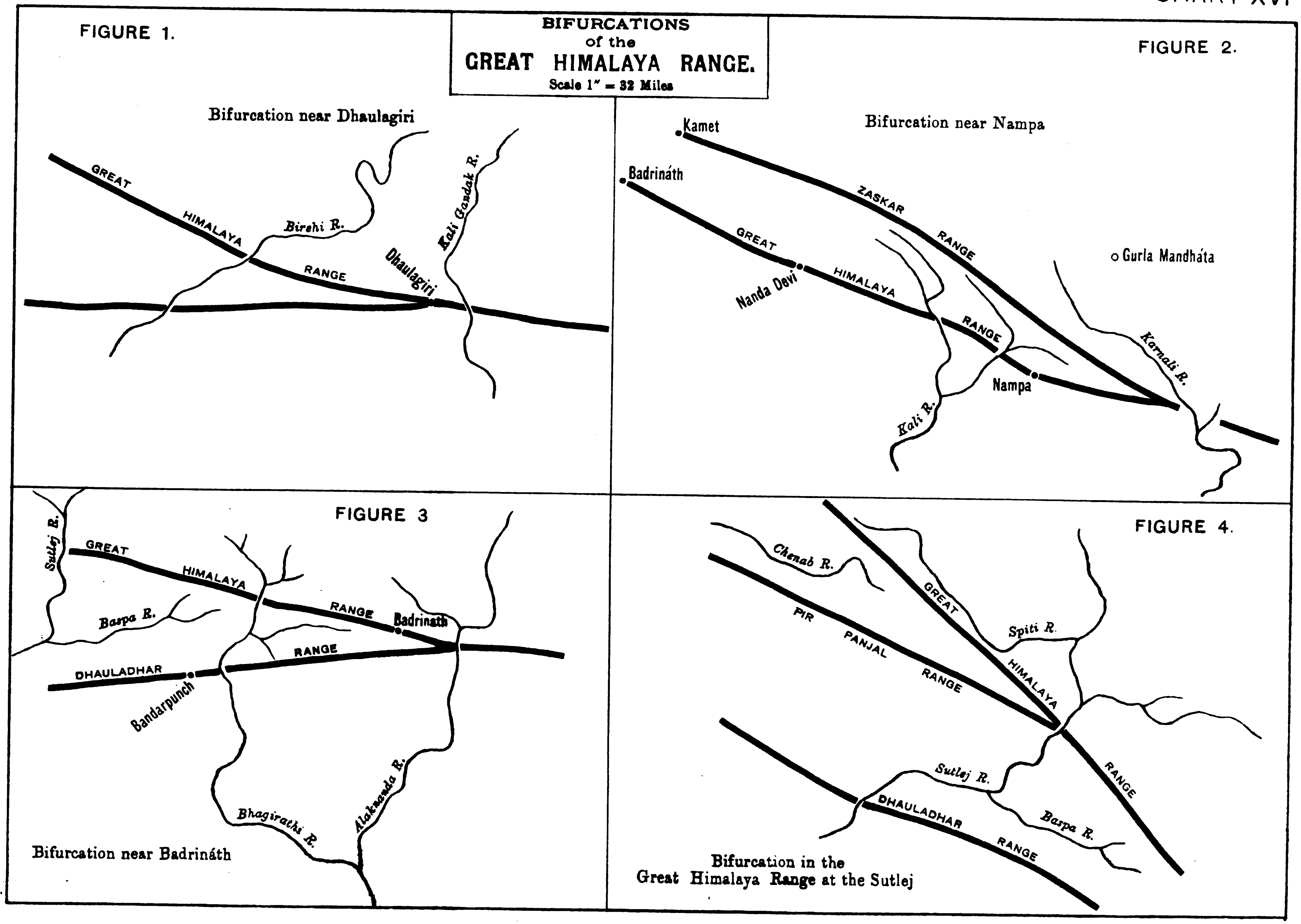
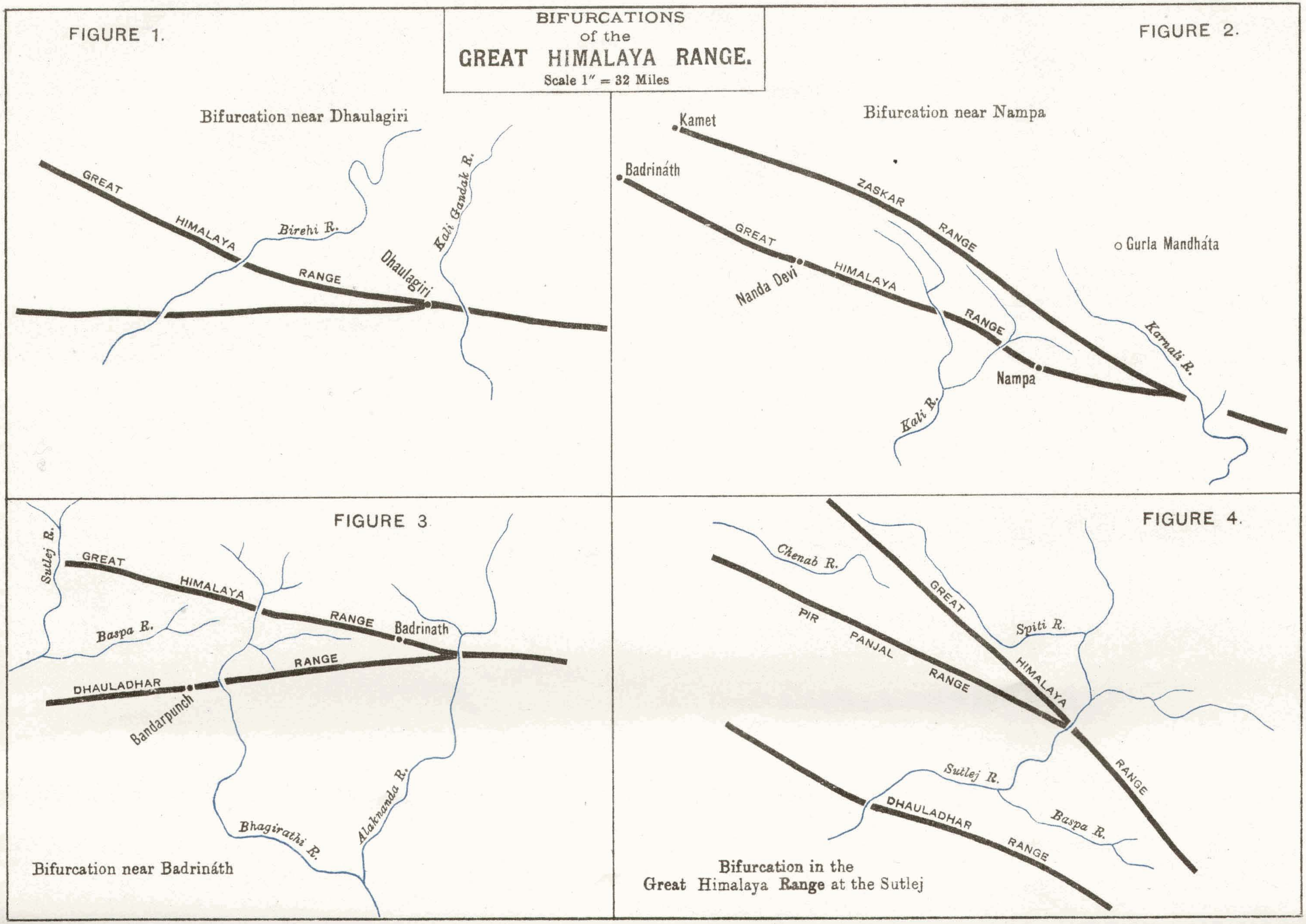


CHART XVI


BIFURCATIONS
of the
GREAT HIMALAYA RANGE.
Scale 1" = 32 Miles
FIGURE 1.
Bifurcation near Dhaulagiri
GREAT
HIMALAYA
RANGE
Birehi R.
Dhaulagiri
Kali Gandak R.
FIGURE 2.
Bifurcation near Nampa
Kamet
Badrináth
ZASKAR
RANGE
GREAT
HIMALAYA
RANGE
Nanda Devi
Nampa
Kali R.
Karnali R.
Gurla Mandháta
FIGURE 3
Sutlej R.
GREAT
HIMALAYA
RANGE
Badrinath
Baspa R.
RANGE
DHAULADHAR
Bandarpunch
Bhagirathi R.
Alaknanda R.
Bifurcation near Badrináth
FIGURE 4.
Chenab R.
PIR
PANJAL
RANGE
GREAT
HIMALAYA
RANGE
Spiti R.
Sutlej R.
DHAULADHAR
RANGE
Baspa R.
Bifurcation in the
Great Himalaya Range at the Sutlej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PANJAL
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DHAULADHAR
RANGE
Bifurcation in the
Great Himalaya Range at the Sutlej

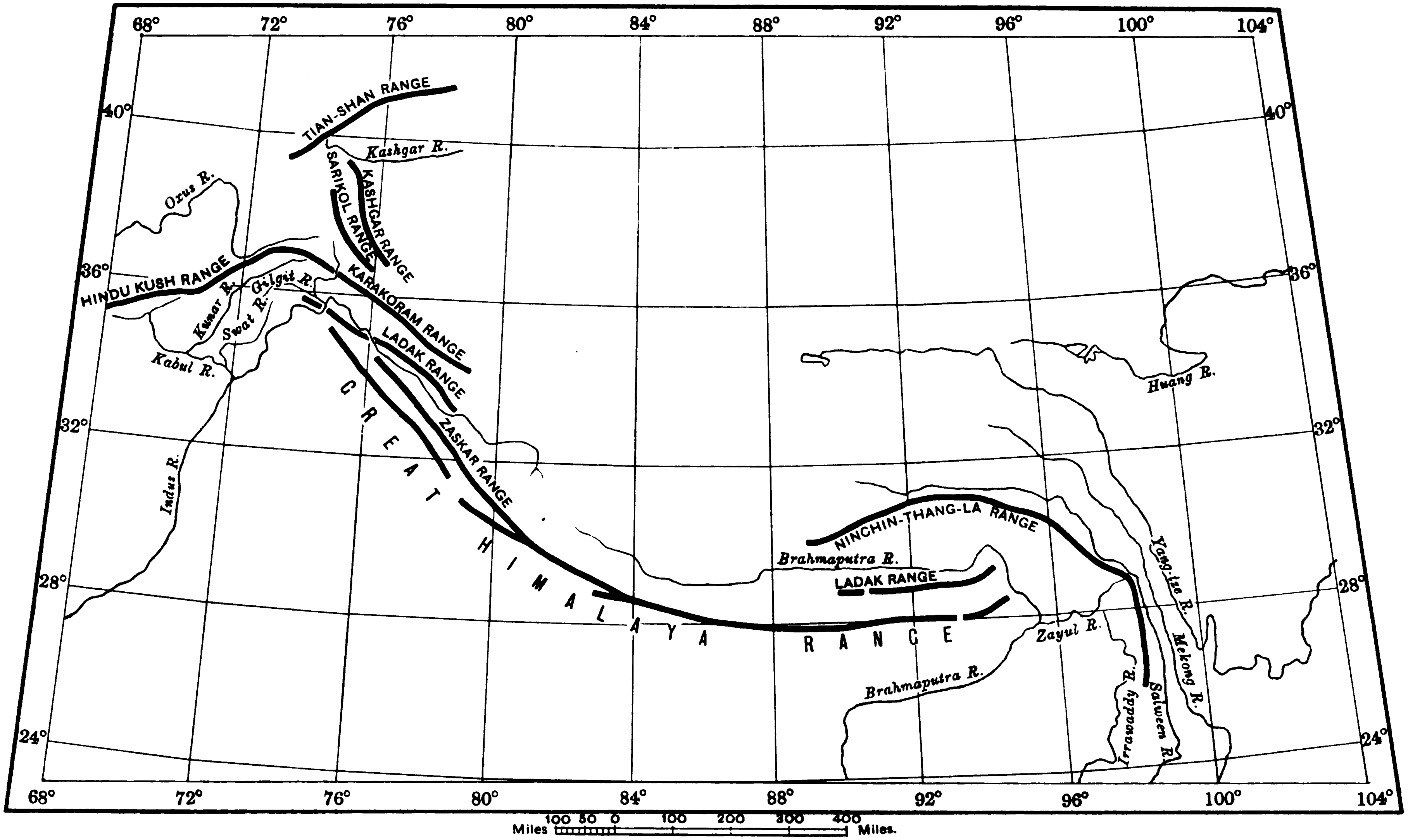
CHART XVII

CHART

to illustrate

how the **GREAT HIMALAYA RANGE**

terminates firstly at the **INDUS** secondly at the **BRAHMAPUTRA**



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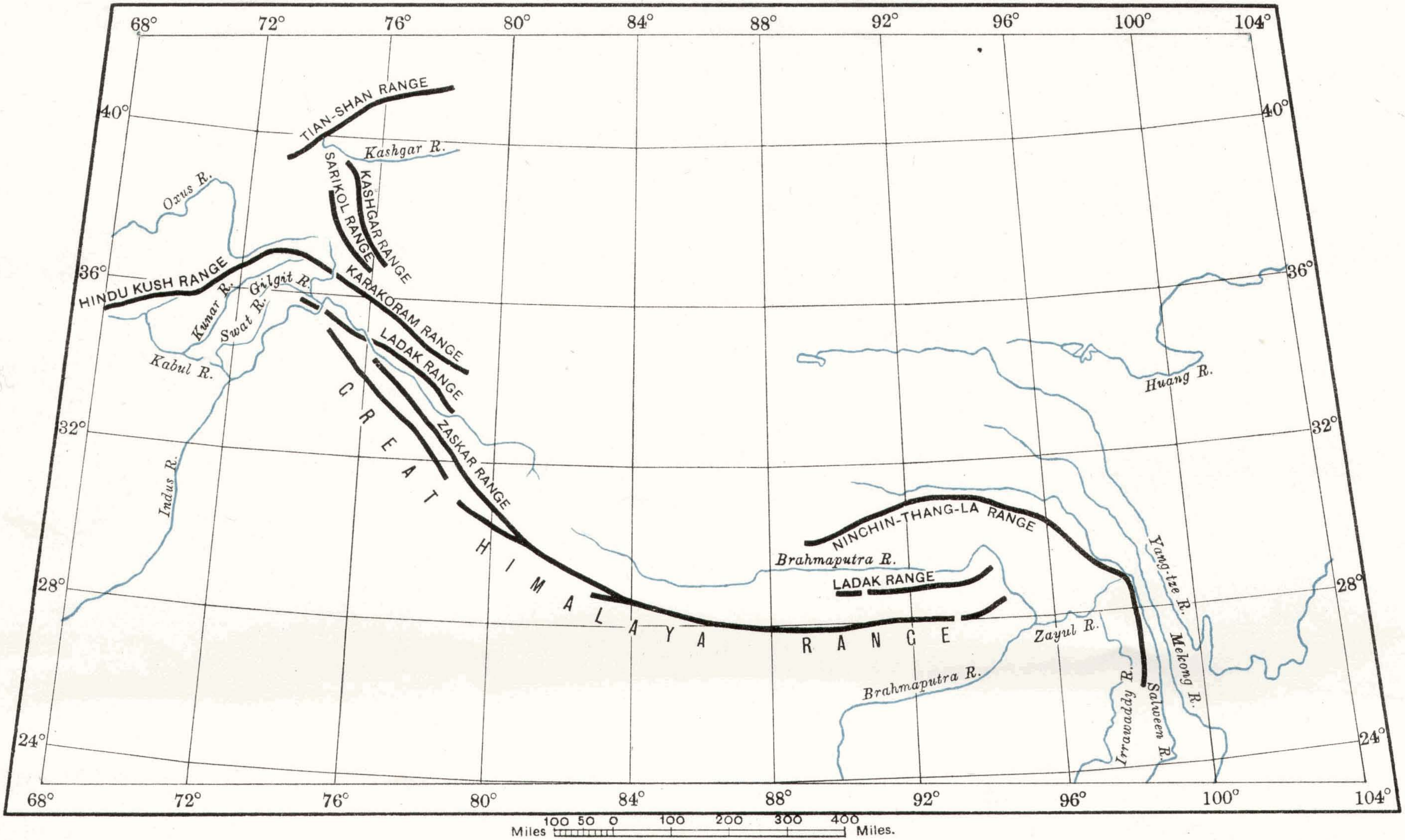
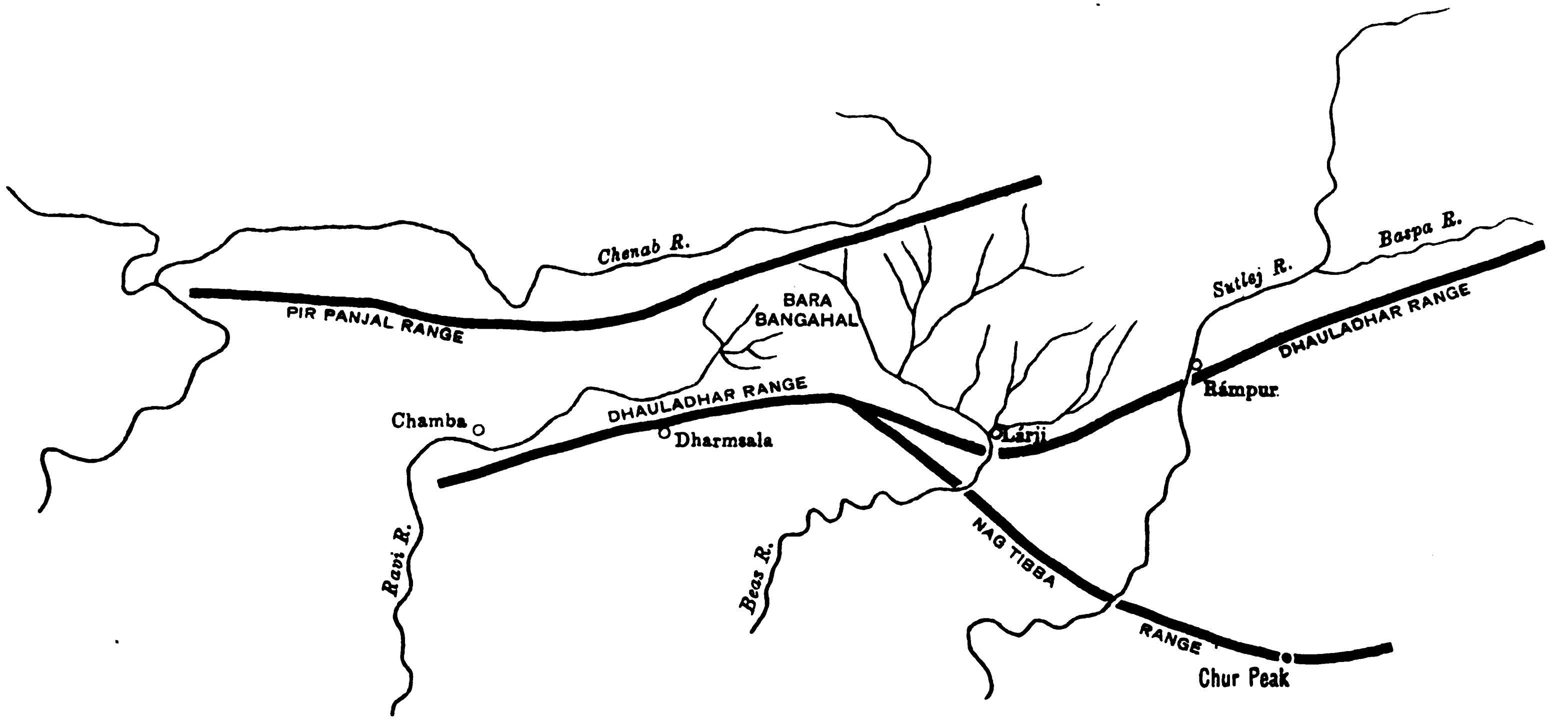
how the GREAT HIMALAYA RANGE

terminates firstly at the INDUS secondly at the BRAHMAPUTRA



Conjunction of Ranges at the Source of the RAVI

Scale 1" = 32 Miles



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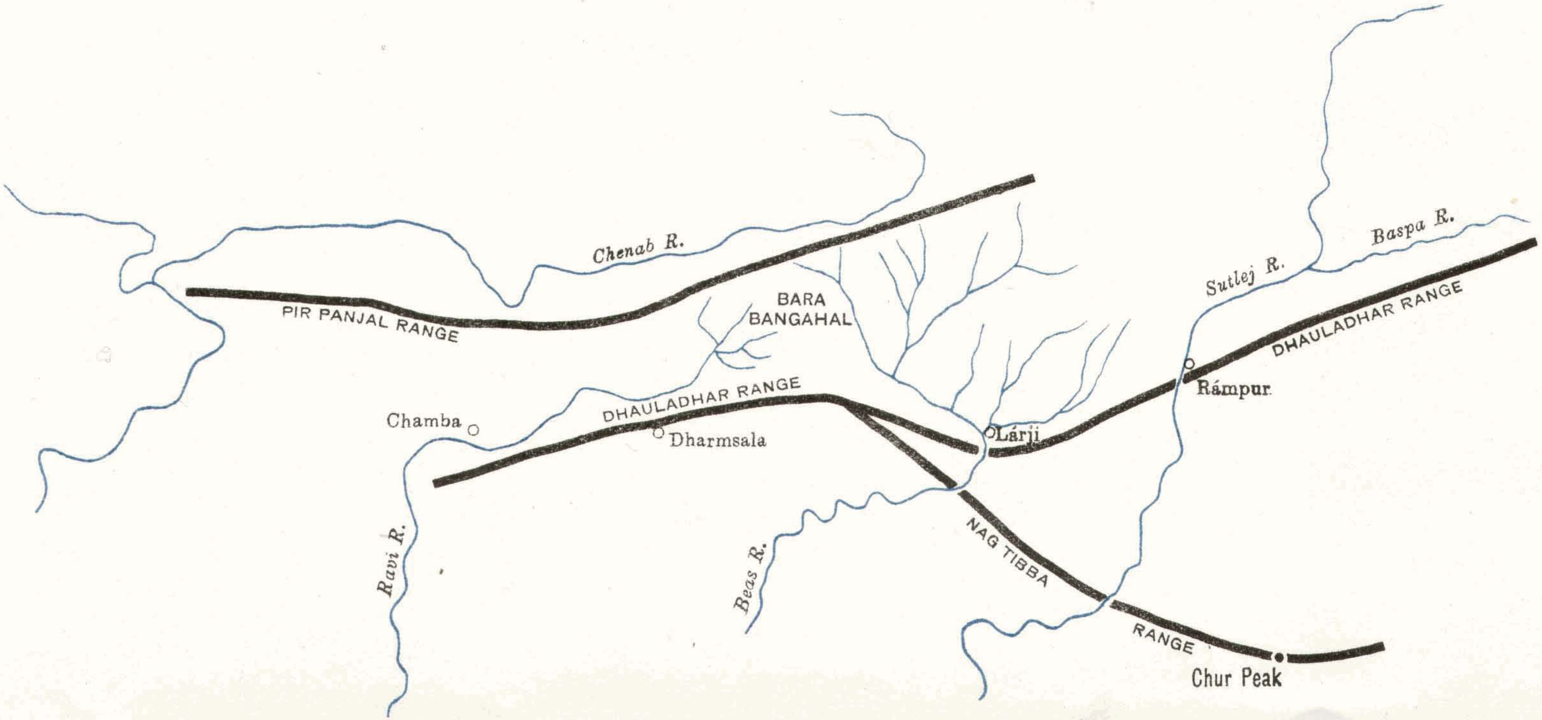


Lessons from the SIWALIK Range

FIGURE 1.

Bifurcation of the Siwalik Range
South of Kángra

Scale 1″ = 4 Miles

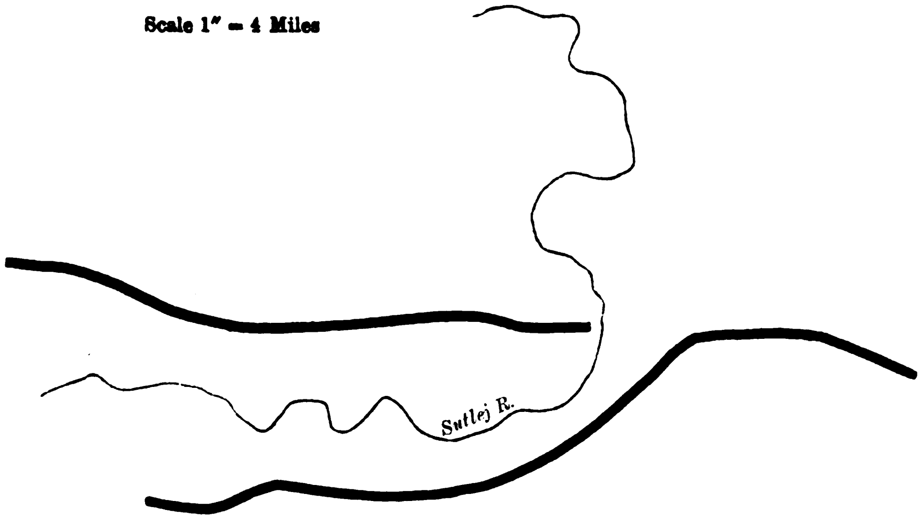


FIGURE 2.

Passage of the
Sutlej through the Siwalik Range
at the place where the range
alters its alignment

Scale 1″ = 32 Miles

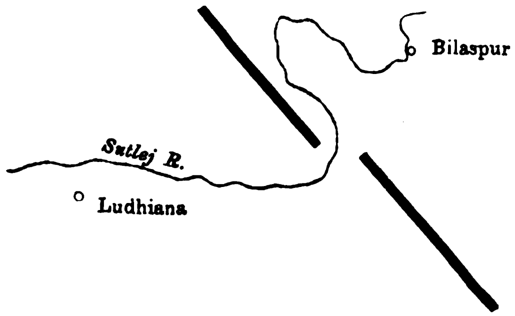
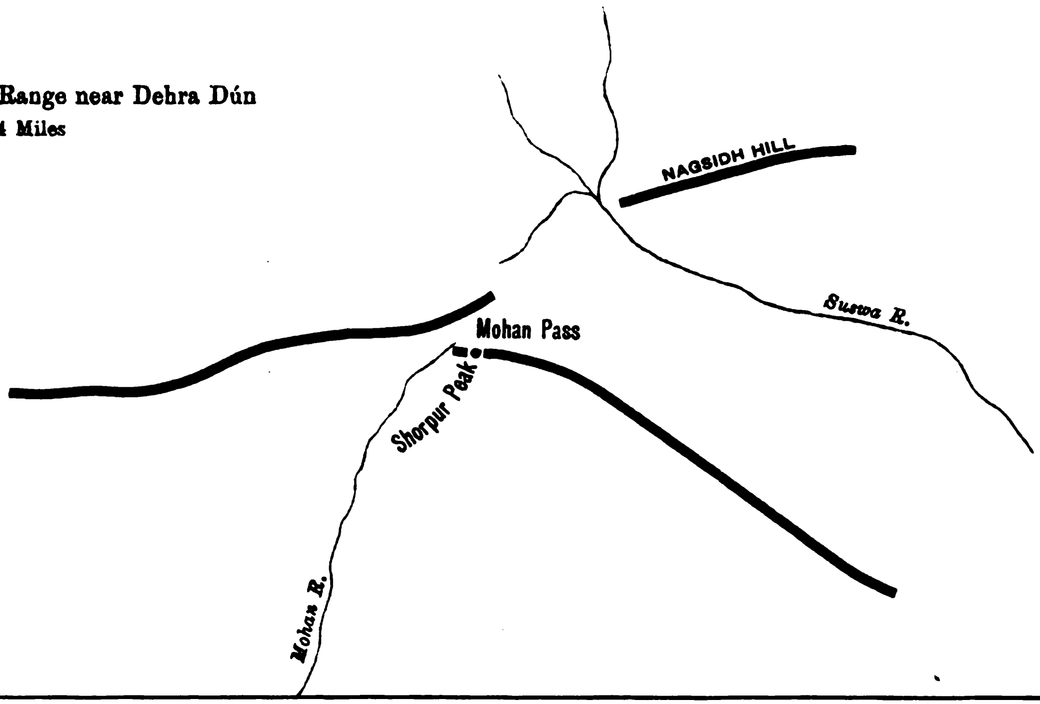


FIGURE 3.

Bifurcation of the Siwalik Range near Dehra Dún

Scale 1″ = 4 Miles



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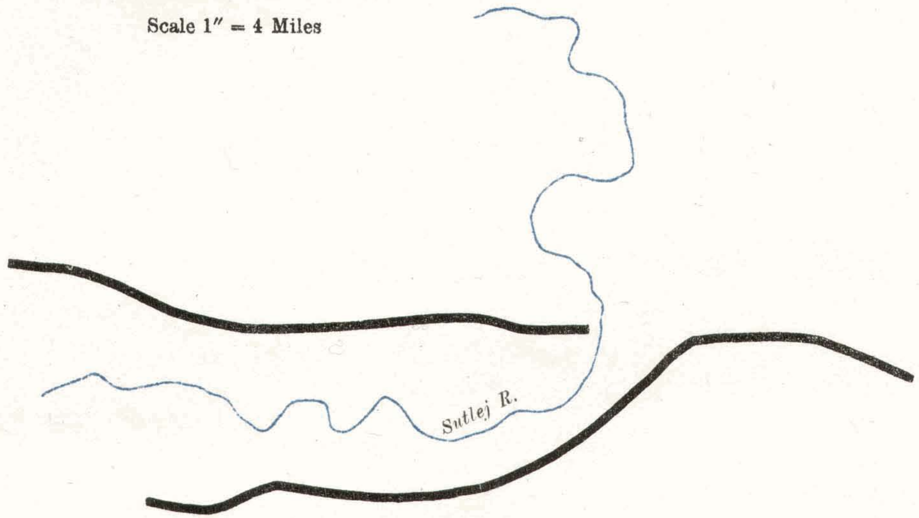

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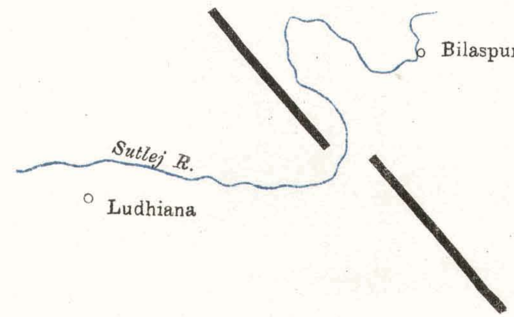

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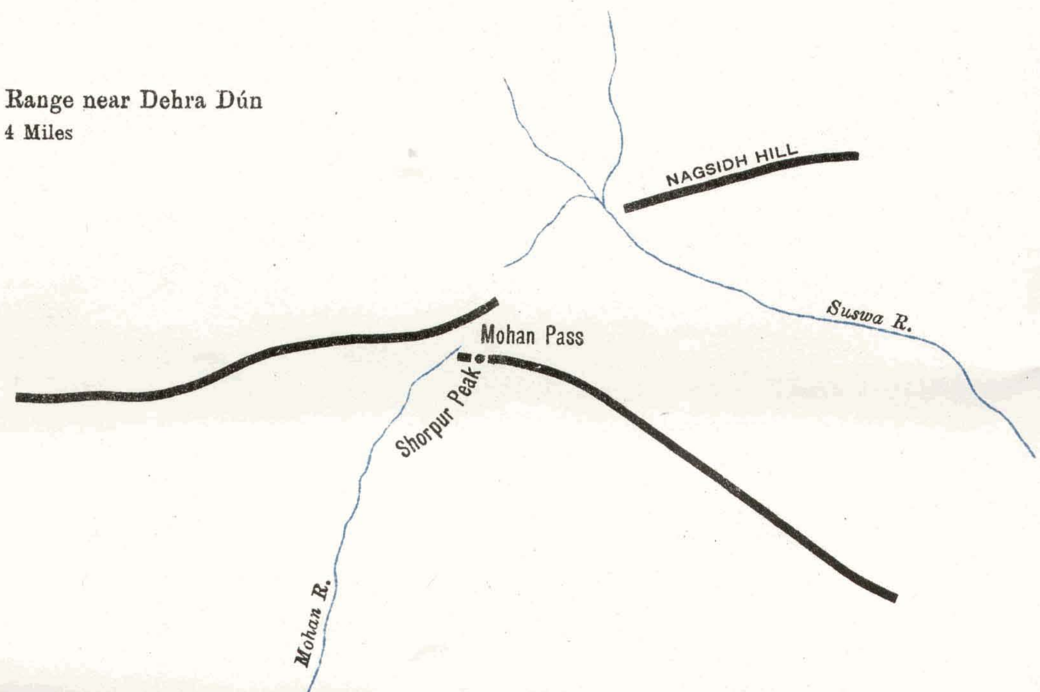
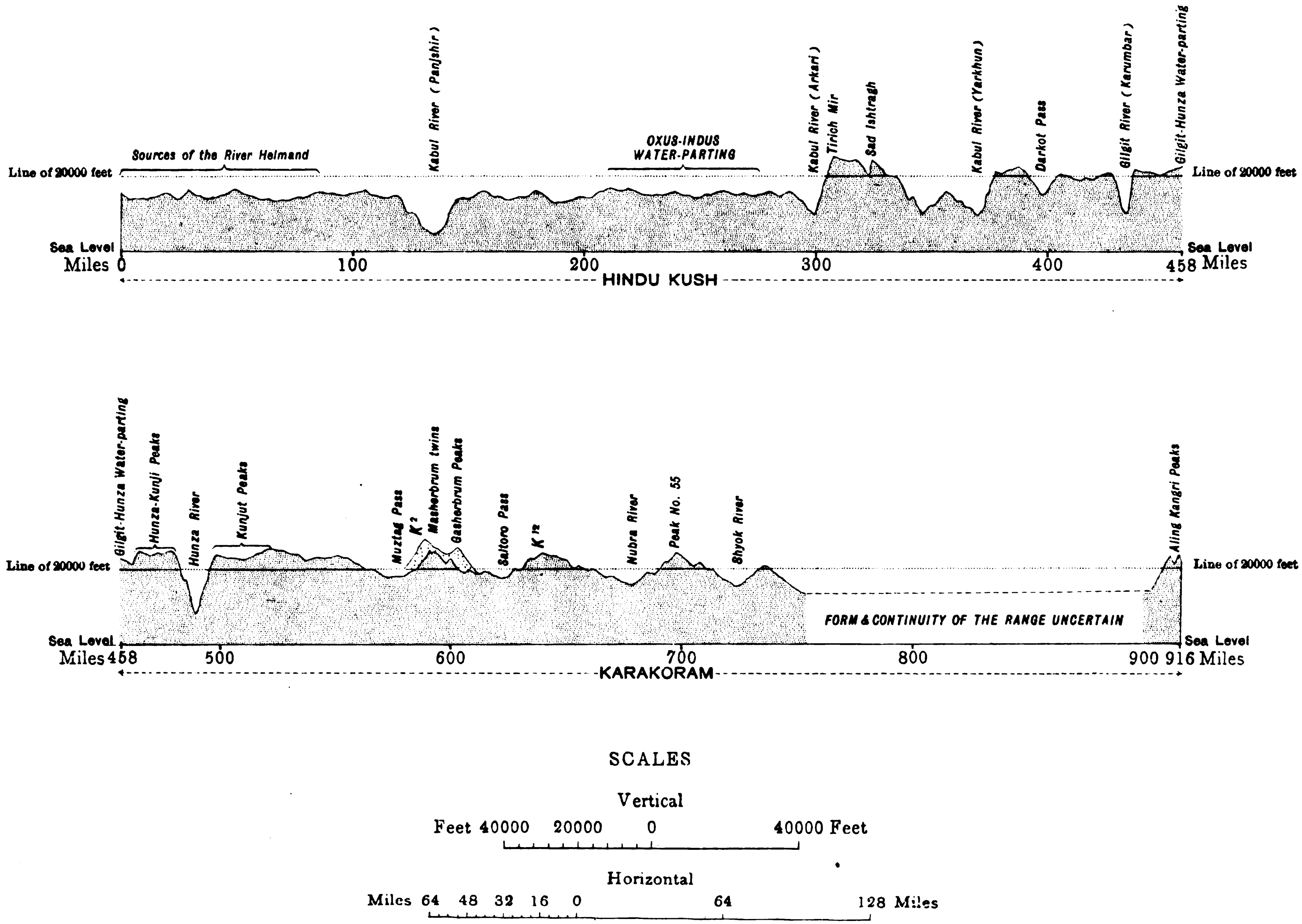


CHART XX

SECTION
along the crest-line of the
HINDU KUSH-KARAKORAM RANGE
from Afghanistan to Tibet
showing how the range is being cut
by rivers into isolated blocks



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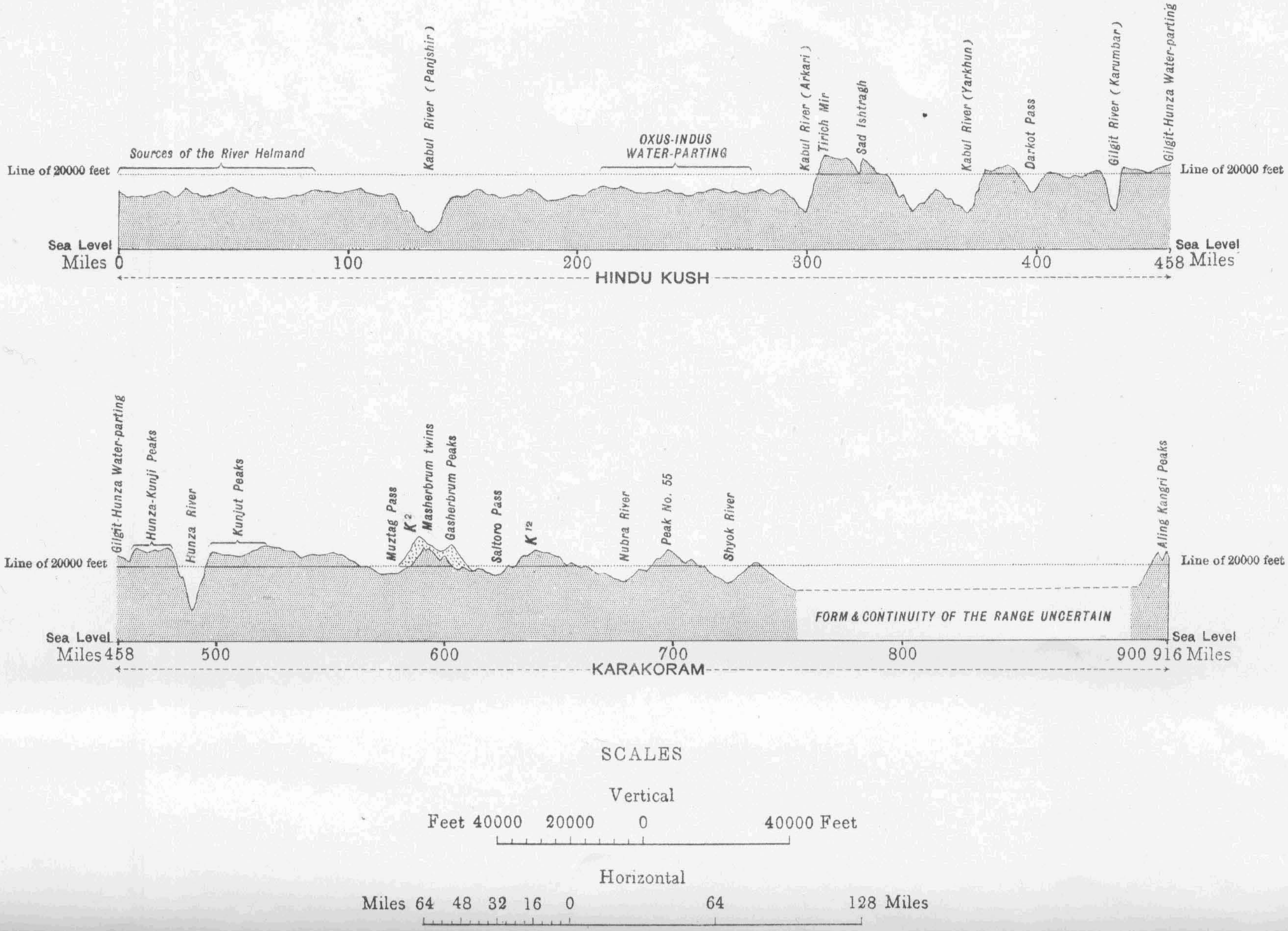


FIGURE 1.

Conjunction of the KAILAS and LADAK, also of the LADAK and ZASKAR Ranges

Scale 1" = 32 Miles

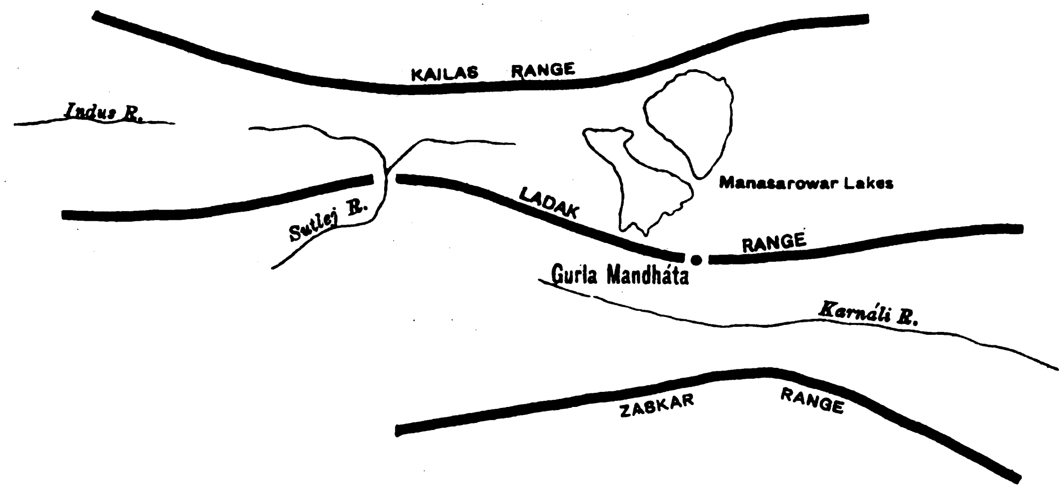
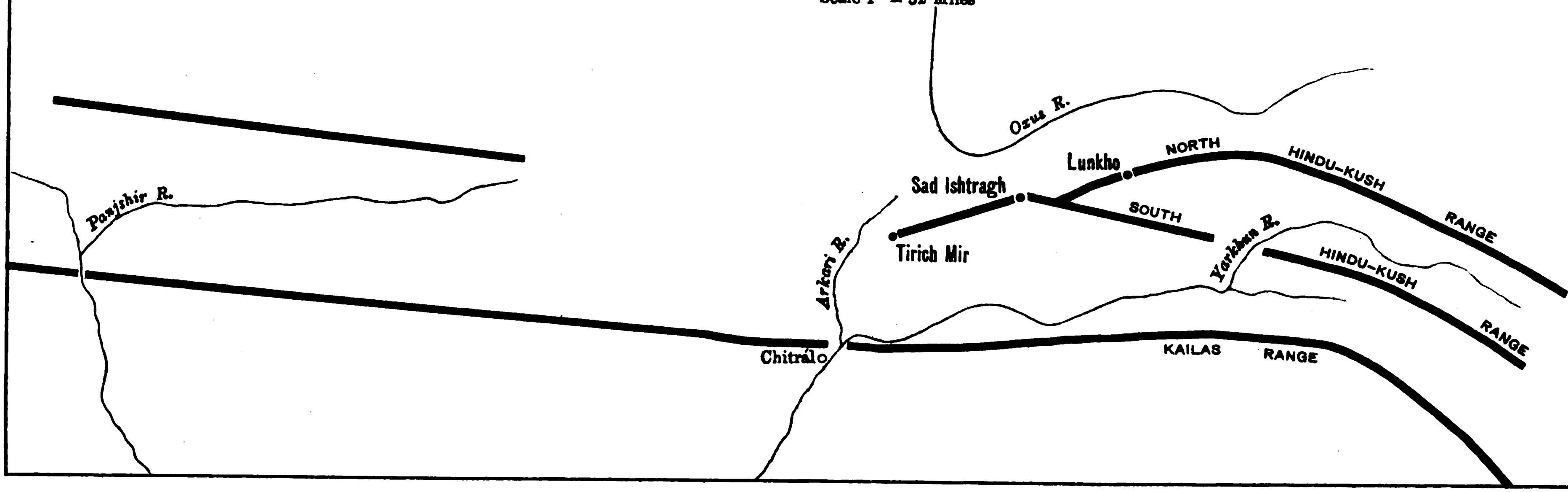


FIGURE 2.

Conjunction of the two HINDU-KUSH Ranges at TIRICH MIR

Scale 1" = 32 Miles



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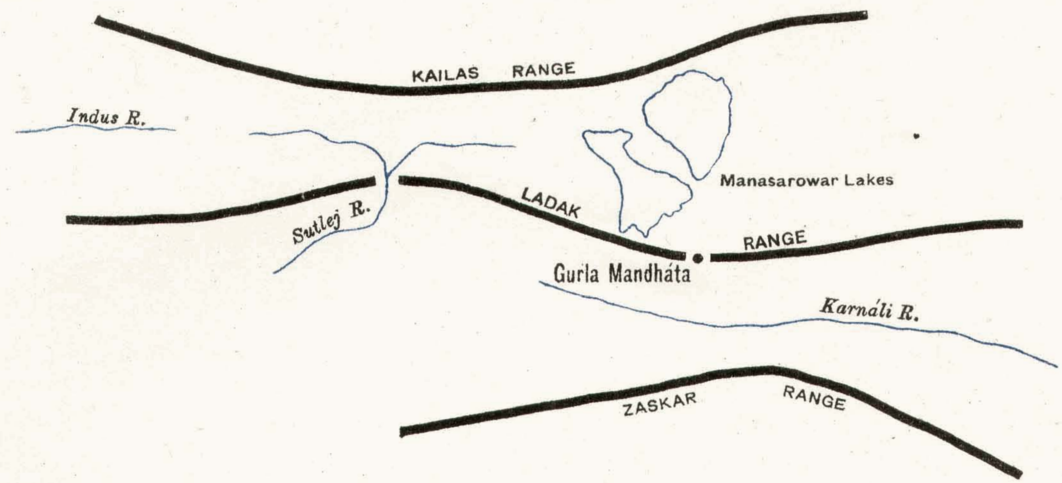

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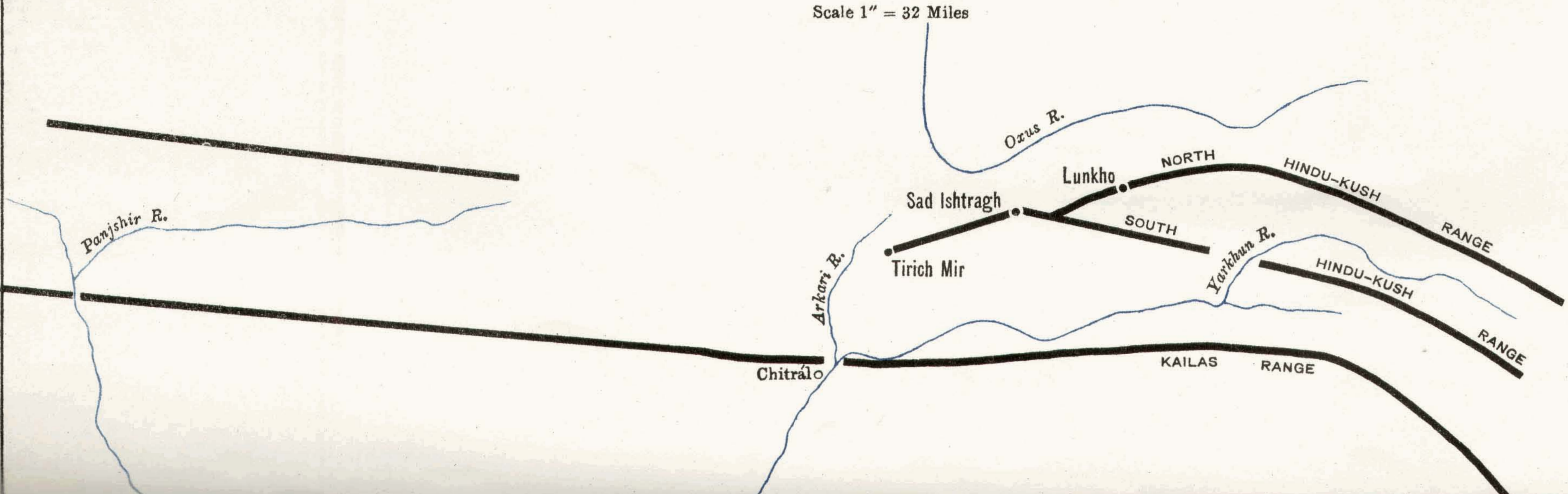
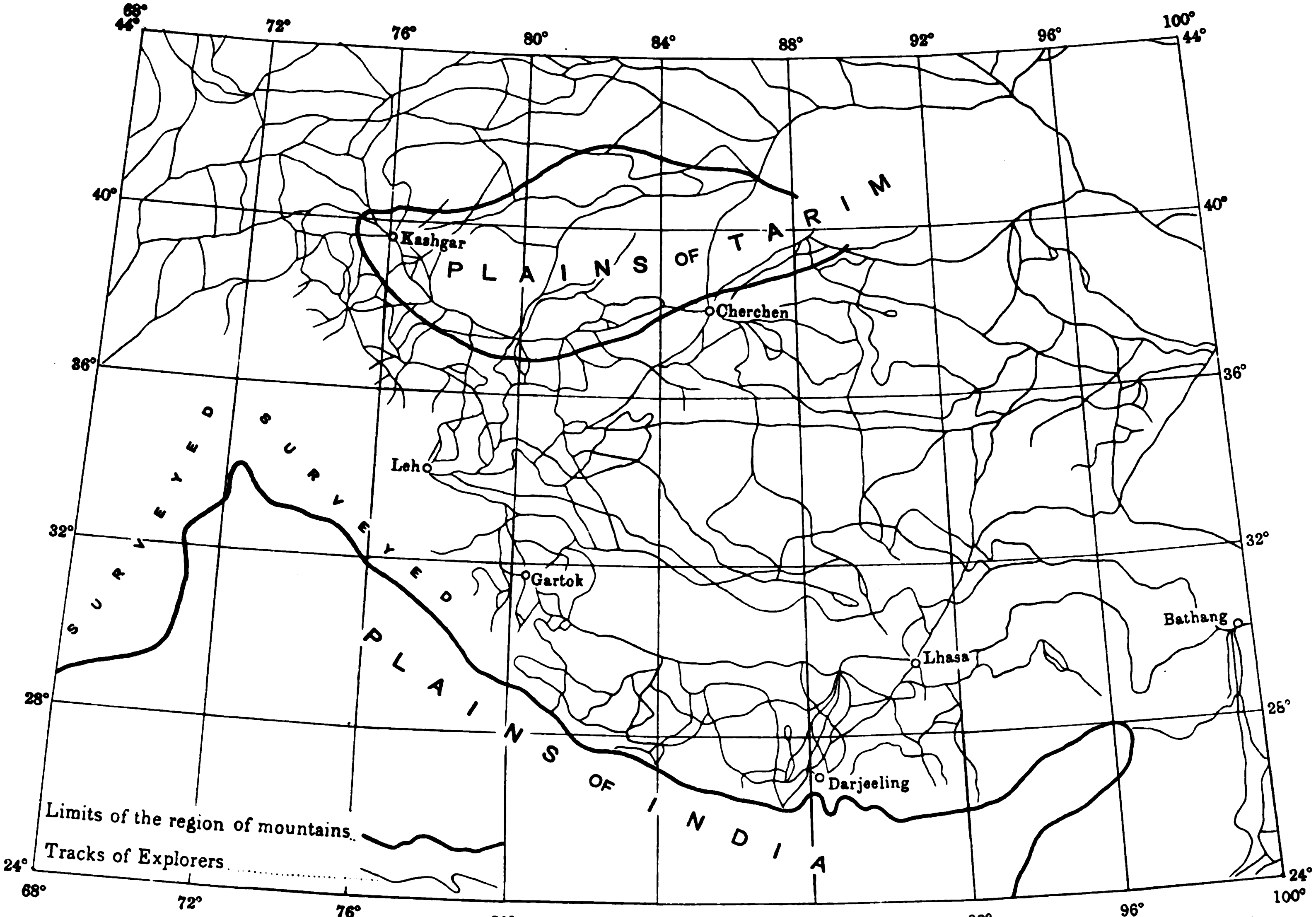


CHART XXII

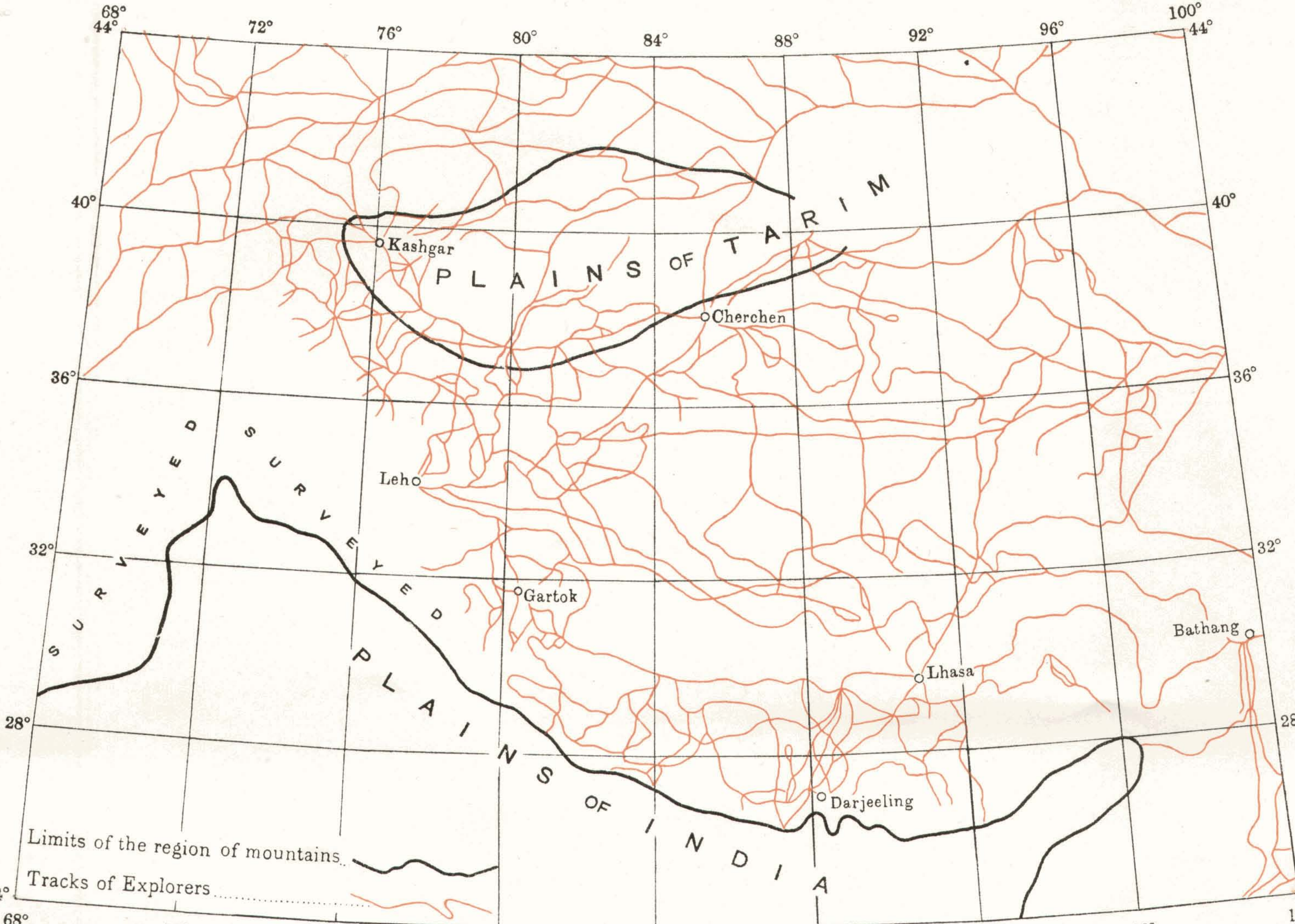
ROUTES of EXPLORERS in TIBET 1865 to 1905



Scale 1 Inch = 256 Miles

CHART XXII

ROUTES of EXPLORERS in TIBET 1865 to 1905



Scale 1 Inch = 256 Miles

A SKETCH

OF THE

GEOGRAPHY AND GEOLOGY

OF THE

HIMALAYA MOUNTAINS AND TIBET

BY

COLONEL S. G. BURRARD, R.E., F.R.S.,
SUPERINTENDENT, TRIGONOMETRICAL SURVEYS,

AND

H. H. HAYDEN, B.A., F.G.S.,
SUPERINTENDENT, GEOLOGICAL SURVEY OF INDIA

PART III

THE RIVERS OF THE HIMALAYA AND TIBET

Published by order of the Government of India.

CALCUTTA
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PREFACE

IN 1807 a Survey detachment was deputed by the Surveyor General of Bengal to explore the source of the Ganges: this was the first expedition to the Himalaya undertaken for purely geographical purposes. A hundred years have now elapsed, during which geographical and geological information has been steadily accumulating, and we have at length reached a stage where there is danger of losing our way in a maze of unclassified detail: it is therefore desirable to review our present position, to co-ordinate our varied observations and to see how far we have progressed and what directions appear favourable for future lines of advance.

The present paper originated in a proposal submitted by the Survey of India to the Board of Scientific Advice at the meeting of the latter in May 1906. The proposal was as follows:—"The number of travellers in the Himalaya and Tibet is "increasing, and a wider interest is being evinced by the public in the geography of "these regions. It is therefore proposed to compile a paper summarising the geographi-"cal position at the present time."

Subject to the modification that the scope of the paper should be geological as well as geographical, this proposal has received the sanction of the Government of India and the work has been entrusted to us to carry out. On the understanding that the paper is intended primarily for the use of the public, we have endeavoured to avoid purely technical details and to present our results in a popular manner.

Our subject has fallen naturally into four parts, as follows:—

Part I.—The high peaks of Asia.

Part II.—The principal mountain ranges of Asia.

Part III.—The rivers of the Himalaya and Tibet.

Part IV.—The geology of the Himalaya.

Though the four parts are essentially interdependent, each has been made as far as possible complete in itself and will be published separately. The first three parts are mainly geographical, the fourth part is wholly geological: the parts are subdivided into sections, and against each section in the table of contents is given the name of the author responsible for it.

PREFACE

The endeavour to render each part complete must be our apology for having repeated ourselves in more places than one: the relations, for instance, of a range to a river have been discussed in Part II, when the range was being described, and have been mentioned again in Part III under the account of the river.

As the mountains of Asia become more accurately surveyed, errors will doubtless be found in what we have written and drawn: it is not possible yet to arrive at correct generalisations and we have to be content with first approximations to truth.

Maps, too large for insertion in such a volume as this, are required for a study of the Himalayan mountains: the titles of maps illustrating the text are given in foot-notes and are procurable from the Map Issue Office of the Survey of India in Calcutta. Constable's hand-atlas of India will be found useful.

We are much indebted to Babus Shiv Nath Saha and Ishan Chandra Dev, B.A., for the care with which they have checked our figures and names, and to Mr. J. H. Nichol for the trouble he has taken to ensure the correctness of the charts. Mr. Eccles and Major Lenox Conyngham have been kind enough to examine all proofs, and to give us the benefit of their advice and suggestions. Mr. Eccles has also supervised the drawing and printing of the charts, and we have profited greatly by the interest he has shown in them.

S. G. BURRARD.

H. H. HAYDEN.

March 1907.

CONTENTS OF PART III

CHARTS OF PART III.

Charts I to VIII are included in Part I.

Charts IX to XXII are included in Part II.

20

THE DRAINAGE OF THE PLATEAUX.

THE high plateaux and mountains which we have been describing in Part II contain the sources of the principal rivers of Asia. In chart XXIII the drainage is illustrated.

If we commence at the Tian Shan and work round by west to south, and thence to east, we find that the rain and snow, which fall on the plateaux, flow to the lower levels of Asia in the following ways:—

(i) The northern slopes of the Tian Shan are drained by small rivers that flow on the east into the Mongolian lakes and on the west into lake Balkash.

(ii) The western portions of the Tian Shan are drained by the Jaxartes (Syr Darya) and the western flank of the Pamir plateau by the Oxus (Amu Darya). The Jaxartes and the Oxus empty their waters into a flat shallow depression of western Asia, and create the sea of Aral.

(iii) The Helmand, draining the western portions of the Hindu Kush, has its course stopped by a small range of hills on the borders of Afghanistan and Persia, and, being forced to empty itself into a flat inland desert basin, it creates the lagoon of Seistan.*

(iv) Feeders of the Indus, described in detail hereafter, drain the southern slopes of the Hindu Kush and Karakoram ranges, and both the northern and southern slopes of the Punjab Himalaya.

(v) Feeders of the Ganges and Brahmaputra carry off all the water and snow that fall on the Kumaun, the Nepal and the Assam Himalaya.

(vi) The Irrawaddy, the Salween and the Mekong drain the south-eastern portions of Tibet, and flow, the two first into the Bay of Bengal, and the last into the Pacific Ocean.

(vii) The Yangtze and Hoang Ho drain Eastern Tibet, and flow through China to the Pacific Ocean.

(viii) The rivers of the Tarim system drain the interior of the horse-shoe, and empty their waters into the shallow lagoons of Lob Nor.

(ix) The rivers of Central Tibet flow into one or other of the numerous Tibetan lakes, and have no outlet to the sea.

In comparing rivers we can have regard to the areas of their basins, or to the volumes of their discharges, or to the populations they support; and the following table, though not based altogether upon trustworthy data, will give some idea of the order of

* Vide *Journal, R. G. S.*, Vol. 43, 1873, page 278: also Holdich's geographical notes, Afghan Boundary Commission, *Proceedings, R. G. S.*, Vol. VII, 1885: also *Annual Report of the Board of Scientific Advice for India*, 1905-06.

importance of the different drainage systems.* In this table the most important system is that numbered "1" and the least important is that numbered "13."

TABLE XXIX.

Drainage system.	Order of importance of the several rivers, as estimated:		
	from size of basin.	from discharge of water.	from population supported.
Yangtze	1	1	1
Hoang Ho	2	2	2
Ganges	3	3	3
Mekong	7	5	4
Indus	6	7	5
Brahmaputra	8	6	6
Irrawaddy	9	4	7
Tarim	4	10	9
Oxus	10	8	8
Rivers flowing into Tibet lakes	5	11	13
Salween	11	9	12
Helmand	12	12	11
Jaxartes	13	13	10

The primary water-partings.

Chart xxxv has been drawn to illustrate the primary water-partings of the high plateaux. The highest ranges of mountains† are shown by dotted lines with heavier dots at intervals to symbolise peaks, and the main water-partings are shown by black continuous lines. In places where the highest range forms the main water-parting a dotted line and a continuous line have been drawn side by side. The water-parting between India and Tibet has been shown by a double line.

In order to study this chart we will commence with the Tarim basin.‡ The Tarim basin lies between the Tibet plateau and the Tian Shan. Its surface is a sandy desert, and the Tarim river, which drains the Karakoram, the Kuen Lun, the Tian Shan and the Pamirs, is the only source of life. "This great depression," writes Prince Kropotkin, "is only relative in comparison "with the high plateaux which surround it, and represents on the contrary a vast mas-"sive swelling of the Earth's crust. In its western portion it has still an altitude of "from 3000 to 4000 feet, and 2600 feet in its lower part,—the depression of the Lob Nor."§ On the east the ranges of the Tian Shan approach those of north-east Tibet, and the mouth of the Tarim basin becomes narrow, but the two systems of mountains do not actually come into contact at this point, and the plains of Tarim are continued without interruption into Mongolia and the deserts of Gobi. The surface of the desert inside the basin is at a lower level than that of Gobi outside.

The Tarim basin.

* Rivers draining the northern slopes of the Tiau Shan are omitted from the table.

† Compare chart xxxv with frontispiece to Part I and with chart xxiii.

‡ Map of Turkistan, 1 inch = 32 miles.

§ *Geographical Journal*, Vol. XXIII, 1904. *The Orography of Asia.*

The rivers of Tarim empty their waters into the lagoons of Lob Nor (see frontispiece to Part I). Sven Hedin has shown that whilst these lagoons are getting choked with sand, the desert on their north is being excavated by wind: their water, he says, will ultimately overflow and seek the lower level. This has happened before, and in 265 A.D. Lob Nor lay considerably north of its present position. As the lakes move, so do the vegetation, the animals, and the fisher-folk; and Sven Hedin calls Lob Nor the oscillating pendulum of the Tarim river.*

The rivers of the Tarim basin may be divided into four classes:—

(i) There are the rivers rising in the Tian Shan mountains. The water-parting of the Tian Shan dividing the drainage of the Jaxartes from that of the Tarim is north of the principal range in one place only.† At the peak of Tengri Khan (*vide* table VI), near the meridian of 80°, the Tian Shan range appears to bend to the south-west, and to throw off a northern branch. The river Sariati drains the basin enclosed between the branches, and breaking through the southern and principal range it flows into the Tarim basin. The area drained by the Sariati north of the Tian Shan main range is marked A on chart XXXV.

(ii) There are the rivers that drain the trough between the Sarikol and Kashgar ranges; these have carved passages through the latter and flow eastward into the Tarim basin. The areas drained by these rivers behind the main Kashgar range are marked D on chart XXXV.

These rivers are:—(*a*) The Ulu-Art (or Yanymya or Muji) which drains the whole trough north of Muztagh Ata, and which pierces the main range by the Gaz defile. (*b*) The Tashkurgan river, which, rising north of the Kilik pass on the Indus-Tarim water-parting, drains the trough south of Muztagh Ata, and passes eastwards through the Kashgar range by the Chiragh Tar gorge 60 miles south of the Gaz defile.‡

Many rivers rise on the eastern slopes of the Kashgar range and flow into the sandy deserts of Tarim.

(iii) The Yarkand river, which drains the area marked E on chart XXXV.

The Yarkand river is the largest and the most important of all the rivers of Tarim;§ it collects the drainage of two parallel troughs, the Karakoram-Aghil trough, 100 miles long, drained by the Oprang tributary, and the Aghil-Kuen Lun trough, 170 miles long, drained by the Raskam; it pierces both the Aghil and Kuen Lun ranges, and it carries water from the glaciers of peak K^2 to the lagoons of Lob Nor.

South-east of K^2 the Indus-Tarim water-parting leaves the main Karakoram range and bends sharply to the north-east: feeders of the Yarkand river

* *Geographical Journal*, Vol. XXI, 1903. *Three years' Exploration in Central Asia.*

† Not knowing how reliable the maps of Tian Shan may be, we can only refer to topographical features with diffidence.

‡ The Chiragh Tar gorge was explored by Rai Sahib Ram Singh in 1906.

§ In its mountain course it is known as the Raskam Darya and the Zarafshan river.

receive the drainage of the re-entering angle thus formed, as far east as the meridian of 78°.

(iv) The Karakash river drains the area marked F on chart xxxv, and the Kiria river drains the area marked J. The Karakash river flows for 100 miles in a trough south of the Kuen Lun, before it pierces the range at Shahdulla.

The northern slopes of the Kuen Lun, between the areas F and J of the water-parting chart, are drained by the Yurangkash river: the Karakash and Yurangkash are within fifteen miles of one another when passing the town of Khotan, but they do not unite for another 80 miles.

After their junction they are called the Khotan river.

A vast number of minor rivers drain the northern slopes of the Kuen Lun and lose themselves in the sands of the desert.*

The Yarkand river contains water all the year round, but the Khotan river remains dry during the greater part of the year. "The Khotan river," writes Sven Hedin, "flows through the worst section of the Takla Makan "desert, and has a far harder fight of it with the drift sand than its "sister stream to the west (Yarkand). Indeed the sand is seriously "threatening to choke it up and cut it off from the main river—a fate "which has already overtaken the Kiria Darya."† Sven Hedin reached the point where the Kiria river died away in the sand, "finally giving "up its desperate struggle against the desert."

The water-parting between the Tarim basin and the Tibet lake-basin was taken for chart xxxv from old maps and is shown too far north in longitude 84°. According to modern maps the water-parting in this longitude is hardly north of latitude 36°, and chart XXIII is probably more nearly correct. In the frontispiece chart of Part I the axis of the Kuen Lun was shown too far north in longitude 84°.

The Jaxartes and the Oxus.

Chart xxxv shows that the Jaxartes drains the western portions of the Tian Shan, and that the Oxus drains the Pamir plateau: the Sarikol range forms the water-parting between the Oxus and the Tarim.

The Hindu Kush consists of two parallel ranges of which the southern is a westerly extension of the Karakoram fold, and carries the highest peaks. The northern however forms the water-parting between the Oxus and the Indus, except for a length of 50 miles south-west of Tirich Mir, where the southern Hindu Kush range is the divide.‡ Further to the west the southern range becomes for a similar length the water-parting between the Oxus and the Helmand.

* Royal Geographical Society's map published in Holdich's *Tibet the Mysterious*.

† Sven Hedin: *Through Asia*, 1898.

‡ North-West Trans-frontier Sheet No. 26, 1 inch = 8 miles.

The Indus.

The two Hindu Kush ranges will be seen from chart xxxv to enclose a long narrow trough, and the drainage of this trough flows alternately north and south.* On the west the trough forms the narrow basin of the Hari Rud river, flowing westwards into the desert. East of the Hari Rud basin comes a portion of the trough that is drained by streams flowing northwards: then follows the long area marked B on the chart, which is drained by the Panjshir tributary of the Kabul river, and which belongs to the basin of the Indus.

Thus in the first instance the two Hindu Kush ranges form water-partings enclosing a single river: then the southern range becomes the water-parting, and subsequently throughout area B the northern range. Near the meridian of 71° occurs another change, the southern range becoming the water-parting again and the trough draining northwards into the Oxus. A few miles west of Tirich Mir appears a third change, the Arkari river rising in the northern range and flowing into the Indus. Eastwards from Tirich Mir the northern Hindu Kush range remains the water-parting, and the trough between the ranges is drained by affluents of the Indus.†

The Kilik pass is very near the point of trijunction of the basins of the Tarim, the Oxus and the Indus:‡ from this locality rivers take three different directions; the Panj branch of the Oxus flows towards the west, the Tashkurgan tributary of the Tarim flows east, and the Hindu Kush feeders of the Indus flow south.

The long area marked C on chart xxxv stretching east from Tirich Mir is drained by the Kunar, Gilgit and Hunza rivers, which force separate passages through the Karakoram range:§ the two latter unite near Gilgit and eventually join the Indus at its knee-bend above Bunji. The range which forms the water-parting in rear of the area C is lower than the main range to the south.

The area marked H is drained by the Shyok tributary of the Indus: the water-parting north-east of H will be seen to be in the same alignment as the water-parting north-east of C, and it has been surmised that the two are perhaps different portions of one range; if this proves to be the case it will furnish another example of how a water-parting alternates between one and the other of two parallel ranges, clinging to the north-eastern range behind areas C and H, and to the Karakoram in the interval.

The water-parting in Tibet between the Karakash tributary of the Tarim (area F) and the Shyok tributary of the Indus (area H) is however not in all places a mountain range, as the following extracts from a letter from Mr. Shaw to Sir Roderick Murchison will show:—‖ "What was my astonishment after walking a few yards to find some water "trickling westwards towards the mountains. I had, therefore, already passed the "imperceptible watershed between the great river systems of the Indus and of Central "Asia. Beyond the lake we had just passed, the waters feed the Karakash; while the

* The longitudinal section in chart xx shows the portion of the southern Hindu Kush range that forms the water-parting between Indus and Oxus.

† Map of Afghanistan, 1 inch = 16 miles.

‡ Northern Trans-frontier Sheet No. 2, 1 inch = 8 miles.

§ See longitudinal section in chart xx.

‖ *Proceedings, Royal Geographical Society*, Vol. XV, 1870-71.

"trickling stream which I had reached pierces the great limestone range and much "augmented on the way runs through the rocky gorges into the Shyok, which is one "of the chief sources of the Indus."

"Thus the great water systems of southern and of Central Asia are here separated "by no gigantic mountain range, but merely by a few yards of level sand, at a prodigious "elevation it is true."

Between the area H and the Aling Kangri the Kailas range is believed to be the Indus-Tibet water-parting.

The great Himalayan range runs north-westward from the Badrinath-Gangotri peaks to Nanga Parbat, and west of the meridian of 78° both its faces are drained by feeders of the Indus: it may be argued then, that this range south-east of Nanga Parbat should not have been shown on chart XXXV as a primary water-parting, the whole region being in the basin of the Indus. But we have not accepted this view; we are treating in this paper of the Himalaya and Tibet, and not of the hydrography of Asia: the Punjab Himalaya form a water-parting between great Himalayan rivers,—the Indus on one side and the Jhelum and Chenab on the other; and the fact that the Jhelum and Chenab subsequently join the Indus in the south-west of the Punjab does not affect the question. The coincidence of the Indus-Chenab, and of the Indus-Jhelum water-partings with the crest-line of the Punjab Himalaya presents a most interesting contrast to the divergence that obtains in the Kumaun, Nepal, and Assam Himalaya.

The rainfall on the Indian side of the Punjab Himalaya is greater than on the Tibetan side, and the slopes on the Indian side are steeper than on the Tibetan. The tributaries then of the Chenab and Jhelum, descending from the crest-line, should have greater volumes and velocities, and should be able to deepen their channels and expand their basins more rapidly than the feeders of the Indus on the opposite side of the crest, and the water-parting should now be slowly retiring towards the Indus. But if this process had been actually in operation, the water-parting would be a more sinuous line than it is.

There are but two sinuosities in the crest-line of the Punjab Himalaya. The first is in the shape of an S, of which the Nun Kun peaks form the central point: on the south of the Nun Kun the water-parting is being shifted towards Tibet, but on the north it appears to be moving towards India. The second sinuosity has been caused by the Rupal glacier cutting back from the north immediately south of Nanga Parbat, and in this instance the water-parting is being shifted towards India and not towards Tibet. The Punjab Himalaya thus furnish an interesting example of a range, on which the water-parting seems in places to be moving towards the side of greater rainfall and steeper slopes.

The Sutlej.

The area marked L is drained by feeders of the Sutlej; and that marked K by the Spiti tributary of the Sutlej. The area marked Z denotes the Manasarowar basin.*

* Northern Frontier Sheet No. 14 S. W., 1 inch=4 miles.

As will be described hereafter, the Manasarowar lakes overflow at times into the Sutlej and on chart xxxi the lake-basin has been included in the area drained by the Sutlej. If the Manasarowar lakes had been held to belong to the Tibet lake-basin, the double line of chart xxxv would have been made to encircle them.

The drainage system that obtains between Manasarowar and the great Himalayan range is complex. The Ganges and the Kali drain the northern slopes of the great range in Kumaun, the Zaskar range forming the limit of their basins in Tibet. The water-parting between the areas Z and M is, however, not the Zaskar but the Ladak range. The area L is drained by the Sutlej flowing north-west, and the area M by the Karnali flowing south-east, the Sutlej and Karnali basins being in contact across the Tibetan plains. The Zaskar range separates the basins of the Sutlej and Karnali on the one side from those of the Ganges and the Kali on the other. The Sutlej and Karnali drain the trough between the Zaskar and Ladak ranges, and the Ganges and Kali drain that between the Zaskar and the Great Himalayan ranges. The Ganges and Kali rise behind the Great Himalayan range but not behind the Zaskar; the Sutlej and the Karnali rise behind the Zaskar range, and their basins touch behind the basins of the Ganges and the Kali.*

The Ganges of Bengal.†

The areas M, N, P and R are all drained by tributaries of the Ganges of Bengal which rise in the Ladak range behind the great Himalaya and pierce the latter. East of Nampa there is no range like the Zaskar intervening between the great Himalayan and Ladak ranges, and the drainage is less difficult to unravel. The parallelism here of the water-parting and the great Himalayan range is very marked; it seems to indicate that the water-parting is following an original axis of elevation.

The Brahmaputra.

Near Chumalhari the great range becomes, for a short length only, the water-parting between India and the Brahmaputra in Tibet.‡ In the Assam Himalaya the area S behind the great Himalayan range is drained by the Assam rivers Raidak and Manas. The Ladak range forms the water-parting between the Ganges of Bengal and the Brahmaputra throughout the areas N, P, R and S, all of which are drained by rivers which pierce the Great Himalayan range and flow *southwards*: but near Chumalhari occurs the solitary exception; here the Nyang river pierces the Ladak range and flows *northwards* into the Brahmaputra.§

The water-parting between the Indian and Tibet basins cannot be drawn with certainty: in places it is without doubt the Kailas range, but the latter has been cut through from the north by feeders of the Brahmaputra whose basins have not been determined. The Lhasa river, the Charta and others drain the trough north of the Kailas range, and pierce the Kailas range in the same way as the Himalayan rivers pierce the Himalayan

* The basins of these rivers are described in detail hereafter.

† We must endeavour to avoid confusion from a double use of the name Ganges: we have in chart xxiv applied the name Ganges to the Himalayan basin drained by the river above Hardwar: but in Part III we have employed the name Ganges to include the whole basin drained by the Ganges of Bengal and its tributaries. Both applications are correct, and the context must be trusted to indicate the meaning in each case.

‡ North of Chumalhari is a small lake-basin containing the Kala Tso. See Ryder's note on overflows from this basin in his *Report on Survey operations with the Tibet Frontier commission*, 1904.

§ North-Eastern Frontier sheet No. 7 N. W., 1 inch=4 miles. North-Eastern Frontier sheets Nos. 6 N. W., 6 S. W., 6 N. E., 6 S.-E., 1 inch=4 miles.

ranges. Their waters flow into India and their basins belong not to Tibet but to the Brahmaputra.

From the basin of Tibet (charts XXIII and XXXV) no water escapes to the sea.

The closed basin of Tibet.

In the interior of the plateau the troughs contain long series of lakes. Several rivers of considerable volume are known to rise in Tibet, and to empty their waters into one or other of its lakes.

The rainfall over the basin was doubtless greater in former ages than at present: the rise of the great Himalayan range during recent geological periods must have cut off much of the rain that would have formerly reached Tibet. The clouds laden with moisture from the Indian Ocean now drop the greater portion of their burden on the outer Himalayan ranges: each successive range receives less rain than the one immediately exterior to it. Central and western Tibet are consequently sterile regions; eastern Tibet, however, is watered by rain-bearing winds from the Pacific Ocean.

In drawing chart XXIII we were in doubt whether the inland basins of Tsaidam and Koko Nor should be included as part of the closed basin of Tibet or not. We have excluded them, and on this chart they form part of the area allotted to the Mongolian lakes.

If the Tibet lake-basin is held to include the whole elevated area from which no water escapes to the sea, then Tsaidam and Koko Nor perhaps belong to it: Tsaidam is, however, 6000 feet and Koko Nor 4400 feet lower than Tibet.

The closed basin of Tsaidam is in contact with the closed basin of Tibet on one side, and with the closed basin of Koko Nor on the other, and the three form one continuous area encircling the upper Yangtze and Hoang Ho. But continuity of area does not justify the assumption that the three enclosed basins are parts of one geographical whole, for the inland basins of Tarim and Mongolia, neither of which possesses any outlet for drainage, are also in contact with Tsaidam and Koko Nor.

The Kuen Lun range separates Tsaidam from Tibet, and we have taken this range to be the north-eastern boundary of the Tibet lake-basin: the basins of the Yangtze and Hoang Ho separate Koko Nor from Tibet.

The Tibet lake-basin, it will thus be seen, does not coincide with the Tibet plateau: the plateau includes besides the lake-basin the upper valleys of the Indus, Yangtze, Hoang Ho, Salween and Brahmaputra and the outlying plains of Tsaidam and Koko Nor: the lake-basin consists only of the compact portion of the Tibet interior that has no outlet for drainage.*

The peculiar feature of the Irrawaddy (chart XXIII) is its immense volume of water

The Irrawaddy.

in northern Burma: Mr. Gordon estimated the high flood discharge of this river above Bhamo as 1000000 cubic feet per second: its width at Bhamo is six miles.

* An idea of the shape and size of the Tibet plateau can be obtained, if we recollect the longitudes of three of its principal lakes. Pangong, the extreme western lake of the plateau, is in longitude 80°: Nam Tso (Tengri Nor) at the south-eastern corner of the Tibet basin is in longitude 90°: Koko Nor at the extreme north-eastern corner of the *plateau* is in longitude 100°.

The catchment basin above Bhamo has according to modern maps an area of 18000 square miles, and is smaller than the Himalayan basins of the Kosi, the Karnali or the Sutlej. Its immense discharge, issuing as it appears to do, from the drainage of a small area led Mr. Gordon to believe, that the old Chinese surveyors had been right, and that the Sangpo of Tibet flowed into the Irrawaddy.

During the latter half of the nineteenth century, however, geographical evidence continued to accumulate, and the identity of the Sangpo of Tibet with the Brahmaputra of India has now been proved.

General Walker has endeavoured to account for the great volume of the Irrawaddy by assuming that the Lu river of Tibet flows into it. The Lu had always been supposed to be the upper course of the Salween, and General Walker was led to adopt his view by the account of the explorer Kishen Singh, who described the Salween south of latitude 30° as an *insignificant stream.* But the casual observations of explorers are unsafe data, and General Walker's view has not been accepted by geographers.

What Kishen Singh did prove was that no Tibetan river *west* of the Lu was flowing into the Irrawaddy. In 1895 Prince Henry of Orleans marched across from Southern China into Assam: he crossed the Mekong and the Salween, but not the Irrawaddy: he stated that the most northern branch of the Irrawaddy rises in a latitude not higher than 28° 30′.*

The three rivers of south-eastern Tibet.

The parallelism and proximity of the Yangtze, the Mekong and the Salween in their exits from Tibet are amongst the most extraordinary features of the earth's land surface: each of these rivers drains a large area of eastern Tibet (chart XXIII), and on the surface of the plateau they flow at considerable distances from one another. But during their descent they bend to the east-south-east, and assume absolutely parallel courses, the Mekong in the centre being 28 miles from the Yangtze and 20 miles from the Salween. Here then are three trunk rivers, each larger than the Sutlej, flowing through a mountain zone 48 miles wide.

In 1880 Kishen Singh crossed the three parallel rivers near latitude 30°: of the Yangtze he wrote:—"At 10 A.M. we crossed the Di Chu, here about 300 paces "wide and having a rapid current."

Of the Mekong he wrote:—"The arrangement for crossing consists of a thick "leather rope stretched very tight from an elevated point on one bank to a lower "level on the opposite bank. The length of the rope-bridge was estimated to be "about 130 paces."

Of the Salween he wrote:—"We crossed the river Giama Nu Chu, also called "Nu Chu, which is deep and rapid and about 200 paces wide."

The Salween.

Since Mr. Hennessey published his account of Kishen Singh's explorations, the Tibetan course of the Salween has been shown on maps as the Giama Nu Chu. No reliable observer has as yet traced the course of the Salween from its source in Tibet to the point where it appears

* *Geographical Journal,* Vol. VII, 1896.

in Burma. At its exit from Tibet it is shown on maps to be confined between two mountain ranges, and as possessing no affluent for 200 miles. If geographers are justified in doubting still the identity of the Sangpo of Tibet with the Brahmaputra, when 40 miles of its course alone remain unexplored, how much greater uncertainty must they feel over the identity of the Lu river of Tibet with the Salween of Burma, when the unexplored link exceeds 200 miles.

The geography of the Salween has been rendered obscure by the multitude of names which have been applied to its supposed upper courses. "It is mentioned," writes Mr. Gordon, "in the Yuking of China 2200 B.C., as the Black River issuing from "the Black Lake of Tibet, where it has already had a long course from the Northern "Himalaya through the high plains of the great lake region, as the Targot or Shyal "river, and it successively takes the names of Nag Chu Kha, of Lu Chu and of Nu Chu "and finally emerges from the plateau in about latitude 26° as the Salween."*

In his report on the trans-Himalayan explorations of 1873-74-75 Colonel Trotter expressed doubts as to whether the Nag Chu Kha of Tibet, which Mr. Gordon assumes to be a feeder of the Salween, was not a branch of the Yangtze or the Mekong.

In the map published by the Royal Geographical Society in 1894, the river which rises in Tibet north-east of lake Tengri Nor was made in accordance with General Walker's views the upper course of the Irrawaddy. The exploration of Prince Henry of Orleans led to the basin of the Salween being largely expanded in maps of Tibet and that of the Irrawaddy being greatly reduced.

The Mekong.

The Neg Chu Kha of Tibet, which is now, and perhaps prematurely, identified on maps with the Salween, was crossed by Fathers Huc and Gabet, who were told that it was the Mekong. According to Dutreil de Rhins, who believed that he had traced the Mekong to its source, its Tibet name is the Chiamdo Chu. Other names are however applied to the Mekong, notably the Da Chu and the Nam Chu.

Whilst we owe much to the intrepid explorers who have penetrated eastern Tibet, our geographical knowledge of this region is still very imperfect. We have not yet ascertained the true positions of the sources of the Salween and the Mekong (chart XXIII), and future surveys will probably discover great errors in existing maps. The problem has been complicated by the convergence of the Salween, the Mekong and the Yangtze as they issue from Tibet: when the courses of three great rivers lie within 50 miles of one another, it is hardly possible for an explorer to decide to which of the three a very distant feeder belongs, unless he follows the stream down: hitherto explorers have only crossed the rivers at right angles, and none have yet succeeded in following their courses.

Mr. Gordon estimated the discharges of the Salween, Mekong and Irrawaddy in the same latitude to be in the proportions of one, three and nine.†

* *Proceedings, Royal Geographical Society*, Vol. VII, 1885.

† *Proceedings, Royal Geographical Society*, Vol. IV, 1882.

The Yangtze.

The Yangtze is the largest river of Asia, and it traverses the most thickly populated provinces of China. It is over 3000 miles in length and is navigable for 600 miles. It rises in eastern Tibet, and its source is believed to be west of longitude 90°, further west than the sources of the Hoang Ho, Mekong or Salween (chart XXIII).

It is known in Tibet as the Di Chu, and as the Dre Chu, and as the Ndu Chu, and as the Murui-ussu. In its Tibetan course it flows eastwards for 500 miles, and then bending to the south it is confined for a great distance between two close parallel ranges, running at right angles to the direction of the Himalaya.

In 1873 Prejevalsky reached a point on the Tibetan course of the Yangtze in latitude 34° 43′ and longitude 94° 48′, and 13143 feet above sea-level: it is here that the two principal Tibetan branches of the Yangtze join, the Napchitai-ulan-muren rising in the Kuen Lun range on the north, the Murui-ussu flowing from a lake from the west. Prejevalsky described the river as a rapid torrent, 5 to 7 feet deep and 750 feet wide; from bank to bank the bed of the river was a mile wide and in the rainy season the whole expanse was under water.*

In 1879 Prejevalsky crossed both the great tributaries above their point of confluence: the Napchitai-ulan-muren he struck in latitude 35° 20′, longitude 93° 10′, and the Murui-ussu in latitude 33° 50′, longitude 92° 20′. He followed an affluent of the latter almost to its source at 16400 feet in the Tangla range.

Part II of this paper (page 110) will have shown how little is known of this Tangla range of Tibet: it is drawn in the frontispiece to Part I in latitude 33°, and it forms the water-parting between the Yangtze and Salween. The Tibetan basin of the Yangtze is bounded by the Kuen Lun range on the north and the Tangla range on the south, and is 250 miles broad.

East of longitude 94° the Baian Kara Ula range separates the basins of the Yangtze and Hoang Ho, and forces the former river to bend to the south.

In 1879 the explorer Kishen Singh crossed the Murui-ussu branch of the Yangtze in Tibet: he described it as flowing in seven channels each about 40 paces wide, the entire river-bed having a width of 800 paces: the greatest depth was 3 feet, and the height above sea-level 14040 feet.†

The Hoang Ho.

The Hoang Ho rises about longitude 95° in the trough between the Shuga and Baian Kara Ula ranges. The Shuga range separates the basin of the Hoang Ho from the marshy depression of Tsaidam, and the Baian Kara Ula forms its water-parting from the Yangtze. In this trough the Hoang Ho is divided into two or three channels, each from 70 to 90 feet wide and two feet deep at the fords. Further east it passes through the great Tibetan lakes of Tsaring and Oring, 13704 feet above the sea, and then making a sharp bend to avoid

* N. Prejevalsky: *Mongolia*, Vol. II, 1876.

† Mr. Hennessey's report *on the Explorations of A-K in great Tibet and Mongolia.*

the snowy Amneh-machin range,* bursts through the chains of the Kuen Lun and hurries on to China proper.† It is known in Tibet as the Ma Chu.

Feeders of the Hoang Ho drain the exterior slopes of the mountain chains, which encircle Koko Nor, the great lake of north-eastern Tibet, but there is no connection between the lake and the river: in one place the water-parting stands only 1000 feet above the level of the lake.

At 3500 feet above the sea the Hoang Ho is 1421 feet broad.‡

* This is perhaps a prolongation of the Shuga range, and in piercing it the Hoang Ho escapes from its original trough after the manner of the Himalayan rivers.

† *Proceedings, Royal Geographical Society*, Vol. IX, 1887. *Prejevalsky's journeys and discoveries in Central Asia, by Delmar Morgan.*

‡ *Prejevalsky.*

21

THE HIMALAYAN RIVERS: INTRODUCTION.

The Himalaya mountains from Afghanistan to Burma are drained by nineteen principal rivers, the drainage areas of which are illustrated in charts XXIV to XXXIV. Chart XXIII furnishes an index to the several river charts. Eight section lines have been drawn across the index chart: they indicate the positions of the eight cross-sections of the great Himalaya given in charts XIV and XV of Part II, and, if scrutinised, they will be found to explain the positions given to the different Tibetan troughs in the cross-sections.

In describing the nineteen rivers of the Himalaya we might have commenced at either end of the range and taken the rivers in their geographical order. It was found more convenient, however, to start from the centre near Simla, and to take the rivers in order, firstly from west to east, and then to return to Simla and to complete the remainder from east to west. By this arrangement the river Jumna comes first (see chart XXIII), and the Ganges second, and when the Brahmaputra has been reached, we return to the Sutlej, and end with the Indus.

Though there may be certain objections to classifying rivers by magnitude, when the limits of the several orders of magnitude are arbitrary, yet it is a course that has many advantages. It corrects erroneous preconceptions, it gives true ideas of proportion, and it helps to save us from the mental confusion that long lists of new and meaningless geographical names are apt to produce.

We have therefore divided the Himalayan rivers into six orders of magnitude, classifying them by the dimensions of the mountainous areas they drain.

TABLE XXX.—The Rivers of the Himalaya.

Name of river.	Order of magnitude.	Himalayan area included in the catchment basin.	Total discharge of water in one year (estimated*).	Ratio of discharge to area, taking that of the Ravi to be unity.
		Square miles.		
Indus	First	103823	9	0·3
Brahmaputra	First	99246	15	0·5
Kosi	Second	23992	8	1·1
Karnali	Second	20623	8	1·1
Sutlej	Second	18554	3·5	0·6

* The numbers in this column do not represent any actual units of measure. The total discharge of the river Ravi has been taken as unity; and the numbers opposite the other rivers show the ratios of their discharges to that of the Ravi. These numbers, it must be noted, are almost all dependent on short observations and rough estimates.

TABLE XXX.—The Rivers of the Himalaya—*contd.*

Name of river.	Order of magnitude.	Himalayan area included in the catchment basin.	Total discharge of water in one year (estimated).	Ratio of discharge to area, taking that of the Ravi to be unity.
		Square miles.		
Gandak	Third	14653	7	1·4
Jhelum		13030	5·5	1·3
Manas		12380	unknown	....
Chenab	Fourth	10588	5·5	1·6
Raidak		10161	unknown	....
Ganges		8949	5·5	1·6
Kali	Fifth	6318	4	2·0
Beas		5663	2·5	1·3
Tista		4823	3	1·9
Jumna		4546	2	1·3
Ravi	Sixth	3123	1	1·0
Ramganga		2611	....	....
Rapti		2406	....	....
Baghmati		1597	....	....

The discharges of Himalayan rivers have not been sufficiently observed to justify any close study of the results obtained. The discharges of the smaller rivers vary from nothing at all in the hot season to thousands of cubic feet per second in the rains; their beds may remain dry for months, and be flooded for a few days in the year. It is not possible under such circumstances to deduce any average values of daily or monthly discharges. The discharges of the larger rivers that have sources in glaciers never cease entirely, but their variations are yet sufficiently large to render averages meaningless. The discharge of the Indus will vary from 9000 cubic feet a second to a million, and in almost all the Himalayan rivers the maximum discharge is 100 times as great as the minimum. Spasmodic observations of discharges possess but little value: before we can compare two rivers, the diurnal and seasonal and long-period variations in their discharges are required to be known, and these can only be ascertained by systematic measurements.

Nomenclature.

The nomenclature of the rivers of Asia is a source of perpetual trouble. In certain regions the main channel of a river assumes a different name after every bend ; Chitral, Asnar, Yasin, Kunar and Mastuj are all names given to the same river. Tashkurgan, Taghdumbash, Dangubash, Sarikol, Karat-chukor, Tisnaf, Chiragh Tar and Almaligh are all names applied to one river. In Ladak the Indus is known by many names : so is the Sutlej. The names Karnali, Gogra, Sarda and Kurriali all belong to one river, and these in addition to its purely Tibetan names.

Where two main affluents join, the combined stream is frequently given a name differing from either tributary, but this system has many advantages to recommend it. Ganges is the name given to the river formed by the junction of the Alaknanda and Bhagirathi, and no one would suggest that any of these three names is superfluous. But to change the name of a main river after its junction with every feeder, or upon its approach to every town, is a course that cannot be justified in geography.

Multiplicity is, however, not the only source of confusion, for whilst it is common for a river to be given many names, it is equally common for the same name to be given to different rivers. The names Sarju, Ramganga, Kali, Dhauli, Kosi, Sarda are all applied to more than one Himalayan river ; the great Kali river for instance has the alternative name of Sarda, but the neighbouring river Karnali is also called the Sarda. One of the upper feeders of the Kali in Kumaun is the Dhauli, and the principal affluent of the Alaknanda in Kumaun is the Dhauli. Two rivers rise at a pass in the Alai valley and flow in opposite directions, one towards the east and one towards the west : both are named the Kizil-su. It would be wearisome to mention all the numerous cases of one and the same name being applied to different rivers : instances are to be found in every mountain tract of Asia.

In order to place the geography of High Asia on firmer foundations two reforms in river nomenclature are necessary : *firstly*, we must limit the number of alternative names for a single river ; and *secondly*, we must avoid the use of the same name for different rivers. The preservation of every local name is incompatible with scientific geography ; the multiplication and repetition of names may not be troublesome to hill men, whose lives are confined to a single valley, but they become unmanageable, when the mountains of Asia are being considered as a whole.

Some native geographical names are undoubtedly of great age, and have been handed down from successive generations. These have to be carefully preserved and their disappearance from maps would be a serious loss ; but vast numbers of names after being in vogue for perhaps twenty or fifty years die out, and new names are invented. A traveller, following a Himalayan river, will be astonished at the apparent errors of his fifty-year-old map : many important names on the map, he will see, are unknown to the natives and many names employed by the natives he will not find on the map. His first tendency is to blame the original surveyors and to attribute the discrepancies to their want of care, but the true explanation of the differences is, that the old names have died out and new names have come into existence.

22

THE RIVERS OF THE KUMAUN HIMALAYA.

A separate chart (XXIV to XXXIV) has been drawn to illustrate the Himalayan area drained by each of the principal rivers. Streams have been shown in light blue and boundaries of basins in heavy black lines: the ranges, being facts of deduction rather than of observation, have not been entered, but the highest peaks in each river basin have been plotted, and these indicate the alignments of main axes of elevation.

The thick lines, representing the basin boundaries, are water-partings but not necessarily mountain ranges: the line, for instance, in chart XXXI between the Sutlej and the Karnali crosses a flat plain in Tibet, and that between the Ganges and Jumna in chart XXIV is in nature not a significant feature.

The principal rivers of the Kumaun Himalaya are the Jumna, the Ganges, the Ramganga and the Kali.

The Jumna.

The Jumna (chart XXIV), called also the Jamuna, is supposed to be the Saraswati of the Vedas. On debouching from the mountains it now sweeps round to the south-east, and joins the Ganges at Allahabad; but it is believed to have pursued a westerly course to the Arabian Sea in former times.* The great change in its course may have been caused by alterations in the level of the land west of Saharanpur, or by the constant advance of the sands of the Rajputana desert under the influence of the south-west winds.

Within the mountains the Jumna, like other rivers, flows alternately through narrow gorges and over wide alluvial expanses. Wherever a defile through a range is narrow, the flow of water is retarded above it, and the stream drops its load of gravel and silt; when the gradient and current increase, the stream is able to re-lift its load and to carry it a further stage.

The Himalayan basin of the Jumna has been surveyed, and the courses of its affluents are well-known. The two principal affluents are the Tons and the Giri, the former of which is larger than the Jumna itself.†

The Jumna and the Tons unite in rear of the Mussooree range of the lesser Himalaya, and their combined waters are joined by the Giri in the trough between this range and the Siwalik.

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* *A Manual of the Geology of India*, page 450.

† Atlas sheet 48 N.E., 1 inch = 4 miles.

The defiles in the Mussooree and Siwalik ranges through which the Jumna passes are directly opposite to one another, and the conclusion is justified that the river was able to deepen its channel and maintain its former course, when the Siwalik range rose across its path.* In crossing the axis of the Siwalik range the Jumna makes a curious bend for a mile or two, and this may perhaps be regarded as evidence that its waters were held in check for a time by the rising range, and had difficulty in cutting a passage. But the barrier could never have been sufficiently high to cause a lake to form behind it, or the Jumna would have taken a south-easterly course across the Dehra Dun and passed the Siwalik range at Hardwar by the gateway created by the Ganges.

The Jumna is older than the Siwalik range.

A striking feature of the basin of the Jumna is the Chur, an isolated pyramid of the Nag Tibba range of the lesser Himalaya, surmounted by twin peaks. The Chur rises from the interior of the river basin and not from the boundary line.†

The structural trough between the outer Himalaya and the Siwalik range is very distinct on the two sides of the Jumna: on the north-west this trough is known as the Kyarda Dun, and on the south-east as the Dehra Dun.

The outer range of hills west of the Jumna is drained by a small river called the Ghaggar (chart XXIV); this stream is of interest, because the Ghaggar is said to have crossed the plains of the Punjab at one time as a considerable river. In the Rajputana desert the wide bed of an extinct river, called the Hukra, can still be traced for miles through the sand and the Hukra may have been a continuation of the Ghaggar.‡ This we cannot decide, but one thing seems certain; the Ghaggar could never have been a large river, had its Himalayan catchment basin been always as small as at present; and the question arises as to whether the Giri could formerly have drained into the Ghaggar and given to it the volume of water that tradition ascribes to it.

The Ghaggar.

An objection to this idea is that the Ghaggar is reported to have been a large river within the historic period, whereas the deflection of the Giri,—whether caused by the slow upheaval of a range across its course, or by a feeder of the Jumna cutting back to it south of the Chur and capturing its waters,—must have occurred long before the period of history, if it ever occurred at all.

The Ganges.

The Ganges (chart XXIV) is the great river of northern India that drains the Vindhya mountains and the Kumaun and Nepal Himalaya, and that waters the plains of Rohilkhand, Oudh and Bengal. Regarded as a Himalayan river, the name Ganges is applied to the particular affluent that issues from the mountains at Hardwar.

It was believed by Rennell that the Ganges had a course 800 miles long above Hardwar, and that it drained Kashmir and Ladak; and these views were represented in his

* United Provinces of Agra and Oudh, sheet No. 1 : 1 inch = 1 mile.

† Atlas Sheet 47, 1 inch = 4 miles.

‡ It may possibly have been a former bed of the Sutlej.

map of India published in 1790. He also thought that the Ganges after draining Tibet passed under the Himalaya through a natural tunnel. "This great body of "water," he wrote, "forces a passage through the ridge of Mount Himalaya, and sapping "its very foundations rushes through a cavern and precipitates itself into a vast basin "which it has worn in the rock at the hither foot of the mountains. The Ganges thus "appears to incurious spectators to derive its original springs from this chain of "mountains, and the mind of superstition has given to the mouth of the cavern the form "of the head of a cow, an animal held by the Hindus in a degree of veneration almost "equal to that in which the Egyptians of old held their God Apis."*

Rennell was relying upon the descriptions given to him by travellers: what he thought was a cavern under the Himalaya was merely the ice-cave at the end of the Gangotri glacier, from which the Bhagirathi issues. Captain Hodgson has described this cave of ice:—† "The Bhagirathi or Ganges issues from under a very low arch at the "foot of the grand snow-bed. The river is here bounded to the right and left by high "snow and rocks, but in front over the debouch the mass of snow is perfectly perpendi-"cular, and from the bed of the stream to the summit we estimate the thickness at "little less than 300 feet of solid frozen snow, probably the accumulation of ages."

By 1807 geographers had begun to doubt the correctness of Rennell's conclusions, and in that year the Government of Bengal authorised a survey of the river Ganges in the mountains to its source. Captains Raper and Webb were directed to "survey the "Ganges from Hardwar to Gangotri, where that river is supposed either to force its way "by a subterraneous passage through the Himalaya Mountains, or to fall over their "brow in the form of a cascade, to ascertain the dimensions of the fall, and delineate its "appearance, and to observe its true geographical situation in latitude and longitude."‡

After following the two great branches of the Ganges until they became narrow torrents, the survey officers reported that the sources of the river were on the southern side of the Himalayan chain. We know now, from modern surveys, that both the Alaknanda and Bhagirathi rise north of the Himalaya and pass through the great range in narrow gorges. The mistake of Raper and Webb is more instructive than that of Rennell: the latter was merely basing conclusions on hearsay evidence; the former actually penetrated and passed the great Himalaya through a stupendous defile carved by the Ganges, but so hemmed in were they by mountains, that they entirely failed to understand that they had crossed the snowy range. From the bed of the Ganges on the northern side of the Himalaya, Raper and Webb reported that they had found the source of the river on the southern side. Mr. Colebrooke summed up the results of the Raper-Webb expedition as follows:—§ "If the Bhagirathi and Alaknanda rivers "had a passage through the Himalaya, it should follow that the channel of its stream "would form the Ghatti (or pass) by which the snowy range became passable. But "since this principle holds good in practice, and since it is utterly impossible to cross the

* *Memoir of a Map of Hindoostan*, 1793.

† *Asiatic Researches*, Vol. XIV, 1822.

‡ *Asiatic Researches*, Vol. XI, 1810.

§ *Asiatic Researches*, Vol. XI, 1810.

"snowy range in a direction which the channels of these rivers might be expected to "assume, I consider that at least all former reports are determined fictitious. No "doubt can remain that the different branches of the river above Hardwar take their "rise on the southern side of the Himalaya or chain of snowy mountains."

In 1812 Moorcroft made a similar mistake: he passed through the great Himalayan range by the valley of the Ganges and crossed the Niti pass into Tibet. The Niti pass is situated on a hinder range, and is thirty miles in rear of the Himalaya; nevertheless when Moorcroft, who was an accurate and capable observer, arrived at the pass, he was quite unaware that he had crossed the Himalaya.*

Such mistakes as these bring home to us what a bewildering maze the unmapped Himalayan area really is. "From an extensive experience in Himalayan surveying," wrote Colonel Tanner, "I can safely state that even when carrying on our work with "the aid of the best maps, instruments and requisite knowledge of surveying, we are "liable, until we compute out the positions of our points, to mistake one mountain for "another, even though we may have learnt their appearance by heart from other "stations."†

Colebrooke's conclusions were held to be correct until the fallacies underlying them were exposed in 1817 by Captain Herbert, who showed that both the Alaknanda and Bhagirathi rise on the Tibetan side of the great Himalayan range.

The Alaknanda has many feeders that rise north of the line of snow, the Dhauli ‡ and the Vishnuganga being the principal. The Dhauli has its source at the Niti pass of the Zaskar range, and the Vishnuganga behind Badrinath: they join at Joshimath (6000 feet) and here the passage through the great range commences (chart XXIV).

Feeders of the Ganges.

At Karnprayag the course of the Alaknanda is deflected by the lesser Himalayan range (Nag Tibba), which also determines the direction of the Pindar tributary. At its junction with the Pindar the height of the Alaknanda's bed is 2600 feet.§

The Bhagirathi issues from the Gangotri glacier behind the Kedarnath peaks at a point called Gau Mukh, 13000 feet high.|| When Captain Hodgson and Lieutenant Herbert visited Gangotri in 1817, they named four prominent snowy peaks, standing near the head of the glacier, St. George, St. Andrew, St. Patrick and St. David: these names have now fallen into disuse and it would be a pity to revive them: the four peaks of Hodgson and Herbert can be identified with the group, known to modern geographers as Satopanth.

The Jahnavi, the westernmost feeder of the Ganges, joins the Bhagirathi seven miles below Gangotri temple: their combined waters cut through the great Himalayan

* *Asiatic Researches*, Vol. XII, 1818.

† *General Report, Survey of India*, 1883-1884.

‡ Dhauli or Dhauliganga: there are many rivers of this name in the Himalaya, but none as large as this tributary of the Alaknanda.

§ The range south of the Pindar river has on a small scale a resemblance to the Pamir plateau: on the north the Pindar river like that of Tashkurgan flows for a long distance parallel to the range: on the south several rivers, like the affluents of the Oxus, rise in the range and flow down at right angles to it.

Vide Atlas sheet 66 N.W. and sheets of the Kumaun and Garhwal Survey.

|| Atlas sheet 65, scale 1 inch=4 miles.

range between the peaks of Srikanta and Bandarpunch, four miles west of the former, eight miles east of the latter, and 13000 feet below them (chart XXIV). This gorge of the Bhagirathi is "one of the most remarkable in the Central Himalaya, and for "picturesqueness can hardly be surpassed by any valley in the world. Its sides are "often absolutely vertical, smoothed down by the torrent, which rushes 600 feet or "more down below through a narrow slit in the rocks."*

At Tihri the Bhagirathi has cut down 20 feet into the solid rock below the bed of its tributary, the Behling. This is characteristic of the Himalayan rivers, the development of the trunk streams being commonly in advance of that of the lateral feeders.

The Alaknanda and Bhagirathi unite at Deoprayag in rear of the Mussooree range of the lesser Himalaya, and their combined waters pass the latter through a defile.

The Kaliganga or Mandakini is an important tributary of the Ganges draining the southern faces of Kedarnath and Badrinath (table VI).

The source of the Ganges.

During the earlier half of the nineteenth century controversies frequently arose over the claims of different affluents to be the main source of the Ganges, and Captain Herbert, who was for many years the greatest living authority on the Himalaya, was of opinion that the Jahnavi was the true source.†

It has come however to be recognised that a river, which is being fed from great numbers of glaciers, cannot be referred to any one source, and the question has ceased to be of interest: it is probable that not a twentieth part of the water in the Ganges is derived from any single glacier. If, however, we were to be called upon now to select the most important source of the Ganges, we should not be able to support Herbert's view. Herbert, not having seen the Alaknanda, assumed that the Bhagirathi was the true Ganges, but Sir Richard Strachey has pointed out that the Alaknanda is twice the size of the Bhagirathi, and that, if a source is to be named, it must be the Dhauli.‡

Some writers define the source of a river as the point of its course, that is most remote from its mouth. Colonel George Strahan has shown that if this definition be applied to the Ganges, its source will not be Himalayan at all, but will lie near Mhow in Central India at the head of the Chambal (chart IX).

The following descriptions are taken from Captain Herbert's report on the Mineralogical Survey of the Himalayan mountains.§ "I must not leave the Dhauli, however, "without saying something of those great accumulations of boulder stones, the very "sight of which strikes the traveller with astonishment, and forces him to admit the "action of some great rush of waters. These diluvian beds are here seen on a scale, "which sets at nought any theory that would derive its agent from the body of water "at present occupying that channel."

"The beds of some of the rivers are, for a part of their course, in the solid rock. In "these cases, the depth is often considerable, while the appearance is such as leaves

* *Geology of the Central Himalayas* by Griesbach, *Memoirs, Geological Survey of India*, Vol. XXIII, 1891.

† The name Jahnavi does not now appear on Indian maps, but it is still employed locally though more commonly corrupted to Jadganga. The Jahnavi joins the Bhagirathi at Kopang. Atlas sheet 65.

‡ *Journal, Royal Geographical Society*, Vol. XXI, 1851.

§ *Journal, Asiatic Society of Bengal*, Vol. XI, Part II, 1842.

"not a doubt in the spectator's mind but that the present channel was once filled up "with solid rock. This is a conclusion we cannot escape from however difficult it may "be to understand the removal of so many thousand cubic feet of solid rock by the "agency of water."

"In all the river beds too we see that there are accumulations of gravel and bould-"er stones, all perfectly rounded, and consequently all of them such as have been subject "to the action of water. These collections, it appears from the details I have given, "are in many cases of very great extent, and frequently occur at a height of even 300 feet "above the present bed of the river. That these collections should ever have been "formed by such bodies of water as are found at present in their vicinity, is altogether "inadmissible. Their extent, the size of the fragments, the distance from which they "are derived, above all their great depth, and the height at which they are found above "the present bed of the river—all forbid so incredible a supposition."

Captain Hodgson described how the Ganges was at one time obstructed by the fall of a cliff.* "Five hundred yards further on," he wrote, "are the falls of Lohari Naig "where the river is more obstructed than in any part of its course, and tears its way "over enormous masses of rock, which have fallen into it from the mural precipice which "bounds its left shore. This frightful granite cliff of solid rock, of above 800 feet high, "appears to have been undermined at its foot by the stream, and the lower and middle "parts have fallen into it, while the summit overhangs the base and the river. The "vast ruins of this fall extend for about a quarter of a mile; the river has now forced its "way through, and partly over the rocks with a noise and impetuosity, we thought "could not be surpassed, but on our return in June when the Ganges was doubled in "depth, the scene was still grander."

The Ramganga.

The Ramganga (chart xxv) is an unimportant river, draining the southern face of the lesser Himalayan range in Kumaun.† Its basin has been accurately surveyed.

The principal affluent of the Ramganga is the Kosila or lesser Kosí: it rises in the lesser Himalayan range and does not join the Ramganga, until they have escaped from the mountains and entered the plains.

During the gradual rise of the Siwalik range the Ganges had sufficient water to wear down the growing range and to maintain a direct passage across, but the Ramganga's small volume was unequal to the task of cutting down the new range, as it rose, and the river was deflected by the latter for ten miles to the north-west, before it found a suitable place for an outlet.‡

The structural trough between the lesser Himalaya and the Siwalik range through which the Ramganga flows is known as the Patli Dun: it is of a crescentic shape

* *Asiatic Researches*, Vol. XIV, 1822.

† There are several Ramgangas in the Himalaya, but all are smaller than the one under description.

‡ *Memoirs. Geological Survey of India*, Vol. XXIV, 1890, part 2, page 15.

with the concave side facing south : * it contains immense terraces of gravel of different heights which have been deposited by the Ramganga. "It is," writes Mr. Middlemiss, "one of the most beautiful spots that the North-West Provinces of India can "boast. It is undisfigured by villages and bazars. A solitary forest bungalow is all "that breaks the magnificent monotony of its billowy forests and grass-grown alluvial "flats."†

In its course through the Patli Dun the Ramganga flows parallel to the Pindar tributary of the Ganges at a distance of 45 miles, and at a level lower by 1400 feet.

The trough intervening between the lesser Himalaya and the Siwalik range through which the Kosila flows is known as the Kotah Dun ; it is 14 miles long and stretches from north-west to south-east : its level is 750 feet higher than that of the alluvial plains on the outer side of the Siwalik range.

The Kali.

The Kali or Sarda (chart XXV) rises near the Lankpya Lek pass behind the great Himalayan range, and after running for 30 miles parallel to the latter turns and pierces it (figure 2, chart XVI). The height of its bed when it commences to force a passage through the great range is 10000 feet.

The Api-Nampa group of peaks stands immediately east of the Kali : Takachull peak (22661 feet) rises between the Dharma and Gori affluents, and further west on chart XXV, we see the axis of the great Himalayan range marked by Nanda Devi (25645 feet), and Badrinath (23190 feet).

In its upper courses the Kali river and its two affluents the Dharma and Lissar flow in long parallel beds five miles apart. No one of them rises north of the Zaskar range, but the Kali itself appears to flow along a furrow in the crest-zone. The long parallelism of the Kali, Dharma and Lissar rivers in their upper courses shows, perhaps, that minor wrinkles have in this region been superposed on the primary Himalayan folds.‡

The Sarju § affluent of the Kali flowing south-east is on the same alignment as the Pindar tributary of the Ganges ;|| for 100 miles these two rivers continue in one line and the beds of both are possibly occupying an original trough created in rear of the Nag Tibba range of the lesser Himalaya when the latter was upraised.

Colonel Tanner describes a remarkable waterfall, which he discovered in the basin of the Kali.¶

"Taking some guides from Garbiang," he wrote, "I went down the Kali instead of ascending the moraine, and after a difficult journey found myself at the bottom of the wildest place I have ever been in. On one side rose the cliff of the moraine backed by the mountains on the right bank

* Atlas Sheet 66 S.W., 1 inch=4 miles.

† *Memoirs, Geological Survey of India*, Vol. XXIV, 1890, part 2, page 55.

‡ "The Lissar river flows during the greater part of its course along the axis of a symmetrical anticlinal formed of carbon-"iferous rocks, leaving it near the end of the Chingchingmauri glacier ...... this anticlinal is flanked on both sides by a "system of other plications more complicated on the north-east." Griesbach's *Geology of Central Himalaya. Memoirs, Geological Survey of India*, Vol. XXIII, 1891.

§ There are many Sarjus in the Himalaya.

|| Compare charts XXIV and XXV, and Atlas sheets 66 N.W., 66 S.W., and 66 S.E.

¶ *General Report, Survey of India*, 1884-85.

of the Kali; opposite towered more cliffs fringed, wherever there was standing room, by forest trees, and down the face of the overhanging scarp in front of me poured the waters from Api in a feathery cascade of great volume and with a fall of between three and five hundred feet."*

"The foot of the fall we could not see, as it descended into a deep abyss, where it was lost in the unseen Kali, which thundered and roared along immediately below our feet, but how far below us we could not say. Sheets of spray filled the cleft of the Kali and were blown hither and thither across the face of the cliffs, and the sun which was well overhead lit up the great hollow at our feet with a mass of bright prismatic colors."

"Having visited this fall, which is called the Yangla Dhar, it was a question whether we should return by the way we had come or try and reach my camp by continuing our journey down the valley of the Kali. We decided on the latter course and though none of my men had previously visited this extraordinary place, they said that there might possibly be a means of skirting the cliffs, but that of course there would be bad places. Bad places there were indeed, and before long when clinging to the rough places in the face of a slope that was nearly a cliff, I fervently wished I had not come, and sometimes had it not been for the friendly grasp of Rinzin's hand, I believe that I should not have emerged safely out of this awful valley. Gradually the dangers of the road became less, and towards evening we reached the most beautiful and charming village of Budi—literally the most delightful place I have seen in the Himalaya."†

"Four valleys converge on Budi; the view of each could occupy an artist for a month. Spreading terraced cornfields skirt the foaming Kali, and here and there on the mountain sides small terraced spots, surrounded with many tinted forest trees, support the quaint houses of the cultivators."

"At one day's march below Budi the passage of the Nirpania-ki-Danda or waterless ridge commences; it has taken the ceaseless toil of generations to construct the series of stone steps or ladders over which the traveller has to make his way for a day and a half before he reaches an ordinary mountain path. This extraordinary trade-route consists of a kind of winding stair-case, which is carried up and down in the face of cliffs in many places overhung with crags and with seemingly an almost bottomless abyss below. The rough steps are built into the rock wherever it has been possible to find foothold."

The Yangla Dhar falls are not true falls in the usual acceptation of the term. When a great river in its course drops suddenly and perpendicularly the drop may be described as "falls;" but the cascade on the Kali is due to the difference in level between the bed of the main stream and the bed of a tributary. The Kali river has cut a deep channel for itself with a perpendicular wall on each side, and it is over one of its lateral precipices that the Yangla Dhar falls occur.

The falls at Kishtwar on the Chenab are also over the face of a side precipice and are not on the main course of the river. Throughout the Himalaya similar cascades can be seen, though rarely so grand as that described by Tanner; trunk streams, that drain extensive trans-Himalayan troughs, deepen their channels at a greater rate than the lateral streams can do, and consequently flow at a lower level at the points of junction. In the higher mountains the differences of level between trunks and their

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* For the peak Api, see table VI.

† Atlas Sheet 66 N.E.

branches might be attributed to former glacial action, but this is not possible in the outer hills.

Though there are innumerable cascades throughout the Himalaya only two instances of falls have been recorded ; one is on the Indus where the drop is 20 feet, the other is at Pemakoi on the Brahmaputra, where the drop is 150 feet.

23

THE RIVERS OF THE NEPAL HIMALAYA.

The principal rivers of the Nepal Himalaya are the Karnali, the Rapti, the Gandak, the Baghmati, and the Kosi.*

The Karnali.

The Karnali, called also the Kauriala or Kurriali, is a great Himalayan river (chart XXVI); in its passage across the plains of India after its exit from the hills it is known as the Gogra.†

The sources of the Karnali have been explored by the brothers Richard and Henry Strachey, by Colonel Tanner and by other reliable observers, and its course has been traced in Tibet from Takla Khar to the shrine of Kojarnath; but it then enters Nepal, and with the exception of the information gained by a native explorer, nothing more is known of it, until it reaches the plains of India.

The basins of the Karnali and the Sutlej are in contact in Tibet, behind the basins of the Kali, the Ganges and the Jumna. In escaping from Tibet the Karnali passes through a remarkable trough with Gurla Mandhata (25355 feet) on the one side and peaks of 22000 and 23000 on the other: near Kojarnath this trough is less than 18 miles wide at a height of 20000 feet, a peak of 21800 feet standing eight miles north-east of the river and one of 20300 feet ten miles south-west.

Between Gurla Mandhata and Nampa the Karnali is now creating a canyon similar but inferior to that of the Sutlej.

The great tributary of the Karnali is the Birehi;‡ the two rivers do not unite until they have left the mountains; as their courses in the Himalaya are convergent their delay in conjoining is noteworthy. The two main affluents of the Ganges unite behind the lesser Himalaya range to force a common passage; the tributaries of the Gandak and Kosi do the same; and the Karnali alone of the greater Himalayan rivers possesses two outlets through the lesser range.§

It may be thought that the lesser Himalayan range is but slightly developed across the lower basin of the Karnali, but this is not the case. The number of peaks that have been fixed on one alignment across the basin, and the number of minor rivers that are believed to rise in this alignment are sufficient indications of the presence of a distinct range.

* Map of Nepal, 1 inch=16 miles.

† For an account of the Karnali see *India*, by Sir John Strachey.

‡ Known as the Birehi in its upper course, as the Babai in its middle, and as the Sarju in its lower.

§ The reference here is to the outer parallel range (Mahabarat) and not to any oblique range.

The following extracts are taken from the diary of a native explorer who followed the upper course of the river Birehi in 1873 from a place called Tibrikot (7226 feet) as far as the Digi pass (16880 feet), which is on the water-parting of the Gandak.

"From Tibrikot I followed the course of the Bheri (*Birehi*) river and reached Charka on the 4th September, having passed some lama-serais on the road. One of them called Barphang Gonpa contains 40 or 50 lamas. Near another named Kanigang Gonpa, the river has high perpendicular rocky banks, and the people have made a tunnel 54 paces in length through the rock. There was originally a crevice, and the rock on either side of it was cut away sufficiently to allow of a man with a load to pass through with a squeezing, the height of the tunnel not being sufficient in all parts to admit of his going through standing."

"Charka is the last village on the river Bheri: on the opposite side of the river is a gonpa (lama-serai) to which the first-born male of every family in the village, as is the practice amongst the Buddhists generally, is dedicated as a lama. I left Charka on the 5th and ascended the Digi La, about 16880 feet above sea-level (called by Goorkhas Balali-Patan) by a gentle incline."

"On either side of the pass there are snow-covered ridges. The pass is broad, and there is a cairn on it at the watershed."*

The Karnali has deepened its bed to a far greater extent than the Birehi. The height of the bed of the Birehi at the point where the river crosses the great range, is believed to be about 6000 feet: the bed of the Karnali is between 3000 and 3500 feet high, where it intersects the zone of great peaks: in its passage across the granite axis of the great Himalayan range the Karnali flows at possibly a lower altitude than any other Himalayan river, excepting perhaps the Indus.

The Rapti.

The sources and course of the Rapti in Nepal have never been thoroughly explored; the maps of the Survey of India show it as rising in the lesser Himalaya and chart XXVI of this paper gives it a small longitudinal basin situated in the outer hills between the Karnali and the Gandak;† but other maps place its sources in the great Himalayan range west of Dhaulagiri. Neither plan has been constructed from surveys and neither deserves much weight.

A river that rises in the lesser Himalaya receives its water from the periodical rains only, and is almost dry for a great part of the year. But a river that is fed by glaciers has a perennial stream. The Rapti is never dry enough in the plains of India to be generally fordable: it is at its lowest in January and February; snow water comes down in May, and the river rises considerably early in June, and remains in flood till September. These facts throw doubt upon the correctness of the Survey of India maps from which chart XXVI has been drawn. In a letter dated September 8th, 1906, Mr. H. Spencer, C.S., writes:—"This year there were two heavy floods in the Rapti "in August simultaneously with unprecedented floods in the Sarju (Birehi) and Kauriala "(Karnali) which unite to form the Gogra. The local rainfall had nothing to do with

* *Explorer's narrative of his journey from Pitoragarh in Kumaon viâ Jumla to Tadum and back along the Kali Gandak river to British territory. General Report, Survey of India*, 1873-74.

The Digi pass is shown on chart XXVI.

† On the authority of the Survey of India, *see* Map of India, scale 32 miles = 1 inch.

"these floods, and it might be inferred that these rivers come from the same tract "of mountain ranges."

The Gandak.

The Gandak has three principal affluents, which have been named by survey explorers the Kali Gandak, the Buria Gandak and the Trisuli Gandak (chart XXVII). Of these three the Kali Gandak is *known*, and the other two are *believed* to rise in the trough behind the great Himalayan range. Having pierced the range independently, they join their waters on its southern side, and in one great stream force an opening through the lesser Himalayan range. It would thus appear that each of the three principal affluents of the Gandak has been able to carve a defile through the greater range, but that all have been stopped and deflected by the rise of the lesser range.

Absence of proper surveys.

The geography of the Gandak basin is, however, so largely theoretical and conjectural, that it is not possible to arrive at definite conclusions. The courses of the great tributaries have been followed by a native explorer, and Colonel Tanner sketched what he could see of the country from great distances: but results obtained by such methods can only be regarded as first approximations to truth, and they will certainly require to be corrected when Nepal becomes accessible to scientific surveys. The following extracts from Colonel Tanner's writings will illustrate his own opinions:—

(i) "From the Someshwar hills which rise at their highest point to a little over 2000 feet, my assistants were able to secure a certain amount of Nepal topography and to fix a considerable number of peaks, but a low range about 20 miles to the north masked all but the snowy range which lay behind it, and no portion of the larger streams such as the Buria Gandak, the Kali and the Trisuli Gandak could be seen."

"The hydrography of this part of Nepal is in considerable confusion, and though we were able to fix with fair precision the upper courses of one or two of these rivers, where the great snow-clad mountains give forth glaciers, yet in the lower ranges their courses have been laid down from the route-surveys of native explorers only, and as some of these route-surveys show a want of completeness in this neighbourhood, the points of junction of the rivers above named remain largely open to doubt. One glance at a tract north of the low range above noted would furnish more geography than could be derived from years of work by explorers; yet I regret to say, access to any point north of the Someshwar range is denied us." *

(ii) "Distant sketching based on trigonometrically fixed peaks affords a fairly good basis whereon to adjust the traverses and topography of the explorers, but it is very difficult work and can only be prosecuted during the very few days in each year, when haze is absent from the atmosphere, and when clouds do not envelop the hill ranges. With the exception of a blank of some ten miles wide which occurs on the west of the Gandak river in Central Nepal, the whole country has been sketched in some form or other, from the towers and other stations of the Great Trigonometrical Survey in the plains and from the hill stations of Kumaun in the west and of Sikkim in the east, but such work being the result in some cases of sketching done from points a hundred miles distant is necessarily vague and incomplete and at the most only secures the tops of the more conspicuous ranges."†

* *Our present knowledge of the Himalaya*, by Colonel Tanner. *Proceed., R. G. S.*, Vol. XIII, 1891, page 419.

† *General Report of the Survey of India*, 1887-88. Notes by Colonel Tanner on *reconnaissances and explorations in Nepal, Sikkim, Bhutan and Assam.*

Names of affluents.

In 1849, Mr. Brian Hodgson wrote of the Gandak as follows* :—

"In the basin of the Gandak we have, successively from the west, the Barigar, the Narayani, the Sweti-Gandaki, the Marsyangdi, the Daramdi, the Gandi and the Trisul. These are the 'Sapt-Gandaki' or seven Gandaks of the Nepalese, and they unite on the plainward verge of the mountains at Tribeni above Saran. They drain the whole hills between Dhaulagiri and Gosainthan, the Barigar and one head of the Narayani rising from the former barrier, and the Trisul with every drop of water supplied by its affluents from the latter. Nor does a single streamlet of the Trisul arise east of the peak of Gosainthan, nor one driblet of the Barigar deduce itself from the westward of Dhaulagiri."

With the exception of the Trisul, Mr. Hodgson's names for the principal affluents differ from those given by the explorers: he obtained his information by questioning Nepalese at Katmandu, and the explorers gained theirs from the inhabitants of the respective localities. It is not uncommon in the Himalaya and Tibet to find a name used for a geographical feature by people at a distance differing from that employed by the local natives.

Exploration of the Gandak basin.

In our description of the Karnali we quoted from the diary of a native explorer who followed up the Birehi tributary to the Digi Pass: this man crossed the Digi Pass, and descending into the basin of the Gandak, reached the town of Kagbeni. Kagbeni is situated at the junction of the Kali Gandak and the Muktinath stream; it is about 9000 feet above sea-level and consists of 100 houses inhabited by Bhotias.

The explorer followed the Kali Gandak to its source at the Photu Pass, and crossed over into the valley of the Brahmaputra. The height of the Photu Pass he found to be 15080 feet above sea-level and 250 feet above the plains of the Brahmaputra to the north. This low depression in the Ladak range is a peculiar feature. It may have been carved by the Kali Gandak in a former geological age, when that river had its sources in Tibet and further north than at present.

Our information concerning the Trans-Himalayan trough of Muktinath is so scanty that the following note by the explorer is of interest: "To the east and south-east of "Muktinath, about two miles, are lofty snowy mountains extending in a north-east "and south-west direction, from which the stream takes its rise which flows by Muk-"tinath to the north, takes in the temple water and joins the Kali Gandak river at "Kagbeni."†

If we are to rely upon the description in this extract, there must be a transverse ridge higher than the snow-line (16000 feet) separating the basins of the Kali Gandak and Buria Gandak north of the Great Himalaya. No observer, however, has actually crossed this ridge, and its existence may be doubted.

The explorer from whose diary we have quoted is the only geographical observer who has ever traversed the defile of the Kali Gandak through the great Himalayan

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* *Journal, Asiatic Society of Bengal*, Vol. XVIII, Part II, 1849.

† *General Report, Survey of India*, 1873-74, page xiii.

range. This defile cuts the range 4 miles east of Dhaulagiri peak; the height of the peak is 26795 feet, that of the bed of the defile 5000 feet, and the fall from the one to the other exceeds 5000 feet a mile. The explorer's narrative of his journey along this extraordinary river is disappointing, though not without interest. "On the 5th of "October," he wrote, "no villages were met with during the march, and the road passed "through jungle the whole distance, crossing several small streams running into the "Kali Gandak. I passed the night in the jungle." He was thus unaware that he was crossing the great Himalayan range: he did not see Dhaulagiri and was ignorant of its proximity. His references to the jungle and his failure to notice the rocky precipitous sides of the gorge tend to show that the Kali Gandak possesses a wider passage than many of the Himalayan rivers.

Little is known of the upper courses of the Buria and Trisuli Gandak. In 1865 an explorer marched from Katmandu up the Trisuli Gandak, and passed 15 miles west of peak Dayabhang: he was able to follow the river and did not describe the passage as difficult. He estimated the height of the river's bed, where it crossed the axis of the great Himalaya, to be between 6000 and 7000 feet. He found no open plain nor flat basin behind the great Himalaya, the spurs of the latter being apparently separated by ravines from those of the Ladak range to the north. He crossed a pass (15400 feet) over a ridge behind the great range, and found himself in the basin of the Buria Gandak.

The Buria Gandak rises at the No pass (16600 feet) on the Ladak range: it is possible that the Shorta Sangpo, now a tributary of the Brahmaputra, once flowed over the No pass into the Buria Gandak.

The Buria Gandak and the Trisuli Gandak unite on the south side of the great Himalaya, and after flowing as one river they join the Kali Gandak at Deb Ghat, a goal of pilgrimage. Below the junction of the streams, the explorer stated, the river is called the Narayani; this is one of the names given by Mr. Hodgson in the extract we made from his writings.

The Baghmati.

The Baghmati rises in the Mahabarat range of the Lesser Himalaya, and drains the central valley of Nepal (chart XXVII). This famous valley is a rock-basin filled with alluvial deposits; it is of an oval shape, its greatest diameter being 12 miles and its smallest 9 miles; it is small compared to Kashmir, and unlike the latter is not enclosed between the Great and Lesser Himalaya.

Colonel Kirkpatrick visited Katmandu in 1793, and subsequently published an account of the Nepal valley. In 1805 Colonel Crawford, who was afterwards Surveyor General of India, conducted surveys in Nepal, and measured some of the peaks of the Himalaya, being the first to discover their immense height.* The records of Colonel

* *A Memoir on the Indian Surveys*, by Clements Markham.

Crawford's observations were lost, but a few of his results were given in Buchanan Hamilton's *Account of the Kingdom of Nepal.* From 1805, when Colonel Crawford took observations, to 1903, when Captain Wood was permitted by the Nepalese Government to observe the peaks of Gaurisankar and Mount Everest, no survey officer was allowed to enter Nepal.

The Kosi.

The Kosi (chart XXVIII) is one of the most important of the Himalayan rivers. Its principal affluent is the Arun which drains an immense trough in rear of the great Himalayan range. Chart XXVIII has been taken from the most recent maps of the Survey of India: its main features are probably correct, but it can lay no claim to accuracy of detail.

In the *General Report of the Survey of India* for 1883-84, Colonel Tanner wrote: "I now have to dispose of the various branches of the Kosi river, which wind about "out of view behind the Mahabarat range, and this I confess I am at present unable to "do. Between us, Mr. Robert and I have dotted the country south of the snows with "trigonometrical points, and I can find no room between any of them for a valley "wide enough to contain the western Kosi in its course from west to east."

No additional geographical information has been gained, since Colonel Tanner explained his difficulty, and the course given to the Sun Kosi on the chart is conjectural. All we know is that the tributaries of the Kosi west of Mount Everest are deflected by the Lesser Himalayan range, and that they pass through the latter in the defile carved by the Arun.

The fact that the Arun flows now in a straight course from the great range to the plains shows that it was able to maintain its passage across the lesser range during the latter's growth: the Bhotia Kosi, the Dudh Kosi and all other Kosi affluents were stopped by the rising range, and have had to escape through the gorge forced by the more powerful Arun.

Mr. Brian Hodgson divided the Kosi into seven principal affluents. "The basin "of the Kosi," he wrote, "has seven principal feeders. These are as follows:—the "Milamchi, the Bhotia Kosi, the Tamba Kosi, the Likhu, the Dudh Kosi, the Arun and "the Tamor. Of these the Milamchi rising from Gosainthan is the most westerly and "the Tamor rising from Kangchang (Kinchinjunga) is the most easterly feeder."

"And those two great peaks with the pre-eminent ridges they send forth southwards "include every drop of water that reaches the great Kosi of the plains through its seven "Alpine branches. All these branches, as in the case of the Gandak, unite within the "hills, so that the unity of this Alpine basin also is as clear as are its limitary peaks "and its extent. The Alpine basin of the Kosi is denominated by the Nepalese the "Sapt-Cousika, or country of the seven Kosis."*

* *Journal, Asiatic Society of Bengal,* Vol. XVIII, Part II, 1849. We quote Mr. Hodgson for the information that he gives concerning names: we do not agree with his theories. The basin of the Kosi is not bounded by two great peaks; it is traversed by a whole line of them. The peaks in the interior of the basin are as high as those on the lateral water-partings. The affluents of the Kosi have not been forced to converge by the ridges running southwards from Kinchinjunga and Gosainthan, but by the recent rise of the lesser Himalayan range across their paths.

It will be seen on chart XXVIII that one affluent is named the Tamba Kosi and another the Tambar Kosi: it is doubtful whether these names are correct. Hodgson mentions the Tamba Kosi, but the Tambar he calls the Tamor; Hooker called Hodgson's Tamor the Tambur, and Montgomerie called it the Tamru.

The Arun Kosi.

The Arun Kosi is a very large river and possesses a considerable drainage area: rising in rear of the great Himalayan range, its eastern feeders encircle Kinchinjunga to the north, and its western feeders drain the northern slopes of Mount Everest.

The eastern branch in rear of the Himalaya is known as the Khantongiri, the Hangtang and the Yaru; the western branch is always called the Arun.

The trough between the great Himalaya and Ladak ranges drained by the Arun is a wonderful example of a structural or tectonic hollow; its length exceeds 200 miles. In no other part of the Himalaya is the trough between these two ranges so clearly defined and so free from transverse ridges or interruptions.* The western portion of this remarkable trough contains the lake of Palgu (15000 feet in height), and the eastern the lake of Tso Motretung † (14000 feet). Neither lake has at present any perennial outlet, but Tso Motretung is surrounded by feeders of the Arun and is believed to overflow occasionally into the Yaru. ‡

The central portion of the trough is drained by the Arun, which has created for itself a gorge of escape through the great Himalayan range between Mount Everest and Kinchinjunga.

In its Trans-Himalayan trough the Arun is 75 paces broad in October, and it meanders over flat plains of alluvium, known as the Dingri Maidan.

Sir Joseph Hooker describes its upper valley as "the broad sandy valley of the "Arun." § Mr. Hodgson once asked a Nepalese soldier if the Dingri Maidan was as large as the Central Nepal valley. "Horsemen," the man replied, "could not gallop "about Nepal; they would have to keep to the roads and pathways. But numerous "regiments of cavalry could gallop at large over the plains of Dingri."||

The height of the plains in the upper valley of the Arun is between 13000 and 14000 feet. The glaciers of Nepal do not now descend below 15000 feet, but there are many proofs that they once occupied the plains of Dingri. Sir J. Hooker describes an ancient moraine, deposited in the upper Arun valley by a former glacier, but now remote from existing ice. "In front," he writes, "close above my tent was a gigantic wall of "rocks, piled—as if by the Titans—completely across the valley for about three-quarters "of a mile. This striking phenomenon had excited all my curiosity on first obtaining "a view of it. The path I found led over it, close under its west end, and wound

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* The valley of the Arun is larger than that of Kashmir: a comparison, however, is hardly suitable, as the former is situated in a structural trough on the Tibetan side of the great Himalayan range, whilst the latter is in a trough on the Indian side.

† Tso Motretung was called Chomto Dong in former reports and maps of the Survey.

‡ North-Eastern Frontier Sheet No. 6 N.W., scale 1 inch=4 miles.

§ *Himalayan Journals*, Vol. II, page 167.

|| *Selections from the records of the Government of Bengal*, Vol. XXVII, page 92.

"amongst the enormous detached fragments of which it was formed, and which were "often 80 feet square: all were of gneiss and schist with abundance of granite in "blocks and veins. A superb view opened from the top, revealing its nature to be "a vast moraine, far below the influence of any existing glaciers, but which at some "antecedent period had been thrown across by a glacier descending to 10000 feet "from a lateral valley on the east flank."*

The Bhotia Kosi.

The Bhotia Kosi rises at the Thanglang pass, which is 35 miles north of the crest-zone of the great Himalaya range and 10 miles south of the upper Arun. The height of this pass is 18460 feet: the source of the Bhotia Kosi is thus 5000 feet above the Arun valley to the north, and 6000 feet below the nearer peaks of the great range. The Bhotia Kosi as a river is thus interesting in that it rises behind the axis of the great range, though it has not tapped the trough in rear.

In 1871 a native explorer of the Survey of India crossed the Thanglang pass from the north, and marched down the Bhotia Kosi, and from his accounts the following description was compiled by Colonel Montgomerie :—

"Between Nilam (north of the great range) and Listi Bhansar (south of the range) "the explorer followed the general course of the Bhotia Kosi river, and though it is "but some 25 miles direct distance between the two places, the explorer had to cross the "Bhotia Kosi river 15 times by means of 3 iron suspension and 12 wooden bridges, each "of from 24 to 60 paces in length. At one place the river ran in a gigantic chasm, "the sides of which were so close to one another, that a bridge of 24 paces was sufficient "to span it. Near this bridge the precipices were so impracticable, that the path had "of necessity to be supported on iron pegs let into the face of the rock, the path being "formed by bars of iron and slabs of stone stretching from peg to peg and covered with "earth. This extraordinary path is in no place more than 18 inches and often not more "than 9 inches in width, and is carried for more than one-third of a mile (775 paces) along "the face of the cliff, at some 1500 feet above the river, which could be seen roaring "below in its narrow bed. The explorer, who has seen much difficult ground in the "Himalaya, says he never in his life met with anything to equal this bit of path."†

From Listi Bhansar the explorer's route passed through country characteristic of the Himalaya south of the great range, being extremely rugged for considerable distances, and easy in the troughs or 'duns': he crossed the Indrawati feeder of the Kosi, and found that it drained five small tarns called Panch Pokri.

The Dudh Kosi.

The Dudh Kosi, like the Bhotia Kosi, rises in the great Himalayan range behind the crest-zone and the great peaks. It separates Mount Everest from Gaurisankar, and rises close to the great peak T^{42} (25433 feet).

In 1885 an explorer followed the course of the Dudh Kosi from the south, crossed the Pangula pass at its source and descended into the upper Arun valley behind.

* *Himalayan Journals*, Vol. I. Chap. X. This moraine stood 700 feet above the floor of the valley.

† *General Report on the operations of the Great Trigonometrical Survey of India*, 1871-72.

The Pangula pass he described as the highest and the most formidable one that he had ever crossed ; it is 24 miles west-north-west of Mount Everest, and the explorer's route passed within 15 miles of the great peak.* He thus approached nearer to the highest point of the earth's surface than any other geographical observer has ever succeeded in doing: he, however, saw nothing of it, as it was hidden from view by intervening cliffs and ridges.

It has always been regretted that this explorer failed to make any determinations of height: he estimated the height of the Pangula pass at 20000 feet, but no reliance can be placed upon his guesses.

The Tambar Kosi.

The Tambar or Tamor or Tamru is the most easterly affluent of the Kosi : it rises behind the crest-zone of the great Himalayan range, and drains the south-western face of Kinchinjunga and the western slopes of the Singalila ridge. The peaks of Jano and Kambachen stand within its basin, and the glacier of Yalung feeds its waters.

* *General Report of the Survey of India*, 1885-86.

24

THE RIVERS OF THE ASSAM HIMALAYA.

The principal rivers of the Assam Himalaya are the Raidak, the Manas and the Brahmaputra: the Tista has been included with them in this section, but it is the river of Sikkim, and does not enter Assam. Sikkim is the name given to the Himalayan area drained by the Tista; it is situated at the junction of the Nepal and Assam Himalaya, and separating the two belongs to neither. Some writers have referred to the mountains of Sikkim as the Sikkim Himalaya, but in this paper we have endeavoured to limit the numbers of Himalayan divisions, and as Sikkim is a very small area, we have regarded the bed of the Tista as the eastern boundary of the Nepal Himalaya and as the western boundary of the Assam Himalaya.

The Tista. *

Compared with the basins of other Himalayan rivers that of the Tista possesses exceptional features (chart XXVIII). The Lesser Himalayan range and the Siwalik range seem both to be absent, and the great Himalayan range has been cut back into a bay instead of being pierced by a river gorge. †

The great Himalayan range trends from Kinchinjunga to Chumalhari, but it may be questioned whether its alignment between the two peaks was originally straight. It is possible that the great range was slightly curved east of Kinchinjunga. But whether the Tista originally flowed down from a straight range, or whether its development was assisted by a concave bay in the range, there is but little doubt that it has succeeded in cutting back through the great Himalaya by head erosion, and that its sources are now situated behind the original line of crest.

The Tista rises on the northern side of the Himalayan crest-zone, but not north of the range itself, and it does not drain any structural trough in rear of the range as the Arun does. The drainage of the northern slopes of the Kinchinjunga mass, though not of the supreme summit, passes into the Arun.

The basin of the Tista has probably a heavier rainfall than any other Himalayan basin; not only is it situated at the head of the Bay of Bengal but there are no outer ranges of mountains to bar the progress of the moisture-bearing winds.

On issuing from the mountains the Tista flows near the water-parting between the alluvial basins of the Ganges and Brahmaputra: formerly its course in the plains was southwards and it joined the Ganges at Jaffirganj, but in 1787 it suddenly changed its direction and opened out a new channel to the eastward, in which it has since flowed, joining the Brahmaputra above Divanganj.‡

* Much interesting information concerning the Tista and many beautiful views of Sikkim will be found in Douglas Freshfield's *Round Kangchenjunga.*

† North-East Trans-frontier Sheet, 7 N. W., 1 inch = 4 miles.

‡ *Rudiments of Physical Geography,* by H. F. Blanford.

From Sir Joseph Hooker's descriptions of the Tista it would appear that it does drain a *comparatively* level valley in rear of the great granite range, though not a tectonic trough. "Above 11000 feet," he wrote, "the valley expands remarkably, the "mountains recede, become less wooded and more grassy, while the stream is suddenly "less rapid, meandering in a broader bed and bordered by marshes."*

"The upper portion of the course of the Tista (Lachen-Lachoong) is materially "different from what it is lower down, becoming a boisterous torrent as suddenly as "the Tambur does above Mywa Guola. Its bed is narrower, large masses of rock "impede its course."†

"From its principal source at lake Cholamo it descends from 17000 to 15000 feet "with a fall of 60 feet to the mile; from 15000 to 12000 feet the fall is 140 feet to the "mile; in the third part of its course it descends from 12000 to 5000 feet with a fall "of 160 feet to the mile: and in the lower part the descent is from 5000 feet to the "plains of India at 300 feet giving a fall of 50 feet to the mile. There is, however, no "marked limit to these divisions; its valley gradually contracts, and its course gradually "becomes more rapid."‡

Sir Joseph Hooker calls attention also to the remarkable absence of large stones or boulders from the bed of the Tista.§

The Raidak and the Manas.

The Himalayan area drained by the Raidak and Manas is known as Bhutan (chart XXIX). The positions and heights of a few peaks in the basins of these rivers have been fixed, and the courses of the main streams followed; but observations have been insufficient to justify any definite statements, and to a great extent the country is a *terra incognita*.||

"In Bhutan," wrote Colonel Tanner in 1891, "all the rivers can be set down "as unknown, except the Lhobrak of Tibet, which emerges into India as a part of those "large rivers which, united, form the Manas of the plains."¶

Captain Pemberton traversed Bhutan from west to east in 1838, and he discovered that there were several passes leading from Tibet into the basin of the Manas.

The interesting feature in the geography of the Raidak is that the hill rivers flow out independently parallel to one another and perpendicularly to the ranges, instead of combining behind one of the outer ranges to force a joint passage. The reason of this peculiarity is that the outer Himalayan and Siwalik ranges are not represented by any marked chains of mountains in the basin of the Raidak.

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* *Himalayan Journals*, Vol. II, page 66.

† *Himalayan Journals*, Vol. II, page 15.

‡ *Himalayan Journals*, Vol. II, page 399.

§ *Himalayan Journals*, Vol. I, page 397.

|| For exploration of the Manas basin, see *General Report, Survey of India*, 1866-67.

¶ *Proceedings, Royal Geographical Society*, Vol. XIII, 1891, page 416.

In the Manas basin the lower ranges re-appear and gain their normal elevation, and the phenomenon of rivers converging and uniting in the mountains is again witnessed.

The valley of Chumbi is drained by the Ammu tributary of the Raidak, and consequently forms part of the basin of the latter.* This valley is the only portion of the Himalayan area south of the great range, that belongs to Tibet. The rainfall in Chumbi is very small compared to that of the contiguous province of Sikkim.

The Brahmaputra.

The basin and tributaries of the Brahmaputra are shown in chart xxx: this river rises near the sources of the Karnali and Sutlej in Tibet at a height of 16000 feet. Unlike the Indus, or Sutlej, or Karnali, it has cut no deep channel for itself in Tibet, and in spite of its immense elevation it is, south of Lhasa, a sluggish and navigable river. Its basin is nowhere in contact with that of the Indus. Its bed is 14840 feet high at Tradom, 11800 feet at Shigatze, 8000 feet at Gyala Sindong and 442 feet at Sadiya in Assam.

Change in direction of flow.

The remarkable feature of the Brahmaputra in Tibet is the tendency of its feeders to flow in a direction opposite to that of the trunk river.† If but one feeder had been observed to take a course contrary to that of the river, the phenomenon might have been attributed to some local topographical peculiarity; but when all the principal affluents of a long section of the river are found to follow the same contrary course, it becomes evident that the Brahmaputra must at no distant time have flowed from east to west in Tibet, and that its tributaries were developed during that period of its history.

It has been held by some authorities that the Brahmaputra has been diverted from an original course through China, and has been forced to cut a passage through the Assam Himalaya.‡ But in our opinion the evidence furnished by its feeders is conclusive; the Brahmaputra formerly flowed through Tibet from east to west. It is not possible to express an opinion at present as to where it escaped through the Himalaya: it may have flowed over the Photu pass and through the defile of the Kali Gandak; it may have passed through the basin of the Karnali, and it may have followed the present Himalayan course of either the Sutlej or the Indus: arguments can be adduced to show that each of these hypotheses is worthy of future investigation, but with our present knowledge no conclusion can be reached. §

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* North-East Frontier Sheet, 7 N. W., 1 inch = 4 miles.

† *Annual Report of the Board of Scientific Advice for India*, 1905-06.

‡ *India, by Sir T. Holdich*, 1905, page 111.

§ The following evidence supports the idea that the Brahmaputra once escaped from Tibet along the present course of the Kali Gandak. The Photu pass separating the basin of the Kali Gandak from the present basin of the Brahmaputra is an extraordinary depression in the Ladak range and is only 250 feet higher than the Brahmaputra plains of Tibet. The gorge of the Kali Gandak intersecting the great Himalaya is immensely deep and can hardly have been cut by the volume of water issuing from so small a catchment basin, as the river now possesses behind the great Himalaya.

That the Brahmaputra once flowed out from Tibet by the channel of the Sutlej is an hypothesis that helps to explain the present existence of the great canyon in Tibet; the small stream that now trickles along the floor of the canyon cannot have sufficed to cut such a mighty ravine. The course of the Sutlej in Tibet follows the same alignment as that of the Brahmaputra, and the channels of the Spiti and the Chenab are further extensions of the same line. (*continued on next page*).

Of the great rivers of the world, the Brahmaputra furnishes the only instance of drainage flowing in a diametrically opposite direction to what it formerly did, though still occupying the same bed.

The principal Tibetan tributaries of the Brahmaputra, that may be observed to flow against the present river, are:—

(*i*) The Kyi, or Lhasa river.
(*ii*) The Nyang, joining the Brahmaputra at Shigatze.
(*iii*) The Rang.
(*iv*) The Shang.

Many smaller feeders adopt contrary courses also.

The most recent maps show that shortly before their junctions with the Brahmaputra, these tributaries are beginning to bend in their courses, and to turn towards the present direction of the Brahmaputra's flow, and in their future development they will doubtless adapt themselves to the altered conditions.

The Nyang tributary.

The Nyang tributary rises near two lakes north of Chumalhari, forces its way through the Ladak range, and falls into the Brahmaputra near Shigatze.* It is the only Tibetan tributary of the Brahmaputra that drains the great Himalayan range, and the only river east of Manasarowar that pierces the Ladak range. The peculiar bay, which is to be noticed in the water-parting on chart xxxv between Kinchinjunga and Chumalhari, is due to the passage of the Ladak range by the Nyang river. The Arun, the Kali Gandak, the Birehi and others rise in the Ladak range and pierce the great Himalaya, the Nyang rises in the great Himalaya and pierces the Ladak.

The Kyi and Raga tributaries.

The Kyi or Lhasa river rises in the Ninchinthangla range, and forces a passage through the Kailas range.

The frontispiece chart shows how the Kailas range bifurcates in Tibet: it is this bifurcation that gives rise to the Raga river.

Yamdrok lake.

The great lake of Yamdrok is situated at a distance of five miles from the Brahmaputra: it is confined between two ranges, the Ladak range to the south and the branch of the Kailas to the north.† The level of water in the lake is 14350 feet, that of the bed of the Brahmaputra opposite to it is 11700 feet, a fall of 2650 feet in five miles. In the range separating the lake from the river is a notch 15400 feet high,—about 1000 feet above the level of the lake. It is doubtful whether any connection exists between this lake and the Brahmaputra;‡ the water of the lake is believed to flow westwards by an

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The belief that the Brahmaputra was formerly an affluent of the Indus in Tibet rests only upon the great depth to which the Indus has cut down its bed in Tibet. The bed of the Sutlej at its exit from Tibet is 10000 feet high, that of the Brahmaputra is 8000 feet, but that of the Indus is only 4600.

The suggested explanations of the former course of the Brahmaputra are the merest conjectures; it will be noticed that they all depend upon the tacit assumption that existing streams cannot have accomplished the work of erosion that has been accomplished. We possess however no sufficient data upon which to build estimates of the eroding power of streams acting through millions of years, and seeing that Tibet once possessed a moist climate, we are not warranted in assuming that the volume of water discharged by rivers has never been larger than at present.

* North-East Frontier Sheets, 6 N. W., and 6 S. W., 1 inch = 4 miles.

† North-East Frontier Sheets, 6 N. E., and 6 S. E., 1 inch = 4 miles.

‡ *See* Ryder's notes. *General Report, Survey of India*, 1903-1904, Appendix, p. xviii.

underground channel into the Rang tributary. For many years it has been an open question whether the lakes of Manasarowar ever overflow into the Sutlej, and the connection between Yamdrok and the Brahmaputra presents a similar problem.

The identity of the Sangpo and Brahmaputra.

The Tibetan portion of the Brahmaputra was formerly known in geography as the Sangpo. For many years uncertainty prevailed as to whether the Sangpo flowed into the Brahmaputra of Assam, or into the Irrawaddy of Burma. The idea that the Irrawaddy was the debouchment of the Sangpo originated with D'Anville and the Chinese surveyors. Their view was maintained by Dalrymple, the author of the Oriental Repertory, and by Klaproth, but it was opposed by Rennell in 1793. In 1885 it was revived and ably argued by Robert Gordon, but was combated by General Walker, who was one of Rennell's successors as Surveyor General at Calcutta.* The problem was solved by the explorations of Pandit Kishen Singh, and it is now known for certain that the Sangpo of Tibet is the upper course of the Brahmaputra.

A brief account of the exploration of the Brahmaputra in Tibet.

The existence of the Sangpo river of Tibet first became known to western geographers through D'Anville's maps, which were compiled from surveys made at the beginning of the eighteenth century by Chinese lamas. The river was actually crossed by Bogle on his way to Lhasa in the year 1774, and a few years later by Turner and Manning.

It was about 1860 that Colonel Montgomerie first commenced to train natives of the Himalaya in the rougher branches of surveying and to work out his plan for the systematic exploration of Tibet and Central Asia. In 1865, Pandit Nain Singh, one of Montgomerie's explorers, penetrated through Nepal to Lhasa, crossing the Brahmaputra at Tradom : this was the first occasion on which an Indian surveyor had seen the Sangpo river of Tibet. Nain Singh returned from Lhasa to India *viâ* the Manasarowar lakes : he estimated that the average height of the road between Lhasa and Tradom was 13500 feet and between Tradom and Manasarowar 15000 feet.†

He discovered that the great river flowed in a south-easterly direction for about 170 miles, and thence adhered very closely to a due east course for at least 500 miles more : at 600 miles from its source he measured its discharge, which he found to be 35000 cubic feet a second in December. "The navigation at 13500 feet above the sea," wrote Colonel Montgomerie, "rude though it may be, is an extraordinary feat : "navigation of any kind at such an altitude being quite unknown in any part of either "the old world or of the new. If the Pandit had any doubt as to the great volume of "the river it was completely removed by a squall which suddenly swept across the broad "expanse of water; the wind raising such large waves that the small fleet of boats "carrying the Pandit and his companions only escaped swamping by taking to the "nearest shore."

* *Proceedings, Royal Geographical Society*, Vol. VII, 1885.

† *Report of a route survey made by Pandit Nain Singh*, by Captain T. G. Montgomerie, R.E. Tradom is in longitude 84° 15′ : Northern Frontier sheet 22 N. W.

In 1874, Pandit Nain Singh started from Leh in Western Tibet, and marched over 1200 miles of previously unknown country. He reached Chetang, a town on the Brahmaputra, 50 miles east of Lhasa. At Chetang, the lowest point on the course of the Brahmaputra in Tibet that had up till then been visited by an explorer, the Pandit found the width of the river to be 500 yards; the stream was very sluggish and the depth of the water nowhere more than 20 feet. On the left bank of the river was an expanse of sand, one and a half miles wide, which was said by the Tibetans to be under water during the river floods of the summer.*

In 1875, an explorer named Lala traced the Brahmaputra from Shigatze to Chetang, but went no further eastwards than Nain Singh had done.

Nem Singh.

In 1878 Lieutenant Harman, R.E., trained a Bhutia explorer, named Nem Singh,† and sent him to Chetang with orders to survey the course of the river eastwards. Nem Singh was able to follow the Sangpo to a place called Gyala Sindong (chart xxx) which was 200 miles from Chetang: 120 miles below Chetang the explorer found the river still very sluggish, but it was now only 250 paces broad and had become considerably deeper. To Gyala Sindong Nem Singh gave the height of 8000 feet.‡

The exploration of the Dihang.

The largest tributary of the Brahmaputra in Assam is the Dihang; and it had been generally recognised by geographers, even in the early part of the nineteenth century, that if the Sangpo of Tibet did flow into the Brahmaputra of Assam, it must come by the course of the Dihang—it must in fact be that tributary of the Brahmaputra, which was called in Assam the Dihang.§

Gyala Sindong, situated on the Tibetan side of the Himalaya, was only 100 miles distant from a point which had been fixed on the Dihang on the Assam side of the Himalaya. Nem Singh was told by the Tibetans at Gyala Sindong that the Sangpo after flowing through the mountains entered a land ruled by the British.||

In 1880, a Chinese Lama of Giardong was despatched by Captain Harman to explore the Sangpo below Gyala Sindong, and to follow the great river through the Himalaya to the plains of India. If he was unable to penetrate the mountains, he was directed to throw marked logs into the stream at the lowest point reached, and Captain Harman arranged that men should always be watching the Dihang river in

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* *Report on Trans-Himalayan Explorations*, 1873-74-75, *Great Trigonometrical Survey of India.*

† The G. M. N. of the Indian Survey.

‡ *Report on Trans-Himalayan Explorations in* 1878.

§ Harman found that the Dihang had a minimum discharge in Assam of 55500 cubic feet per second, or four times that of the Subansiri tributary and twice that of the Dibang (chart xxx).

Discharge of	Cubic feet per second.
Dihang	55500
Lohit and Tenga . .	33800
Dibang and Sesiri . .	27200
Subansiri . . .	10900

|| *General Report, Survey of India*, 1878-79.

Assam for the arrival of the logs. The identity of the great river of Tibet with the Brahmaputra would then be proved.

Kinthup, a native of Sikkim, who had previously accompanied the explorer Nem Singh to Gyala Sindong, and had been employed on explorations in Bhutan, was sent with the Chinese Lama as his assistant. Captain Harman's plans were upset by the treachery of the Lama, who sold Kinthup as a slave in the Pemakoi country and decamped to his home in China. Kinthup on regaining his freedom followed the Sangpo down from Gyala Sindong and reached a place called Onlet (chart XXX). Onlet is only a few miles from Miri Padam, the abode of the Miri and Padam tribes, who are known to inhabit the country near the place, where the Dihang breaks through the hills into Assam. Kinthup was informed at Onlet that Miri Padam was 35 miles from the plains of India.* The Sangpo of Tibet was thus traced to Onlet, which is less than 50 miles from the place where the Dihang passes out of the Himalaya into Assam. "I conceive," wrote Colonel Tanner, "that no further doubt should remain "even in the minds of the most sceptical as to the identity of the great river of "Tibet with the Dihang."†

In 1881, the explorer Kishen Singh, proceeding from the east, crossed the water-parting between the Salween and the Brahmaputra, and entered the horse-shoe shaped basin of the Zayul, the easternmost feeder of the Brahmaputra (chart XXX). He travelled down the bed of the Zayul to Sama which is only 100 miles from Sadiya in British territory, but being prevented from entering Assam he had to retrace his steps.‡

The falls of the Brahmaputra.

Near Pemakoi, ten miles below Gyala Sindong, the Sangpo has a vertical drop in its bed, and here occur the only considerable falls, which have been discovered on the trunk stream of a Himalayan river.

Kinthup described these falls of the Sangpo as follows:—"The Sangpo is two "chains distant from the monastery, and about two miles off it falls over a cliff "called Sinji Chogyal from a height of about 150 feet. There is a big lake at the foot "of the falls, where rainbows are always observable."§

Geographers have predicted that great falls would be discovered on the Sangpo between Gyala Sindong and Assam, but there are no real grounds for such a belief. The average fall of the Sangpo below Gyala Sindong to Assam is no greater than that of numerous other Himalayan rivers, on none of which are great falls to be found. Chart XXXVII has been drawn to show that the further a river rises behind the great Himalaya, the less prospect is there of great falls being discovered on its course: rivers that rise on the south side of the great Himalaya experience the severest drop, whilst rivers, like the Brahmaputra, that rise in Tibet have an easier fall than the Arun, the Kali Gandak, or the Alaknanda.

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* *Account of Trans-Himalayan Explorations, General Report, Survey of India,* 1886-87.

† *General Report, Survey of India,* 1886-87.

‡ *Mr. J. B. N. Hennessey's Report on the Explorations of A-K in* 1879-82.

§ *K-P's narrative,* translated by Norpu.

In 1877 Captain Woodthorpe penetrated the mountain basin of the Subansiri: this tributary of the Brahmaputra was supposed at one time to be the continuation of the Sangpo of Tibet, but there is no evidence tending to connect the two, and as a river it is very inferior to the Dihang.

The Subansiri.

"That the Subansiri," wrote Captain Woodthorpe, "rises behind the high snowy "peaks seen from Tezpur, I think very likely from its size and velocity, but its volume "is only one-fourth that of the Dihang. The Subansiri is a noble river in the hills, "and the gorges through which it emerges into the plains are singularly fine: the banks "are formed of precipitous masses of rock enclosing deep pools, in which measurements "give a depth of 70 and 80 feet: the river is about 70 yards broad at Ganditula and "flows with great velocity."*

A trunk stream is almost always joined by a large tributary at the point, where it bends to pierce a range. The Gilgit river joins the Indus near the knee-bend of the latter above Bunji: the Maru Wardwan joins the Chenab near the knee-bend at Kishtwar: similarly the Spiti joins the Sutlej near its bend, and a large eastern affluent joins the Arun. But so far no great tributary has been found to join the Brahmaputra in Tibet at the point where it bends above Gyala Sindong.

Comparisons with other rivers.

The Sutlej in issuing from Tibet pierces the border range of mountains within 4½ miles of Leo Pargial, the highest peak of its region; the Indus when turning the great Himalayan range passes within 14 miles of Nanga Parbat, the highest point of the Punjab Himalaya; the Hunza river cuts through the Kailas range within 9 miles of Rakaposhi, the supreme point of the range. It will form an interesting problem for investigation whether the Brahmaputra of Tibet has cut its passage across the Assam Himalaya near a point of maximum elevation.

* *General Report, Survey of India*, 1877-78.

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THE RIVERS OF THE PUNJAB HIMALAYA.

The Punjab Himalaya is the name given to that portion of the great range which lies between the Sutlej and the Indus. Its principal rivers are the Beas, the Ravi, the Chenab, and the Jhelum. With these we have included the Sutlej as a Punjab river. but have reserved the Indus for a separate section of this paper.

*The Sutlej.**

The mountain basin of the Sutlej (chart XXXI) lies mainly north of the Himalaya; the area of the Himalaya proper drained by this river, between the great range and the plains of India, consists of an insignificant transverse strip, and it is an interesting problem to study how it can have come about that such a great river drains such a narrow zone in its Cis-Himalayan course.

Narrowness of its basin.

The Sutlej is bounded on the east by the water-parting of the Giri (Jumna) and on the west by that of the Beas: at corresponding points in the mountains the beds of the Giri and Beas are relatively higher by 600 or 700 feet than that of the Sutlej, so that the latter is running along a deeper trough than the rivers on either side of it. Increased depth of trough means steeper slopes, and steeper slopes give to the tributary streams greater erosive power. The mountains should therefore be more rapidly denuded by the feeders of the Sutlej than by those of the Giri or Beas, and the basin of the Sutlej in the outer Himalaya should now be slowly widening—the eastern water-parting retiring towards the Giri, the western towards the Beas. The fact that the Sutlej has no Cis-Himalayan tributaries comparable to those of the Jumna or Beas tends to show that it is the youngest river of the three. Whether these speculations are correct or not, the question as to how the Giri and Beas have confined their giant neighbour to a trough less than 20 miles wide remains worthy of consideration.

The Sutlej rises in the distant high-lands of Tibet, and possesses a very long course through the mountains. The Trans-Himalayan portions of its basin, however, receive but little rain, and table XXX shows its annual discharge to be small.

The sources of the Sutlej.

Much of the rainfall in the higher Himalayan valleys is said to be due to moist winds rushing up the mountain passages cut by the rivers. The rain-bearing winds of the monsoon blow from the Bay of Bengal across the Gangetic plains, and the valley

* Known as the Sutluda by natives of the hills.

of the Sutlej, lying as it does at right angles across their path, is not favourably placed for their reception.

In drawing chart XXXI to illustrate the catchment area of the Sutlej, we were in doubt whether to include the lake basin of Manasarowar; we eventually decided to do so, and will now briefly discuss the evidence available.*

A great number of streams flow down from surrounding mountains into the two Manasarowar lakes, and the water of the eastern lake (Manasarowar) overflows into the western (Rakas Tal) (chart XXXI).

The connection between the two lakes was discovered by Henry and Richard Strachey in 1846, and has been confirmed by other reliable observers. "We came," wrote Henry Strachey, "to a large stream 100 feet wide and 3 feet deep, running rapidly "from east to west through a well-defined channel: this was the outlet of Manasaro-"war. It leaves that lake from the northern quarter of its western shore, and winding "through the isthmus of low undulating ground, for four miles perhaps, falls into "Rakas Tal."†

Fifty-eight years later the same channel was visited by Major Ryder, and he has given the following description: "We struck the channel a mile below the outlet, a "small stream only partly frozen over; this we followed up and found that it did not "flow from the lake but from a hot spring, at which we found and shot some mallard. "We then followed up the dry nullah to the lake and proved that Strachey was, as was "to be expected, quite correct. No water was flowing at this time of the year, but the "local Tibetans all agreed that for four months in each year there was a flow during the "rainy season and the melting of snows, *i.e.*, about from June to September. As a rise of "about 2 feet in the level of the lake would cause water to flow down the channel, this "appears quite worthy of belief."‡

The connection between the two lakes may be taken as established, but that between the western lake and the Sutlej basin is still open to question. The following is Henry Strachey's description: "There is no visible channel from the lake, and the only effluence "is by filtration through the porous soil of the intermediate ground, unless it be at times "of extreme flood, when the level of the lake may possibly rise high enough to over-"flow the margin."§

Richard Strachey wrote as follows: "A stream, the head of which we visited, "flows from Manasarowar into Rakas Tal, and the latter occasionally, when high, sends "off a feeder into the Sutlej."||

Captain Rawling refers to the question in his book *The Great Plateau*, which was published after his visit to the lakes in 1904. "It is evident," he writes, "that no "water had flowed from Rakas Tal down the passage for a considerable time, but there

* Northern Frontier Sheet 14 S. W., 1 inch = 4 miles.

† *Journal, Asiatic Society of Bengal*, Vol. XVII, 1848.

‡ *Report on Survey operations with the Tibet Frontier Commission*, 1904.

§ *Journal, Asiatic Society of Bengal*, Vol. XVII, Part II, 1848.

|| *Journal, R. G. S.*, Vol. XXI, 1851.

"was nothing here to prove that such might not be the case during the melting of the "snows in an exceptionally wet season."

The following further extract is taken from Major Ryder's report.* "We found "an old stream bed issuing from the Rakas Tal, but every Tibetan we asked told the same "story, that no water ever flowed along it now, but in days gone by, one man saying "before the Sikh war, water did flow out of the lake and down this channel. We followed "it down for some six miles along the plain, and could find none of the ordinary signs "of water flowing down it, until we reached some low hills; here evidently from the lie "of the sand, water flowed at some time of the year and away from the lake."

If the water of the Manasarowar lakes overflows *occasionally* into the Sutlej, they must be regarded as belonging to the basin of the latter. We define a basin as the whole tract of country drained by a river and its tributaries: by the word "drained" we do not imply any perpetual flow, but refer only to times of rain and flood. All the small tributaries of the Himalayan rivers are dry at certain times of the year, but a dry tributary remains a branch of the drainage.

If the water from Rakas Tal flows into the Sutlej once a century, and then only for such a short period as to be observed by no one, we shall still be justified in including the lakes in the catchment area of the river.

Subterranean drainage.

Henry Strachey was probably right in thinking that the water of the lakes filtered through the porous soil: examples of such filtration are common in the alluvial valleys of the Himalaya. Rivers disappear and subsequently re-appear at the surface. In the underground observatory of the Trigonometrical Survey at Dehra Dun water accumulates in the subterranean drains after heavy falls of rain in the neighbouring hills, even when no rain has fallen locally; the intervening river bed remains dry, and the water flows along an underground course. These underground systems of drainage seem to follow closely the beds of surface streams. The latter hold water only when the volume of flood is too large to sink into the ground, but when the surface is dry, there is often a flow at a lower level.

The course of the Sutlej in Tibet.

From Rakas Tal to Shipki, at the base of Leo Pargial, the Sutlej takes a north-westerly direction through the Tibetan province of Nari Khorsam.† The best known portion of Nari Khorsam is the plateau situated between the Zaskar and Ladak ranges. This plateau is 15000 feet in height. It has been formed by successive deposits of boulders, gravel, clay and mud in the trough between the two ranges; the deposits lie in parallel and nearly horizontal beds. Nari Khorsam furnishes in fact another example of the common Himalayan type of rock valley filled up with recent alluvium.‡

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* *Report on Survey operations with the Tibet Frontier Commission*, 1904.

† *Nari Khorsam* is the Tibetan name: *Hundes* is the name used by natives of the Himalaya.

‡ Map of Nari Khorsam, 1 inch=8 miles. Atlas sheet 65, 1 inch=4 miles. Northern Frontier sheet, 9 N. E., 1 inch =4 miles.

In one part of Nari Khorsam the water-parting between the Sutlej and Karnali traverses the level plain of alluvium, and a man can walk from one river to the other without crossing a hill of any sort.

In its course through Nari Khorsam the Sutlej has gradually cut into the unconsolidated deposits and has created an extraordinary canyon—a canyon that bears comparison even with the famous American canyon of Colorado. The Jhelum has created no canyon in Kashmir because the rainfall over the basin is sufficient there to lower gradually the whole alluvial area; but Nari Khorsam is an arid region, and whilst the Sutlej has been able to excavate a channel 3000 feet deep through the plateau by means of water received from the glaciers of Kailas, no rain has fallen locally to erode its perpendicular cliffs.

The Sutlej is joined by several tributaries in Nari Khorsam, the beds of which lie 1000 feet or more below the surface of the plain: their overhanging cliffs like those of the Sutlej have been spared from destruction by rain, and flat portions of the plateau now remain standing between profound gorges.

The water-parting between the Sutlej and the Indus in Nari Khorsam is the Ladak range with peaks of 19000 and 20000 feet. Twenty-five miles north-west of Manasarowar feeders of the Sutlej have cut back through the Ladak range into the trough behind; the water-parting between the Sutlej and Indus is at this point as low as 16200 feet, only 900 feet above the Indus near Gartok.

The passage of the Sutlej through the Zaskar range is near Shipki and within 4½ miles of the summit of Leo Pargial, the highest peak on this part of the range: the proximity of the gorge to the peak is a striking phenomenon. The height of Leo Pargial is 22210 feet, that of the bed of the gorge 10000 feet, a difference of 12210 feet. Ten miles below Shipki the right bank of the Sutlej is a perpendicular wall of rock 6000 or 7000 feet in height.*

The Spiti river.

The principal tributary of the Sutlej is the Spiti river, which drains a large area behind the great Himalayan range. Its bed lies deep below the alluvial terraces, and its water is consequently rarely available for cultivation. The terraces are stratified deposits of gravel and sand, and rise to a height of 400 feet above the river: on the terraces rest immense accumulations of débris which have fallen from the surrounding mountains. The basin of Spiti like that of Kashmir is surrounded by mountains, and except for the channel of the river can only be entered by passes.† It consists of two parallel troughs separated by the Zaskar range both of which drain towards the south-east and away from the Indus.

After its junction with the Spiti the Sutlej becomes a furious torrent dashing over a rocky bed, and forms one continuous rapid from its source to the plains. There are, however, signs of the former existence of a series of lakes along its course: terraces composed of stratified deposits are to be seen in many places, and these are evidences

* *Narrative of a journey from Cawnpore to the Boorendo pass made in* 1821, by Lloyd and Gerard, 1840.

† Atlas sheet No. 65, 1 inch = 4 miles.

that the Sutlej once meandered slowly through Himalayan lakes, as the Jhelum does now through the Wular lake. Many of the feeders of the Sutlej in the hills show signs of having run at higher levels within recent times.

Passage of the Himalaya by the Sutlej.

The Sutlej crosses the great Himalaya at a point where the range bifurcates, and it is difficult to trace a connection between the ranges on either side of it. At Rampur it crosses the Dhauladhar range through a narrow gorge of solid rock. The passage of the Sutlej across the great Himalaya and the Dhauladhar ranges is illustrated in figure 4 of chart XVI (see also chart XVIII). Figures 1 and 2 of chart XIX show the Sutlej escaping through successive Siwalik ranges. It is interesting to observe on chart XIX how effectually these small ranges stopped and deflected the Sutlej below Bilaspur.*

In its course over the plains the Sutlej is supposed to have flowed at one time through the Patiala and Bikanir states and to have joined the Indus in southern Sind: it now bends to the west on leaving the mountains, and joins the Beas. It is believed to have changed its old and straighter course to the sea for its present and less direct one about the end of the tenth century: † the advancing sands of the Rajputana desert have been supposed to be the cause of the change.‡

The fall of the Sutlej from its source to the plains of India is very uniform, and averages on every section of its length about 30 or 35 feet per mile: the height of its bed is 15000 feet near Rakas Tal, 10000 feet near Shipki, 3000 feet at Rampur, 1000 feet at Bilaspur.

The Beas.

The Beas or Beyah (*Sanskrit* Vipasa, the Hyphasis of the Greeks) rises in the Pir Panjal range at the Rohtang pass near the source of the Ravi (chart XXXII): its several affluents combine to pierce the Dhauladhar range at Larji § (chart XVIII). In the 75 miles from its source to Larji, its fall averages 125 feet a mile,|| but after Larji the gradient rapidly decreases, and in the valleys of the outer Himalaya is hardly more than 10 feet a mile.

The upper basin of the Beas encloses the district of Kulu, which for beauty of scenery is the rival of Kashmir.

Six miles from its source the Beas enters the gorge of Koti. "Here the river "plunges into a vast chasm, enclosed on either side by a precipitous barrier of rock and 20 "feet apart and often almost touching. For some 300 yards the Beas races through "this almost subterranean passage, when it again bounds into the sunlight, its exit on "the further side being most strikingly beautiful."¶

South of Larji the Beas passes through another precipitous defile intersecting the Dhauladhar range; below the defile its valley widens out.

Sir Alexander Cunningham estimated the minimum discharge of the Beas at not less than 3000 cubic feet per second.

* Atlas sheet No. 47, 1 inch = 4 miles.

† *A Manual of the Geology of India*, page 450.

‡ *Annual Report of the Board of Scientific Advice for India*, 1905-06.

§ Atlas sheet No. 47.

|| Alexander Cunningham's *Ladak*, page 124.

¶ *Selections from the records of the Government of the Punjab, No.* 10, *Himalayan districts*, by Captain Harcourt.

The Ravi.

The Ravi (*Sanskrit* Iravati, the Hyaraotes of the Greeks), illustrated in chart XXXII, is the smallest of the five rivers of the Punjab : it has its sources in a remarkable mountain knot formed by a conjunction of lesser Himalayan ranges (chart XVIII). The Nag Tibba range appears here to have been forced from the south-west against the Dhauladhar range, and the latter has combined with the Pir Panjal range to form the rock-basin of Bangahal.* The Ravi rises in the basin of Bangahal, and drains the southern slopes of the Pir Panjal and the northern slopes of the Dhauladhar. The basin of Bangahal is sixty miles in circumference. Numerous tributaries of the Ravi flow down its inner walls, many of them with steep gradients ; the Bhadal rises on the north at 16000 feet, and falls 314 feet a mile for 35 miles ; the Nai, which rises in the mountain known as Kali Devi, has a length of 30 miles, and an average fall of 366 feet a mile.†

The height of the bed of the Ravi at the lowest point (Wulas) of the Bangahal basin is about 5000 feet. Gathering together all the water that runs off the inner walls of this extraordinary rock cauldron, the Ravi flows out to the west.‡

The gorge, by which it escapes from Bangahal, may without exaggeration be described as inaccessible : it appears to have been scooped out of solid rock and its sides are perpendicular.

After leaving Bangahal the Ravi flows through the valley and state of Chamba in a north-westerly direction parallel to the Dhauladhar range (chart XVIII). West of the Chamba capital it makes a sudden bend at right angles and cuts its way through the Dhauladhar to the south-west. The defile that it has carved through the range is a few miles north-west of the station of Dalhousie.

The Ravi leaves the Himalaya at Basaoli: the length of its course in the mountains is 130 miles, and its total drop 15000 feet ; its fall therefore averages 115 feet a mile.

The Chenab.

The Chenab (*Sanskrit* Asikni, the Acesines of the Greeks) has two chief upper streams, the Chandra and the Bhaga, and the river below their junction is called by their joint name the Chandra Bhaga (chart XXXIII).

The Chandra and the Bhaga rise on opposite sides of the Baralacha pass (16047 feet), the Chandra on the south-east, the Bhaga on the north-west.§ They unite at a place called Tandi, 7500 feet above sea-level. The course of the Bhaga above Tandi is direct and only 60 miles in length : that of the Chandra is in the form of a loop, and is 115 miles long. The fall of the Bhaga is 150 feet a mile, twice that of the Chandra.||

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* The flanks of the ranges are in contact, not the axes.

† Sir Alexander Cunningham's *Ladak.*

‡ Map of Kangra, sheet 2 (1 inch = 2 miles) ; Atlas sheet 46.

§ Atlas sheet 46.

|| General R. Maclagan, R.E., on *The rivers of the Punjab. Proceed., R. G. S.*, Vol. VII, 1885.

"A mile from its source the Bhaga enters the Suraj-dul, a lake about a mile and a "half in circumference, 16000 feet above sea-level, and escaping through this flows for "ten or eleven miles to below Zingzingbar, a barren encamping ground."*

"Leaping from a bed of snow on the south-eastern slopes of the Baralacha, the "Chandra is from its commencement a stream of some size. It passes through a totally "barren land, where there are no signs of life, the solemn mountains clad in eternal snow "lying on its either flank. No villages adorn its banks, no attempts at cultivation, no "signs of human life are to be met with, and nothing greets the eye but the never-ending "and monotonous cliffs, which are lapped by the fierce stream, as it rushes in wild fury "against its banks. Now widening out the Chandra passes the remains of the Shigri "glacier, which some 80 years ago spread across the river and dammed it up, causing "what is known as the cataclysm of the Chandra."†

After their junction at Tandi the Chandra and the Bhaga flow as a joint stream in a north-westerly direction for over 100 miles: throughout this length the valley of the river is the structural trough formed by the great Himalayan and the Pir Panjal ranges (*vide* figure 4 of chart XVI and chart XVIII). Instead of continuing on the same alignment through the valley of Kashmir, the Chenab makes a great bend at Kishtwar, and escapes through the Pir Panjal by a gorge, which it has carved for itself. In the long trough from Tandi to Kishtwar the fall of the river averages 34 feet a mile.

The following description of Kishtwar is taken from Mr. Frederic Drew's well known work, *The Jummoo and Kashmir territories*:‡

"The mountains around are rocky below and have wooded slopes above. The wood "is oak on the eastern hills and deodar and fir on the opposite ridge. The "mountain on the south-west of the plain (of Kishtwar) is a remarkable one; it "is separated from us, as we stand at the western edge of our plateau, by the river valley "(Chenab) which has been cut down to some 1300 feet below us; as we look across, a great "cliff of some 3000 feet in height faces us, from the summit of which the ground slopes "back to the wooded ridge. The most conspicuous and beautiful feature is made by the "drainage from the upper part coming over the cliff in a waterfall of great height. Of this "fall it is impossible to obtain a near and at the same time general view, but by going "some way down the slope, we get a fair sight of it, though at the distance of a mile or "more. The water comes down not in one but many jumps; the aggregate height of the "falls within view is about 2500 feet, and above these are a few hundred feet more, "which can be seen from other points. The first two falls are each of about 500 feet; "these are conspicuous from the town; below them are two or three small ones, making "up six or seven hundred feet more; then there are irregular drops and cascades, partly "hidden by vegetation and by the irregularities of channel, these extending for some "eight hundred feet to the river; thus the two and a half thousand feet are made up."

* *Himalayan districts*, by Captain A. F. P. Harcourt, *vide Selections from the records of the Government of the Punjab*, No. 10.

† *On the Himalayan Valleys, Kulu, Lahaul, and Spiti*, by Captain A. F. P. Harcourt. *Journal, R. G. S.*, Vol. XLI, 1871.

‡ Published 1875.

At Kishtwar the Chenab is joined by the Maru Wardwan river, that has its sources in the glaciers of the Nun Kun peaks.

The Chenab passes the diminishing range of Dhauladhar near Arnas, and leaves the mountains at Akhnur. Akhnur is 180 miles below Kishtwar, and the average fall of the river between the two places is 26 feet a mile.

Above Akhnur "the banks of the Chenab," Mr. Drew writes, "are in places low or "may be cliffs of no more than 100 to 200 feet in height; this is where the river cuts across "one of the flat longitudinal valleys. In other parts opposite the ridges, the river is "bounded by high irregular rocks, which is the range seen in section."*

From the Baralacha pass to Akhnur the length of the Chenab is 400 miles and the total fall is 15500 feet, or 39 feet a mile.

It is worthy of notice that the general course of the Chenab resembles on a smaller scale that of the Sutlej, and that the course of the Ravi resembles on a still smaller scale that of the Chenab. The basins of these three rivers, unlike the symmetrical basins of Nepal, lie obliquely across the mountain ranges.

The Jhelum.†

The valley of Kashmir.

The Jhelum (the Hydaspes of the Greeks), illustrated in chart XXXIII, rises near Virnag at the south-east end of the valley of Kashmir, and flows in a north-westerly direction across a wide alluvial plain, until it enters the Wular lake. Its most distant source is in the lake of Shesha Nag at the head of the Lidar tributary. At its exit from the Wular lake it assumes a south-westerly direction as far as Baramula, where it escapes from Kashmir through a gorge in the Pir Panjal range.‡

The upper basin of the Jhelum forms part of the trough between the great Himalaya and the Pir Panjal ranges, and is known as the valley of Kashmir. This famous valley is of oval shape, its long diameter lying parallel to the general direction of the ranges. From crest to crest the transverse ridges on the south-east and north-west of the basin are about 120 miles apart, and from the crest of the Pir Panjal range to that of the great Himalaya the distance is 75 miles: the flat alluvial bottom of the basin measures 90 miles from south-east to north-west, and 25 miles from south-west to north-east. On the north-east side peaks of the great Himalaya rise above 17000 feet: on the south-west the loftiest peaks of the Pir Panjal exceed 15000 feet. Those of the two transverse ridges attain to 13000 feet. The height of the alluvium of the valley varies from 5200 to 6000 feet.

Through the alluvial flats of Kashmir the course of the Jhelum is navigable and is the chief artery of traffic: the fall averages a little over 3 feet a mile, and the usual rate of the current is about a mile and a half an hour. At Baramula where its course

* *Jummoo and Kashmir territories*, by Frederic Drew, 1875.

† The Sanskrit *Vedesta*, sometimes known in modern times as the *Behat.*

‡ Map of Kashmir, 1 inch = 2 miles; Atlas sheet 28, 1 inch = 4 miles.

through the open valley terminates, the river rushes through a narrow chasm in the rocks and entirely changes from a placid stream to a raging torrent.*

The alluvial deposits filling up the basin of Kashmir were held by the earlier geologists to have been formed from the waste of the surrounding mountains, and to have been laid down at the bottom of a great lake. It has been stated that these deposits once covered the whole valley to a height of 1000 feet above its present level, and that the greater portion has been carried away by the Jhelum to the plains of the Punjab. The Wular lake which now measures 10 miles in length and 5 in breadth, was regarded by Montgomerie as a last relic of the great expanse of water which once covered all Kashmir. But this idea of a great prehistoric lake has been abandoned by Mr. R. D. Oldham. Mr. Oldham studied the *Karewas* and the present lakes of the Kashmir valley in 1903, and came to the conclusions that the *Karewas* are of fluviatile and not of lacustrine origin, and that there was never at any time a materially larger lake than at the present day.†

"The country of Kashmir," writes Mr. Frederic Drew,‡ "has justly a reputation "for something distinctive, if not unique, in its character. Its position and form together "are such, that there is no parallel to it in the whole of the Himalaya. It is a "plain embedded among the mountains, a wide vale enclosed by mountain ranges, lying "at such a height above the sea as on the one hand to be of a climate entirely different "from that of India, being saved from the heat that parches its plains, and on the other "hand to be free from the severity of cold that visits the more lofty plateaux or wide "valleys."

When Mr. Drew described Kashmir as unique, he had in mind the excellence of its climate: from a geographical or a geological point of view the Kashmir valley is typical of the Himalaya, the Nepal valley, the plains of Dingri, and the plateaux of Tibet being other examples, though at different stages of development.

Passage across the Pir Panjal.

The Jhelum enters the Pir Panjal range near Baramula (5040 feet) in a direction approximately perpendicular to the strike of the mountains and continues on a straight course for 20 miles to Uri.

The defile below Baramula, called by the Kashmiris Basmagul, is 7000 feet in depth, and has almost perpendicular sides In places it is but 70 feet across, and its bottom is wholly occupied by the river.§

At Uri the river changes its course and follows the direction of the range to Muzaffarabad (2470 feet). From Baramula to Muzaffarabad the distance is 80 miles and the fall 2600 feet or 33 feet a mile.

At Muzaffarabad the Jhelum joins the Kishanganga and bending to the south follows the course of its affluent. The strike of the rocks changes at the very point

* See synoptical volume VII, Great Trigonometrical Survey of India.

† *Records, Geological Survey of India*, Vol. XXXII, p. 152.

‡ *The Jummoo and Kashmir territories*, 1875.

§ *On the Trigonometrical Survey and physical configuration of the valley of Kashmir*, by W. H. Purdon. *Journal, R. G. S.*, Vol. XXXI, 1861.

where the Jhelum alters its direction and may be the cause of the latter's bend.* From Muzaffarabad to the plains the fall of the Jhelum is 21 feet a mile.

The Kishanganga.

The Kishanganga rises in the mountains west of Dras and south of the Deosai plateau. It flows through the districts of Tilail, Gurais and Shardi, and skirts the northern rim of the Kashmir basin. After following the strike of the ranges it makes a knee-bend at Shardi, similar and parallel to the knee-bends of the Indus at Bunji, of the Jhelum at Wular, of the Chenab at Kishtwar and of the Ravi in Chamba.

Colonel Montgomerie, who superintended the survey of Kashmir from 1854 to 1863, described the valley of the Kishanganga as being throughout very precipitous, and for the greater part little better than a chasm in the mountains. Its basin is peculiarly narrow and elongated, being in places only 17 miles wide from water-parting to water-parting.

The Kunhar tributary of the Jhelum flows between the Kishanganga and Indus rivers and through the district of Khagan; it joins the parent stream a few miles below the great bend at Muzaffarabad.

The Zoji pass.

The Zoji pass over the Great Himalayan range forms a notch in the rim of the Jhelum's basin: this pass is 500 yards broad and 2 miles long, and its surface is so flat that a pedestrian cannot tell where the actual water-parting is. The ascent from Kashmir to the top of the Zoji is steep, the descent on the northern side is gentle. The height of the pass is 11300 feet; on each of its flanks the crest of the range rises to 13000 feet, and then by slow degrees to peaks of 19000 feet. The Zoji was probably cut by an extinct river or glacier during the growth of the Great Himalaya.†

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* *Memoirs, Geological Survey of India*, Vol. XXII, 1883. *The Geology of the Kashmir and Chamba territories, and the British District of Khagán*, by R. Lydekker.

† *Records, Geological Survey of India*, Vol. XXXI, 1904. *Note on the glaciation and history of the Sind Valley, Kashmir*, by R. D. Oldham.

26

THE INDUS.

Intersections of the Ladak range by the Indus.

The Indus, or Sind (chart XXXIV), rises in the trough between the Kailas and Ladak ranges, and for its first 180 miles flows in a north-westerly direction along the inner flank of the Ladak range. It then forsakes the trough, and bending at right angles cuts through the Ladak range near Thangra. Having pierced the barrier it resumes its north-westerly direction, and this it maintains along the outer flank of the Ladak range for over 300 miles. Near Skardo (8900 feet) it cuts again through the Ladak range, and having crossed back to its original trough, pursues the same north-westerly direction.* A hundred miles below Skardo it makes its third bend; and pierces the Ladak range at Bunji. From Bunji it rushes towards the peak of Nanga Parbat, but is deflected to the west near the foot of the mountain, and after a tortuous passage across the Himalayan ranges it emerges on the plains of the Punjab at Attock. †

We have read in preceding pages of this paper of many instances of rivers piercing mountain ranges, but the Indus furnishes a unique example of a river, that passes backwards and forwards across the same range three times.

The gradient of the Indus.

From the source of the Indus to Pitak opposite Leh the distance is 400 miles, and the fall of the river 6000 feet or 15 feet a mile. The whole length of the mountain course of the Indus from its source to Attock is 1100 miles, and the whole fall is 16000 feet or 15 feet a mile. Over a considerable length of its course in Tibet the fall is hardly more than 3 feet a mile; between Skardo and Bunji the fall averages 21 feet a mile. The equable and comparatively gentle fall of the Indus, as it crosses the Himalaya, is very remarkable: it is due to the low level to which it has cut its bed on the plateau of Tibet. When the Brahmaputra leaves Tibet the height of its bed is still above 8000 feet, but the height of the Indus at Bunji when it turns to quit the plateau is only 4600 feet.

The fact that the Indus has cut down its bed in Tibet to a greater extent than the Brahmaputra has promoted the development of its Tibetan tributaries.

"At Ohind," wrote Sir A. Cunningham, 15 miles above Attock, I found the "current of the Indus much more rapid than that of any other river of the Punjab. From "its source to Ranak the Indus is a broad and fordable stream, rolling its sluggish waters "through open grassy plains. Its general width is about 250 feet. From Ranak to "the junction of the Zaskar river the stream is a brawling rapid from 100 to 150 feet "broad, and thence to the confluence of the Shyok it is a furious torrent raving from "side to side of a narrow ravine."‡

* The gorge near Skardo where the Indus breaks across the Ladak range is said to run between precipices 14000 feet sheer: see article *Indian, Imperial Gazetteer, first edition.*

† Map of Turkistan, 1 inch=16 miles. Punjab map, sheets 5 and 6 (1 inch = 8 miles), atlas sheets 27a S. E., and 44, 45, 46 and 64.

‡ *Ladak and surrounding countries,* page 89.

General Maclagan estimated the fall of the Indus as follows: "Twenty-four feet "per mile from the source to Skardo, 600 miles. Seventeen feet per mile from Skardo to "Attock, 440 miles. Fifty inches per mile from Attock to Kalabagh, 110 miles. Twelve "inches per mile from Kalabagh to Mithan Kot, 370 miles. Six inches per mile from "Mithan Kot to the sea, 470 miles."*

It is so seldom that a truly vertical drop has been discovered on the course of a main Himalayan river, that a fall of the Indus is perhaps worthy of mention. It was observed by Sir Martin Conway north of Kashmir. "The Indus itself," he wrote, "plunges in a single white wave over a drop of about twenty feet, and then races down "a rapid."†

Exploration of the Indus.

The little that is known of the course of the Indus between Bunji and Attock has been derived from the observations of an explorer in 1876. This man, described in the reports of the Indian Survey as the Mullah, made a rough survey of the course of the river for a length of 220 miles above Attock.

In the 220 miles that intervene between Bunji and Attock, the river descends from a height of 4600 feet to one of 1200 feet. Its way winds tortuously through great mountain ranges and its valley is in many places but a narrow deep-cut gorge: as a rule there is more open space and culturable land in the lateral valleys nestling between the spurs than on the trunk stream.‡

On the former and present level of the bed of the Indus.

"The Indus valley," wrote Sir Martin Conway, "in the Bunji reach, is to be pictured "as broad and flat-bottomed. Its western side is a mighty "wall of rock. On the east it is bordered by steep slopes. "The slopes and the wall must meet not less than 500 "feet, and probably as much as 2000 feet below the level of the surface of the débris "accumulations, which fill the valley. By what processes were these vast débris "accumulations brought together?"§

"By far the deepest of all the river valleys," wrote Mr. Lydekker, "is that of "the Indus below Bunji in Gilgit. Between that place and the Darel district, which "has hitherto only been traversed by native explorers, the writer is informed by Lieu-"tenant-Colonel H. C. B. Tanner of the Survey of India that the river flows in a narrow "gorge, bordered by vast precipices ranging up to 20000 feet in height, at a level of a "little over 3000 feet; thus making the river gorge nearly 17000 feet in depth. That "a great part of this tremendous gorge has been cut by the river itself is proved by the "occurrence of river gravels and honey-combed rock surfaces many hundreds of feet "above the present river-level."||

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* *Proceedings, Royal Geographical Society*, Vol. VII, 1885.

† *Climbing and exploration in the Karakoram Himalayas*, page 589.

‡ *General Report, Survey of India*, 1876-77.

§ *Climbing and exploration in the Karakoram Himalayas.*

|| *Memoirs, Geological Survey of India*, Vol. XXII, 1883.

Many observers have noticed that the Indus once flowed at a level considerably higher than its present bed. The following extract is from a report by Adolphe de Schlagintweit written in 1856 :—

"In the valley of the Indus near Skardo, in the valley of Astor near the place "where the Indus enters the Himalaya, I on several occasions observed gravel and "sand beds evidently deposited by these rivers, and ancient marks produced by the "large streams on the rocks, at elevations of 3000 and 4000 feet above the present "level of the rivers. We have many proofs independent of each other to show the great "depth, to which all the valleys of the rivers, tributary to the Sutlej and Indus, have "been excavated."

"The decrease of glaciers as observed by us must be due to some general change "in the climate of the surrounding country, and I think that we have numerous obser- "vations to show that this change of climate is due in a great measure to the great "excavation of the Tibetan and Himalayan valleys by the action of the rivers."

"Many of the valleys of western Tibet exhibit ancient water marks at 3000 and "4000 feet above the present bed of the river. The sides of these rocky valleys, thus "gradually excavated, are now heated under the influence of the sun to a much greater "extent than was the case formerly; the warm air, thus produced, ascends the valleys, "and tends to melt the ice of the glaciers near the origin of the valleys, to a greater "extent, than was the case before the excavation of the valleys had taken place."*

Referring to the same subject Colonel Godwin-Austen wrote: "The height of "the upper lacustrine deposit at Kuardo is quite 4000 feet above the present river, and "this deposit also rests on the rock of Skardo in the town. Once this Skardo basin "contained a vast lake with swampy grassy margins, long subsequent to the time when "the higher deposits were settling down in the first deep lake."†

Sir Alexander Cunningham wrote: "The bed of the Indus, like that of all the "other rivers, has once been crowded with a series of lakes."‡

The principal tributaries of the Indus.

We have so far been treating of the Indus itself, and we have now to refer to its Himalayan tributaries; of these the following are the most important:—

(i) the Singhgi, (ii) the Zaskar, (iii) the Dras, (iv) the Shyok, (v) the Shigar, (vi) the Gilgit and (vii) the Kabul.

The areas of the catchment basins drained by the seven tributaries may be approximately estimated as follows:—

Kabul	river	35000	square miles.
Shyok	,,	13000	,,
Gilgit	,,	10000	,,
Zaskar	,,	10000	,,
Singhgie	,,	7000	,,
Dras	,,	5000	,,
Shigar	,,	5000	,,

* *Journal, Asiatic Society of Bengal*, Vol. XXVI, 1857.
† *Journal, Royal Geographical Society*, Vol. XXXIV, 1864.
‡ *Ladak and surrounding countries.*

It will be noticed that four of the tributaries have larger mountain basins than the Ganges, and that the Kabul river has a larger basin than seventeen out of the nineteen rivers of table xxx.

Colonel Montgomerie compared the tributaries of the Indus with those of the Brahmaputra as follows: * "Judging from my knowledge of these rivers I should "say they were not equal to the six tributaries of the Brahmaputra above Lhasa "as described by the Pandit. But supposing that they are equal and that the sizes "of rivers are somewhat in proportion to their lengths of course, *i.e.*, that they "would drain the same area, I conclude that the Brahmaputra below the junction "of the Lhasa river is at least equal to the Indus at Attock. The latter probably "drains a country which receives very much less moisture than the Lhasa "territory."

One of the native explorers expressed astonishment to Montgomerie, that the Brahmaputra in Tibet became no broader, after it had received its largest tributaries. Montgomerie referring to this peculiarity wrote that it is "quite in accordance with "what is known of the upper course of the river Indus. The Indus receives the Zaskar, "a river nearly as large as itself, below Leh, and yet the increase in the breadth of the "main stream is hardly perceptible to an ordinary observer. The same thing happens "at its junction with the Dras river, and again it is still more remarkable at the point "where the Shyok river joins the Indus, both great streams with but little difference "in volume, yet the combined stream appeared to me almost narrower than either of "them separately: the increased volume of water having simply made the stream "deeper."

The Singhgi.

The Singhgi is the name given to the eastern branch of the Indus, which drains the slopes of Aling Kangri peak. The existence of this eastern branch was doubted at one time by geographers, but it was indicated by Henry Strachey from native information on his map of Ladak in 1853. In 1867 a route survey by the Pandit Nain Singh proved that the eastern branch was in truth the main stream of the Indus. The Pandit named this river the Singhgi Chu or Singhgi Kamba.†

The branch of the Indus, known as the Garjung or Gartang, and which flows by Gartok, and which is generally accepted as the source of the great river, is smaller than the Singhgi.‡

The Zaskar.

The Zaskar rises between the Indus and the great Himalaya range; at its commencement it flows towards the range, as though it were going to pierce it, but it sweeps round through two right angles, and turning away from the great Himalaya, it pierces the Zaskar range, in which it had its source, and joins the Indus below Leh.

From its source to Padam the distance is 140 miles, and the fall 4000 feet, or 28 feet per mile. At Padam (12000 feet) the Zaskar makes its second bend, and adopts

* In his reference to *six* tributaries Montgomerie was omitting the Singhgi.

† *Report of the Trans-Himalayan Explorations during* 1867, by Captain Montgomerie.

‡ Northern Frontier sheet, 14 N.W., 1 inch = 4 miles.

its final direction towards the Indus: from Padam to the Indus the length of the river is 90 miles, and the fall 2000 feet or 22 feet per mile. According to Henry Strachey the main supply of water in the upper part of the Ladak Indus is derived from the Zaskar river: this river has its sources in Himalayan glaciers, whilst the other affluents, though longer, rise in drier climates.

The Dras.

The Dras river drains the plains of Deosai by means of its two tributaries, the Shingo and southern Shigar:* it also drains the mountain slopes north of the Zoji pass. Its great tributary is the Suru, which like the Zaskar starts on a course towards the great Himalaya, but eventually bends completely round and flows away from the range.

The Suru makes an extraordinary loop at the base of the Nun Kun peaks.† Dr. Neve writes that the Suru river, having cut a deep and narrow gorge at the bend, has become roofed in by boulders and débris for 300 yards.

The Shyok.

The Shyok rises behind the Karakoram range, and after piercing the range joins the Indus near Kiris: the great bay, which is to be seen in the water-parting line of the Indus in rear of the main range on chart XXXV, is drained by the river Shyok. The Trans-Karakoram basin of the Shyok contains the well-known plains of Dapsang. The passage of the Shyok across the Karakoram range is indicated in the longitudinal section of chart XX.‡

From its sources near the Karakoram pass § to its junction with the Indus, the length of the Shyok is 400 miles, and the total fall is 11000 feet or 27 feet a mile.

"The general character of the Shyok," wrote Sir A. Cunningham, "is exactly "the reverse of that of the Indus. Its upper course is rushing and turbulent, down "a narrow glen, but its middle course is either broad or divided into numerous "channels in an open valley: and in these places where the waters are much scattered, "the river is generally fordable, although not without difficulty. Between Tertse and "Unmaru there are seven distinct branches, of which three are between 300 and 400 "feet in width and the others much smaller, with an average depth of two feet."

"At the Turtuk bridge the river narrows to 70 feet, and in the lower part of its "course, the Shyok is generally a furious rapid confined between precipitous cliffs."||

At 10000 feet elevation the bed of the Shyok is four miles wide.¶

The principal tributary of the Shyok is the Nubra which has its source in a large glacier, the Saichar; this glacier lies across the Karakoram range, and appears to have cut back to a point 35 miles behind the crest-line of the range. The Nubra rises and flows amid great mountains; on the portion of the Karakoram range, which is situated between the Nubra and the Shyok, the principal peaks vary from 24000 to upwards of 25000 feet in height.

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* Not to be confused with the northern Shigar river, which joins the Indus near Skardo. Map of Turkistan and Punjab Map.

† Ser and Mer of table VI.

‡ Atlas sheets 44 and 45.

§ This pass is not on the main Karakoram range, but on the parallel ridge behind.

|| *Ladak and surrounding countries.*

¶ Dr. Hunter Workman and Mrs. Bullock Workman: *In the ice-world of Himalaya.*

The valley of the Nubra consists of a flat plain, a few miles broad, bounded on each side by almost vertical cliffs which rise 4000 or 5000 feet above the river.*

"From Tsati to Changlung," write Dr. Hunter Workman and Mrs. Bullock Workman, "some forty miles, the Nubra valley is from two to three miles wide, and presents "some features not seen everywhere in Himalayan valleys. The valley bottom is "composed of alluvium, sand and stones, over which the river flows in a broad bed "with many channels and arms, which leave the main stream at various points, and "soon join it again enclosing in their course numerous islands. The river is fed by many "tributary streams."†

The northern Shigar.

The northern Shigar river drains the southern slopes of K^2 and collects its waters from the Biafo, Baltoro and Chogo Lungma glaciers.

The Gilgit.

The Gilgit river has two principal branches, the Gilgit and the Hunza: both branches have pierced the Karakoram range, and both now drain considerable areas behind it.‡ The Gilgit is the more western branch, and has its sources near the Darkot and Baroghil passes of the Hindu Kush.

The following extract is from an account of the Gilgit valley by Sir Martin Conway:—"This accumulation of débris fills up the valley to a depth of probably "from 500 to 1000 feet or more. The Gilgit river flows in a gorge like a canyon, not "so much cut through as built up by this accumulation."

"Mud avalanches appear to be annually discharged by all the gullies, which "reach up to the snow region, and traverse the barren levels beneath. Rapid ærial "denudation, the extraordinary activity of which has been observed by all travellers "in the desert belt of the world, annually provides the materials for these discharges."§

In rear of the Kailas and Karakoram ranges the Hunza valley is broad and open, but it becomes a defile with precipitous sides as the river passes through the ranges. The Hunza river pierces the Kailas range within 9 miles of Rakaposhi, the highest point of the range.

"The Hunza valley," we quote again from Sir Martin Conway, "in its present "condition shows the intermediate stage through which the Indus valley has passed. "The Hunza river flows down a gorge between alluvial cliffs. The ancient alluvial "cliffs of the Indus practically exist no more. It is only here and there at high altitudes "that a fragment of them remains."

"The fact seems to have been that all the valleys of this region were at one time in "the condition exemplified by the Pamirs, filled to a depth of from one to two thousand "feet with mud avalanche débris. In the present geological period this deposit has "been largely washed out again, but the depth of the existing valleys is not much below "that of the old ones in which the deposit was laid."||

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* *Great Trigonometrical Survey of India, Synoptical volume VII.*

† *In the ice-world of Himalaya.*

‡ Northern Trans-frontier sheets, Nos. 2 and 3, 1 inch = 8 miles: also 3 N. E., 3 N. W., 1 inch = 4 miles.

§ *Geographical Journal,* Vol. II, 1893.

|| *Climbing and Exploration in the Karakoram Himalayas.*

The Kabul.

The Kabul river takes its name from the Afghan capital town, near which one of its branches flows. Thirty-five miles east of Kabul it receives the Panjshir affluent, draining a great length of trough between the north and south Hindu Kush ranges.* Subsequently the Kabul receives from the north-east the rivers of Kafiristan, of Chitral and of Swat, which flow parallel to the Indus (chart XXXIV). The most important of its tributaries is the Kunar, which has been graphically described in Sir Thomas Holdich's *Indian Borderland:* this river, known higher up as the Mastuj, rises in the same Hindu Kush trough as the Panjshir and pierces the Southern Hindu Kush range in Chitral.

Floods.

The Indus, like the other rivers of the Punjab Himalaya, is subject to sudden and extraordinary floods: these are due not to excessive rainfall but to the damming of the river by huge landslips.†

In December 1840, a side of the hill known as the Hatu Pir fell into the defile of the Indus at the base of Nanga Parbat, and formed a dam 1000 feet high. An immense lake was created behind the dam, the water in which became at one place 900 feet deep; at Bunji the water rose to the level of the fort, 300 feet above the bed of the river; the lake became nearly 40 miles long and reached almost to Gilgit town. For six months the waters were held back by the débris of the fallen mountain, till they rose to the level of the top of the dam. The dam then burst, and the lake emptied in one day, the immense volume of water rushing down to Attock.‡

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* North-West Trans-frontier sheet 27, 1 inch = 8 miles: Northern Trans-frontier sheets 2 and 3.

† These landslips occur more frequently in the bare mountains of the Punjab than in the more wooded parts of the Himalaya, but all Himalayan rivers are liable at times to be dammed by slips. In 1893 a tributary of the Ganges was dammed at Gohna by the fall across its course of a mountain side.

‡ This account is given on the authority of Colonel Montgomerie. Mr. Fraser in his *Marches of Hindustan* attributes the cataclysm of the Indus in 1841 to the damming of the river by a glacier.

27

THE HIMALAYAN RIVERS: SUMMARY.

On the direction of river-flow in the structural troughs of the Himalaya.

Rivers flowing in troughs of the Punjab Himalaya pursue as a rule north-westerly courses; the Sutlej, the Beas, the Ravi, the Chenab, the Jhelum, the Kishanganga, the Zaskar and the Indus all follow similar directions in the mountains. In the Nepal and Assam Himalaya opposite conditions obtain. The Kali, the Karnali, the Arun, the Sun Kosi, the Narayani, the Lopra, the Onchu and the Brahmaputra all assume easterly courses in the mountains.

In the Punjab Himalaya the only important exception to the rule is the Spiti: in the Nepal Himalaya there is the exception of the Birehi, the principal tributary of the Karnali.

In the Himalaya of Kumaun, which intervene between the Punjab and Nepal, the direction of flow is less regular: in the trough behind the great Himalayan range, the Bhagirathi flows to the north-west, and in the trough behind the lesser Himalaya the Alaknanda does the same, but their courses in general do not altogether conform to the Punjab type of river.

It may be that the rivers which flow to the north-west have had their directions determined by the bifurcating ranges of the great Himalaya: the Chenab, the Ravi, the Kishanganga and the Jhelum all rise in the acute angles formed between the great Himalaya and its offshoots. The Sutlej, however, has cut its course across both the great range and its branches, and has clearly not been deflected by the latter. The evidence furnished by the direction of river-flow perhaps warrants the inference that the heights of the Kumaun Himalaya and of the Manasarowar basin have been increased in recent times;* and that the uplift of this central portion of the mountains has helped to determine the direction of flow in the troughs on either side.

When once the Himalayan rivers have reached the plains, those that belong to the system of the Indus flow directly away from the mountains, but those that feed the Ganges turn to the south-east and tend to flow parallel to the Himalaya.

On the gradients of river beds.

The gradient of the bed of a Himalayan river varies so widely at different points of its course, that it is doubtful whether the calculation of the average drop over the whole length affords information of any value.

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* The relative positions of the peaks of Nanda Devi, Gurla Mandhata, Kamet and Kailas convey the idea that thrusts from the directions of Nepal and the Punjab have in recent times given an additional elevation to the already high mountains of Kumaun along a transverse zone.

When a river descends from a single mountain range, its gradient tends to decrease gradually from its source to its mouth; * in its first stage it is torrential, in its last sluggish. But when a river has to pierce several parallel ranges, as in the Himalaya, the case is different; its stream becomes then confined, in the intervals between its drops, to comparatively level structural troughs lying between two ranges. In these troughs the velocity of the water is checked by the decrease of gradient, and the river, depositing its load of gravel and silt, forms for itself a flat and open bed.

A river confined to a trough will flow for miles with a fall of 5 or 10 or 20 feet a mile; it will then cut a gorge through one of its barrier ranges, and descend to the next trough with a fall of 100 or 200 feet a mile.

The floors of the several Himalayan troughs lie at different heights above sea-level: it is not possible to state exactly the height of any trough, because however level it might have been originally it has now been cut down and given a gradient by the river flowing through it. The heights shown in the following table must therefore be regarded as rough averages.

TABLE XXXI.—Heights of floors of troughs.

Trough.	Region.	Average height in feet of floor above sea-level.
Between the Kailas and Ladak ranges	Brahmaputra	12000
	Manasarowar	15000
Between the Ladak and Great Himalayan ranges	Arun	13000
Between the Great and Lesser Himalayan ranges	Kashmir	5300
	Sun Kosi	3000
	Pindar	3000
Between the Lesser Himalayan and the Siwalik range	Ramganga	1500
	Dehra Dun	2000
Level of plains outside the Siwalik range	Opposite Nepal	600
	Opposite Kumaun	850
	Opposite Punjab	900

The Arun in its high level trough north of the great Himalayan range flows for 70 miles with a fall of 15 feet a mile, but when it forsakes its trough and pierces the great Himalaya, it drops 10000 feet in 150 miles, or 67 feet per mile.

The Arun is not stopped or deflected by the lesser Himalaya, but many rivers, of which the Sun Kosi is one, after rapid descents from the great Himalayan glaciers, flow in the trough below for long distances and with greatly diminished gradients.

* This rule is modified, when the rocks, over which the river passes, possess different powers of resistance to its wear.

The following table gives a few numerical estimates of average gradients; it is not possible as yet to draw any sections along actual river beds, as sufficient numbers of heights are not available.

TABLE XXXII.

Position of source.*	River.	Height at its passage of great Himalayan axis.	Length in the mountains.	Average fall per mile.	Variations of fall.
		Feet.	Miles.	Feet.	
North of Ladak range.	Indus.	4000	1100	15	10 feet per mile near Gartok; nowhere as much as 25 feet per mile except for very short distances.
	Sutlej.	9000	560	30	In Tibet 34 feet per mile; in the Himalaya 39 feet; below Bilaspur 5 feet.
South of Ladak range, but north of the great Himalayan range.	Alaknanda.	6000	200	75	160 feet a mile at the passage of the great Himalaya; from Srinagar to Hardwar 14 feet a mile.
	Kali.	9000	150	100	This river seems to pursue a straight course across the mountains without deviating into longitudinal troughs.
In the great Himalaya.	Bhotia Kosi.	5000	unknown	unknown	This river appears to drop 13000 feet in its first 30 miles—over 400 feet a mile. Though this estimate may be wrong the fall is certainly immense.
	Jhelum.	does not cross	400	28	200 feet a mile near its source; 3 feet a mile for 120 miles in Kashmir; 35 feet a mile below Baramula.
	Chenab.	does not cross	380	40	65 feet a mile near its source: 22 feet a mile from Tandi to Kishtwar: 100 feet a mile at passage of Pir Panjal; 20 feet a mile above Akhnur.
In the lesser Himalaya.	Beas.	does not cross	250	48	125 feet a mile from its source to Larji: 11 feet a mile below Mandi.
	Ravi	does not cross	130	115	200 feet a mile near its source; seldom less than 50 feet a mile anywhere.

Numerical estimates of gradients are always liable to be too steep: the numberless sinuosities of a river flowing through mountains cannot be shown on a map, and the length of the stream is always measured too small.

The following are the various lengths obtained for the river Ganges from Badrinath to Hardwar as measured from different maps:—

	Miles.
from the map of India on the scale of 1 inch = 32 miles . . .	127
from the index map of Kumaun on the scale of 1 inch = 12 miles .	133
from the atlas of India on the scale of 1 inch = 4 miles . . .	143
from Kumaun and Garhwal survey on the scale of 1 inch = 1 mile ,	155

* The sources of all these rivers are above 16000 feet. It is not possible to state the height of the source of a river rising in mountains except approximately. The lower end of the principal glacier marks the point where a stream of water is first visible, but this is not the source of the river. The snow, that falls on the highest peaks, may eventually find its way into the glacier and thence into the river.

Chart XXXVII has been drawn to show that the further back a river rises in the Himalaya or Tibet the less likely it is to have a steep average gradient. The fall of a river like the Brahmaputra rising in Tibet must tend to be less than that of one like the Ravi, which rises in glaciers of the lesser Himalaya.

It cannot, however, be laid down that the gradients of rivers depend only or even mainly upon the positions of their sources, for much depends upon the subsequent straightness of course. A river, for instance, like the Kali, that cuts straight across the hills from its source to its exit, tends to develop a steeper average gradient than one like the Jhelum, which meanders through the trough of Kashmir.

Positions of the sources of the principal Himalayan rivers.

The following rivers rise in the lesser Himalayan ranges :*—

The Ramganga (chart XXV),
Baghmati (chart XXVII),
Beas (chart XXXII),
Ravi (chart XXXII).

The following rise in the great Himalayan range (chart XXXVII) :—

The Mandakini (chart XXIV),
Seti (chart XXVI),
Indrawati (chart XXVIII),
Madi (chart XXVII),
Dudh Kosi (chart XXVIII),
Jumna (chart XXIV),
Tons (chart XXIV),
Jhelum (chart XXXIII),
Kishanganga (chart XXXIII),
Chenab (chart XXXIII).

The following rise behind the great Himalayan range :—

Bhotia Kosi (chart XXVIII),
Tambar Kosi (chart XXVIII).
Tista (chart XXVIII).

The following rise in the Zaskar range :—

Kali (chart XXV),
Alaknanda (chart XXIV),
Bhagirathi† (chart XXIV),
Spiti (chart XXXI).

The following rise in the Ladak range :—

Arun (chart XXVIII),
Kali Gandak (chart XXVII),

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* The position of the source of the Rapti (chart XXVI) is uncertain.

† In diagram 4 of chart XXXVII the Bhagirathi has been shown as rising in the trough behind the great Himalaya. This is correct, but it rises in the Zaskar range and not in the Ladak.

Karnali (chart XXVI),
Birehi (chart XXVI),
Raidak (chart XXIX),
Manas (chart XXIX).

The following rises in the Kailas range:—

Sutlej (chart XXXI).

Affluents of the following rise in Tibet north of the Kailas range:—

Indus (chart XXXIV),
Brahmaputra (chart XXX).

The rivers that rise in Tibet show great differences in the depths to which they have cut down their channels. At its escape from Tibet the Indus is 1000 feet lower than the Karnali, 3400 feet lower than the Brahmaputra, and 5400 feet lower than the Sutlej.

Variations in river-gradients.

It has been suggested that the increase in gradient during a river's passage of a range has been caused by the gradual rise of the range across the course of the river,—that the river has been unable to wear away the range as rapidly as the latter has grown.

The larger rivers, it has been stated,* are usually observed, within ten miles of the line of the great peaks, to be flowing at an elevation of little more than 4000 feet, but "on crossing that line the acclivity suddenly and rapidly increases, and the river "beds are found in a few miles to be at an altitude of 9000 or 10000 feet. Above "this the gradient falls again, and in the Tibetan region the average slope does not "seem to be more than a few feet in each mile of channel."

"This sudden rise in the river beds as they cross the line of highest peaks seems "to show that this has been a region of greater and more rapid upheaval than those "to the north or south."

We do not think that any such deduction is admissible: a river passing from a high level trough to one of low level must necessarily flow on a steeper gradient during the descent than when confined to either trough, and the variation in gradient does not seem to us to furnish evidence as to the rate of upheaval.

It may indeed be questioned whether the gradient of a Himalayan river ever increases, as it passes the *axis* of the great range: the Kali Gandak for instance rising in the Ladak range descends 3180 feet in its first 12 miles, from 15080 to 11900, or 265 feet a mile: in the next 22 miles it is in a trough and falls 2950 feet, or 134 feet a mile: it then commences its drop to the outer trough and descends 6900 feet in 38 miles or 181 feet a mile. If the barometric observations of the explorer are reliable, the river commences its increased fall of 181 feet a mile, not at crossing the great Himalayan *axis*, but at its *entry* into the great range. We believe that this is the case also with

* *Journal, Royal Geographical Society*, Vol. XXI, 1851.
Encyclopædia Britannica, Vol. XI.
A Manual of the Geology of India, 2nd Edition, page 462.

the Alaknanda and the Arun. The great range is 50 miles broad, and the rivers increase their gradient, as they pass not its axis but its northern edge.

Mountain slopes in the Himalaya.

Dr. Hooker found that the peak of Jano was 5 miles distant and rose 13932 feet above the village near which he was encamped. "This," he wrote, "is one of the most sudden slopes in this part "of the Himalaya, the angle between the top of Jano and Kambachen being 2786 "feet per mile, or 1 in 1·8. The slope from the top of Mont Blanc to the Chamouni "valley is 2464 feet per mile, or 1 in 2·1. That from Mont Rosa top to Macugnaga "greatly exceeds either."*

In the basin of the Dhauli (Alaknanda) there is in one place a drop of 7000 feet in one mile. In the basin of the Kali an instance is known of a fall of 14000 feet in $1\frac{3}{4}$ miles, or 8000 feet a mile.† On the north side of the Karakoram from the peak of K^2 to the bed of the Oprang tributary of the Yarkand river the drop is over 3000 feet a mile for 5 miles. From the peak of Haramosh on the Kailas range to the bed of the Indus the drop averages 2350 feet a mile for 8 miles.

The large angles of slope that are to be found everywhere in the great Himalaya are not met with in the outer and lower ranges: perpendicular drops of a few feet are common everywhere, but it is seldom in the lesser Himalaya that we meet with a difference of height of 1500 feet occurring within a horizontal distance of 1 mile.

* *Himalayan Journals*, Vol. I, page 258, footnote.

† This fall takes place between Hasaling peak and the bed of the Gori, *vide General Report, Survey of India*, 1874-75.

28

THE RIVER-GORGES OF THE HIMALAYA.

There is hardly a mountain range in Asia that has not been cut across by a river. A river which has been flowing for miles along an open trough between two parallel ranges will suddenly bend and piercing one of the ranges will escape through a precipitous gorge.*

The lengths and depths and forms of the stupendous gorges, through which the rivers of Asia pass the mountain ranges, have excited the wonder of all travellers who have seen them: the extraordinary narrowness of the defiles, the perpendicularity of their walls and the immense difference of altitude between the beds of the rivers and the peaks towering immediately above them have given to these wonderful chasms an absorbing geographical interest.

In many instances a range is found to possess the same form and character on the two sides of a river-gorge intersecting it, but in others it appears to undergo a complete change. No difference can be observed, for example, in the shape or height or alignment of the Pir Panjal range on the two sides of the gorge of the Jhelum, and the great Himalayan range itself does not change its form at the passage of the Arun Kosi. But at its intersection by the Sutlej the change in the great range is so complete that it is difficult to trace a connection between the mountains on either side of the gorge.

Many controversies have arisen over the origin of the great river-gorges. A century ago the explanation generally accepted was that earthquakes or other convulsions had produced long fractures through the mountains, and that the rivers had found their way along the cracks; but subsequent examinations of rocks below the beds of gorges so frequently showed no signs of fractures, that it is now generally acknowledged that the gorges have been slowly carved by the rivers themselves during the course of ages.

Though, however, the defiles of many rivers are unconnected with transverse fractures, yet a certain few, among which the Alaknanda is one, are now known to follow the lines of geological faults; even in these cases however the gorges have been carved mainly by water and an original structural weakness was merely the determining cause of the position of the gorge in the beginning.

A gorge may be carved by water across a range in many different ways. Firstly, as a new-born range is rising slowly out of the ocean, it may be cut across at intervals by the sea and divided into a series of islands; the channels cut thus in early times may subsequently develop into river-gorges. Secondly, the snow and rain falling on the front slopes of a range may create glaciers and rivers, which slowly cut back by head-erosion and eat through the mountains. Thirdly, the snow and ice accumulating on the crest may gravitate towards the lowest points of the range, and thence flow off in opposite directions and wear away the rock on both flanks simultaneously. Fourthly, a river may be antecedent or older than the mountains, and have maintained its

* *The River valleys of the Himalayas, an address to the Manchester Geographical Society*, 1893, by R. D. Oldham. *The evolution of Indian Geography*, by R. D. Oldham, *Geographical Journal*, March, 1894.

path across the latter as they rose. Fifthly, the flow of a river may be dammed by the rise of mountains across its path, and the waters of the lake so formed may eventually overflow and carve a gorge across the barrier range.

From classifications of the known gorges of Asia geographers were led to believe that the drainage of numerous mountain basins has been dammed by the rise of recent ranges, and that the imprisoned water has risen and overtopped the crests and has eroded narrow channels in its escape. But owing to the entire absence of lacustrine deposits, geologists have been unable to accept this explanation. In view of the differences of opinion that are now existing, we cannot presume in this paper to put forward any theory accounting for the presence of the gorges. The courses of rivers across ranges may have originated, some in one way, some in another, and even a single gorge may have been partly due to one cause and partly to others.*

The charts of rivers bring home to us how different are the forms of basins. On the one hand we see the Kosi, the Karnali and the Gandak possessing numerous branches and draining immense lengths of the snowy range, and on the other we witness the Sutlej a branchless trunk issuing from Tibet and draining a narrow transverse zone of the Himalaya.

The following table shows the heights of the beds of the principal gorges through the great Himalayan range and the widths of those gorges at certain heights :—

TABLE XXXIII.

River-gorge.	Height of bed of gorge in feet near the axis of the range.	Width of gorge between commanding peaks.	Average fall per mile from peak to bed.
Kali Gandak ..	5000	12 miles at 24000 feet	3167 feet
Bhotia Kosi ..	5000	10 miles at 20000 feet	3000 feet
Bhagirathi ..	7000	11·5 miles at 20000 feet	2261 feet
Dudh Kosi ..	16000	14 miles at 22000 feet	857 feet
Sutlej ..	9000	9 miles at 20000 feet	2444 feet
Trisuli Gandak..	6000	16 miles at 19000 feet	1623 feet
Buria Gandak ..	7000	18 miles at 19000 feet	1333 feet
Kali ..	9000	6 miles at 16000 feet	2333 feet
Gori ..	10000	6 miles at 16000 feet	2000 feet
Arun ..	6000	14 miles at 16000 feet	1429 feet
Tista ..	6000	25 miles at 16000 feet	800 feet
Alaknanda ..	6000	30 miles at 16000 feet	666 feet

The proximity of high peaks to deep gorges.

The passage of a river across a range has been observed to occur in many places near the highest point of the range, but our knowledge of the Himalaya mountains is insufficient to justify any statement of a general law. Some supreme summits do not appear to stand on the edges of transverse gorges, and some of the gorges do not appear to

* "Nothing can be certain till the topography and the geology are better known": *vide The valleys of the Himalayas*, by R. D. Oldham, *Geographical Journal*, November, 1907.

have been cut on the flanks of great peaks, yet proximity has been so often noticed that it must now be regarded as a phenomenon deserving attention.

It may be that the great outbursts of granite, which go to form the high peaks, are frequently accompanied by lines of weakness in the original structure, and that whilst the peaks themselves are hard, the rocks on their flanks have feeble powers of resistance.

It may be that the high peaks have from early times, before the mountains attained their present elevation, condensed the moisture of southern breezes and caused more snow and rain to be precipitated in their vicinity than on other parts of the range, and have thus given to glaciers and streams not only a greater fall and a greater eroding power, but a greater volume. *

It may be that, as one portion of the earth's crust becomes elevated to a great height, an adjacent portion becomes depressed, in accordance with the theory of isostasy.

It may be that the highest points of ranges occur at the bends and bifurcations of the latter, and that the bays and angles formed by bends and bifurcations render such places liable to the attacks of glaciers and streams. At present we are unable to determine the cause, and the solution of the problem awaits further and more accurate observations.

The following table contains a few examples of the proximity of extreme heights and depths: all the peaks included in the table are the highest points of their respective regions.

TABLE XXXIV.

River.	Height of bed of gorge near the peak.	Range.	Peak.	Height of peak.	Horizontal distance from peak to bed.	Fall per mile from peak to bed.
	Feet			Feet	Miles	Feet
Sutlej	10000	Zaskar	Leo Pargial	22210	4½	2713
Kali Gandak	5000	Great Himalaya	Dhaulagiri	26795	4	5449
Arkari	10000	Hindu Kush	Tirich Mir	25426	8	1926
Indus	4000	Great Himalaya	Nanga Parbat	26620	14	1616
Hunza	6000	Kailas	Rakaposhi	25550	9	2172
Dudh Kosi	18500	Great Himalaya	T^{42}	25433	4	1733
Gori	10000	Great Himalaya	Nanda Devi	25645	12	1304
Yurangkash	11000	Kuen Lun	Highest peak of region.	23890	10	1289

* If the rate of flow be doubled, the force of the water is increased 64 times. The transportation of boulders, the erosion of gorges and the destruction of mountains are mainly the work of rivers when in violent flood.

The highest points of ranges tend to occur on transverse lines.

In the last paragraphs we dealt with the phenomenon of contrast: in this we refer to the phenomenon of sympathy. The contrasts were between neighbouring points of the same range, the sympathies are between corresponding points of different ranges.

The several parallel ranges of the Himalaya and Tibet tend to culminate in sympathy with each other: we give the following instances to illustrate our meaning.

(i) The Karakoram culminates in K^2 opposite to the Pir Panjal, which is the highest section of the outer Himalaya. Of the intermediate ranges the Punjab Himalaya culminate in Nanga Parbat, and the Kailas range in Haramosh, between K^2 and the Pir Panjal.

(ii) In the Nepal Himalaya the supreme peaks of Everest and Kinchinjunga stand on the great range opposite to what appears to be an exceptional development of the outer range.*

(iii) The Chur peak, the highest of the Nag Tibba range, stands opposite to the great Zaskar peak, Leo Pargial and to the Aling Kangri of Tibet.

(iv) A further example of sympathetic expansion we find in the Kumaun Himalaya. Here the culminating point of the great range is Nanda Devi; on a line at right angles to the range stands Kailas, the culminating point of the Kailas range; south-east of this line is Gurla Mandhata, the highest peak of Ladak range, and north-west is Kamet, the highest peak of the Zaskar range. Thus we see that all four ranges tend to increase in elevation within the same region.

(v) A fine example of sympathetic expansion is furnished by the Hindu Kush. After a stretch of 100 miles from east to west, throughout which its highest peaks rarely exceed 20000 feet, the southern Hindu Kush range rises suddenly to 24171 feet at Sad Ishtragh: immediately opposite to Sad Ishtragh the northern Hindu Kush range shows in its peak of Lunkho (22641 feet) an even more extraordinary rise. Twenty-five miles from Lunkho, north of the Oxus, appear the two highest peaks of the whole Trans-Oxus region, which combine with Lunkho and Sad Ishtragh and a peak (21297 feet) of the Kailas range on the south to form a wonderful line of maximum elevation at right angles to the direction of the ranges.

The lowest points of ranges tend to occur on transverse lines.

The above are examples of sympathetic maxima, and chart XXXVI has been drawn to illustrate sympathetic minima, and to show how the gorges or lowest points of ranges tend to occur on transverse lines.

* Map of Nepal, scale 1 inch = 16 miles.

The following table will explain the meanings of the letters inserted on chart XXXVI.

Table XXXV.

A 1	The Indus turns the great Himalaya west of Nanga Parbat.
A 2	The Hunza river turns the Karakoram north-west of Rakaposhi.
B 1	Passage of the Jhelum through the Pir Panjal range.
B 2	Passage of the Indus through the Ladak range.
B 3	Shimshal pass.
B 4	Passage of the Oprang river through the Aghil range.
B 5	Passage of the Yarkand river through the Kuen Lun range.
C 1	The Chenab crosses the lesser Himalayan range.
C 2	The Zoji pass.
C 3	The Shigar river crosses the Zaskar range.
C 4	The Indus crosses the Ladak range.
	Karakoram pass.
C 5	The Karakash crosses the Kuen Lun range.
D 1	The Chenab cuts through the Pir Panjal range.
D 2	The Zaskar river cuts through the Zaskar range.
D 3	The Nubra cuts through the Kailas range.
D 4	The Yurangkash river cuts through the Kuen Lun range.
E 1	The Beas cuts the Siwalik range.
E 2	The Ravi cuts the Dhauladhar range.
E 3	Great bend in the Zaskar river.
E 4	The Shyok river cuts the Karakoram range.
F 1	The Sutlej passes the Siwalik range at an overlap.
F 2	The Beas passes the Dhauladhar range.
F 3	The Spiti-Indus water-parting bends through a right angle.
F 4	The Indus breaks through the Ladak range.
	The Pangong line of lakes bends in sympathy with the Indus.
F 5	The Kiria breaks through the Kuen Lun range.
G 1	The Jumna passes the Siwalik range.
G 2	The Sutlej crosses the great Himalaya.
G 3	The eastern branch of the Indus crosses the Kailas range.
H 1	The Ganges passes the Siwalik range.
H 2	The Ganges (Bhagirathi) crosses the great Himalaya.
H 3	The Sutlej crosses the Zaskar range.
K 1	The Alaknanda crosses the great Himalaya.
K 2	The Sutlej crosses the Ladak range.
L 1	The Kali Gandak cuts the Himalayan range east of Dhaulagiri.
L 2	The Photu pass, 15080 feet, over the Ladak range.
L 3	A northern tributary (Charta Sangpo) of the Brahmaputra cuts the Kailas range.
M 1	Knee-bend at junction of the Trisuli Gandak and Kali Gandak.
M 2	Southward bend in the Brahmaputra.

TABLE XXXV—*contd.*

N 1	The Buria Gandak cuts the great Himalaya.
N 2	A northern tributary of the Brahmaputra cuts the Kailas range.
	The Baghmati passes the Siwalik range opposite the Bhotia Kosi's passage through the great range. (Charts XXVII and XXVIII.)
P 1	The Arun Kosi breaks through the great Himalaya, lesser Himalaya and Siwalik range on one alignment.
P 2	The Brahmaputra cuts northwards through a branch of the Kailas range.
Q 1	The Ganges and Brahmaputra break between the mountains of Chota Nagpur and Assam.
Q 2	The Siwalik range is destroyed.
Q 3	Bend in the great Himalaya between Kinchinjunga and Chumalhari.
Q 4	The Nyang tributary of the Brahmaputra breaks the Ladak range.
Q 5	Northern tributary of the Brahmaputra cuts the Kailas range.
R 1	Knee-bend of the Manas river.
R 2	Lake Yamdrok.
R 3	The Kyi (Lhasa) river cuts the Kailas range.

It will be held that many of the above so-called examples of sympathy are but coincidences, and doubtless this is the case: but the total accumulation of evidence is considerable, and can hardly be dismissed as a series of accidents.

The higher range of a trough is generally the one pierced by the escaping drainage.

When a river breaks out from a trough, the range that is pierced is generally the higher of the two: rivers, for example, that rise in the Sarikol trough, escape through the higher range to the east; those that rise in the Hindu Kush trough, with the exception of two minor streams, escape through the higher range to the south; those that rise behind the Kuen Lun escape through the higher range to the north; those that rise north of the great Himalaya escape, with one exception, through the higher range to the south.

If it could be proved that the river-gorges in these cases had been caused by the overflows of imprisoned lakes, it would become evident that the higher ranges were younger, and were, at the times when the overflows were commencing, lower than their parallel companions, which they now surpass.

The gorges in the Great Himalaya compared with those of the Ladak range.

The longitudinal section in chart XX illustrates the interesting fact that no river crosses the Punjab Himalaya throughout a length of 360 miles—from the Sutlej to the Indus. The same section shows that, in other portions of the Himalaya, rivers are intersecting the great range at every 50 or 60 miles. The absence of gorges through the Punjab Himalaya seems to be due to the fact that the drainage of the northern slopes all flows towards Ladak and escapes by the Indus.

In Tibet the Indus has cut down its bed to a depth greater by 4000 feet than the Brahmaputra; this lower level of the Indus has given to its tributaries in Ladak a considerable fall, and has perhaps induced them to flow away from the Himalayan crest rather than attempt to cross it.

If we compare the great Himalayan and the Ladak ranges, we find a curious alternation existing; in Nepal the Himalaya are pierced by many gorges but the Ladak range is not; opposite the Punjab the Himalaya are not so pierced but the Ladak range is. In the region where rivers cut across the southern of the two ranges the northern range is not intersected, but where the southern range runs for a long distance intact, the northern is interlaced by the Indus.*

The gorges in the Great Himalaya compared with those of the Lesser Himalaya.

Our charts show that the great Himalayan range has been pierced by more rivers than the lesser range; † it might have been supposed that a river, which had been able to carve a deep gorge through the great range, would be able to maintain its way across the lesser range during the rise of the latter; but surveys teach us that this has not been the case. The lesser range appears to have barred the paths of many rivers, and having forced them to converge inside the mountains has restricted the number of principal basins and exits.

The Alaknanda and Bhagirathi have both cut passages for themselves through the great Himalayan range, but they unite within the mountains and pierce the lesser Himalayan and Siwalik ranges in one joint stream, the Ganges.

Three affluents of the Kali pass the great Himalayan range through independent gorges, but unite within the hills.

One branch of the Gandak, the Kali, rises in the trough behind the great Himalayan range; two other great branches rise behind the crest of that range; yet through the outer ranges there is only one outlet for the three.

One branch of the Kosi, the Arun, rises in the trough behind the great Himalayan range; five other principal branches rise in that range; yet there is but one outlet through the outer ranges.

Two principal branches of the Manas rise behind the great Himalayan range, and at least one in that range; there is but one outlet.

In the basin of the Raidak no tendency has been observed for rivers to converge; the several branches flow independently and directly out of the mountains; it is however in this basin that the lesser Himalayan and Siwalik ranges are absent.

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* We have already described how the Indus in Ladak passes backwards and forwards three times across the Ladak range; it intersects it first near Thangra; at Skardo it crosses back again to its original flank and trough; and at Bunji it pierces the same range again.

† We are referring here to the outer parallel range of the lesser Himalaya, that traverses Nepal and Kumaun, and not to the oblique ranges, *vide* frontispiece chart of Part I.

If we compare the northern and southern borders of the Tibet plateau, the Kuen Lun and the Himalaya, we find that rivers do not converge in the former to the same extent as in the latter, that the basins of the former are narrower, and that the number of rivers issuing from the same length of Kuen Lun is three times as great as the number from the Himalaya.

The cause of this difference is obvious; an outer Kuen Lun range has not dammed its rivers, as the lesser range has done in the Himalaya.

29

THE GLACIERS OF HIGH ASIA.

Former vast extensions of glaciers.

Large and numerous as are the existing glaciers of the Himalaya and Karakoram, they are but the relics of an older and more extensive series of ice-flows. The ancient moraines, the perched blocks and the glaciated surfaces all furnish proofs that the ice in former times covered an area in Asia immensely larger than at present.

On the southern slopes of the Dhauladhar range an old moraine was discovered by the late General McMahon at the extraordinarily low altitude of 4700 feet: * and on the Tibetan side of the Great Himalayan range the glaciation appears at one time to have been almost universal. No reliable observations have yet been made in central or northern Tibet, but in Ladak, in Nari Khorsam, and in Tsang the vast moraines and the transported blocks, perched high on hill sides far from their parent mass, are indications of the former existence in southern Tibet of an almost continuous ice-sheet, and of snow-fields and glaciers, such as are now to be found in polar regions only.

The diminution in the extent of the glaciers of the Trans-Himalayan region has been ascribed to the growth of the great range, which is supposed to have slowly risen and barred the passage of the moisture-laden winds from the south.† But this explanation cannot be regarded as complete, for the decrease in the ice has been as marked on the southern flank of the Himalaya as on the northern.

Secular changes in glaciers.

Although the Himalayan glaciers were at one time far more numerous and extensive than at present, their diminution does not appear to have progressed continuously. The process of contraction seems to have been interrupted at times, and the ice has at intervals spread again over areas, from which it had previously retreated.

Evidence of three separate periods of glacial extension has been discovered by Oldham in Kashmir,‡ and similar oscillations have been observed by Huntington in the Pangong valley of Ladak.

A complete study of Himalayan glaciers has long been recognised as desirable, and numerous references to the subject will be found in the writings of Hooker, Drew, Godwin-Austen and others, and in the records and memoirs of the Geological Survey; § but it has only recently become possible for Indian geologists to commence systematic observations. During the summer of 1906, certain glaciers in Kumaun, Lahaul and

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* *Records, Geological Survey of India*, Vol. XV (1882), p. 49.

† *A Manual of the Geology of India, 2nd Edition*, page 486.

‡ *Records, Geological Survey of India*, Vol. XXXI, pt. 3.

§ *Hooker's Himalayan Journals*, Vol. II, p. 7.
Journal, Asiatic Society of Bengal, Vol. XL, pt. 2, p. 393: Vol. XLIV, pt. 2, p. 209: Vol. XLVI, pt. 2, p. 1.
Memoirs, Geological Survey of India, Vol. III, pt. 2, p. 155: Vol. XIV, p. 116.
Records, Geological Survey of India, Vol. VII, p. 86: Vol. X, pp. 123, 140.
Drew's Jummoo and Kashmir territories
Quarterly Journal, Geological Society, Vol. XXIX, pp. 441, 466: Vol. VII, p 310.

Kashmir were observed, and the positions of their snouts accurately determined; these measurements will form a basis for subsequent work and will enable future observers to ascertain, whether the glaciers are advancing or retreating.*

For many years systematic observations have been made in Europe, and almost every glacier has been found to be retreating.

In the Tian Shan mountains, on the other hand, there is but one glacier only, the Mushketoff, which shows signs of recent retreat.†

In the case of the Himalayan glaciers the *present* direction of secular movement has never yet been determined, but so far as we are able to judge from the mechanical records left by the ice itself and from local traditions, no general rule obtains, such as has been observed to hold in the Alps. Certain Himalayan glaciers appear now to be retreating, others show signs of advance, and others again seem to have remained stationary for a considerable period.

In Hunza-Nagar two glaciers are known, which have advanced rapidly of recent years, and which have spread over fields and stopped cultivation.‡ On the other hand, the snout of the Milam glacier in Kumaun is retreating: the Pandit Kishen Singh—the A-K of Tibetan exploration—states that the glacier at Milam has receded 100 paces in his lifetime of 55 years. "The tradition of my village," he writes, "runs "that the glacier at one time descended almost to within a line with our houses, but "it is now a mile above them."

It will be many years before we shall be able to generalize upon the direction of the secular movement of the Himalayan glaciers. It is difficult to arrange for surveys to be made of all large glaciers, and travellers will be able to render assistance of great value, if they will but take detailed observations of the present positions of the snouts, that they visit. Co-operation such as this will be necessary to render our records complete.

Seasonal variations and subordinate phenomena.

The direction and rate of secular movement are perhaps the most important points for investigation. But other observations of interest are required. The seasonal variations in the lengths of glaciers and the relations of these variations to meteorological conditions will have to be observed. The nature of the ice, the position and movements of the 'dirt-bands,' the lamination, the directions of cracks and crevasses, and the rates of abrasion of the bed of the glacier, both in solid rock and in unconsolidated moraine, are all objects worthy of the attention of observers.

The rate of flow of the ice has also to be determined: this will vary with the gradient of the bed. A *transverse* glacier,—that is a glacier which flows down a valley at right angles to a range—is more likely to have a steep slope than a *longitudinal* glacier, or one occupying a trough between two ranges

* *General Report, Geological Survey of India*, 1906, by T. H. Holland, F.R.S., Director, and *Records, Geological Survey of India*, Vol. XXXV.

† Merzbacher's *Central Tian-Shan Mountains*, p. 192.

‡ Conway's *Climbing and Exploration in the Karakoram Himalayas*.

The longitudinal glaciers of the Karakoram are the greatest ice-flows of the world, outside polar regions: their gradients are gentler than those of the transverse glaciers. Their snouts too are generally situated at higher altitudes than those of the transverse glaciers: the great longitudinal glacier in Hunza-Nagar, known as the Hispar, terminates at an elevation of 10500 feet above sea-level, whilst the transverse glaciers on the slopes of Rakaposhi descend below 8000 feet; the steepness of the gradients on Rakaposhi allows the ice to reach lower altitudes, before being melted.

For the determination of secular movements, longitudinal glaciers like the Hispar, Biafo, Baltoro and Chogo Lungma are, perhaps, more suitable for observation than the transverse. When the snowfall has been abnormally heavy or light for one or more seasons, the lengths of the transverse glaciers are apt to be temporarily affected, and observations confined to a few years lead then to erroneous conclusions. If, however, observations are extended over long periods, there should be no difficulty in disentangling the effects of secular movement from those of seasonal variation.

The principal glaciers of High Asia.

A great number of the glaciers of the Himalaya and Tibet have been roughly surveyed and the altitudes of their snouts determined, but it would be no more possible to classify or enumerate them than it would be to classify or enumerate the rivulets. Glaciers abound at the source of every great river and throughout the mountain ranges.

The following glaciers of High Asia are known to exceed twenty miles in length:—

TABLE XXXVI.

Name of glacier.	Length.	Region.	Position.
Inylchek	44 miles	Tian Shan	. . .
Biafo	39 miles	Karakoram }	Parallel to the Indus in the trough between the Karakoram and Kailas ranges.
Hispar	25 miles	Karakoram }	
Baltoro	36 miles	Karakoram	In the trough between K^2 and Masherbrum on the summit of the Karakoram range.
Koikaf	31 miles	Tian Shan	. . .
Chogo Lungma . . .	24 miles	Karakoram	Parallel to the Biafo and 13 miles south; parallel also to the Indus.
Gasherbrum	21 miles	Karakoram	South of Gasherbrum peaks.
Saichar Ghainri . . .	21 miles	Karakoram	At the source of the Nubra.
Semenoff	20 miles	Tian Shan	. . .

No glacier of the Himalaya attains a length of 20 miles: the Rupal glacier near Nanga Parbat was described by one observer as descending to the village of Tashing and as being 22 miles long, but this account is known to have been inaccurate.

The maps of the Survey of India show the Rupal glacier to be ten miles in length, and they represent *other* glaciers entering the Rupal river from lateral valleys *between* the snout of the principal glacier and Tashing village. In the depths of winter these several glaciers are buried under a continuous mantle of snow, but at the periods of survey they were apparently unconnected.

The following table contains a list of the best-known glaciers of High Asia.*

TABLE XXXVII.

Region.	Name of glacier.	Length.	River into which it drains.
Sikkim Himalaya †	Zemu	16 miles	Tista.
	Kinchinjunga	13 miles	Tambar.
	Yalung	10 miles	Tambar.
Nepal Himalaya	No positive information. Structural troughs may exist in the crest-zone of the Nepal Himalaya, but they are at present quite unknown. Many deep ravines and notches have been cut by rivers across the Himalayan crest, and it is a question whether the sections of the range intervening between them, are sufficiently long and sufficiently intact to hold glaciers rivalling the Biafo. It is well known that glaciers extend over large areas on the slopes of Everest and Makalu.		
Kumaun Himalaya ‡	Milam	12 miles	Gori (Kali).
	Round north base of Nanda Devi.	12 miles	Dhauli (Alaknanda).
	Round south base of Nanda Devi.	12 miles	Dhauli (Alaknanda).
	Satopanth	7 miles	Vishnuganga at Badrinath.
	Bagini	10 miles	Dhauli (Alaknanda).
	Kosa	7 miles	Dhauli (Alaknanda).
	Mana	12 miles	Jahnavi (Bhagirathi).
	Kedarnath	9 miles	Bhagirathi.
	Gangotri	16 miles	Bhagirathi at Gau Mukh.
Punjab Himalaya §	Rupal (northern)	10 miles	Are cutting Nanga Parbat off from the great Himalaya and draining into the Indus.
	Rupal (southern)	11 miles	
	Phungatori	9 miles	Drain into the Indus from the northern slopes of Nanga Parbat.
	Rakiot	8 miles	
	Diamir	7 miles	Drains into the Indus from the western slopes of Nanga Parbat.
	Gauri	7 miles	From the Nun Kun peaks into the Suru.
	Shafut	8 miles	
	Barmal	8 miles	Wardwan.

* The list is not complete: the information upon which it is based is defective.

† *Round Kangchenjunga*, by Douglas Freshfield, North-East Trans-Frontier Sheet, 7 N. W.

‡ Atlas Sheets 65 and 66 N. E. and 66 N. W. Kumaun and Garhwal Survey, Sheets 12 and 20.

§ Atlas Sheets 46 and 45 S. W.: Northern Trans-Frontier Sheet 3 N. E.: Map of Kangra. The glaciers in Kulu are never 5 miles in length, and those of Spiti are smaller.

TABLE XXXVII—*contd.*

Region.	Name of glacier.	Length.	River into which it drains.
Punjab Himalaya .	Rundun . .	12 miles	Suru.
	Durung . .	14 miles	Suru.
	Kungi . .	11 miles	Zaskar.
	Hagshu . .	9 miles	Zaskar.
	Muni . .	11 miles	Zaskar.
	Gowra . .	8 miles	Zaskar.
	Reru . .	10 miles	Zaskar.
	Prool . .	8 miles	Wardwan.
	Brama . .	10 miles	Wardwan.
	Tuan . .	10 miles	Chandra Bhaga.
	——— . .	9 miles	Chandra Bhaga.
	Sisu . .	7 miles	Chandra.
	Sonapani . .	7 miles	Chandra.
	——— . .	10 miles	Chandra.
	Nilang . .	7 miles	Bhaga.
	Nela . .	10 miles	Sutlej.
	Nithal . .	10 miles	Sutlej.
Lesser Himalaya (Punjab) .	Sha . . .	6 miles	Into the Bara Bangahal basin and thence into the Ravi.
Karakoram* . .	Biafo . .	39 miles	Braldo.
	Hispar . .	25 miles	Hunza.
	Baltoro . .	36 miles	Braldo.
	Gasherbrum .	21 miles	Shyok.
	Chogo Lungma .	24 miles	Shigar.
	Remo . .	15 miles	Shyok.
	Saichar Ghainri .	21 miles	Nubra.
	From Rakaposhi	11 miles	Hunza.
	Malungatti .	22 miles	Hunza.
	Barpu . .	19 miles	Hunza.
	Batura . .	20 miles	Hunza.
	Pasu . .	14 miles	Hunza.
	Daintar . .	13 miles	Hunza.
Hindu Kush † .	Kurkulti . .	10 miles	Hunza.
	Wasmu . .	7 miles	Kunar.
	Rich . .	10 miles	Kunar.
	Sakiz Jarab .	19 miles	Kunar.
	Sad Ishtragh .	8 miles	Kunar.
	Tirich Mir .	14 miles	Kunar.

* Bullock Workman's *In the Ice World of Himalaya*, p. 119. Map of Turkistan, Atlas Sheet 44a S.E., Northern Trans-Frontier Sheet 2 S.E.

† Northern Trans-Frontier Sheet No. 2, and North-West Trans-Frontier Sheet No. 26.

TABLE XXXVII—*contd.*

Region.	Name of glacier.	Length.
Kuen Lun	Nissa	10 miles.
Kashgar Range*	Yambulak Koch Korche Koksei	6 miles. 9 miles. 9 miles.
Tian Shan	Inylchek Koikaf Semenoff Jiparlik Mushketoff Sabavchy	44 miles. 31 miles. 20 miles. 16 miles. 13 miles. 14 miles.

Many travellers have remarked upon the dirty colouring of the Himalayan glaciers and have lamented the absence of the beautiful blue-green hues of Norway and Switzerland. The discolouration of snow and ice in the Himalaya is due to dust which is brought by wind in immense volumes from India, Baluchistan and Persia, and deposited upon the mountains of Tibet.

Altitudes to which glaciers descend.

In Sikkim, Kumaun and Spiti the glaciers of our time rarely descend to 11000 feet: indeed it may be questioned whether any instance of a descent to 11000 feet has been discovered in those regions. But in the Karakoram the glaciers frequently descend to 10000 feet. This difference is without doubt partially due to the higher latitude of the Karakoram, but other causes for it exist, and these may possibly be producing even greater effects than the difference in latitude. The great peaks and high snow-clad ridges rise from the glaciers more abruptly in the Karakoram than in the Himalaya, and the horizontal distances between the valleys and the snow-fields which feed them from either side, are less; the slopes are consequently steeper and the glaciers are able to descend to lower altitudes, before their ice is melted.

The longitudinal glaciers of the Karakoram flow, it is true, down gentle gradients, and at 10000 feet portions of their ice are still surviving the attacks of heat. It is because they possess such immense volumes of ice, that these glaciers are able to reach low altitudes.

Differences between glaciers on northern and southern slopes.

Between the valley of the Sutlej in Kanawar and the Nun Kun peaks in Kashmir, the glaciers are few and small, but those on the northern slopes of the ranges are invariably more extensive than those on the southern. In the Punjab Himalaya several glaciers of the northern slopes exceed 11 miles in length, and some exceed 12; but the largest glacier of the southern slopes has a length of 10 miles, although the snowfall south of the crest is known to be greater than that to the north. Similar differences indeed are to be observed throughout the Himalaya. They are probably due to the greater amount of solar heat received by the southern slopes.

* Stein's Map.

30

THE LAKES OF TIBET AND TURKISTAN.

If we examine chart XXIII, which illustrates the basins of the great rivers that drain the plateaux of Asia, we find that in addition to the low-lying self-contained basin of Tarim, there is beside it a very large high-level basin in Tibet, which possesses no outlet for drainage.

Throughout the Tian Shan, the Pamirs and the Himalaya there are inland basins without outlets, but no one of them approaches in size the lake-basin of Tibet, or is indeed large enough to be shown on such a small scale as that of chart XXIII.

Though the Tibet lake-basin is very extensive and is studded throughout with lakes, it contains no single lake that will compare in area with the great lakes of the world.

The area of lake Superior in America is 30000 square miles; the area of the Sea of Aral is 25000 square miles; the areas of the Asiatic lakes Balkash and Baikal are respectively 9000 and 10000 square miles.

The largest lake enclosed among the high mountains of Asia is Issik Kul in the Tian Shan, area 2000 square miles. The largest lake of Tibet is Koko Nor, area 1630 square miles.*

In the following tables are given the heights, areas, lengths, and (when available) the depths of the principal lakes of Tibet and Turkistan. Many hundreds of lakes have been discovered by explorers in High Asia, but the greater number possess areas of ten or fifteen square miles only, and have been excluded from the lists. The names of small lakes have, however, been included for those regions in which no large lakes exist. In the Karakoram and Hindu Kush there are no lakes of importance.

TABLE XXXVIII.—The principal Lakes in the Mountain regions surrounding Tibet.

Region	Name.	Area in square miles.	Maximum length in miles.	Altitude above the sea in feet.	Maximum depth in feet.
TIAN SHAN.	Issik Kul	2000	115	5300	..
	Sairam Nor	200	20	5900	..
	Son Kul	102	19	9400	..
	Chadir Kul	82	14	11195	..
TARIM BASIN.	Baghrash Kul	630	50	3400	..
	Lob Nor (northern)	150	65	2600	31
	Lob Nor (southern)	220	26	2590	14
	Baba Kul, No. 1	120	..	..	..
	Baba Kul, No. 2	80	..	..	..

*As we pointed out on page 126 Koko Nor is situated on the Tibet plateau, but not in the Tibet lake-basin.

TABLE XXXVIII.—The principal Lakes in the Mountain regions surrounding Tibet.

Region.	Name.	Area in square miles.	Maximum length in miles.	Altitude above the sea in feet.	Maximum depth in feet.
PAMIR REGION.	Great Kara Kul .	140	14	13430	756
	Rang Kul .	61	20	12700	6
	Yeshil Kul .	30	15	12460	Very deep.
	Sir-i-Kul (Lake Victoria) . .	30	14	13398	..
	Little Kara Kul .	10	4	12201	79
	Chakmaktin .	8	5	13021	..
KUEN LUN MOUNTAINS.	Aig Kum Kul .	250	38	11710	..
	Achik Kul .	240	26	..	..
PUNJAB HIMALAYA: (on the Tibetan side of the crest-line).	Tso Morari .	46	16	15000	250
	Tso Kyagar .	..	..	15690	67
	Tso Kar . .	..	..	15684	..
PUNJAB HIMALAYA: (on the Indian side of the crest-line).	Wular . .	44	11	5187	14
	Dal . . .	8	4	5200	15
KUMAUN HIMALAYA.	Naini Tal . . (A group of small lakes.)	..	..	6400	..
NEPAL HIMALAYA: (on the Tibetan side of the crest-line).	Palgu Tso .	40	10	15000	..
	Tso Motretung*	40	15	14000	..
NEPAL HIMALAYA: (on the Indian side of the crest-line).	Khewan Tal .	6	3	..	..
	Damodur Kund .	2	2	..	..
	Gum Chu . .	5	3	..	..
	Dudh Kund .	5	3	..	..
ASSAM HIMALAYA: (on the Tibetan side of the crest-line).	Tso Tigu . . .	51	14	15500	..
	Tso Phomo Chang	20	17	16050	..
	Tso Rombudsa .	20	9	..	..

* Formerly called Chomto Dong in the reports and maps of the Survey.

TABLE XXXIX.—The principal Lakes of Tibet.

Name.	Area in square miles.	Maximum length in miles.	Altitude above the sea in feet.	Maximum depth in feet.
Koko Nor	1630	67	10700	..
Nam Tso	950	53	15190	..
Zilling Tso	720	45	14000	..
Dangra Yum Tso . . .	540	45	16580	..
Yamdrok Tso	340	44	14350	..
Montcalm	300	48	16273	..
Kyaring Tso	290	41	15840	..
Kara Nor	250	26	..	..
Nganzi Tso	250	26	..	..
Oring Nor	250	26	13704	..
Naktsong	230	20	..	..
Pangong	230	98	13930	142
Tsaring Nor	220	26	13704	..
Tossun Nor	190	36	..	..
Dara Tso	180	23	..	..
Bum Tso	140	30	15000	..
Mokieu Tso	140	27	..	..
Addan Tso	140	24	..	..
Manasarowar	133	16	14900	..
Shemen Tso	120	22	15500	..
Rakas Tal	100	19	14850	..

Nam Tso is, perhaps, better known to geographers as Tengri Nor.

Yamdrok is the famous ring lake formerly known in geography as Palti,* shown first on D'Anville 's map ; it is now known that the water of the lake does not *surround* the Tungchen mountain entirely ; the mass of the latter is connected with the mainland by two isthmuses.

Table XXXIX contains a list of all the known Tibetan lakes that exceed 100 square miles in area. The list is doubtless incomplete and inaccurate ; there may exist in Tibet a vast number of lakes that have not as yet been discovered, and the dimensions even of those lakes that are entered in the table must be regarded as first approximations only.

Many of the lakes of this table, such as Yamdrok, Manasarowar and Koko Nor, though situated in Tibet, lie outside the Tibet lake-basin.

In addition to the lakes enumerated in table XXXIX there are in Tibet numerous smaller lakes of which the Survey of India possesses measurements.

The area *known* to be under water in Tibet is 14000 square miles ; the actual area under water is considerably larger than this.

* Also called Piahte and Pede. For Ryder's note on this lake see *General Report, Survey of India*, 1903-04, Appendix, p. xvii ; see also his map, *Geographical Journal*, Vol. XXVI.

The principal *extinct* lake of Tibet is the Tsaidam depression; it is 300 miles long, and its trough is 100 miles broad, and 40 miles broad on the flat; it possesses an area of 12000 square miles of salt desert at an elevation of 9000 feet. It is a long flat basin filled up with detritus.

It is interesting to note that throughout the continent of Asia, there is no water-parting line between the Indian and the Arctic oceans; instead of an elevated line crossing the central portion of the continent from east to west there is a succession of closed basins:—the Tibet lake-basin, the Tarim basin, the basin of Lake Balkash, the basin of the Helmand, the Aral basin, and the Caspian.

No range of mountains can be found—not even a single peak—from which the water flows on one side into the Indian Ocean and on the other into the Arctic. The absence of a continental divide is probably due to the great distance and to the mountain barriers, which intervene between Central Asia and the sea. If the moisture-laden winds from the Arctic, Pacific and Indian Oceans could penetrate and give heavy rains to Central Asia, the volumes of the Tarim, Helmand, Oxus and Jaxartes would be increased, and outlets to the sea would be forced.

31

ON THE ORIGIN OF LAKES.

The Tibetan Lakes.

Until comparatively recently the origin of the lakes of Tibet was ascribed to the damming of river valleys by the talus fans of their tributaries; this hypothesis, which was put forward by Mr. Drew * to explain the origin of such lakes as Pangong and Tso Morari in Ladak, and has even been extended to the valley of Kashmir, was based on the fact that in all cases the visible barriers of the lakes are composed of detrital matter. It was, however, pointed out by Mr. R. D. Oldham that, under normal circumstances, a main stream would in all probability be able to keep its channel open and that unless supplemented by other causes the mere deposition of talus could hardly be considered adequate. If, however, elevation of the river-bed were to take place at a rate greater than the rate of erosion of the river, a barrier would be formed and eventually a talus dam would accumulate across the valley.†

That certain lakes in Tibet have been formed in the manner suggested by Mr. Oldham, seems to us probable, and the curious reversal of drainage recorded by the writer at the head of the Rong Valley in Central Tibet seems only capable of explanation on the assumption of a rise of the valley-bottom near the former outlet of Yamdrok Tso,‡ but it is doubtful whether this or indeed any other hypothesis can be of general application.

In some cases, as for instance in that of Kala Tso, a lake would appear to have been clearly caused by the damming of a valley by extensive moraine material brought down by a glacier from the neighbouring mountains, and it is probable that in many cases the lake dams must be attributed to glaciers rather than to rivers.

By a slight modification of Mr. Drew's hypothesis it seems, however, that the origin of many of the Tibetan lakes might be explained without the necessity for assuming concomitant crustal movement. It has been objected by Mr. Oldham that a river would most probably be able to keep its channel open in spite of the material brought down by its tributaries. One of the most marked features in connection with the development and growth of a river system is the tendency of certain branches to grow at the expense of others by cutting into or "capturing" their drainage areas and even by actually tapping a neighbouring tributary at some point in its course; this latter process is known as "beheading." If, therefore, either owing to the beheading of the main stream or to its own vigorous growth by capture, a tributary were to become the predominant affluent of a river system, then owing to its increase of volume and consequent increase of transporting power the amount of material brought

* *Jummoo and Kashmir territories.*

† *Records, Geological Survey of India*, Vol. XXI (1888), p. 156.

‡ H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 2.

down by it would be correspondingly increased. If at the point where it debouched into what was formerly the main valley, the latter were broad and open, its rate of flow would be checked and the transported material might thus be deposited to form a dam across the valley. Such might indeed have been the origin of Tso Morari in Rupshu, the formation of which has been ascribed by Mr. Oldham to an elevation of the river-bed at a point below the present dam. This principle, however, would not apparently be applicable to Pangong. Here a long and narrow valley holds a series of lakes, which were ascribed by Mr. Drew to dams built up by tributary streams; this hypothesis has been rejected not only by Mr. Oldham, but also more recently by Mr. Ellsworth Huntington * who regards the valley as a true rock-basin carved out by a glacier. Such lakes are not uncommon in other parts of the world, but, with the exception of the small lakes in the Kumaun Himalaya, none of those in the Himalaya or Tibet have been hitherto attributed to this cause.

Thus for the mode of origin of the Tibetan lakes, three hypotheses have been put forward:

(1) the damming of the main valley by the fans of tributaries (*Drew*);

(2) rise of the river-bed and consequent deposition of material above the barrier so formed (*Oldham*);

(3) the filling of a rock-basin previously scooped out by a glacier (*Huntington*).

The further suggestion, now made by us, that the damming of the main valley may have taken place owing to its conversion into a tributary valley may be regarded as a modification of Mr. Drew's hypothesis, and if we add to this the damming of tributary valleys by moraines of glaciers occupying the main valley, we shall probably have included all the causes at work to form the more important lakes of Tibet. But we are not disposed to think that any single theory can be of universal application: thus Kala Tso may be regarded as a type of the first hypothesis (with its corollaries), Yamdrok Tso of the second and, according to Mr. Huntington, Pangong is a type of the third.

Glacial Tarns.

We have not yet referred to the innumerable tarns found throughout the higher still glaciated valleys; these, however, offer no difficulties; they are, in almost every instance, merely ponds, each caused by the damming up of its valley by the terminal moraine of a retreating glacier.

The Kumaun Lakes.

Turning now from the Tibetan uplands to the lower valleys of the Himalaya, we find in Kumaun, nestling among the forest-clad hills, a small group of lakes of which Naini Tal and Bhim Tal are the best known. Their size is insignificant, but they are of interest owing to the rarity of such lakes in the Himalaya. Many theories have been propounded to explain their origin; they have been ascribed to glaciers, to landslips, such as that which caused the formation of the famous Gohna lake in 1894,† to faulting or other

* "Pangong: a glacial lake": *Journal of Geology*, Vol. XIV (1906), p. 599.

† T. H. Holland: *Records, Geological Survey of India*, Vol. XXVII (1894), pt. 2.

earth movements and lastly to removal, by solution, of the underlying rock. The first of these theories has now been generally discarded; the second applies to Khurpa Tal and other small lakes near Naini Tal; but the origin of Naini Tal itself still remains uncertain and may be due either to the elevation, by sudden faulting or by slow and gradual rise of the crust, of part of the lower end of a pre-existing valley, or to the gradual eating away, by percolating water, of the limestone underlying the central part of the valley: by this latter process would be formed cavities and "swallow-holes," which gradually becoming enlarged to underground caves would lead to a collapse of the surface over a considerable area; such a process is common when the prevailing rock is limestone and may be observed on a small scale in many places in the hills around Naini Tal.*

The last lakes to which we have to refer are those of the valley of Kashmir. Here we find a great alluvial flat through which the Jhelum meanders in its sluggish bed till it falls into the Wular lake at its south-eastern corner. Seen from the high hills to the north, this lake looks like a mere inundated corner of the great Srinagar plain, and with its marshy borders bears a most striking resemblance to the typical "jhil" or "bhil" so common in the alluvial plains of Bengal. By Mr. Oldham, this small and shallow lake, as also that of Dal in the neighbourhood of Srinagar, was regarded as an inundated hollow in the alluvial plain, and this theory has been supported by Dr. Karl Oestreich in his recent paper on the valleys of the North-West Himalaya.†

Dr. Oestreich, however, goes a step further than Mr. Oldham and attributes their formation to deposition of alluvial dams by the Jhelum, thus increasing the analogy to the *bhils* of the Gangetic plain.

Desiccation of lakes.

That the lakes of Tibet were once very much larger than they now are is almost universally admitted.‡ This has been inferred from the salt-covered flats and dry basins which are so common on the plateau of Tibet, as well as from the old beaches seen on the hill-sides far above the present water-level, which show that the lakes once stood many hundred feet higher and spread over much larger areas than they occupy at the present day.

Thus it has been recorded by almost all explorers who have visited the great lake-basin of Tibet § that almost every individual lake is surrounded by old terraces extending to as much as 200 feet above the present water-level. This feature, too, is clearly visible on the shores of the lakes nearer to India, such as Tso Morari, Kala Tso, Yamdrok ‖ and Pangong, ¶ of which the last shows a large series of old beaches, which remain as records of the rise and fall of the level of the lake. Much interesting information may be gleaned from these old lake terraces and in the case of Pangong,

* C. S. Middlemiss: *Records, Geological Survey of India*, Vol. XXIII (1890), p. 228.
† *Petermann's Mitteilungen, Erg. No.* 155 (1906).
‡ *A Manual of the Geology of India, 2nd Edn.*, p. 486.
F. Drew: *Jummoo and Kashmir territories*, pp. 292-300.
R. Lydekker: *Memoirs. Geological Survey of India*, Vol. XXII, p. 28.
Journal, Royal Geographical Society, Vol. XLVII (1877), p. 107.
§ G. R. Littledale: *Geographical Journal*, Vol. VII (1896), p. 474.
H. H. P. Deasy: *In Tibet and Chinese Turkistan*, p. 32.
C. G. Rawling: *The Great Plateau*, p. 110.
‖ H. H. Hayden: *Memoirs. Geological Survey of India*, Vol. XXXVI, pt. 2.
¶ Ellsworth Huntington: *Journal of Geology*, Vol. XIV (1906), p. 599.

Mr. Huntington regards them as evidence of desiccation, it is true, but of a desiccation that was oscillatory, embracing periods "now drier, now wetter, but the tendency "to aridity generally greater than its opponent."

That the marked contraction in volume of the lakes is due in many cases to evaporation is proved by the intensely saline character of their waters and, like the decrease of the glaciers, it has been attributed to a gradual process of desiccation consequent on the rise of the Himalayan ranges.* That very extensive desiccation has occurred, since the period of greatest extension of the glaciers and the (possibly subsequent) great extension of the lakes, may be safely regarded as an established fact, but whether such a process is still operative is a question which can only be decided by regular and systematic observations extending over long periods of time. The isolated observations made by explorers during the last hundred years in various parts of Tibet are inconclusive, as well as being at times mutually contradictory. This is especially noticeable with regard to two features, outflow and salinity.

It has been generally observed that most Tibetan lakes have no superficial outlet, but at the same time it is by no means unusual to find that there is a well-marked channel through the old river gravels which fill the former outlet, and that this channel, though dry at present, shows evidence of outflow having taken place at no very distant date; such channels are to be seen—to cite the more familiar instances—on Manasarowar in Nari Khorsam, and on Tso Motretung and Kala Tso in Tsang. The well preserved state of these channels shows that either they have only recently become dry or that they are still in intermittent use and the fact that the accounts of different explorers regarding the same channel are often mutually conflicting rather lends colour to the latter alternative. Hence the presence of a dry channel cannot be taken as conclusive proof that desiccation is still in progress, especially as in certain cases—as for instance from Kala Tso—outflow takes place beneath the surface of the deposits through which the superficial channel runs.

Similarly, although the fact that the waters of a given lake are salt may be taken as proof that desiccation has been operative, yet any attempt to establish the continuance of this tendency at the present time is frustrated by the want of systematic observations. This is, in fact, even more noticeable with regard to the salinity than in the case of observations regarding outlets. There is no doubt that many lakes, especially the smaller ones—such as Kyagar Tso and the salt lake of Ladak—are permanently and very markedly salt, but in many others the salinity varies in the most striking manner, water found quite undrinkable by one explorer having been subsequently regarded as perfectly fresh by another: a particularly good example of this peculiarity is furnished by the Aru Tso, which lies in Western Tibet due east of Leh.

This lake was visited in 1891 by Captain Bower,† who writes that the waters were "salt of course, like all the Tibetan lakes." In 1897, Captain Deasy‡ remarked that

* R. D. Oldham: *Rec., Geol. Surv. India*, Vol. XXI (1888), p. 157.
† H. Bower: *Across Tibet*, p. 35.
‡ H. H. P. Deasy: *In Tibet and Chinese Turkistan*, p. 31.

the water was "drinkable," whereas in 1903 it was found by Captain Rawling* to be "without the slightest flavour of salt or soda."

It is evident, therefore, that this character is largely dependent on seasonal variations† and, unless proved to be permanent, cannot be regarded as evidence of *progressive* desiccation.

Admitting, however, that desiccation has occurred to a very great extent in the past, it remains to be proved whether or no it is still operative. This can only be ascertained by systematic observations of the water-level and salinity of certain selected lakes. If we are correct in ascribing the observed desiccation to decreased rainfall due to the rise of the Himalaya, it is evident that if such rise is still in progress and if the rate of elevation exceeds the rate of degradation, then a steadily decreasing amount of moisture will reach the plateau of Tibet; that is to say, if the Himalaya as a mountain system have not yet reached maturity, it is to be expected that desiccation will still be in progress. When, however, this stage has been reached, it may be expected that the rainfall of Tibet will become approximately constant and such variations as may be observed will be of merely seasonal significance, and when, finally, degradation outweighs growth and the Himalaya pass into a stage of decay, the climate of Tibet will become increasingly moist and the lakes and glaciers will regain some measure of their former grandeur. In this connection observations have recently been begun by the Trigonometrical Survey from selected stations near Dehra Dun with a view to determining the absolute values of Himalayan heights and thus eventually to detect any variations that may have taken place in the heights of the great peaks: but it must be remembered that geological processes are usually so gradual as to be almost imperceptible during such periods of time as can be measured by human standards and the many disturbing factors, already referred to in a previous part of this paper, may render it impossible to detect with certainty such movement as may take place in the course of a single century.

Although the hypothesis of a rise of the Himalaya may fully suffice to account for the desiccation observed in the neighbourhood of the mountains and in the great lake-basin of Tibet, it is by no means certain that it can be applied to such areas as the Tarim basin. The disappearance of lakes in this and similar desert areas, such as Baluchistan, has been attributed to the increase and movements of blown sand.‡ The surface rocks of Tibet are everywhere decomposing, and the several rivers that have their sources in Tibetan glaciers carry down immense loads of sand. The annual additions of sand to the deserts of Asia are always increasing the amounts already accumulated in past centuries. The Tarim basin is becoming choked with sand; almost all its rivers now end in its deserts and fail to reach Lob Nor. The sand is always increasing whilst the water is not.

* C. G. Rawling: *The Great Plateau*, p. 111.

† It has also been pointed out by Mr. Ellsworth Huntington that salinity is largely affected by circulation of the water in a lake and a single observation might thus be entirely misleading: see '*Pangong: a glacial lake.*' *Journal of Geology*, Vol. XIV (1906), p. 599.

‡ S. G. Burrard: *Report on Geography to the Board of Scientific Advice for India*, 1905-06.

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INDEX

to the more important

Personal and Geographical names of Parts I, II and III.

PART I contains pages 1 to 46 and Charts I to VIII
PART II contains pages 47 to 118 and Charts IX to XXII
PART III contains pages 119 to 206 and Charts XXIII to XXXVII

Part I contains pages 1 to 46 and Charts I to VIII
Part II contains pages 47 to 118 and Charts IX to XXII
Part III contains pages 119 to 206 and Charts XXIII to XXXVII

* The picture of Bandarpunch peak will be found facing p. 39 of Part I.

PART I contains pages 1 to 46 and Charts I to VIII
PART II contains pages 47 to 118 and Charts IX to XXII
PART III contains pages 119 to 206 and Charts XXIII to XXXVII

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PART II contains pages 47 to 118 and Charts IX to XXII
PART III contains pages 119 to 206 and Charts XXIII to XXXVII

* The name Sangpo should have been spelt Tsangpo. The Imperial Gazetteer of India on pages 19 and 27, Vol. I, and on page 499, Vol. IV spells it Tsan-po.

PART I contains pages 1 to 46 and Charts I to VIII
PART II contains pages 47 to 118 and Charts IX to XXII
PART III contains pages 119 to 206 and Charts XXIII to XXXVII

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Part II contains pages 47 to 118 and Charts IX to XXII
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PART II contains pages 47 to 118 and Charts IX to XXII
PART III contains pages 119 to 206 and Charts XXIII to XXXVII

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Part II contains pages 47 to 118 and Charts IX to XXII
Part III contains pages 119 to 206 and Charts XXIII to XXXVII

* On this Chart Hoang Ho is wrongly spelt Huang.

† The name Sangpo should have been spelt Tsangpo. The Imperial Gazetteer of India on pages 19 and 27, Vol. I, and on page 499, Vol. IV spells it Tsan-po.

Part	I	contains pages 1 to 46 and Charts	I to VIII
Part	II	contains pages 47 to 118 and Charts	IX to XXII
Part	III	contains pages 119 to 206 and Charts	XXIII to XXXVII

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PART II contains pages 47 to 118 and Charts IX to XXII
PART III contains pages 119 to 206 and Charts XXIII to XXXVII

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PART II contains pages 47 to 118 and Charts IX to XXII
PART III contains pages 119 to 206 and Charts XXIII to XXXVII

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PART II contains pages 47 to 118 and Charts IX to XXII
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PART III contains pages 119 to 206 and Charts XXIII to XXXVII

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PART II contains pages 47 to 118 and Charts IX to XXII
PART III contains pages 119 to 206 and Charts XXIII to XXXVII

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Part II contains pages 47 to 118 and Charts IX to XXII
Part III contains pages 119 to 206 and Charts XXIII to XXXVII

* The picture of Nanga Parbat peak will be found facing p. 39 of Part I.
† This name should have been spelt Ngari Khorsum (H. H. Hayden).

PART I	contains pages 1 to 46 and Charts	I to VIII
PART II	contains pages 47 to 118 and Charts	IX to XXII
PART III	contains pages 119 to 206 and Charts	XXIII to XXXVII

* The picture of Nojli Tower will be found facing p. 30 of Part I.

PART I contains pages 1 to 46 and Charts I to VIII
PART II contains pages 47 to 118 and Charts IX to XXII
PART III contains pages 119 to 206 and Charts XXIII to XXXVII

PART I	contains pages 1 to 46	and Charts	I to VIII
PART II	contains pages 47 to 118	and Charts	IX to XXII
PART III	contains pages 119 to 206	and Charts	XXIII to XXXVII

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† Shigatze, spelt thus on the map of the Imperial Gazetteer, is written Shi-ga-tse by Captain O'Connor and Shigatse on page 119, Vol. IV of the Imperial Gazetteer.

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PART III contains pages 119 to 206 and Charts XXIII to XXXVII

* Zaskar is the form of spelling adopted in the Imperial Gazetteer. Mr. Hayden writes "Ladakhis pronounce the "name Zangskar, Central Tibetans pronounce it Zangkar, Kashmiris pronounce it Zaskar."

CHART XXIII

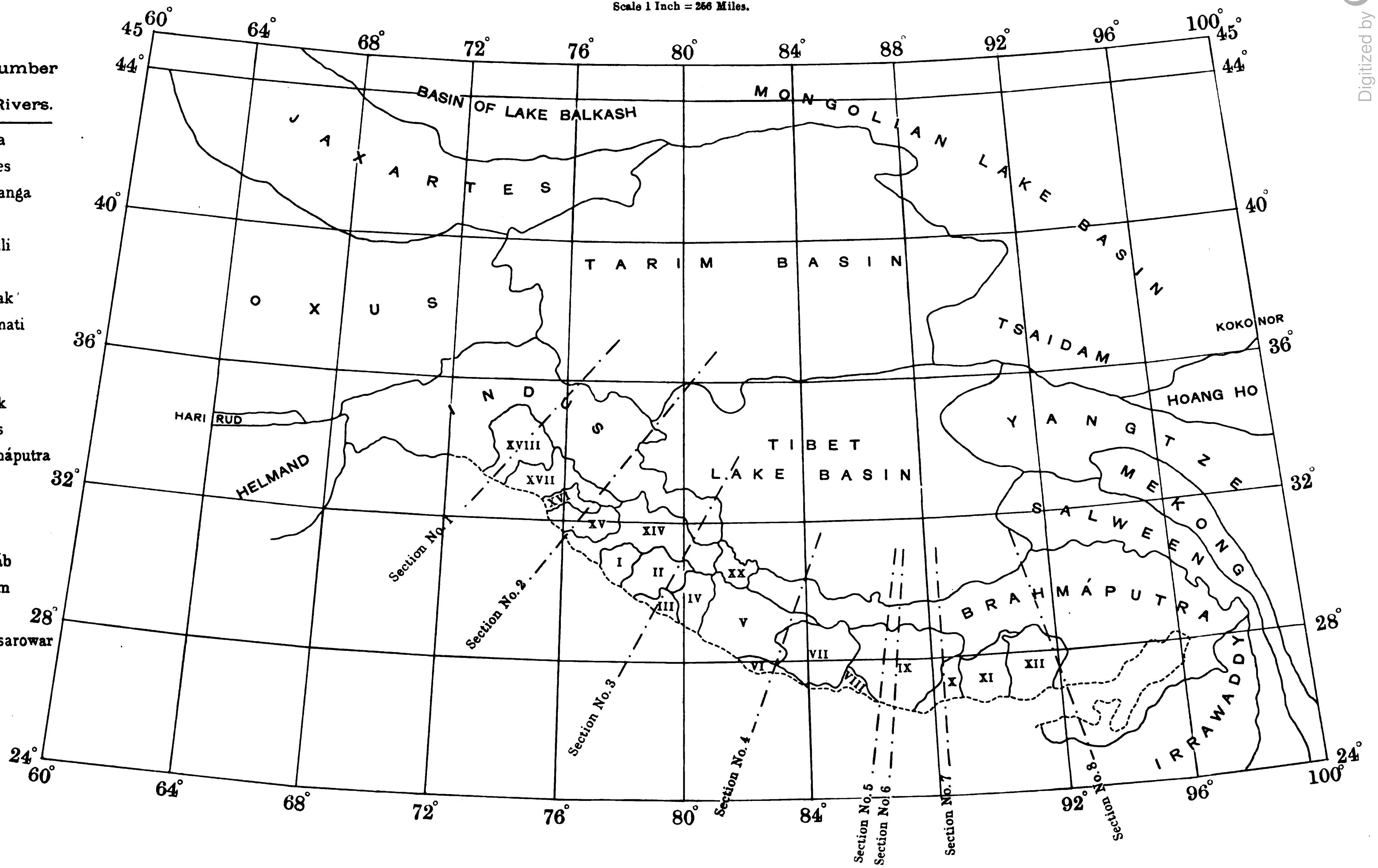
INDEX CHART

showing CATCHMENT AREAS of the HIMALAYAN and TRANS-HIMALAYAN RIVERS and LAKES.

Scale 1 Inch = 256 Miles.

Reference Number to Himalayan Rivers.

I	Jumna
II	Ganges
III	Rámganga
IV	Káli
V	Karnáli
VI	Rápti
VII	Gandak
VIII	Báģhmati
IX	Kosi
X	Tista
XI	Ráidak
XII	Manás
XIII	Brahmáputra
XIV	Sutlej
XV	Beás
XVI	Rávi
XVII	Chenáb
XVIII	Jhelum
XIX	Indus
XX	Manásarowar



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XIX	Indus
XX	Manásarowar

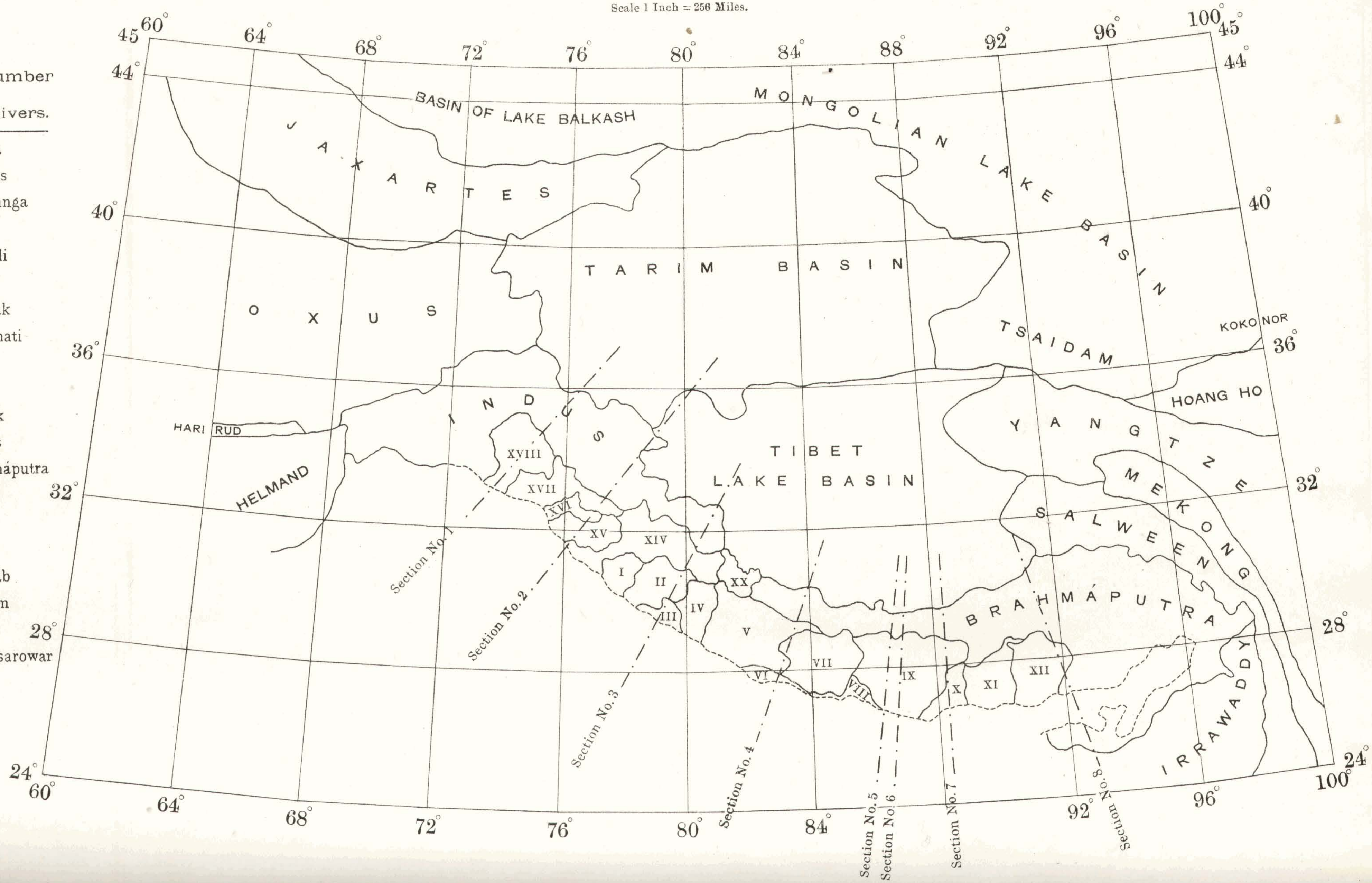
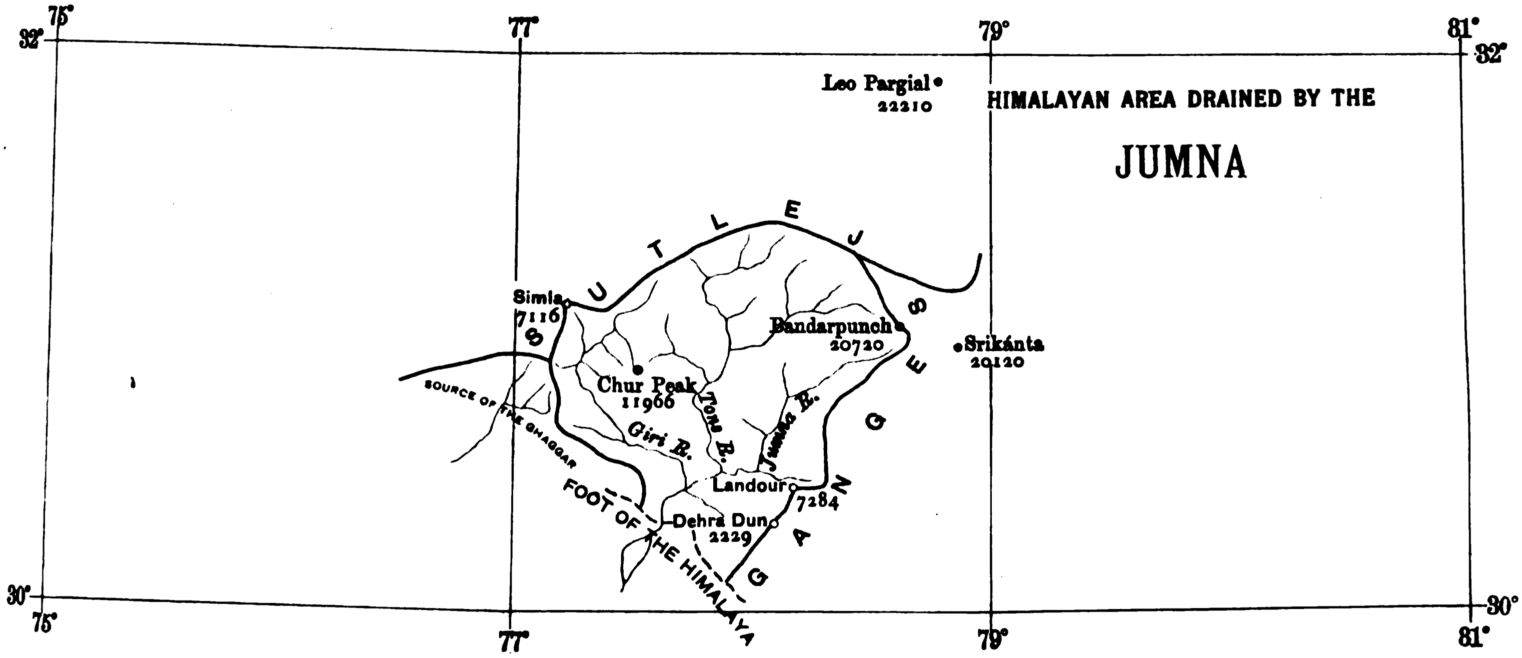


CHART XXIV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Bandarpunch
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Simla
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Chur Peak
11966
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Tons R.
Jumna R.
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SUTLEJ
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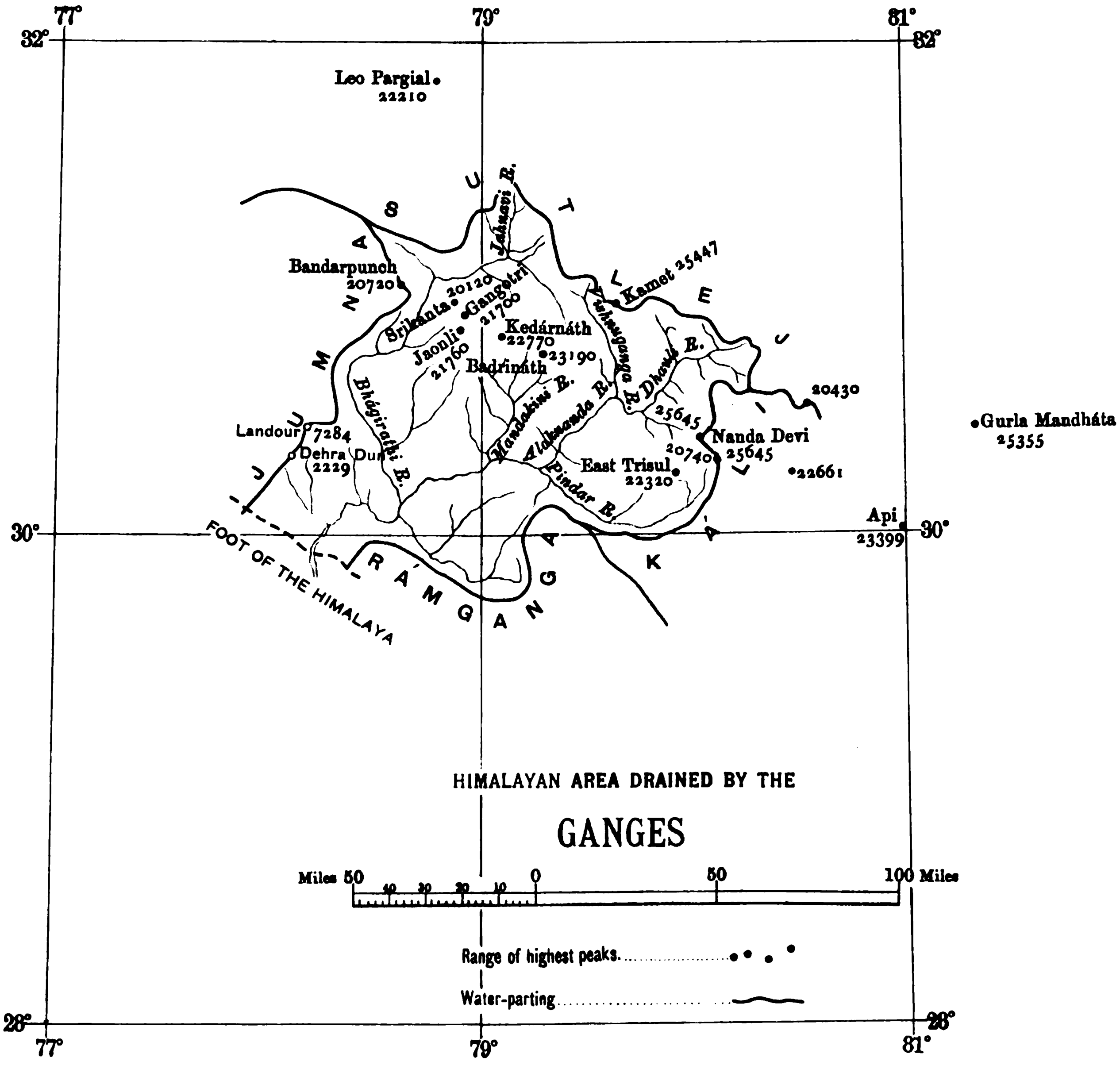
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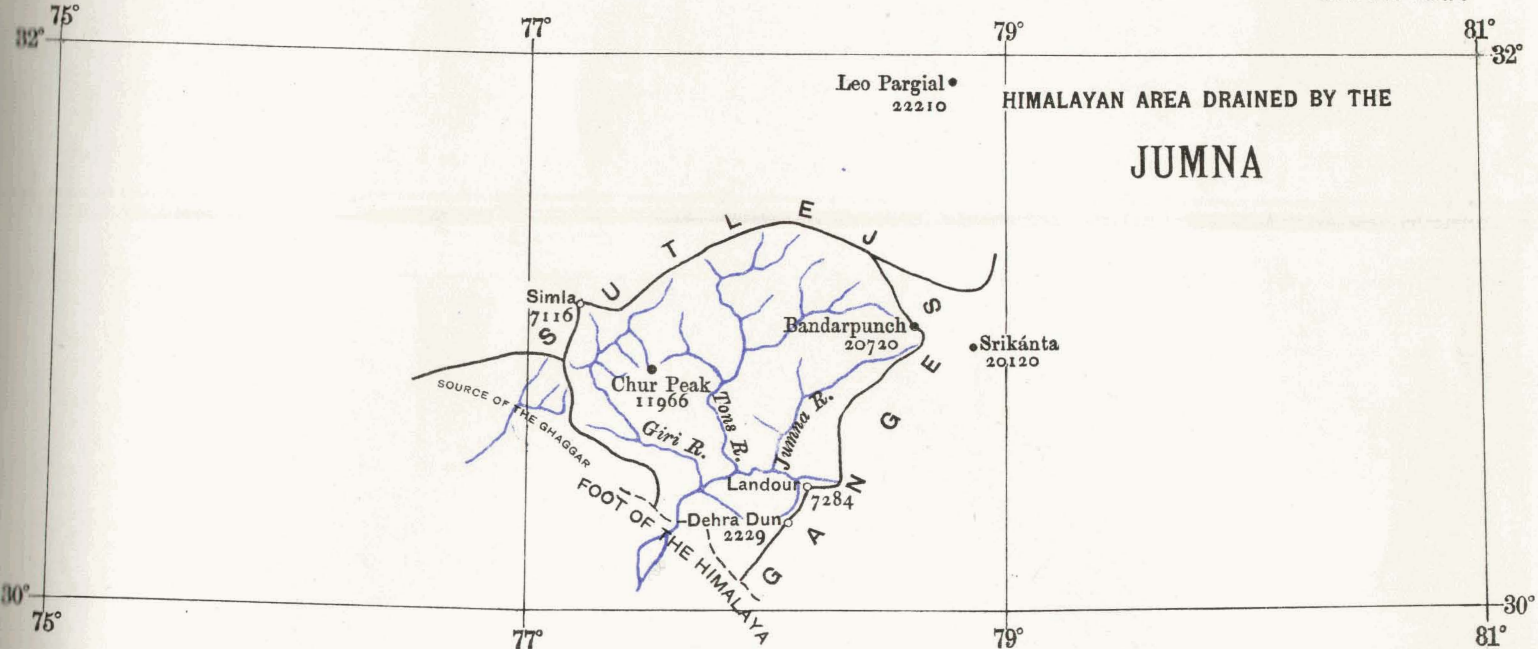
Water-parting

CHART XXIV



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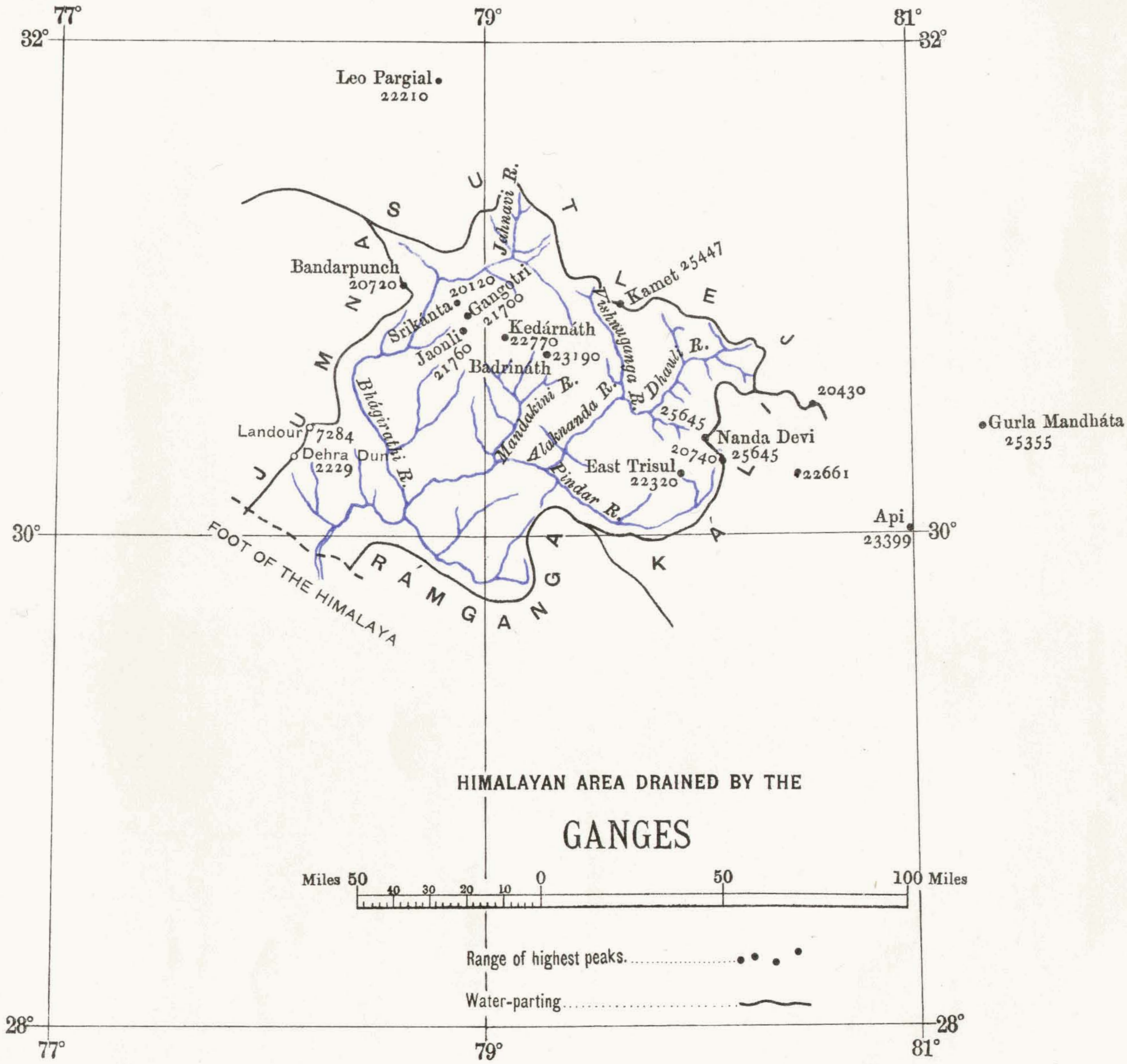
SOURCE OF THE GHAGGAR
FOOT OF THE HIMALAYA



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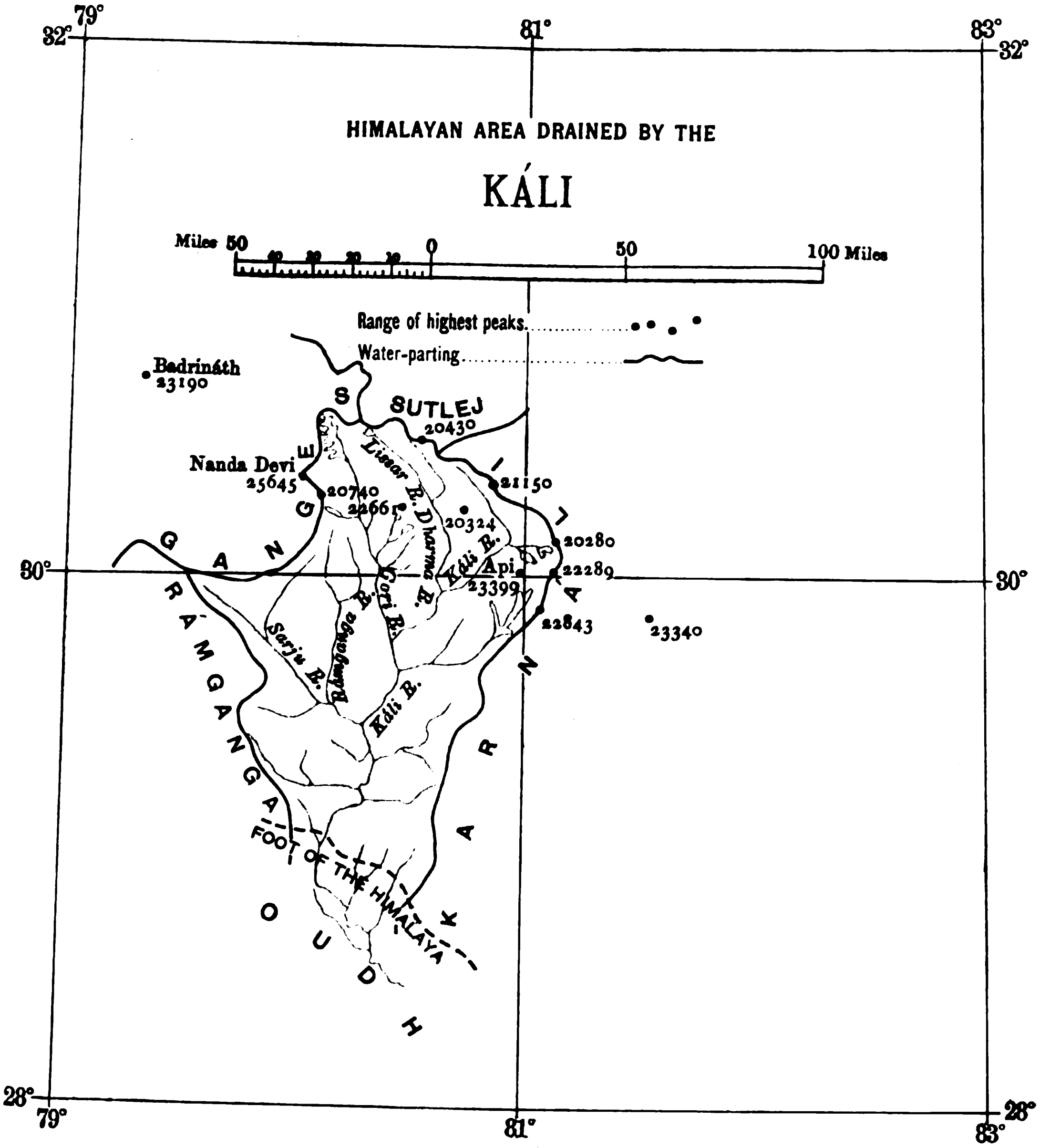
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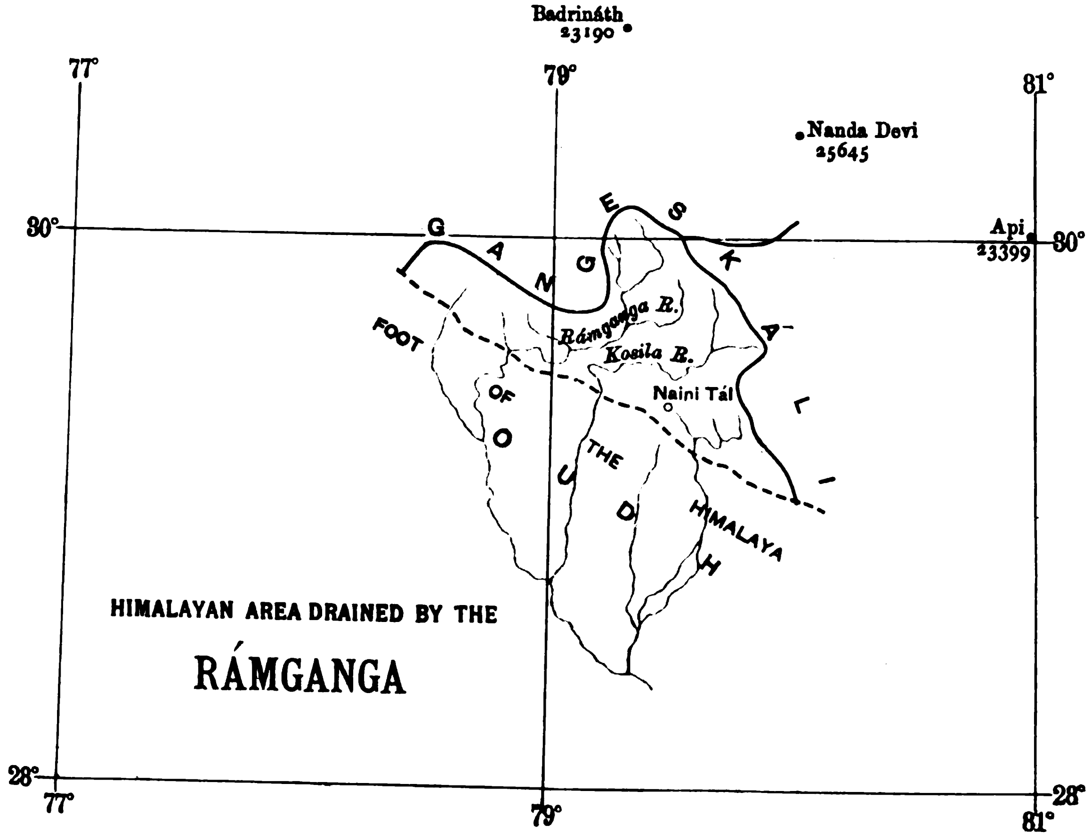
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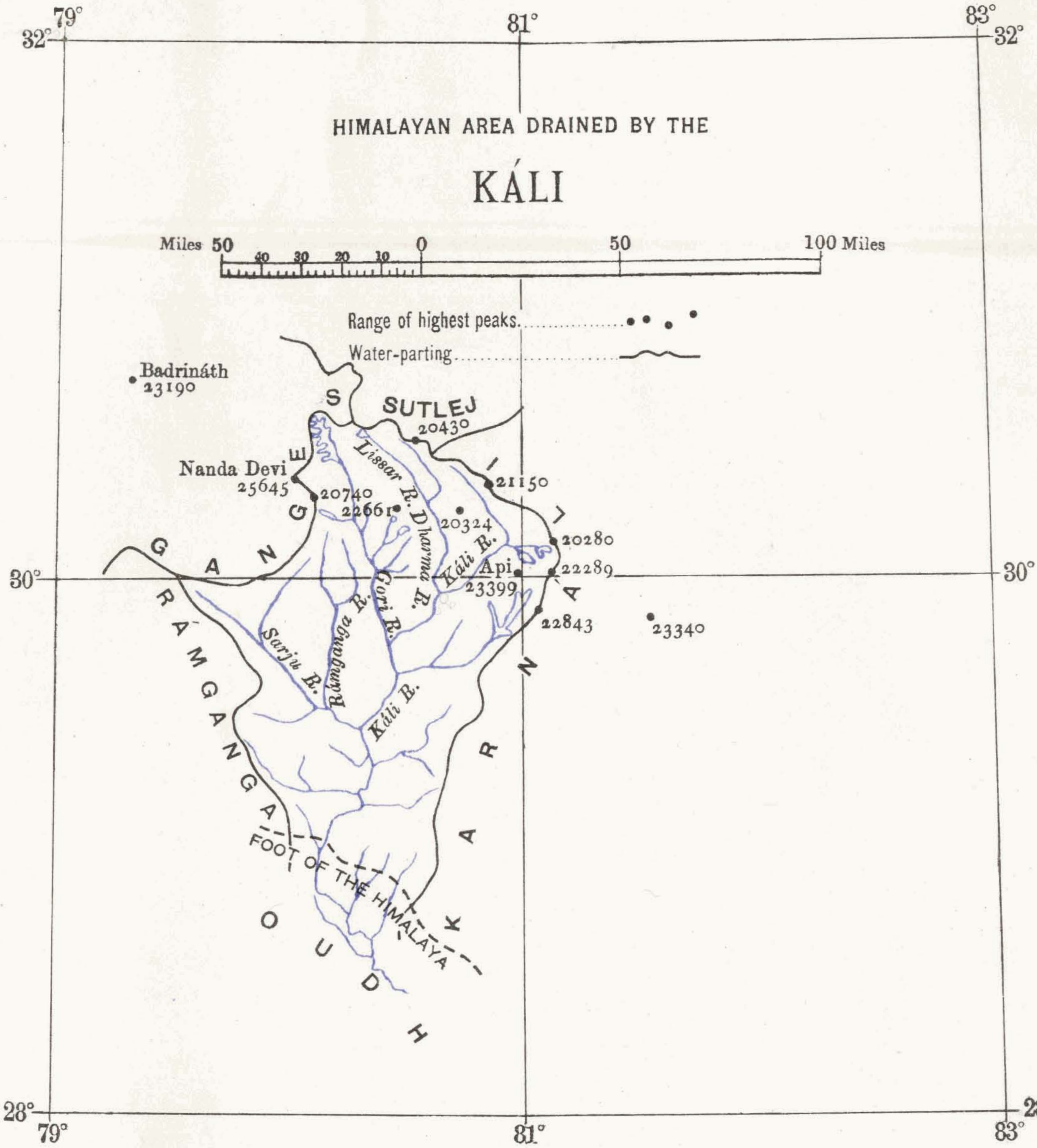
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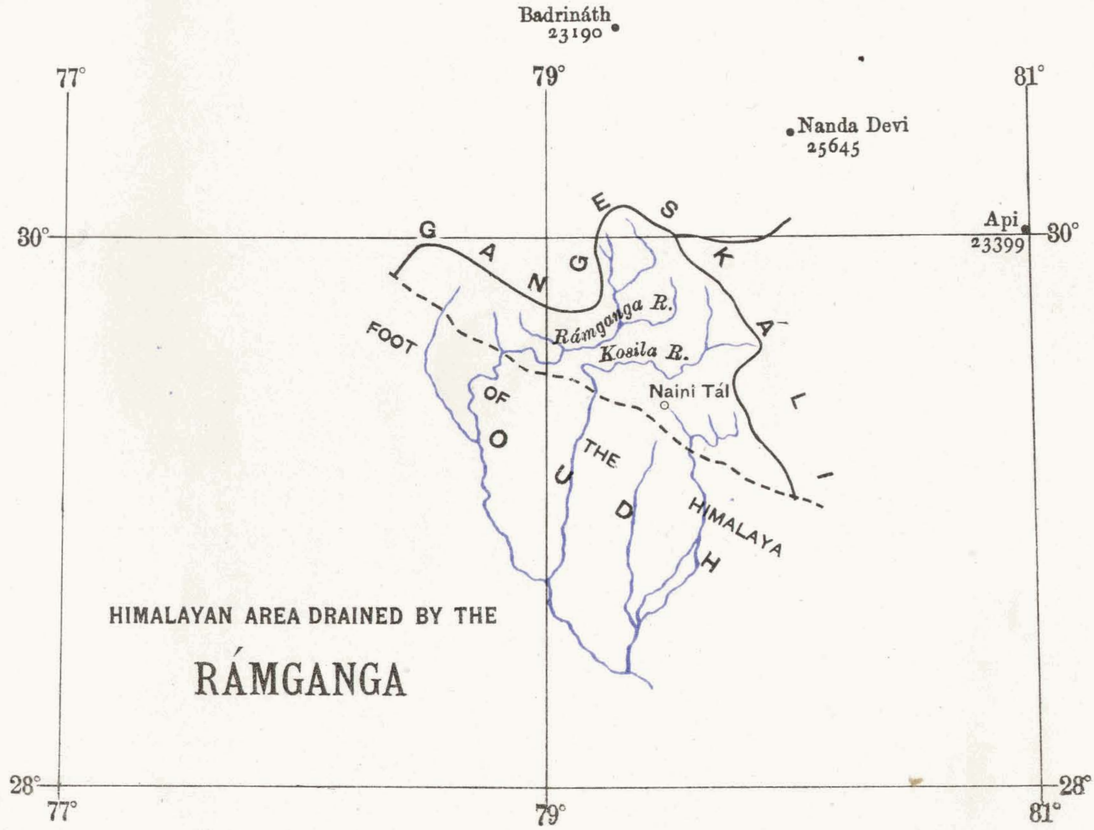
KARNALI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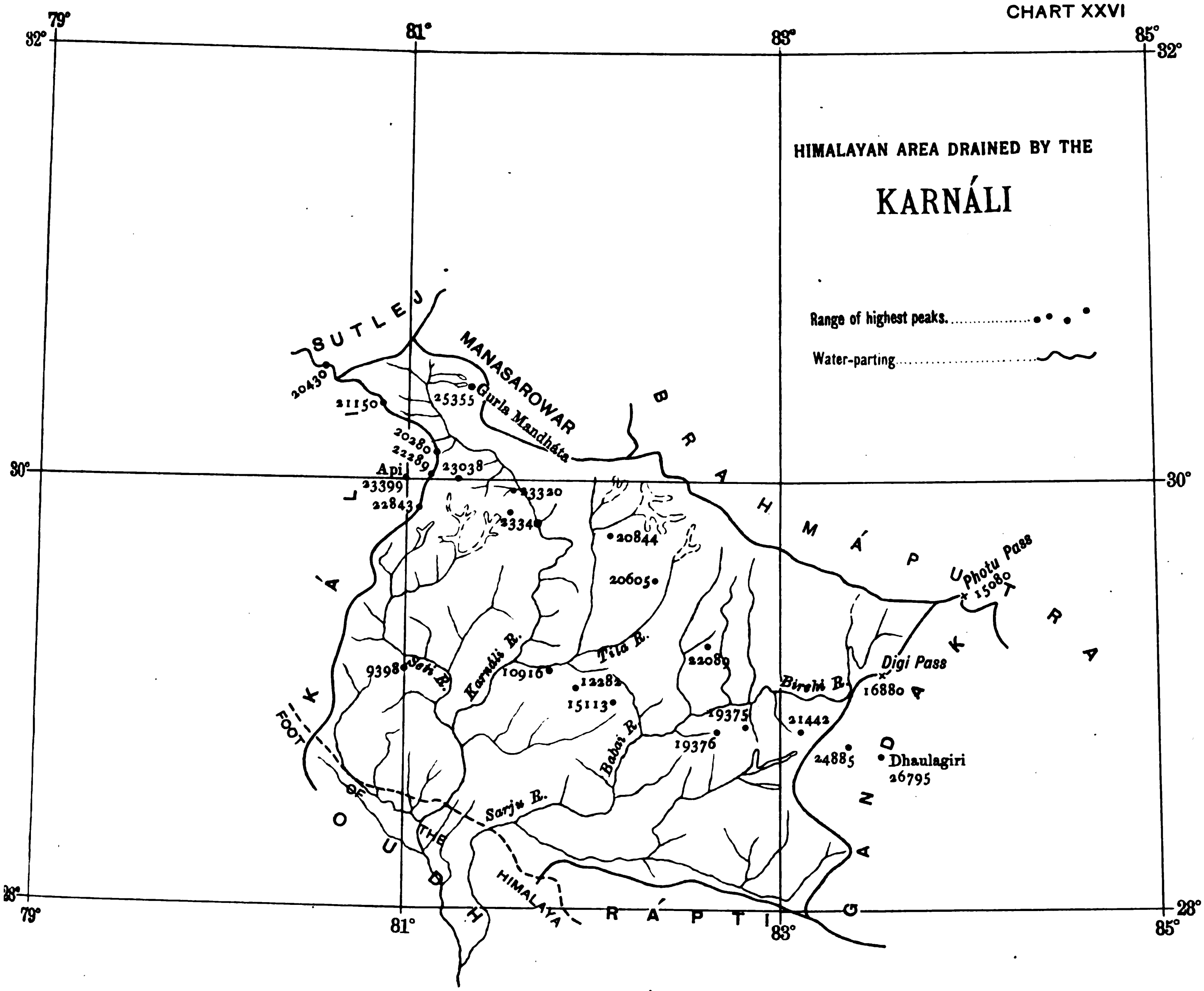
79°
81°
30°
28°
GANGES
KÁLI
Rámganga R.
Kosila R.
Naini Tál
FOOT OF THE HIMALAYA
OUDH
HIMALAYAN AREA DRAINED BY THE
RÁMGANGA


HIMALAYAN AREA DRAINED BY THE
KARNÁLI
Range of highest peaks
Water-parting
SUTLEJ
MANASAROWAR
BRAHMÁPUTRA
KÁLI
GANDAK
FOOT OF THE HIMALAYA
OUDH
RÁPTI
Gurla Mandháta
25355
20430
21150
20280
22289
23038
Api
23399
22843
23320
23340
20844
20605
Photu Pass
15080
Digi Pass
16880
Karnáli R.
Tila R.
Seti R.
Birehi R.
Babai R.
Sarju R.
9398
10916
12282
15113
22089
19375
19376
21442
24885
Dhaulagiri
26795

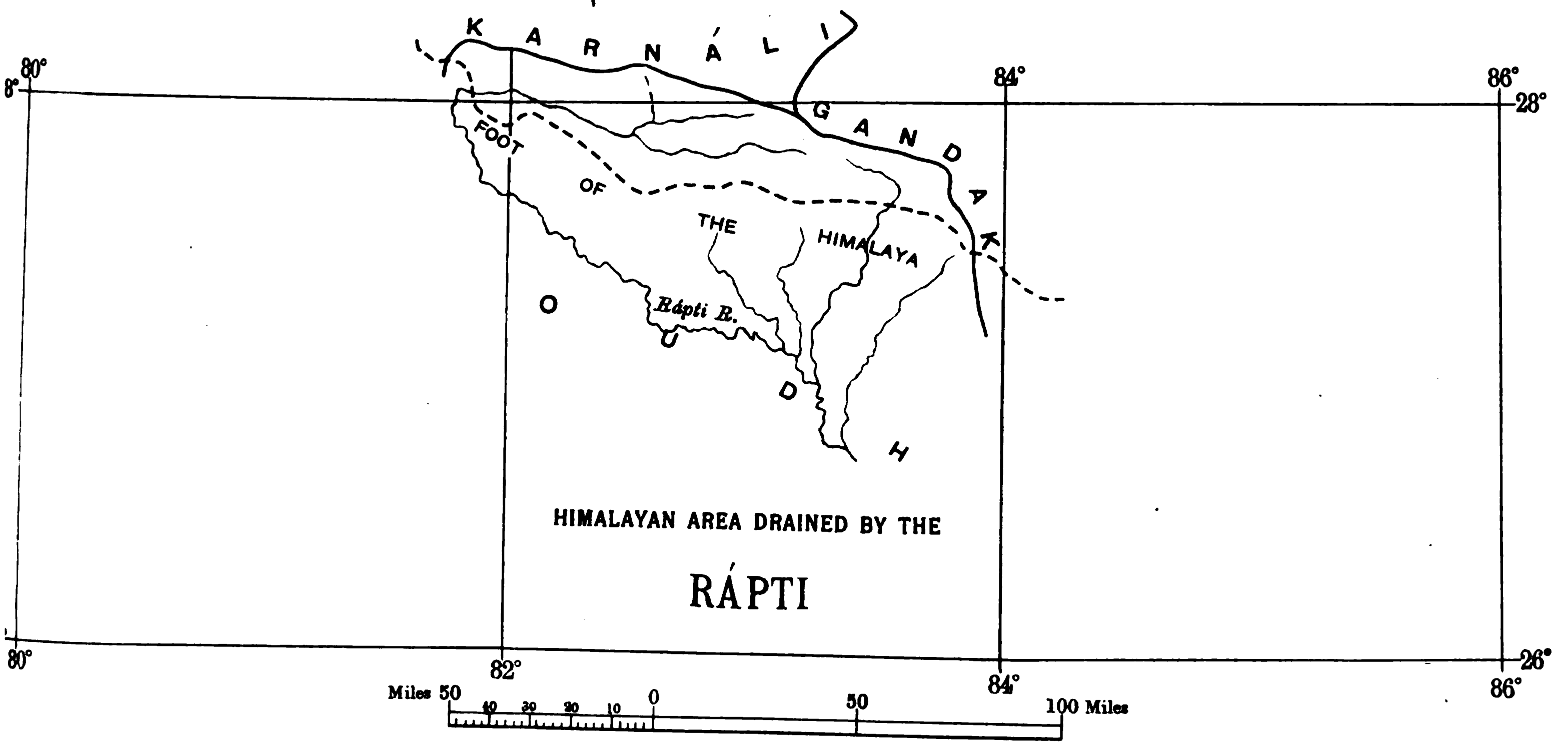

KARNÁLI
GANDAK
FOOT OF THE HIMALAYA
OUDH
Rápti R.
HIMALAYAN AREA DRAINED BY THE
RÁPTI
Miles 50 40 30 20 10 0 50 100 Miles

CHART XXVI

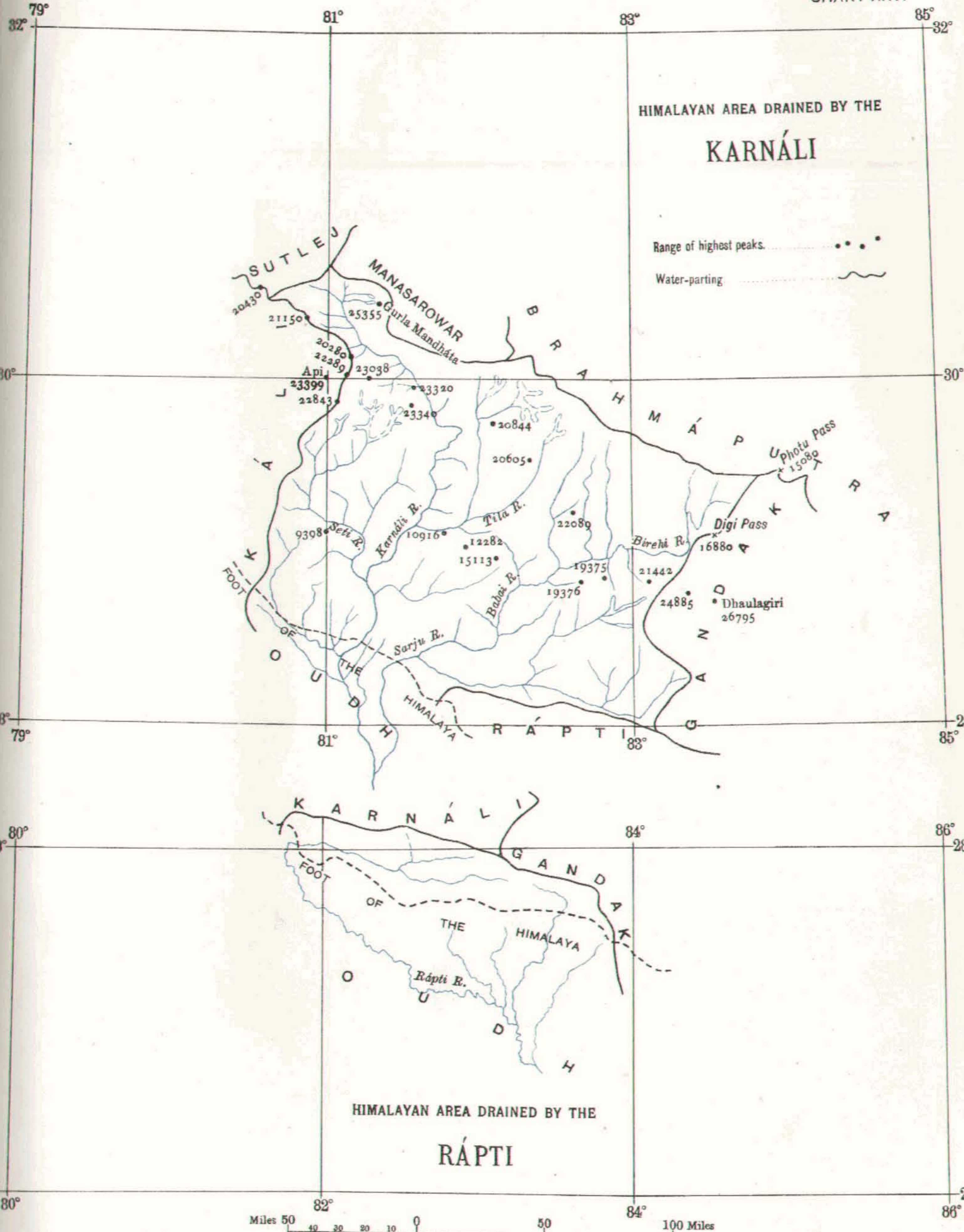
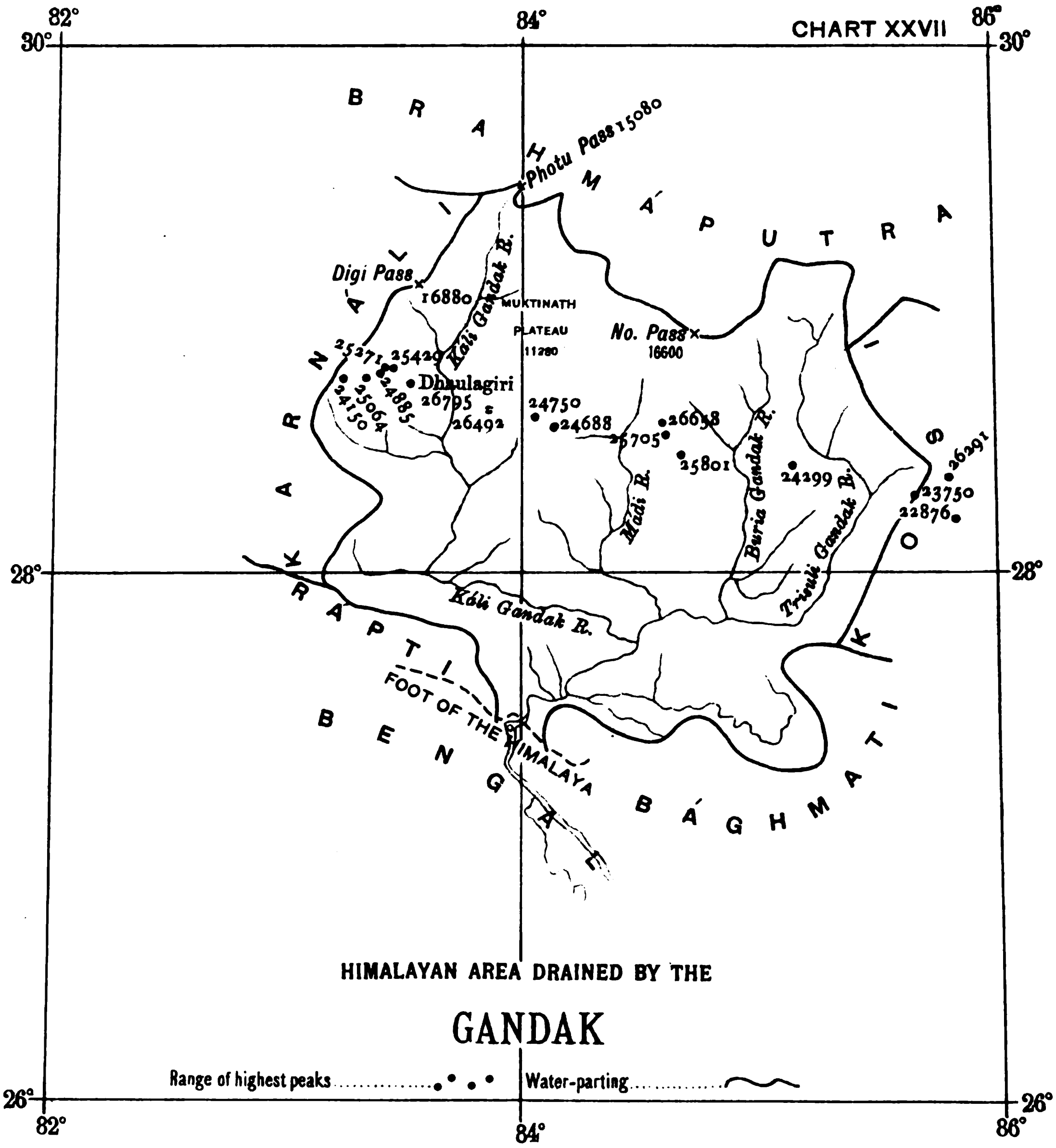
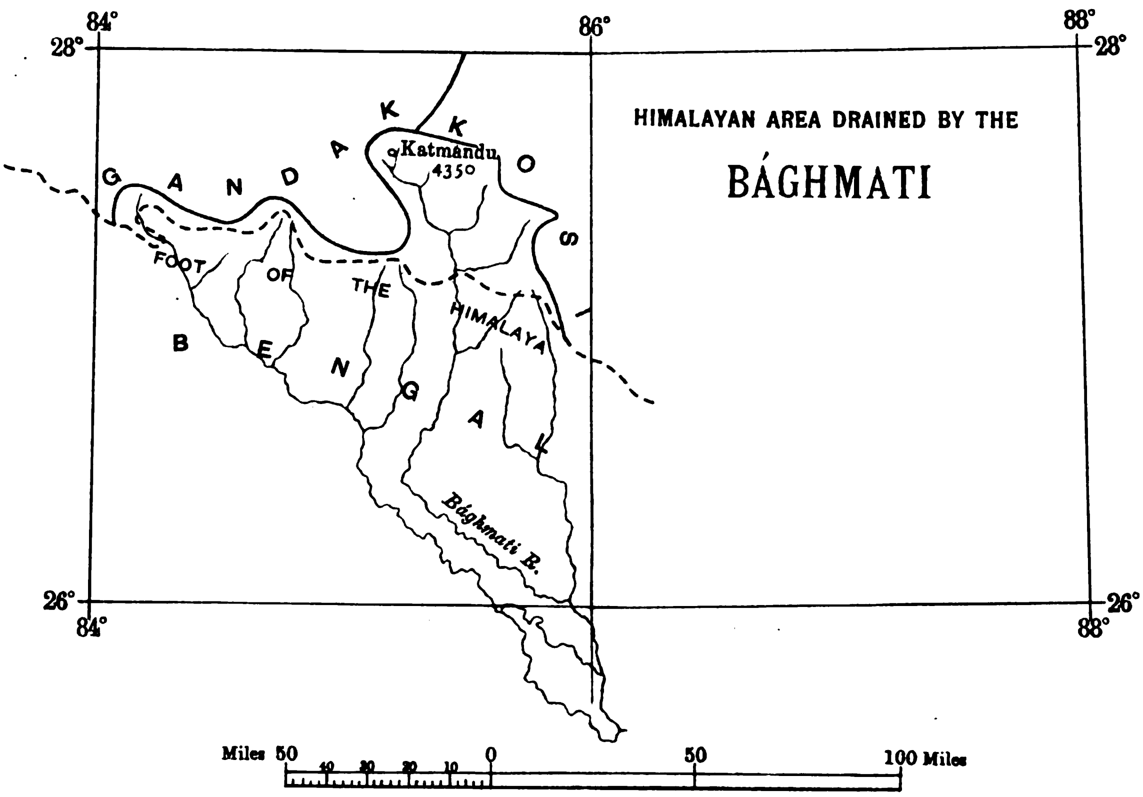
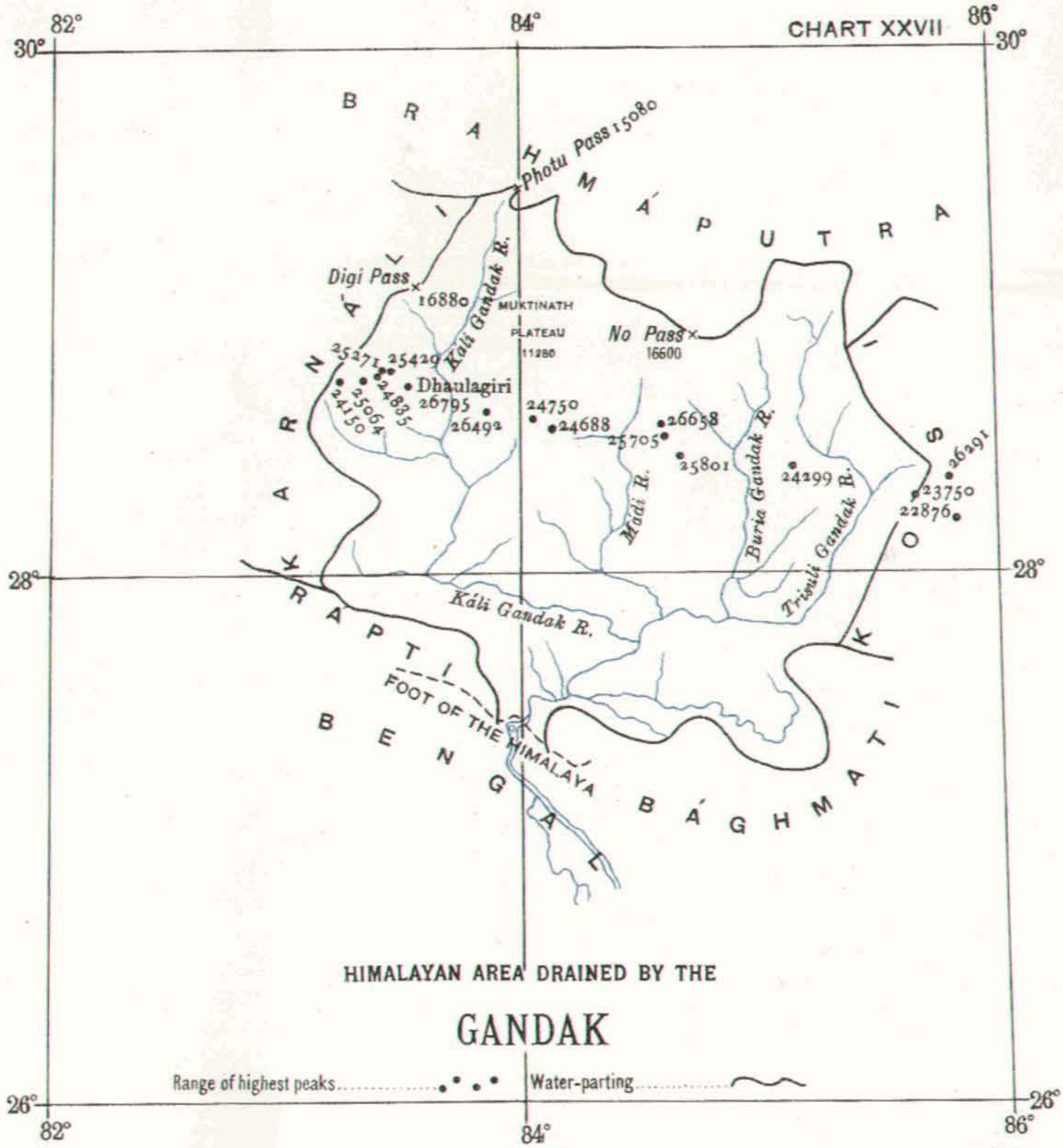

HIMALAYAN AREA DRAINED BY THE
KARNÁLI
Range of highest peaks
Water-parting
SUTLEJ
MANASAROWAR
BRAHMÁPUTRA
Gurla Mandháta
25355
20430
21150
20280
22289
Api
23399
22843
23038
23320
23340
20844
20605
22089
Photu Pass
15080
Digi Pass
16880
Tila R.
Karnáli R.
Seti R.
9308
10916
12282
15113
19375
19376
21442
24885
Dhaulagiri
26795
Birehi R.
Baboi R.
Sarju R.
KÁLI
FOOT OF THE HIMALAYA
OUDH
RÁPTI
GANDAK
KARNÁLI
Rápti R.
HIMALAYAN AREA DRAINED BY THE
RÁPTI
79°
81°
83°
85°
32°
30°
28°
80°
82°
84°
86°
26°
Miles 50
40
30
20
10
0
50
100 Miles

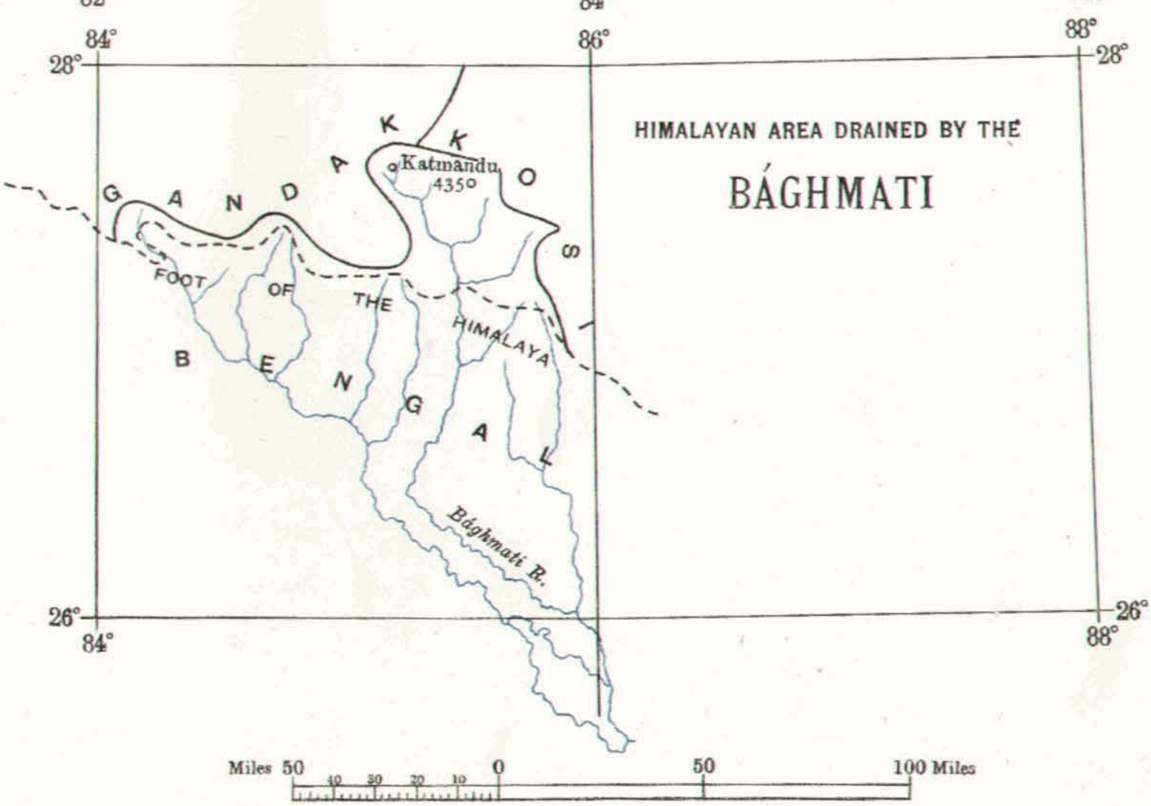
CHART XXVII


HIMALAYAN AREA DRAINED BY THE
GANDAK
Range of highest peaks
Water-parting
BRAHMAPUTRA
KARNALI
RAPTI
KOSI
BENGAL
BÁGHMATI
Photu Pass 15080
Digi Pass
16880
MUKTINATH
PLATEAU
11280
No. Pass
16600
Dhaulagiri
26795
26492
25371
25429
24885
25064
24150
24750
24688
26658
25705
25801
24299
26291
23750
22876
Kali Gandak R.
Madi R.
Buria Gandak R.
Trisuli Gandak R.
FOOT OF THE HIMALAYA
82°
84°
86°
30°
28°
26°

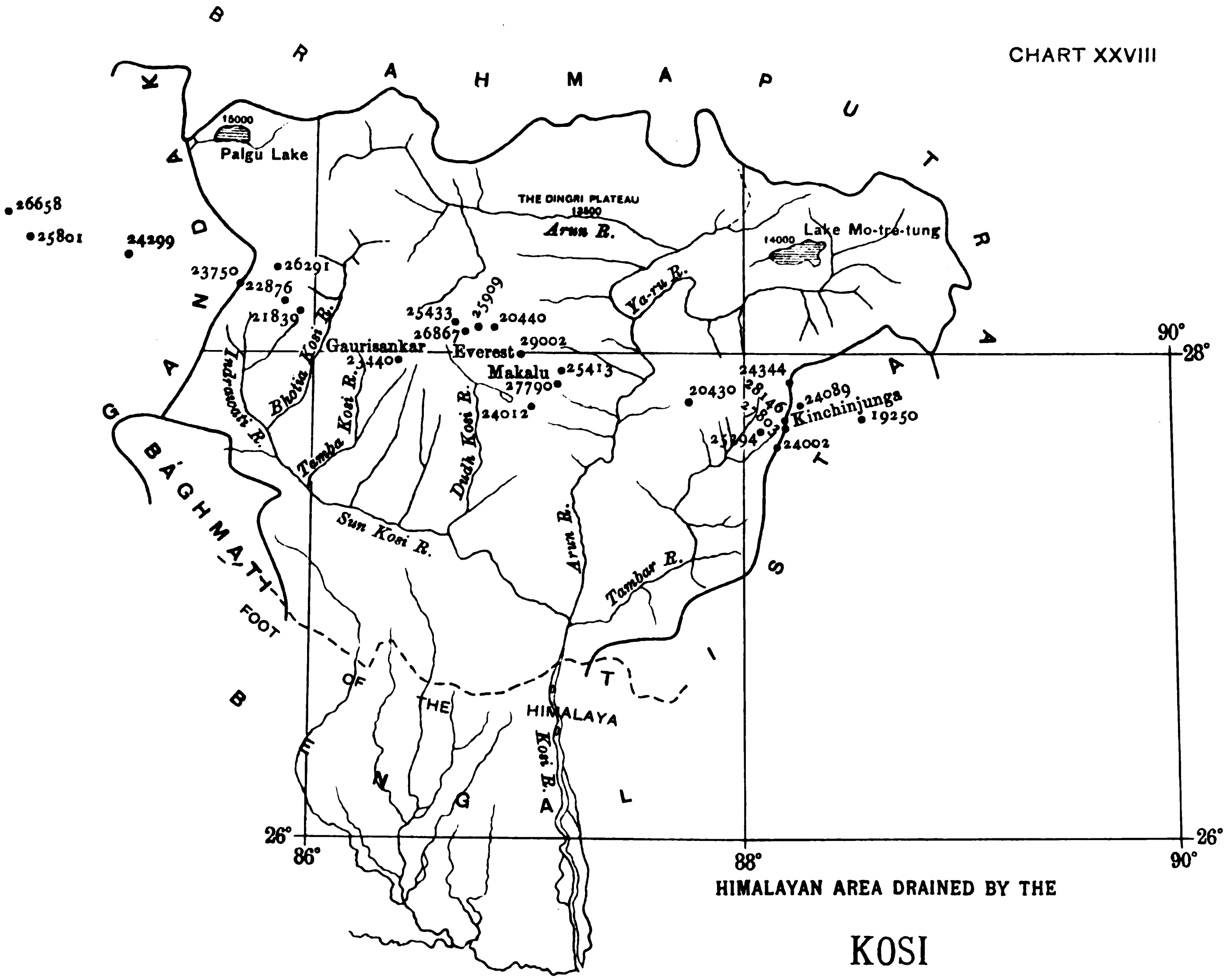

HIMALAYAN AREA DRAINED BY THE
BÁGHMATI
GANDAK
KOSI
BENGAL
Katmandu
4350
FOOT OF THE HIMALAYA
Bághmati R.
84°
86°
88°
28°
26°
Miles 50
40
30
20
10
0
50
100 Miles



82°
84°
86°
30°
28°
26°
B R A H M A P U T R A
K A R N A L I
R A P T I
B E N G A L
B A G H M A T I
K O S I
Photu Pass 15080
Digi Pass
16880
Kali Gandak R.
MUKTINATH
PLATEAU
11280
No Pass
16600
25271
25429
Dhaulagiri
26795
24835
25064
24150
26492
24750
24688
26658
25705
25801
24299
26291
23750
22876
Madi R.
Buria Gandak R.
Trisuli Gandak R.
Kali Gandak R.
FOOT OF THE HIMALAYA
HIMALAYAN AREA DRAINED BY THE
GANDAK
Range of highest peaks
Water-parting

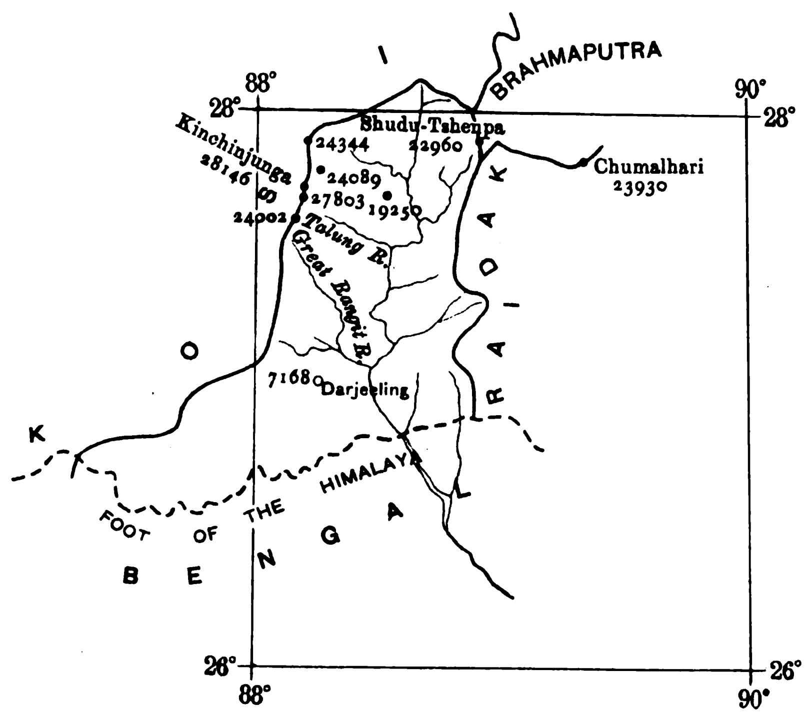


84°
86°
88°
28°
26°
G A N D A K
K O S I
B E N G A L
Katmandu
4350
FOOT OF THE HIMALAYA
Baghmati R.
HIMALAYAN AREA DRAINED BY THE
BÁGHMATI
Miles 50 40 30 20 10 0 50 100 Miles



HIMALAYAN AREA DRAINED BY THE

KOSI



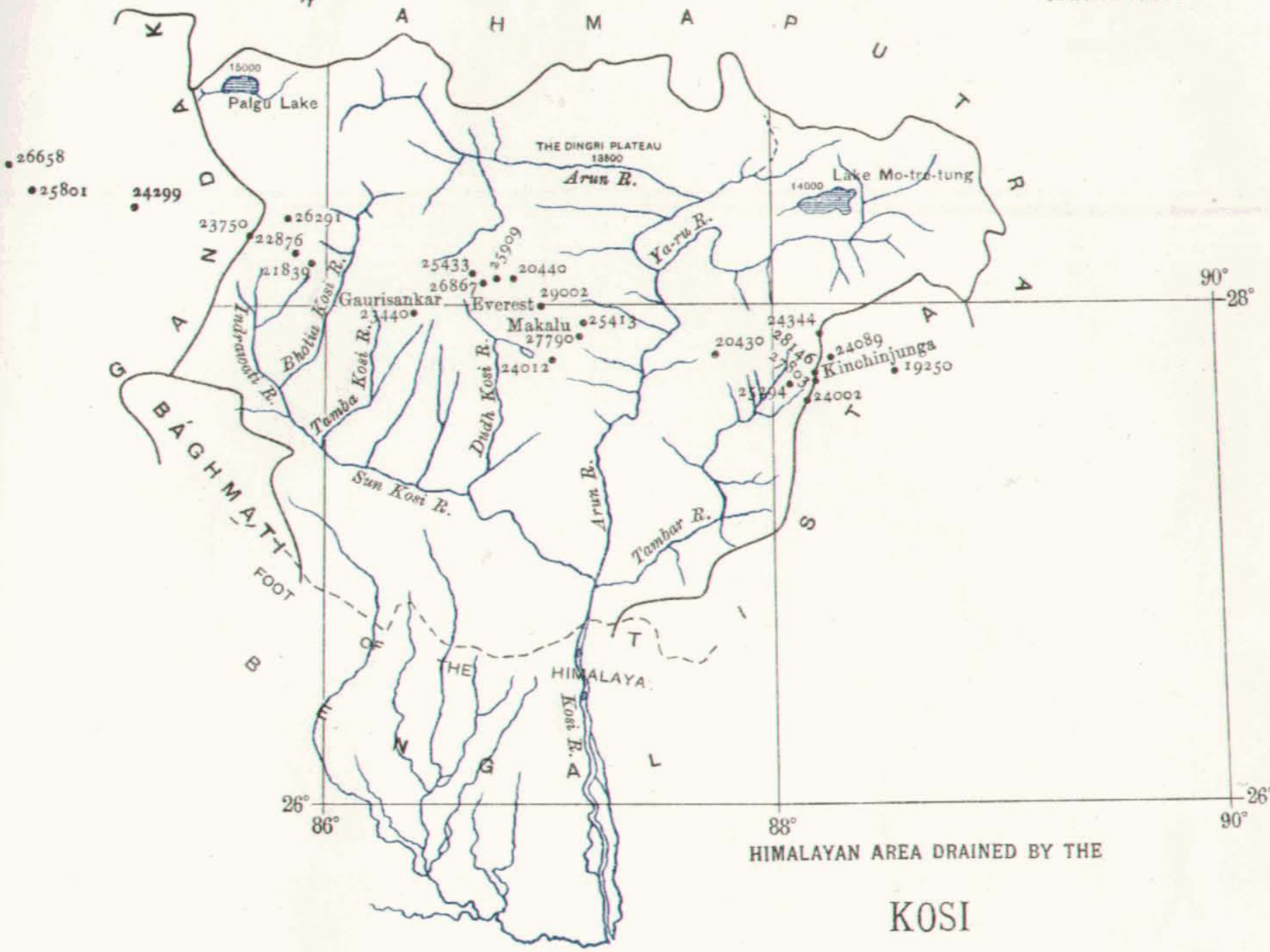
HIMALAYAN AREA DRAINED BY THE

TISTA

Miles 50 40 30 20 10 0 50 100 Miles

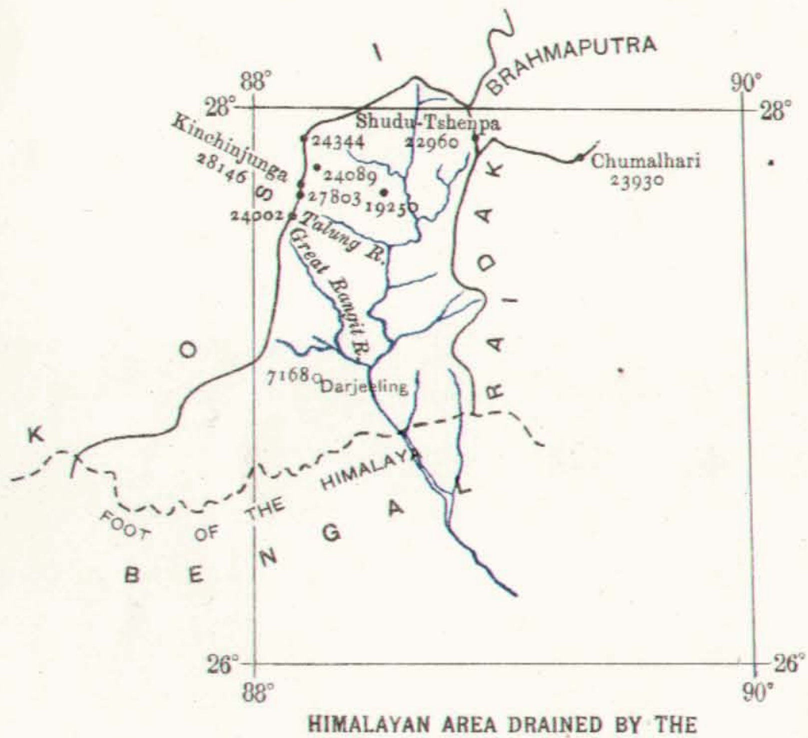
Range of highest peaks . . . . Water-parting . . . .

CHART XXVIII



HIMALAYAN AREA DRAINED BY THE

KOSI



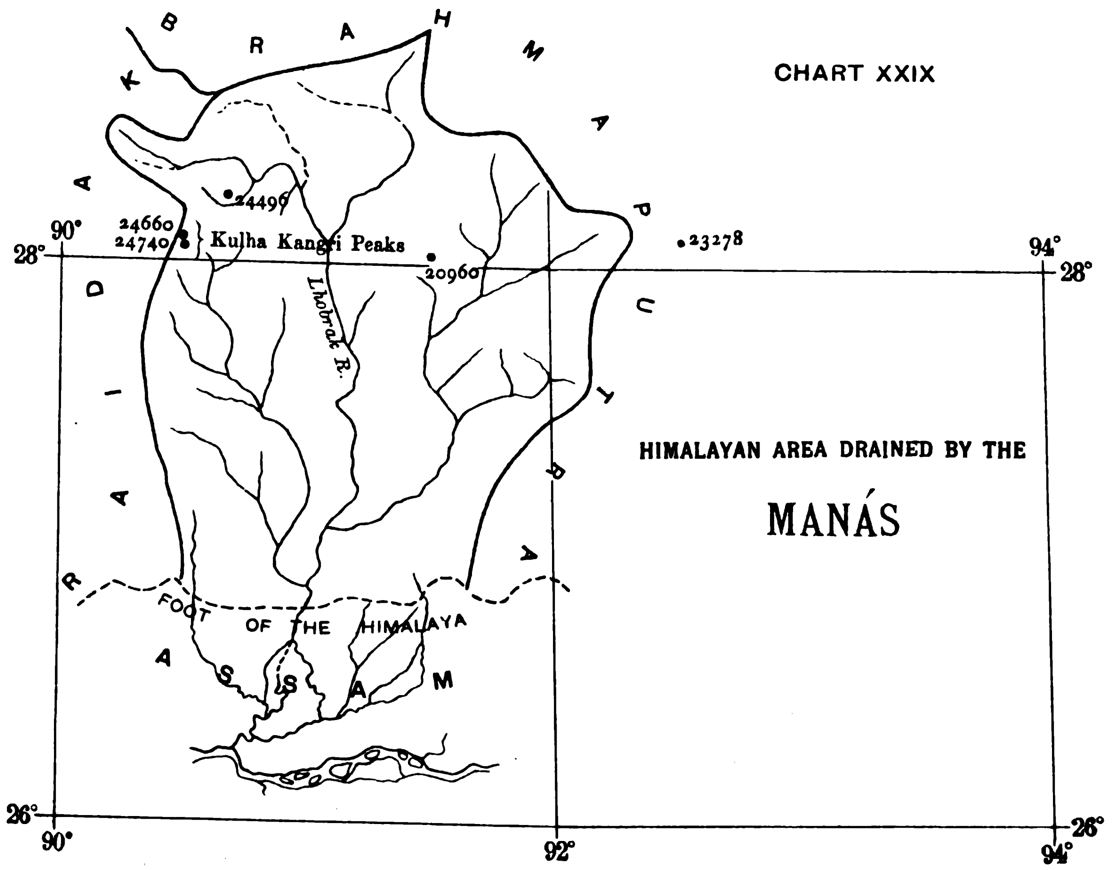
HIMALAYAN AREA DRAINED BY THE

TISTA

Miles 50 40 30 20 10 0 50 100 Miles

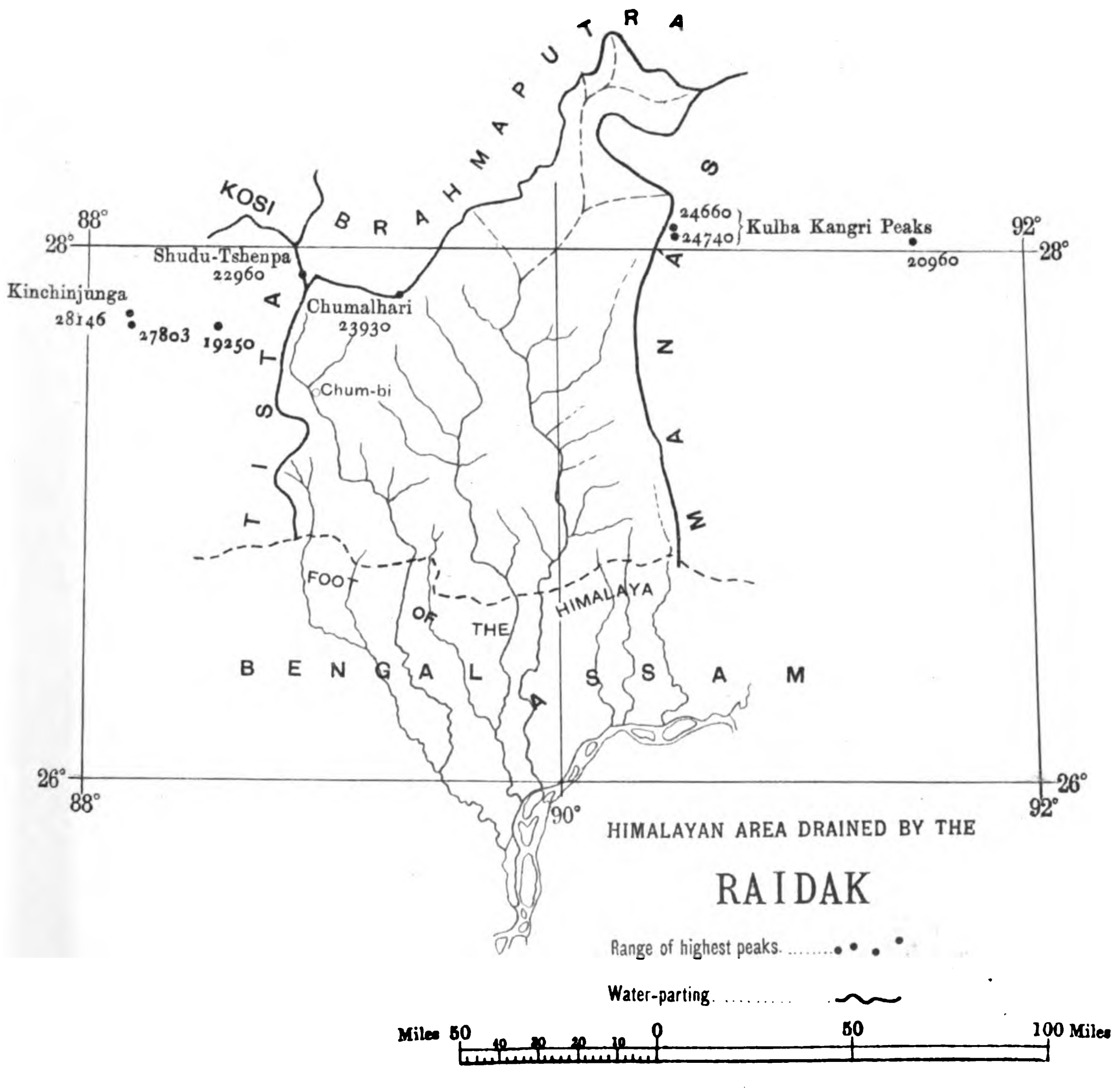
Range of highest peaks . . . . Water-parting . . . .

CHART XXIX



HIMALAYAN AREA DRAINED BY THE

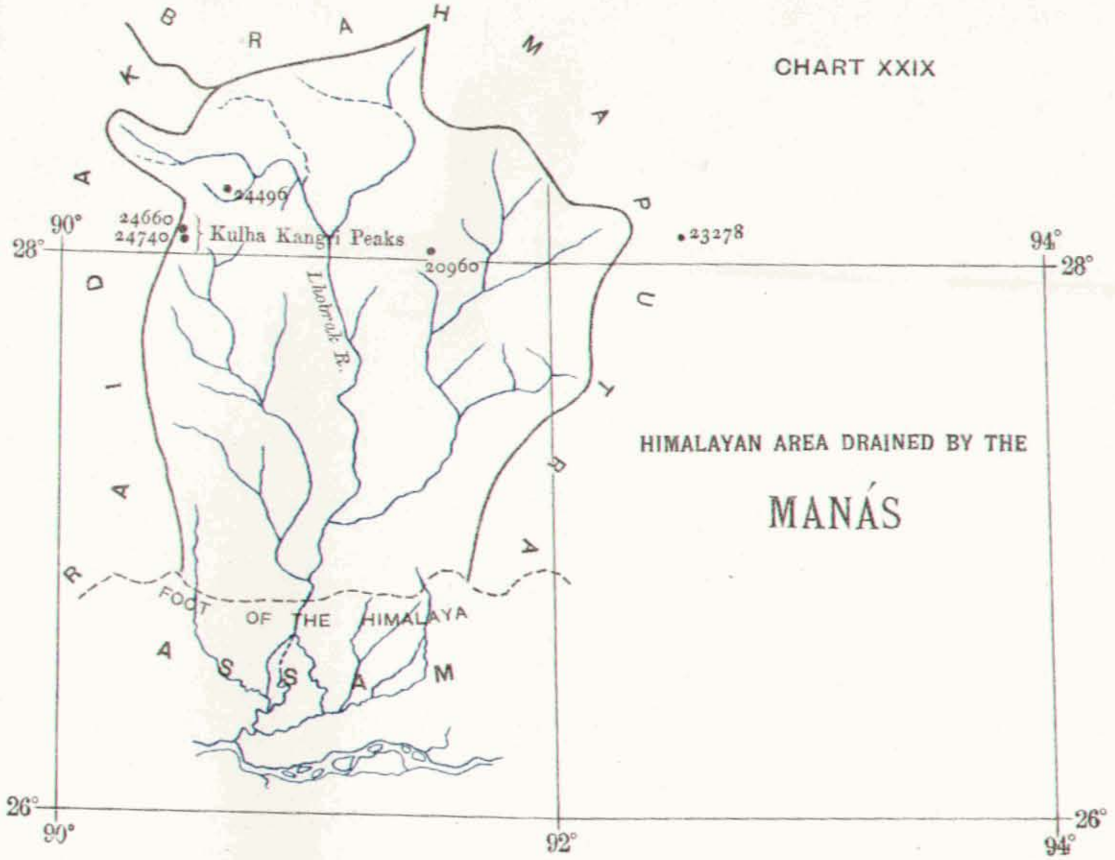
MANÁS



HIMALAYAN AREA DRAINED BY THE

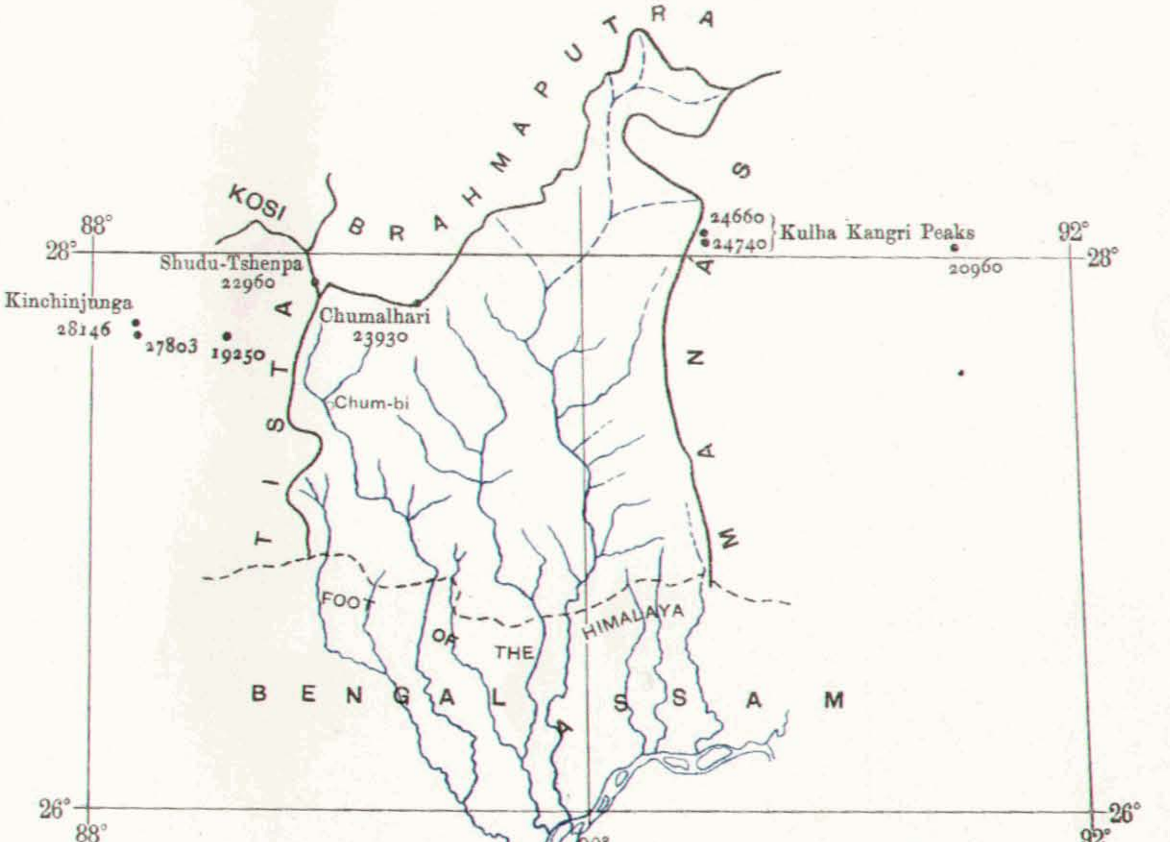
RAIDAK

CHART XXIX



HIMALAYAN AREA DRAINED BY THE

MANÁS



HIMALAYAN AREA DRAINED BY THE

RAIDAK

CHART XXX

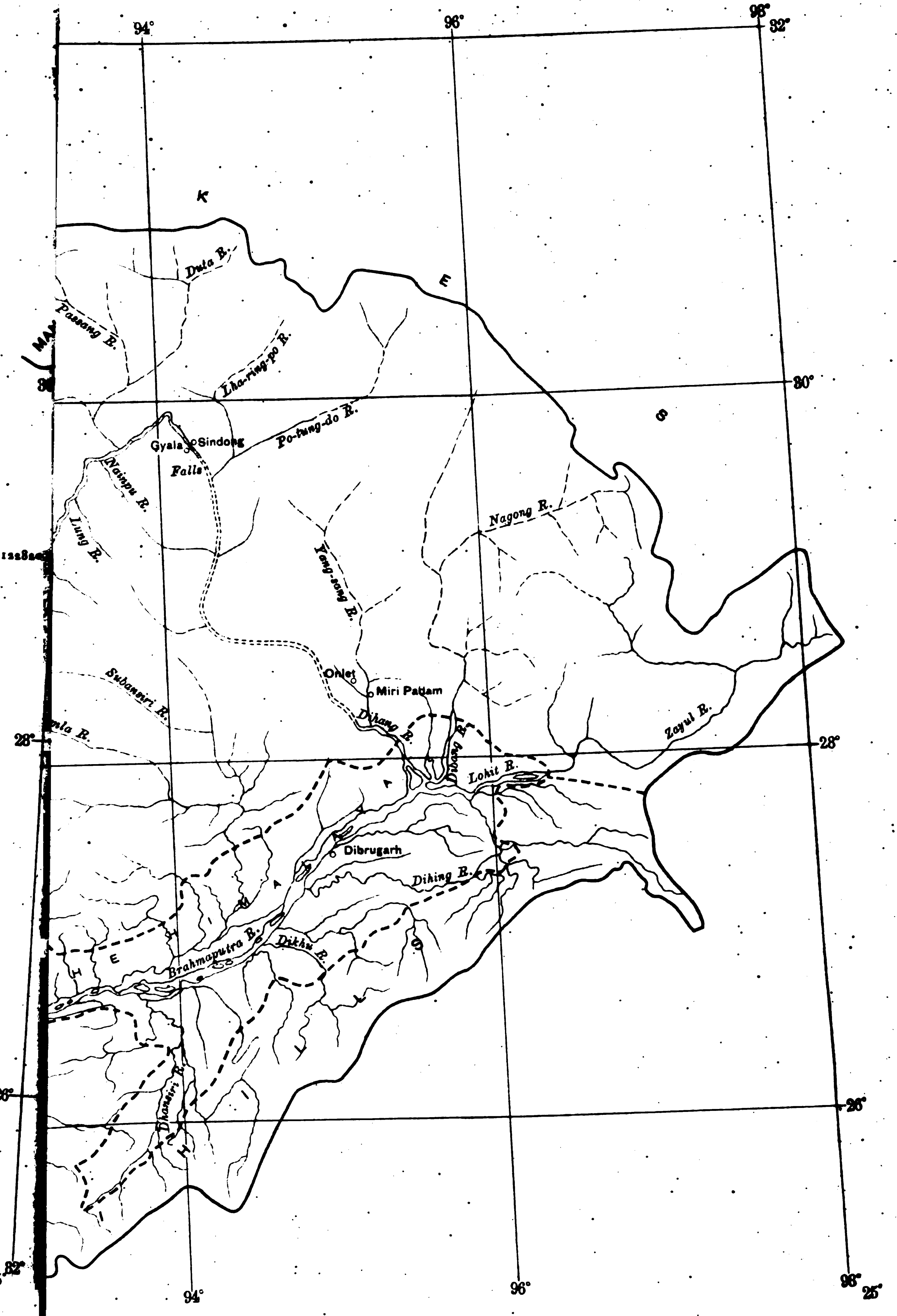

94°
96°
98°
32°
30°
28°
26°
25°
K
E
S
Duta R.
Passang R.
Lha-ring-po R.
Po-tung-do R.
Gyala
Sindong
Falls
Naimpu R.
Lung R.
Nagong R.
Yang-sang R.
Subansiri R.
Onlet
Miri Padam
Dihang R.
Dibang R.
Lohit R.
Zayul R.
Dibrugarh
Dihing R.
Brahmaputra R.
Dikhu R.
Dhansiri R.

CHART XXX


HIMALAYAN AREA DRAINED BY THE
BRAHMAPUTRA.
Miles 50 40 30 20 10 0 50 100 Miles
Range of highest peaks
Water-parting
TIBET
LAKES
MANASAROWAR
KARNALI
GANDAK
KOSI
TISTA
RAIDAK
MANAS
FOOT OF THE HIMALAYAS
THE HILLS
KHASI
ASSAM
Photu Pass 15080
Dhaulagiri 26795
Gaurisankar 23440
Everest 29002
Makalu 27790
Kinchinjunga 28146
Shudu-Tshenpa 22960
Chumalhari 23930
Brahmaputra R.
Ra-ga R.
Shang R.
Nyang R.
Rong R.
Kyi R.
Lhasa
Yamdrok Lake
Migi R.
Dugong R.
Yala R.
Passang R.
Duta R.
Lha-ring-po R.
Po-tung-do R.
Gyala
Sindong
Falls
Nagong R.
Yang-sang R.
Subansiri R.
Kamla R.
Onlet
Miri Padam
Dihang R.
Dibang R.
Lohit R.
Zayul R.
Dibrugarh
Dihing R.
Dikhu R.
Bhoroli R.
Nali Bor R.
Kalang R.
Dhansiri R.
Shillong
23340
20844
20605
22089
12282
15113
19376
19375
21442
25271
25429
25064
26492
24750
24688
26658
25705
25801
24299
26291
23750
22876
21839
25433
26867
25909
20440
25413
24012
20430
24344
24089
25294
24002
19250
24660
24496
24740
20960
23278
32°
30°
28°
26°
25°
82°
84°
86°
88°
90°
92°
94°
96°
98°

CHART XXXI

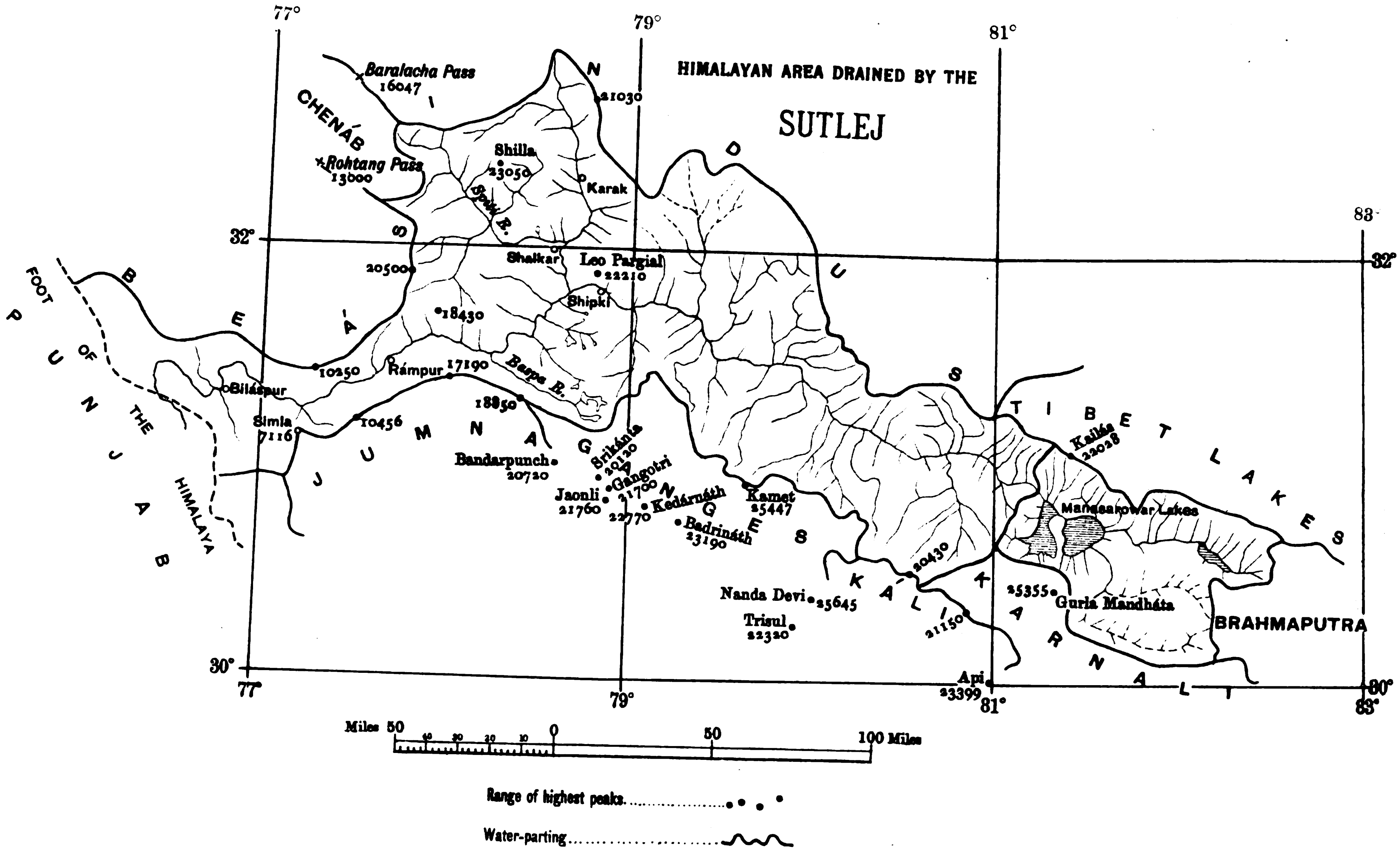

HIMALAYAN AREA DRAINED BY THE
SUTLEJ
Baralacha Pass 16047
CHENÁB
Rohtang Pass 13000
Shilla 23050
Spiti R.
Karak
21030
20500
Shalkar
Leo Pargial 22210
Shipki
18430
10250
Rámpur 17190
Baspa R.
Biláspur
Simla 7116
10456
18850
Bandarpunch 20720
Srikánta 20120
Gangotri 21700
Jaonli 21760
Kedárnáth 22770
Badrináth 23190
Kamet 25447
Nanda Devi 25645
Trisul 22320
20430
21150
Api 23399
Kailás 22028
Manasarowar Lakes
25355
Gurla Mándháta
BRAHMAPUTRA
I N D U S
B E Á S
J U M N A
G A N G E S
K A L I
K A R N A L I
T I B E T L A K E S
FOOT OF THE HIMALAYA
P U N J A B
77°
79°
81°
83°
32°
30°
Miles 50 40 30 20 10 0 50 100 Miles
Range of highest peaks
Water-parting

CHART XXXI

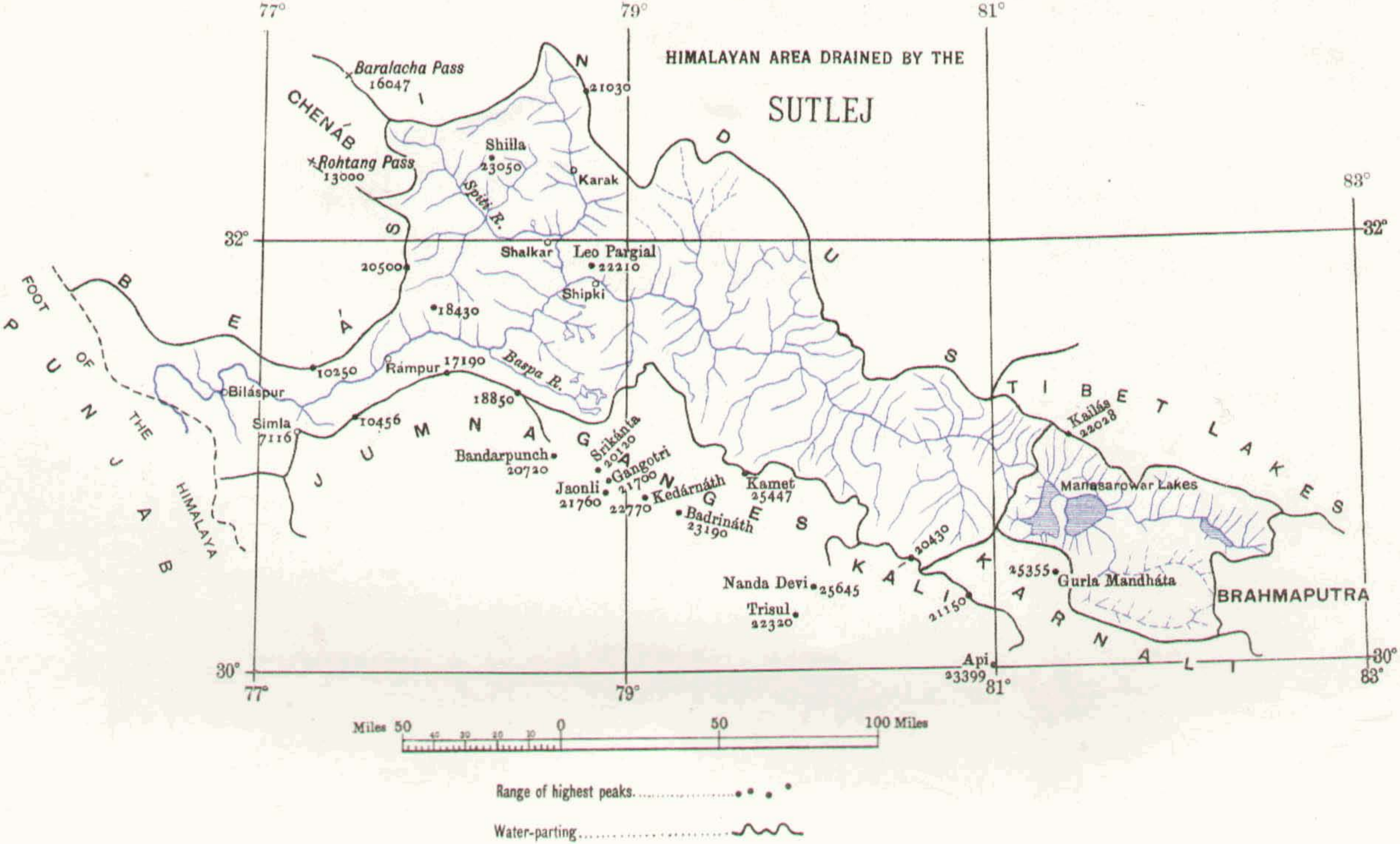
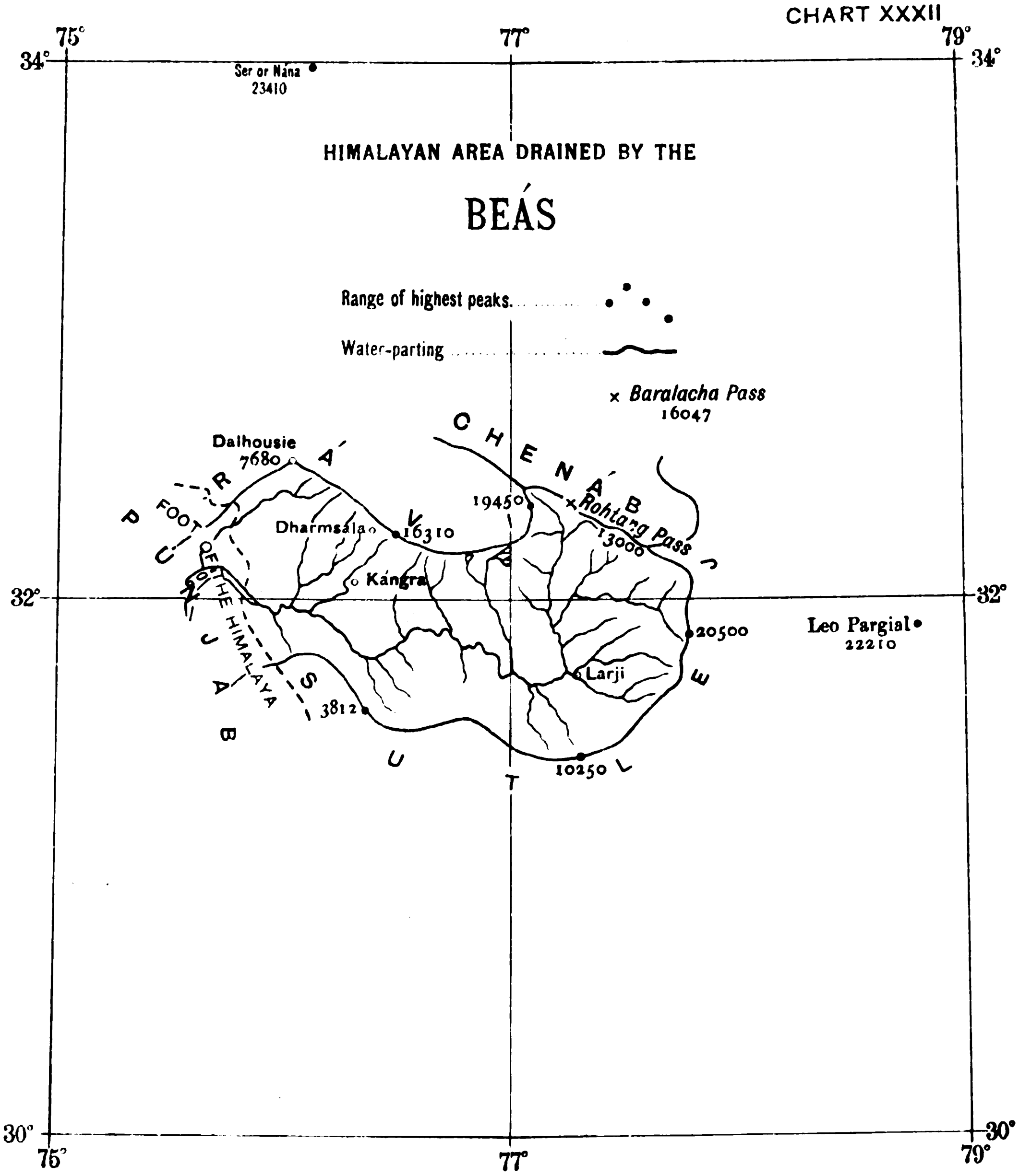

HIMALAYAN AREA DRAINED BY THE
SUTLEJ
77°
79°
81°
83°
32°
30°
Baralacha Pass 16047
Rohtang Pass 13000
CHENÁB
Shilla 23050
Karak
21030
Spiti R.
Shalkar
Leo Pargial 22210
Shipki
20500
18430
Rámpur 17190
Baspa R.
10250
Bilaspur
Simla 7116
10456
18850
Bandarpunch 20720
Srikánta 20120
Gangotri 21700
Jaonli 21760
Kedárnáth 22770
Badrináth 23190
Kamet 25447
Nanda Devi 25645
Trisul 22320
20430
21150
Api 23399
Kailás 22028
Manasarowar Lakes
25355
Gurla Mandháta
BRAHMAPUTRA
INDUS
BEÁS
JUMNA
GANGES
KALI
KARNALI
TIBET LAKES
FOOT OF THE HIMALAYA
PUNJAB
Miles 50 40 30 20 10 0 50 100 Miles
Range of highest peaks
Water-parting

CHART XXXII


HIMALAYAN AREA DRAINED BY THE
BEÁS
Range of highest peaks
Water-parting
Ser or Nána 23410
× Baralacha Pass 16047
Dalhousie 7680
Dharmsála
16310
19450
Rohtang Pass 13000
Kángra
20500
Leo Pargial 22210
Larji
3812
10250
FOOT OF THE HIMALAYA
PUNJAB
CHENAB
RÁVI
SUTLEJ
75°
77°
79°
34°
32°
30°

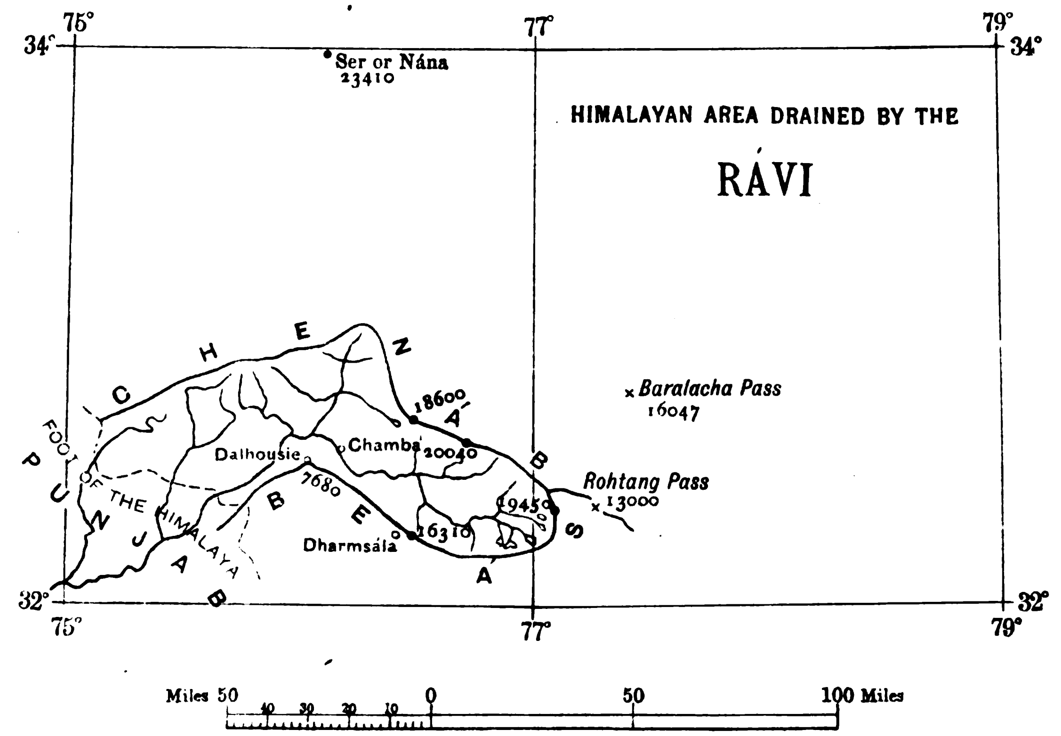
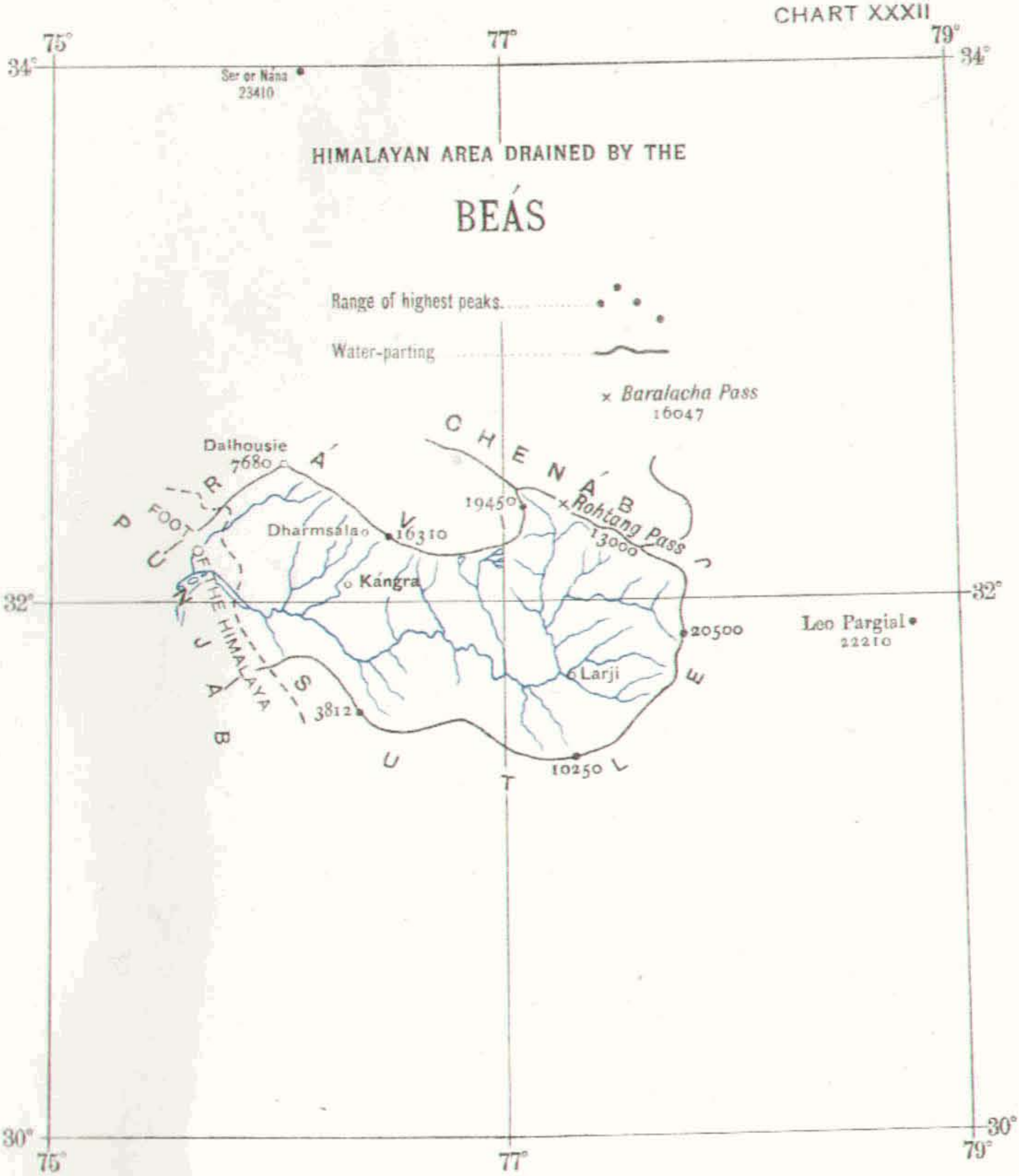
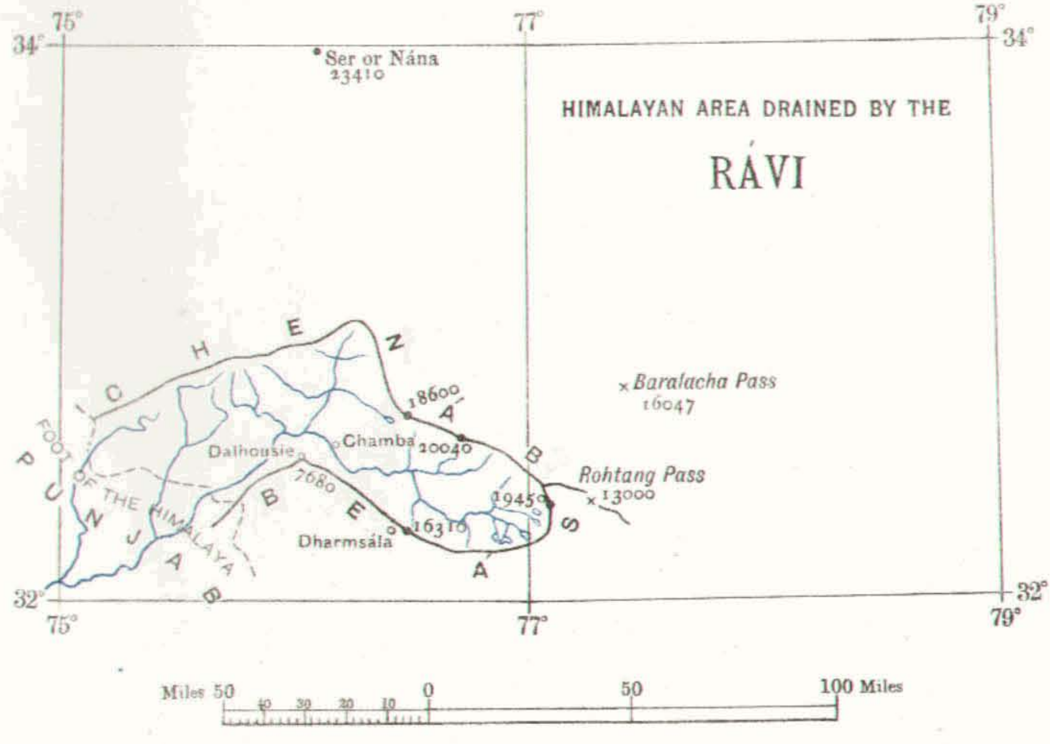

HIMALAYAN AREA DRAINED BY THE
RÁVI
Ser or Nána 23410
× Baralacha Pass 16047
Rohtang Pass × 13000
18600
Chamba
20040
Dalhousie
7680
Dharmsála
16310
19450
FOOT OF THE HIMALAYA
PUNJAB
CHENAB
BEÁS
75°
77°
79°
34°
32°
Miles 50 40 30 20 10 0 50 100 Miles

CHART XXXII



HIMALAYAN AREA DRAINED BY THE
BEÁS
Range of highest peaks
Water-parting
Ser or Nána 23410
× Baralacha Pass 16047
CHENÁB
Dalhousie 7680
RÁVI
Dharmsála
16310
19450
× Rohtang Pass 13000
Kangra
FOOT OF THE HIMALAYA
PUNJAB
20500
Leo Pargial 22210
Larji
3812
SUTLEJ
10250
75°
77°
79°
34°
32°
30°



Ser or Nána 23410
HIMALAYAN AREA DRAINED BY THE
RÁVI
CHENÁB
18600
× Baralacha Pass 16047
Chamba
20040
Dalhousie
7680
Rohtang Pass × 13000
19450
FOOT OF THE HIMALAYA
PUNJAB
BEÁS
Dharmsála
16310
75°
77°
79°
34°
32°
Miles 50 40 30 20 10 0 50 100 Miles

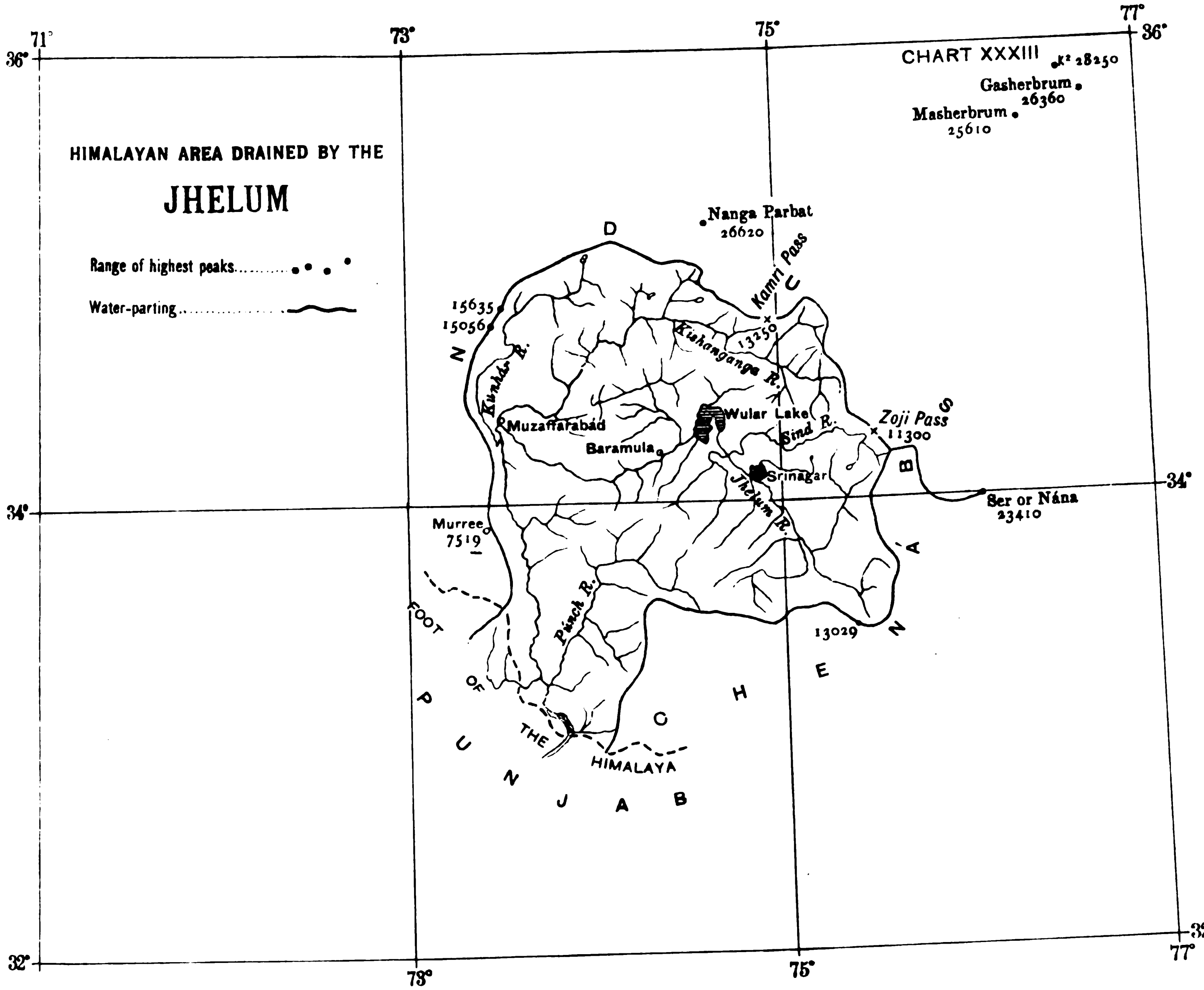


CHART XXXIII
HIMALAYAN AREA DRAINED BY THE
JHELUM
Range of highest peaks
Water-parting
K² 28250
Gasherbrum 26360
Masherbrum 25610
Nanga Parbat 26620
Kamri Pass
13250
15635
15056
Kunhár R.
Kishanganga R.
Muzaffarabád
Wular Lake
Zoji Pass 11300
Sind R.
Baramula
Srinagar
Jhelum R.
Ser or Nána 23410
Murree 7519
Púnch R.
13029
FOOT OF THE HIMALAYA
PUNJAB
INDUS
CHENÁB
71°
73°
75°
77°
36°
34°
32°

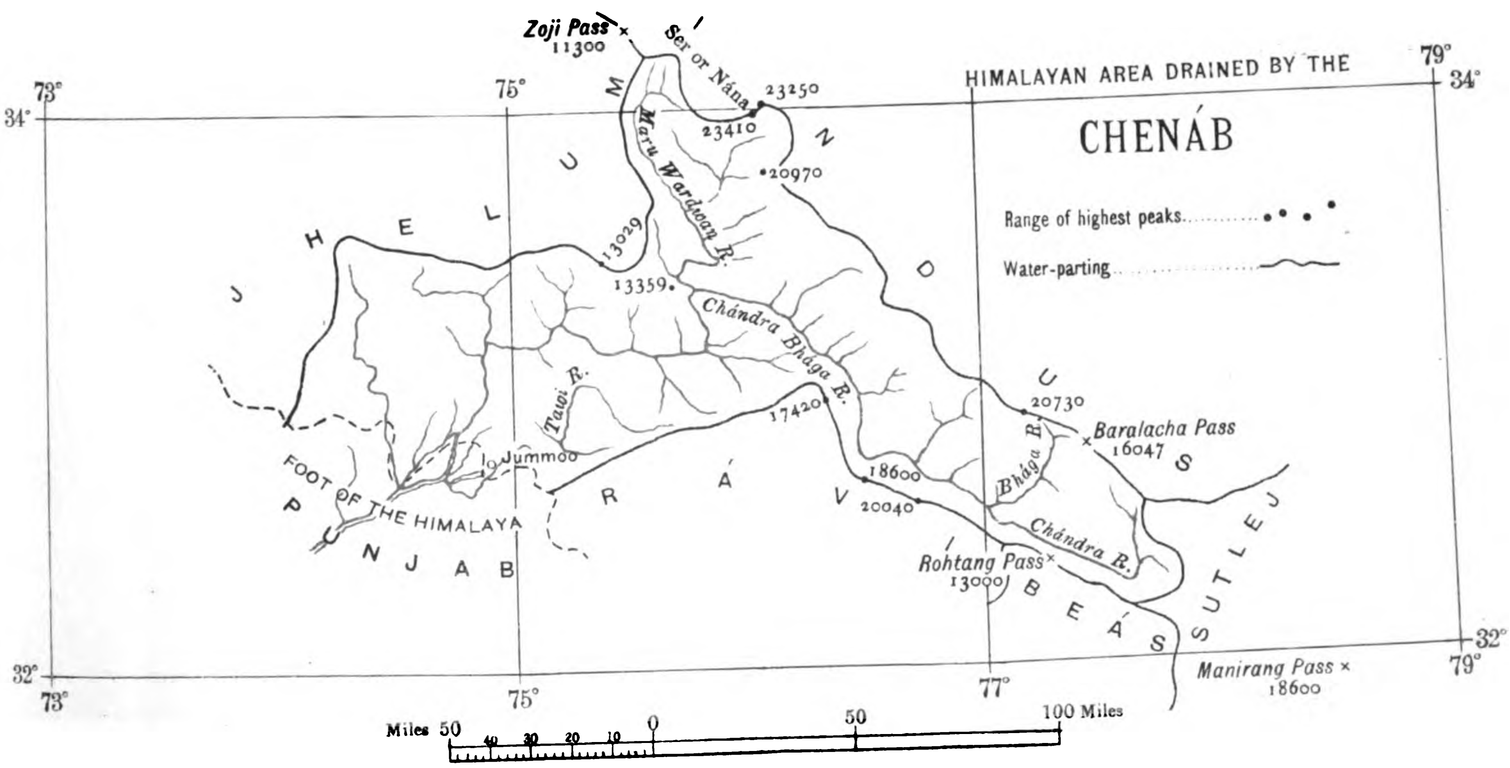
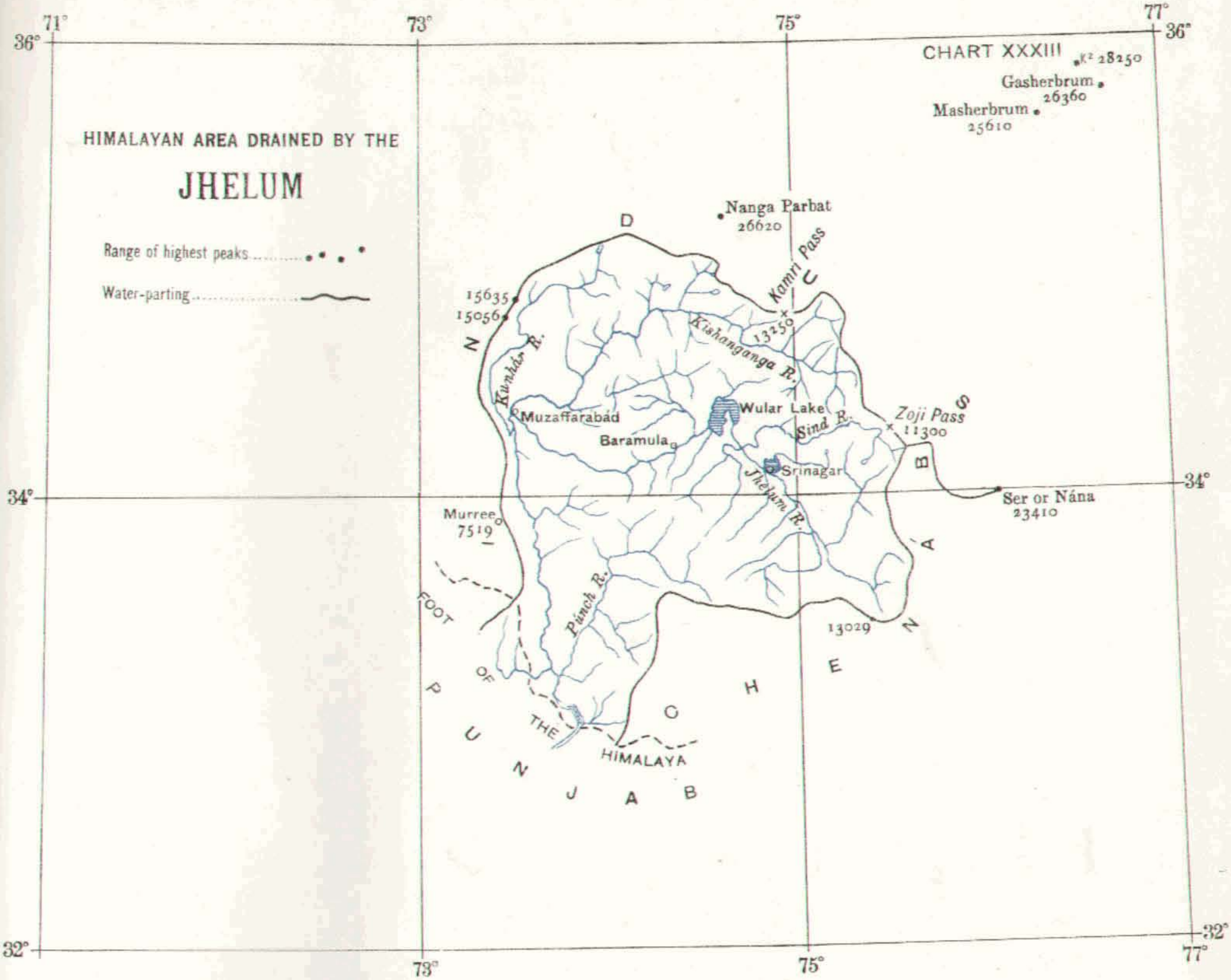
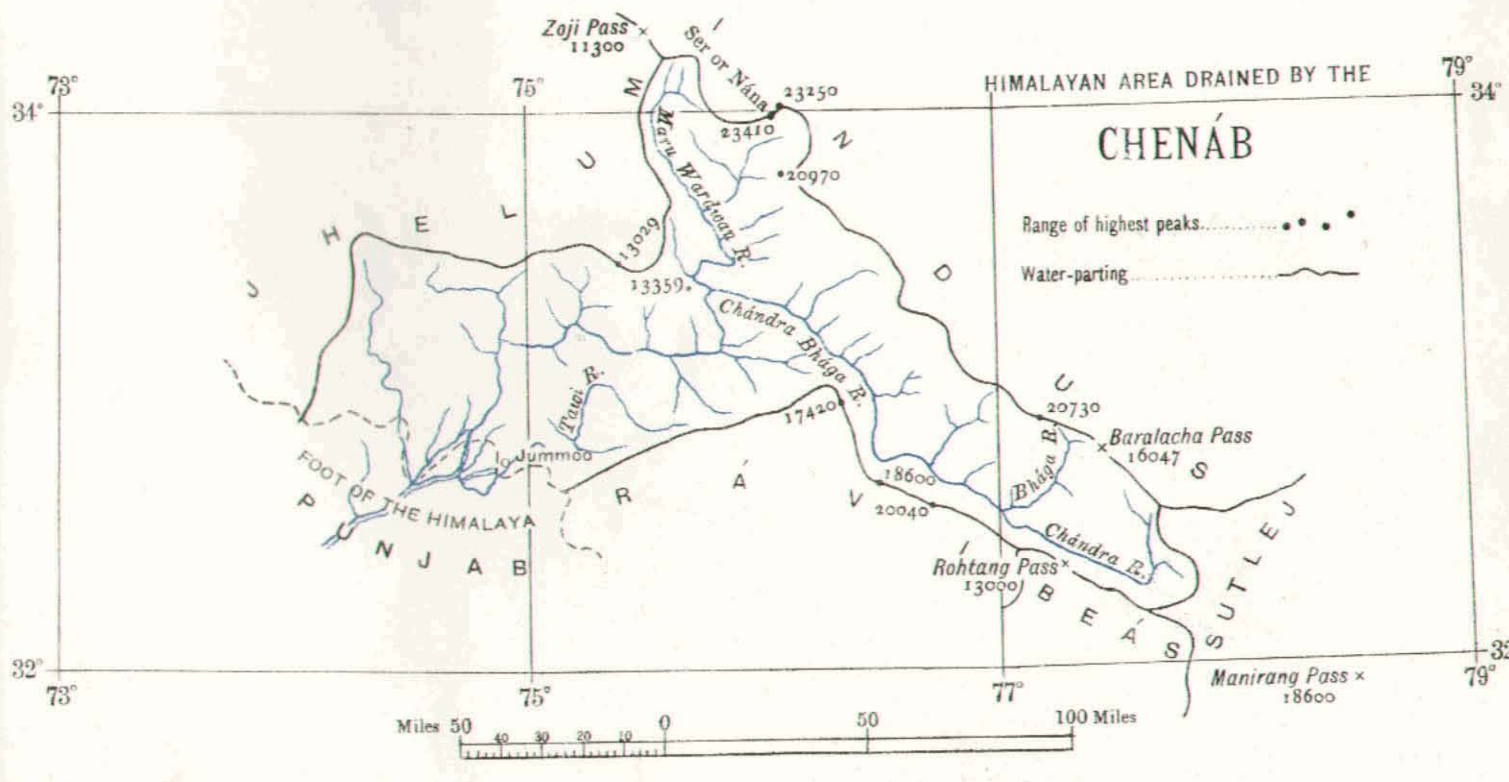
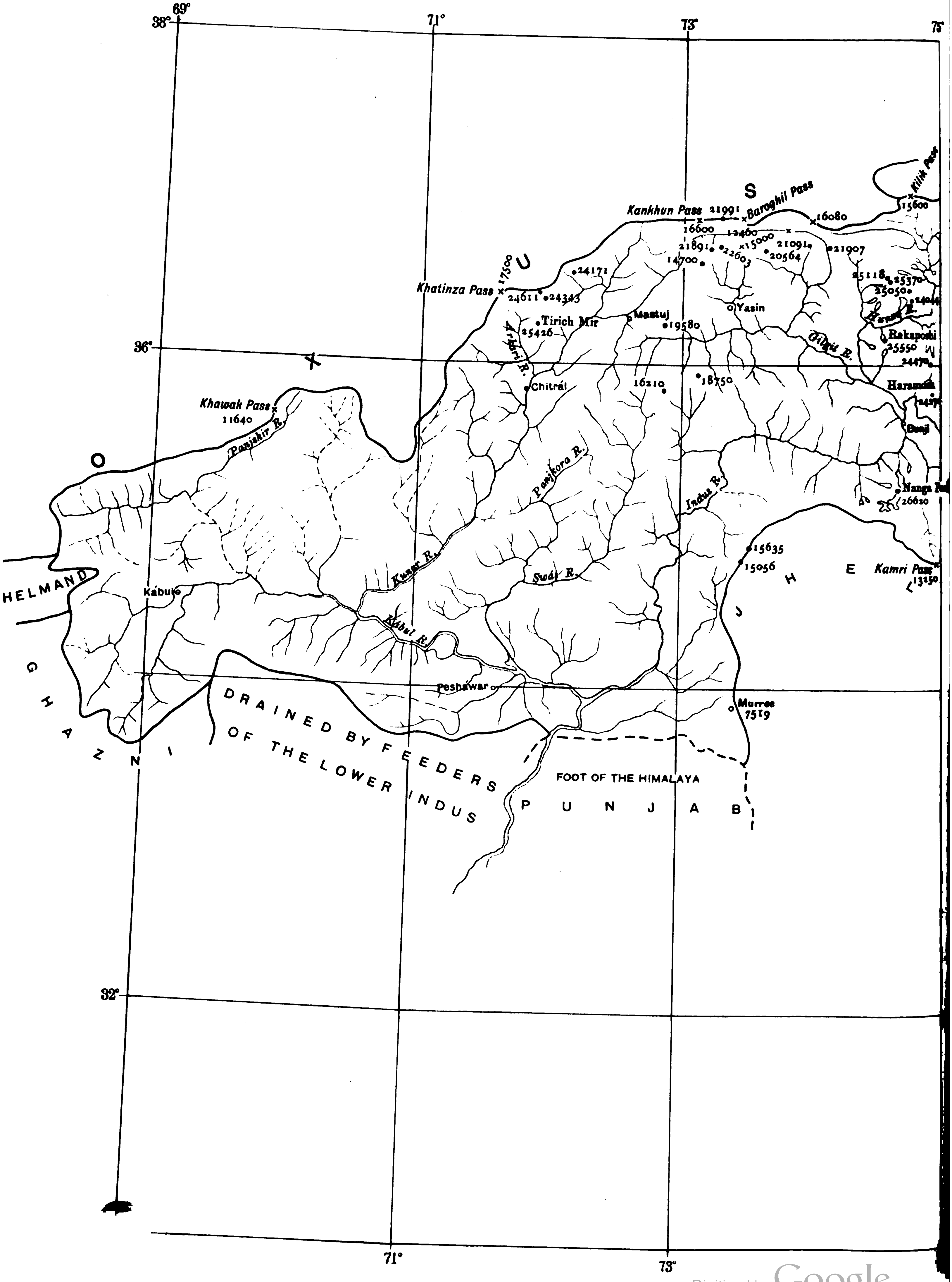

HIMALAYAN AREA DRAINED BY THE
CHENÁB
Range of highest peaks
Water-parting
Zoji Pass 11300
Ser or Nána
23250
23410
20970
Maru Wardwan R.
13029
13359
Chándra Bhága R.
Tawi R.
17420
Jummoo
20730
Baralacha Pass 16047
Bhága R.
18600
20040
Chándra R.
Rohtang Pass 13000
Manirang Pass 18600
FOOT OF THE HIMALAYA
PUNJAB
JHELUM
INDUS
RÁVI
BEÁS
SUTLEJ
Miles 50 40 30 20 10 0 50 100 Miles
73°
75°
77°
79°
34°
32°

CHART XXXIII







69°
38°
71°
73°
75°
36°
32°
S
U
X
O
Kankhun Pass
21991
Baroghil Pass
16080
Kilik Pass
15600
16600
12460
15000
21091
21891
22603
20564
21907
14700
25118
25370
25050
Khatinza Pass
17500
24171
24611
24343
Yasin
Mastuj
Tirich Mir
25426
19580
Gilgit R.
Rakaposhi
25550
Chitrál
16210
18750
Haramosh
Khawak Pass
11640
Panjshir R.
Panjkora R.
Bunji
Indus R.
Nanga Parbat
26620
15635
15056
Kamri Pass
13250
HELMAND
Kábul
Kunar R.
Swát R.
Kábul R.
H
E
L
J
Peshawar
Murree
7519
G H A Z N I
DRAINED BY FEEDERS
OF THE LOWER INDUS
FOOT OF THE HIMALAYA
P U N J A B
71°
73°

CHART XXXIV

HIMALAYAN AREA DRAINED BY THE
INDUS
Miles 50 40 30 20 10 0 50 100 Miles
Ranges of highest peaks.
77°
79°
81°
38°
36°
34°
Khunjeráb Pass 15420
Shimshal Pass 14719
24580
25460
K² 28250
Gasherbrum 26360
26090
26470
N. Braldo R.
N. Shigar R.
25660
Masherbrum
25610
25110
25280
25400
24370
Karakoram Pass 18550
16906
Skardo
17246
S. Shigar R.
17289
18210
24690
Nubra R.
Shyok R.
25170
24590
24650
20660
18900
19280
20090
Zoji Pass 11300
Tongul
Suru R.
Ser or Nána
23410
17930
Leh
20083
Zaskar R.
21000
Padam
20171
Nichung 19971
Chumik 19669
Hanle R.
20091
Baralacha Pass 16047
21030
Aling Kangri 24000
Shilla 23050
Gartok
Leo Pargial 22210
Bandarpunch 20720
20120 Srikánta
Gangotri 21700
Jaonli 21760
22770
Kedárnáth
Kamet 25447
Badrináth 23190
T R I M
T I B E T
L A K E S
U M O H E N N A
B S U T L E J


HIMALAYAN AREA DRAINED BY THE
INDUS
Miles 50 40 30 20 10 0 50 100 Miles
Ranges of highest peaks.
69°
71°
73°
75°
77°
79°
81°
38°
36°
34°
32°
Kankhun Pass
Baroghil Pass
Khatinza Pass
Tirich Mir
25426
Mastuj
Yasin
Gilgit R.
Hunza R.
Rakaposhi
25550
Haramosh
Bunji
Nanga Parbat
26620
Chitral
Arkari R.
Khawak Pass
11640
Panjshir R.
Panjkora R.
Indus R.
Kunar R.
Swat R.
Kabul R.
Kabul
Peshawar
Murree
7519
Kamri Pass
13250
DRAINED BY FEEDERS OF THE LOWER INDUS
FOOT OF THE HIMALAYA
P U N J A B
Khunjerab Pass
15420
Shimshal Pass
14719
Gasherbrum
26470
Masherbrum
25660
Karakoram Pass
18550
N. Braldo R.
N. Shigar R.
S. Shigar R.
Skardo
Nubra R.
Shyok R.
Zoji Pass
11300
Tongul
Suru R.
Ser or Nána
23410
Zaskar R.
Leh
Padam
Nichung
19971
Chumik
19669
Hanle R.
Baralacha Pass
16047
Shilla
23050
Aling Kangri
24000
Gartok
Leo Pargial
22210
Bandarpunch
20720
Srikánta
20120
Gangotri
21700
Jaonli
21760
Kedárnáth
22770
Kamet
25447
Badrináth
23190
TIBETAN LAKES
SUTLEJ

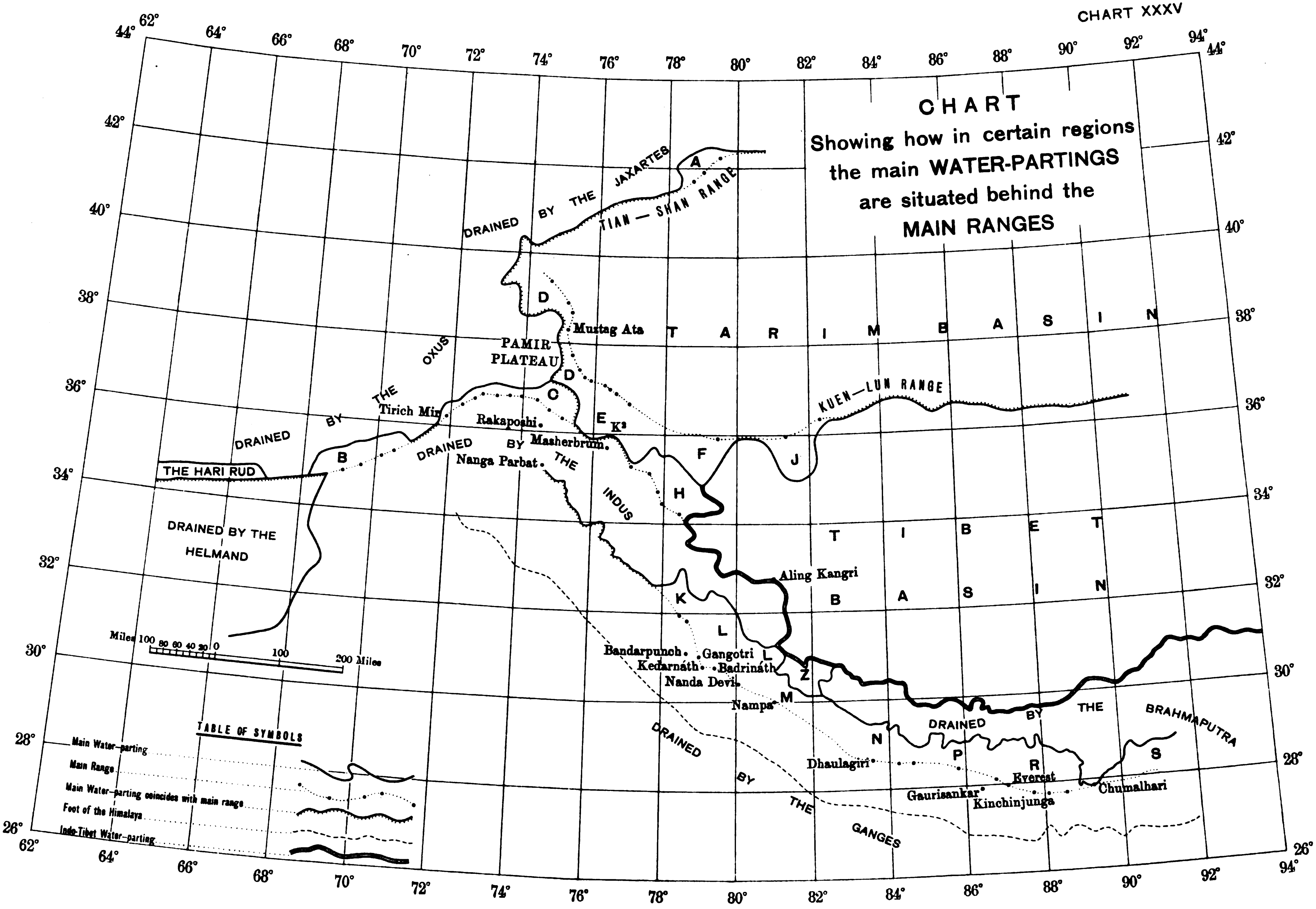


CHART
Showing how in certain regions the main WATER-PARTINGS are situated behind the MAIN RANGES
DRAINED BY THE JAXARTES
TIAN — SHAN RANGE
TARIM BASIN
KUEN—LUN RANGE
TIBET BASIN
PAMIR PLATEAU
OXUS
DRAINED BY THE OXUS
Mustag Ata
Tirich Mir
Rakaposhi
Masherbrum
Nanga Parbat
K²
DRAINED BY THE INDUS
THE HARI RUD
DRAINED BY THE HELMAND
Aling Kangri
Bandarpunch
Gangotri
Kedarnáth
Badrináth
Nanda Devi
Nampa
Dhaulagiri
Gaurisankar
Everest
Kinchinjunga
Chumalhari
DRAINED BY THE BRAHMAPUTRA
DRAINED BY THE GANGES
A B C D E F H J K L M N P R S Z
Miles 100 80 60 40 20 0 100 200 Miles
TABLE OF SYMBOLS
Main Water-parting
Main Range
Main Water-parting coincides with main range
Foot of the Himalaya
Indo-Tibet Water-parting
62° 64° 66° 68° 70° 72° 74° 76° 78° 80° 82° 84° 86° 88° 90° 92° 94°
26° 28° 30° 32° 34° 36° 38° 40° 42° 44°

CHART XXXV


CHART
Showing how in certain regions the main WATER-PARTINGS are situated behind the MAIN RANGES
DRAINED BY THE JAXARTES
TIAN — SHAN RANGE
TARIM BASIN
Muztag Ata
PAMIR PLATEAU
DRAINED BY THE OXUS
KUEN—LUN RANGE
Tirich Mir
Rakaposhi
K²
Masherbrum
Nanga Parbat
DRAINED BY THE INDUS
THE HARI RUD
DRAINED BY THE HELMAND
TIBET BASIN
Aling Kangri
Bandarpunch
Gangotri
Kedarnath
Badrinath
Nanda Devi
Nampa
DRAINED BY THE BRAHMAPUTRA
DRAINED BY THE GANGES
Dhaulagiri
Everest
Gaurisankar
Kinchinjunga
Chumalhari
Miles 100 80 60 40 20 0 100 200 Miles
TABLE OF SYMBOLS
Main Water-parting
Main Range
Main Water-parting coincides with main range
Foot of the Himalaya
Indo-Tibet Water-parting

CHART XXXVI

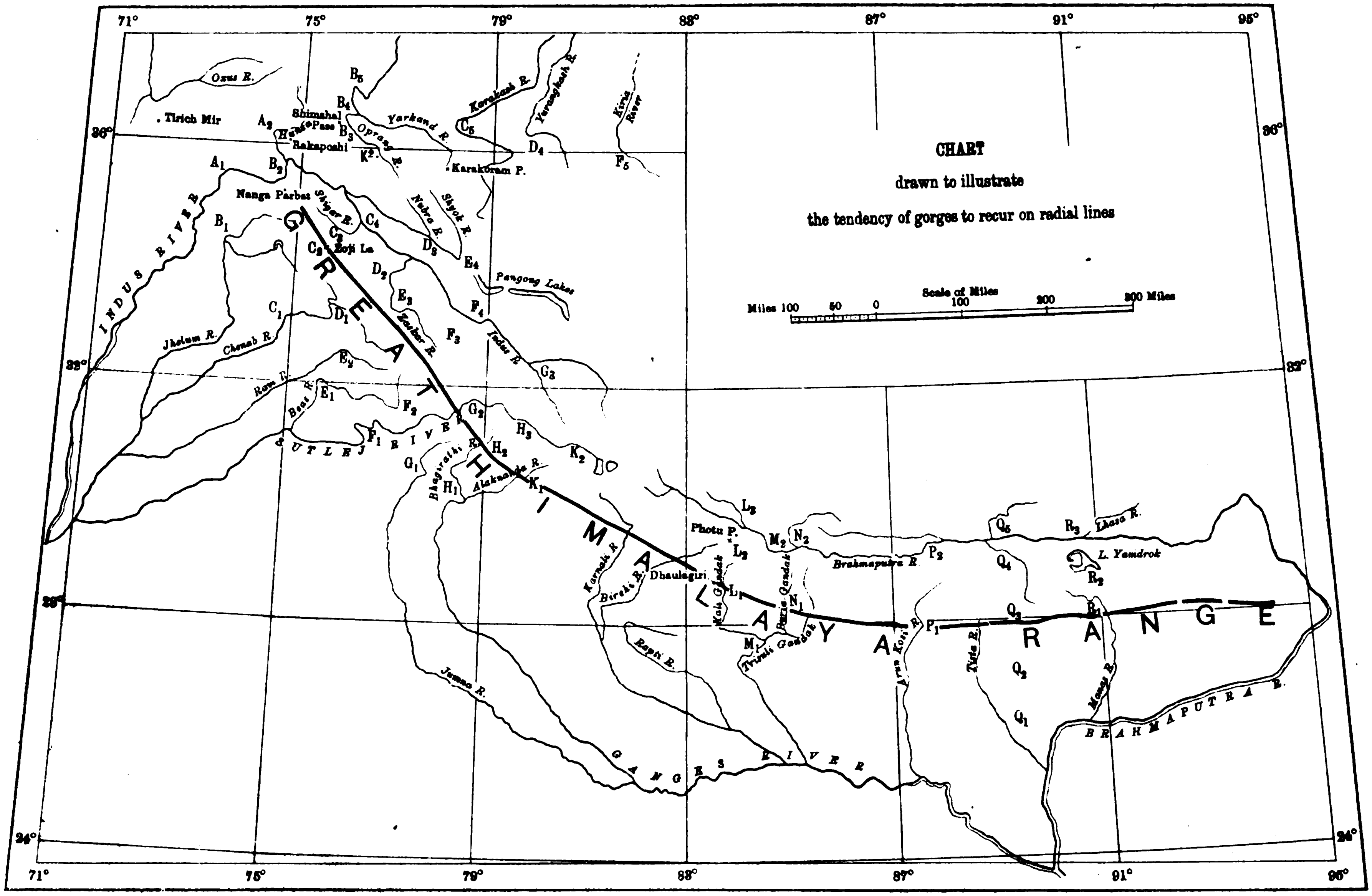


CHART
drawn to illustrate
the tendency of gorges to recur on radial lines

CHART XXXVI

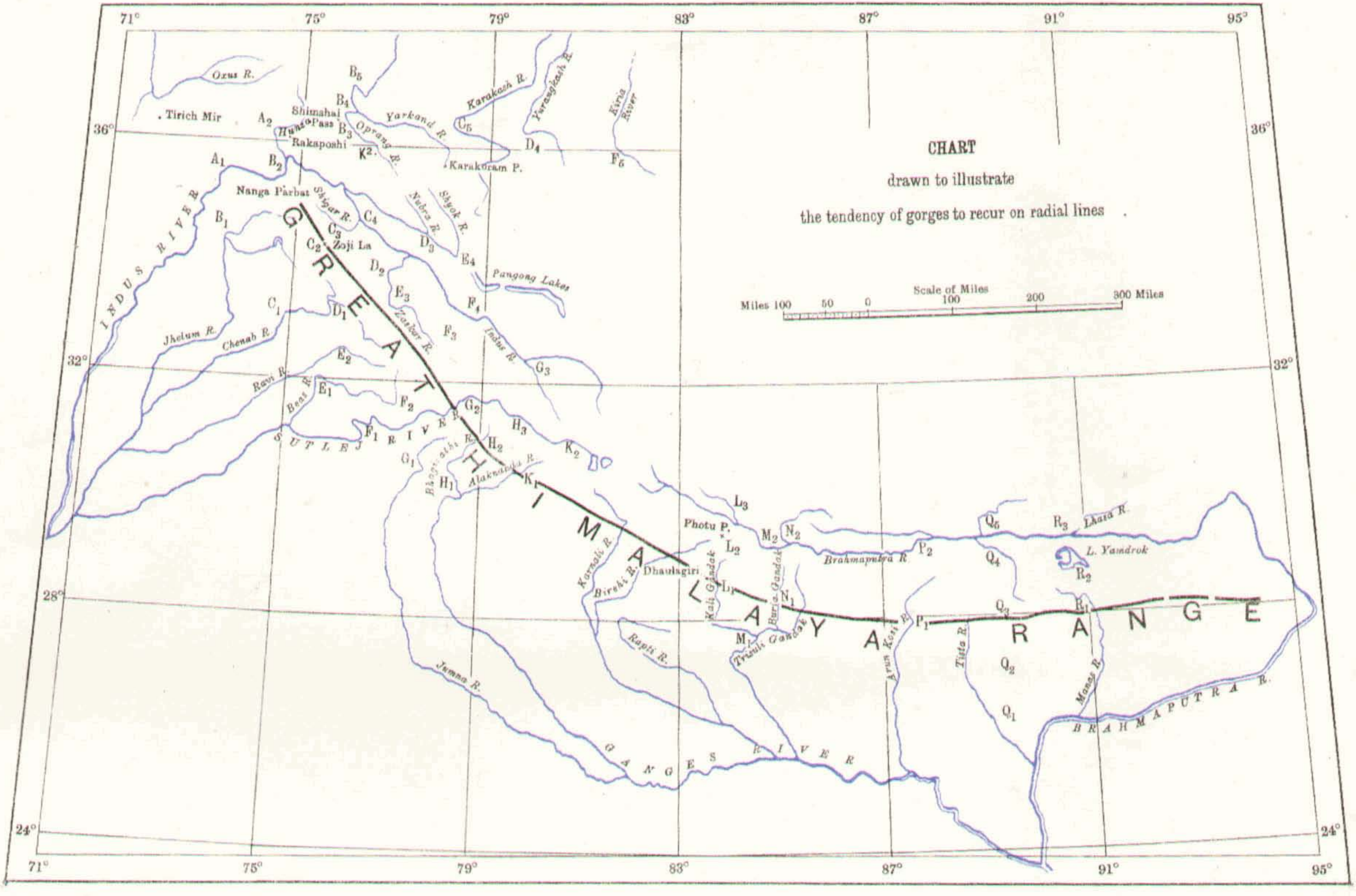


CHART
drawn to illustrate
the tendency of gorges to recur on radial lines
Scale of Miles
Miles 100 50 0 100 200 300 Miles
GREAT HIMALAYA RANGE
INDUS RIVER
SUTLEJ RIVER
GANGES RIVER
BRAHMAPUTRA R.
Oxus R.
Tirich Mir
Shimshal
Hunza Pass
Rakaposhi
Nanga Parbat
Zoji La
K².
Karakoram P.
Yarkand R.
Karakash R.
Yarangkash R.
Kiria River
Oprang R.
Nubra R.
Shyok R.
Shigar R.
Pangong Lakes
Zaskar R.
Indus R.
Jhelum R.
Chenab R.
Ravi R.
Beas R.
Alaknanda R.
Jumna R.
Karnali R.
Birehi R.
Rapti R.
Dhaulagiri
Photu P.
Kali Gandak
Buria Gandak
Trisuli Gandak
Brahmaputra R.
Arun Kosi R.
Tista R.
Manas R.
Lhasa R.
L. Yamdrok
71° 75° 79° 83° 87° 91° 95°
36° 32° 28° 24°

CHART to illustrate the varying gradients of rivers

CHART XXXVII

DIAGRAM 1.
A river rising in the Great Himalaya Range

Examples { Mandakini, Tons, Seti, Indráwati

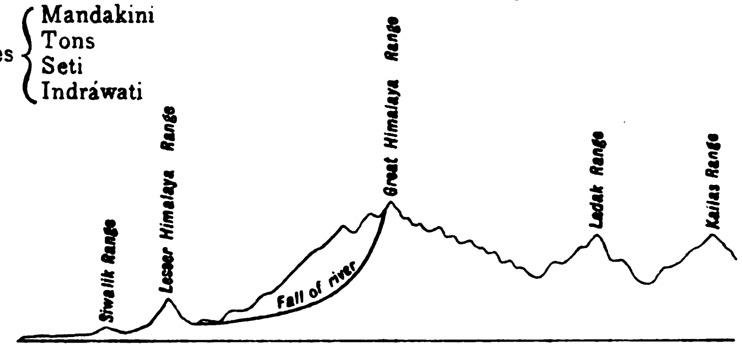


DIAGRAM 2.
A river rising slightly beyond the crest of the Great Range

Examples { Dudh Kosi, Mádi

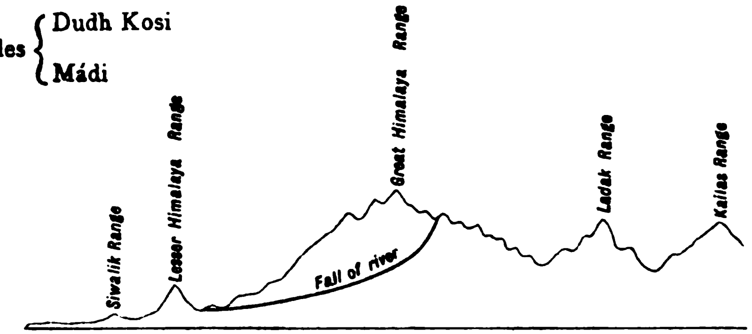


DIAGRAM 3.
A river rising considerably beyond the crest of the Great Range

Examples { Bhotia Kosi, Tambar Kosi

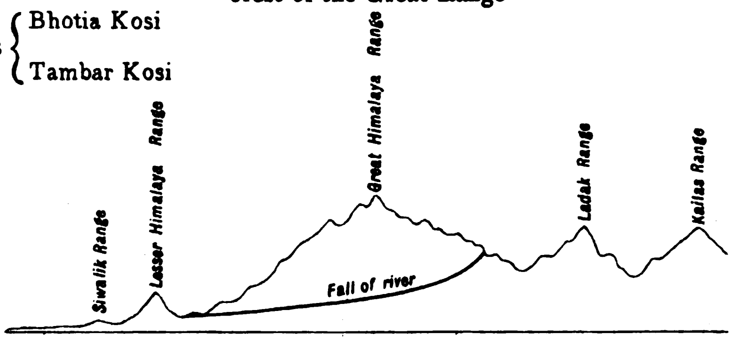


DIAGRAM 4.
A river rising in the trough behind the Great Range

Examples { Arun, Birehi, Bhágirathi, Karnáli

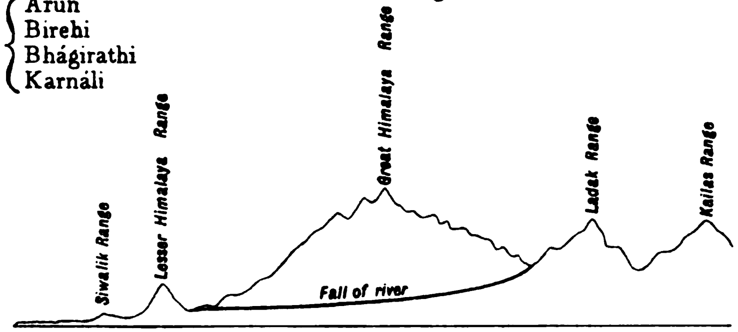


DIAGRAM 5.
A river rising behind the crest of the Ladak Range.

Examples { Káli Gandak, Buria Gandak

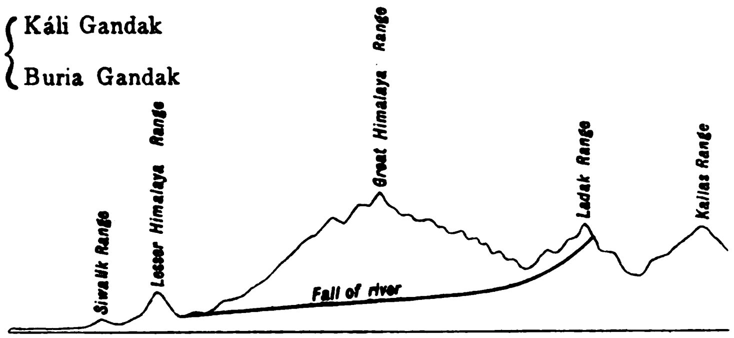


DIAGRAM 6.
A river rising in the trough behind the Ladak Range.

Examples { Indus, Sutlej, Brahmaputra

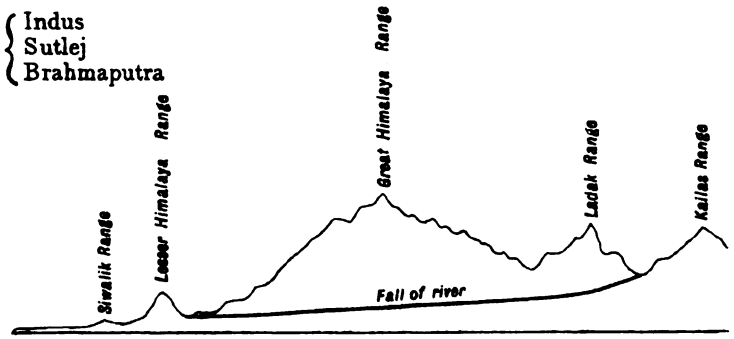


CHART
to illustrate the varying gradients of rivers

CHART XXXVII

DIAGRAM 1.
A river rising in the Great Himalaya Range

Examples: Mandakini, Tons, Seti, Indráwati

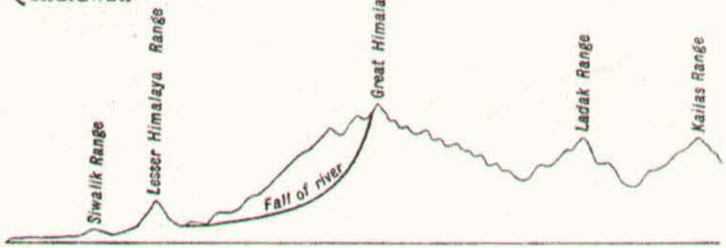


DIAGRAM 2.
A river rising slightly beyond the crest of the Great Range

Examples: Dudh Kosi, Mádi

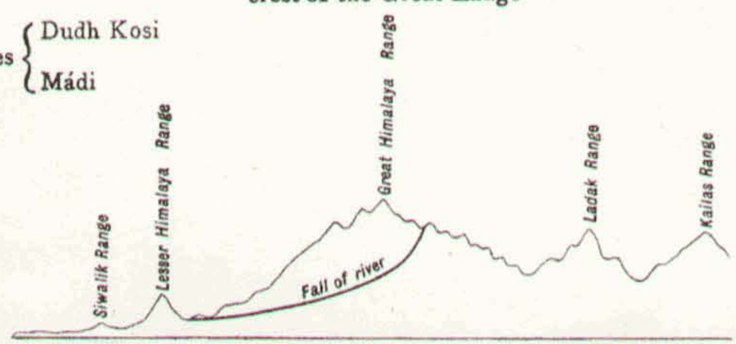
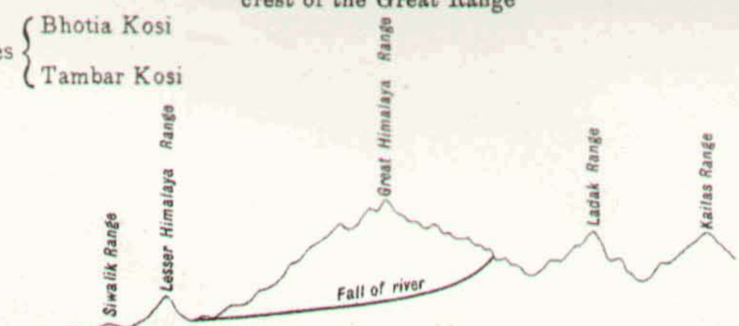


DIAGRAM 3.
A river rising considerably beyond the crest of the Great Range

Examples: Bhotia Kosi, Tambar Kosi



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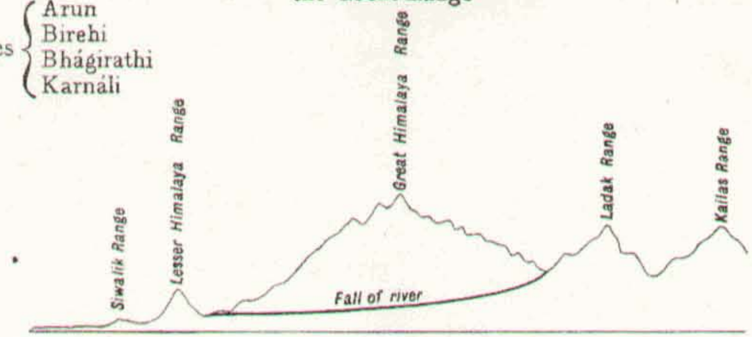
A river rising in the trough behind the Great Range

Examples: Arun, Birehi, Bhágirathi, Karnáli



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A river rising behind the crest of the Ladak Range.

Examples: Káli Gandak, Buria Gandak

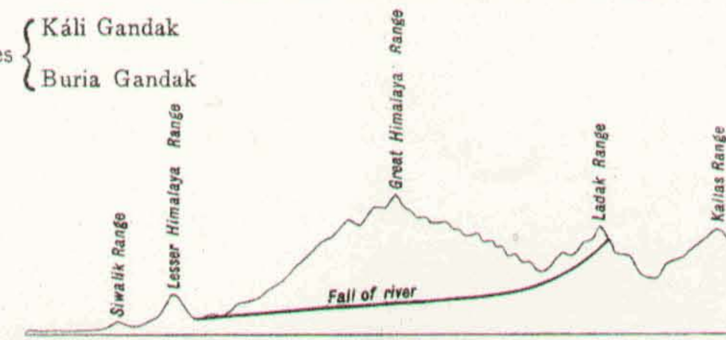
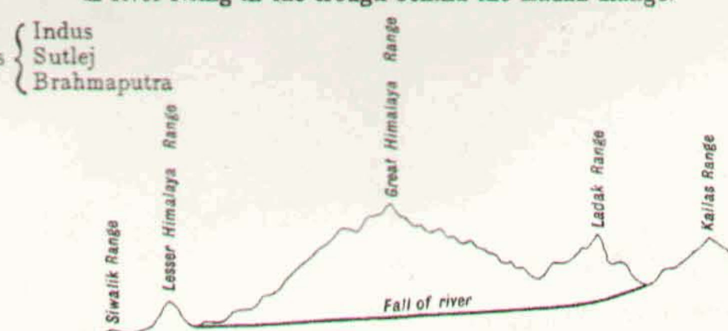


DIAGRAM 6.
A river rising in the trough behind the Ladak Range.

Examples: Indus, Sutlej, Brahmaputra



A SKETCH

OF THE

GEOGRAPHY AND GEOLOGY

OF THE

HIMALAYA MOUNTAINS AND TIBET

BY

COLONEL S. G. BURRARD, R.E., F.R.S.,
SUPERINTENDENT, TRIGONOMETRICAL SURVEYS,

AND

H. H. HAYDEN, B.A., F.G.S.,
SUPERINTENDENT, GEOLOGICAL SURVEY OF INDIA

PART IV
THE GEOLOGY OF THE HIMALAYA

Published by order of the Government of India

CALCUTTA
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PREFACE

IN 1807 a Survey detachment was deputed by the Surveyor General of Bengal to explore the source of the Ganges: this was the first expedition to the Himalaya undertaken for purely geographical purposes. A hundred years have now elapsed, during which geographical and geological information has been steadily accumulating and we have at length reached a stage where there is danger of losing our way in a maze of unclassified detail: it is therefore desirable to review our present position, to co-ordinate our varied observations and to see how far we have progressed and what directions appear favourable for future lines of advance.

The present paper originated in a proposal submitted by the Survey of India to the Board of Scientific Advice at the meeting of the latter in May 1906. The proposal was as follows:—"The number of travellers in the Himalaya and Tibet is "increasing, and a wider interest is being evinced by the public in the geography of "these regions. It is therefore proposed to compile a paper summarising the geographi-"cal position at the present time."

Subject to the modification that the scope of the paper should be geological as well as geographical, this proposal has received the sanction of the Government of India and the work has been entrusted to us to carry out. On the understanding that the paper is intended primarily for the use of the public, we have endeavoured to avoid purely technical details and to present our results in a popular manner.

Our subject has fallen naturally into four parts, as follows:—

PART I.—The high peaks of Asia.

PART II.—The principal mountain ranges of Asia.

PART III.—The rivers of the Himalaya and Tibet.

PART IV.—The geology of the Himalaya.

Though the four parts are essentially interdependent, each has been made as far as possible complete in itself and will be published separately. The first three parts are mainly geographical, the fourth part is wholly geological: the parts are subdivided into sections, and against each section in the table of contents is given the name of the author responsible for it.

The endeavour to render each part complete must be our apology for having repeated ourselves in more places than one: the relations, for instance, of a range to a river have been discussed in Part II, when the range was being described, and have been mentioned again in Part III under the account of the river.

As the mountains of Asia become more accurately surveyed, errors will doubtless be found in what we have written and drawn: it is not possible yet to arrive at correct generalisations and we have to be content with first approximations to truth.

Maps, too large for insertion in such a volume as this, are required for a study of the Himalayan mountains: the titles of maps illustrating the text are given in foot-notes and are procurable from the Map Issue Office of the Survey of India in Calcutta. Constable's hand atlas of India will be found useful.

We are much indebted to Babus Shiv Nath Saha and Ishan Chandra Dev, B.A., for the care with which they have checked our figures and names, and to Mr. J. H. Nichol for the trouble he has taken to ensure the correctness of the charts. Mr. Eccles and Major Lenox Conyngham have been kind enough to examine all proofs, and to give us the benefit of their advice and suggestions. Mr. Eccles has also supervised the drawing and printing of the charts, and we have profited greatly by the interest he has shown in them.

We have also to express our indebtedness to Messrs. T. D. LaTouche and C. S. Middlemiss for their kind assistance in examining proofs of Part IV.

S. G. Burrard.

H. H. Hayden.

December 1908.

CONTENTS OF PART IV.

PLATES IN PART IV.

THE GEOLOGY OF THE HIMALAYA.

32

GEOLOGICAL SUBDIVISIONS OF THE HIMALAYA.

THE rocks of the Himalaya fall into three broad stratigraphical zones (Plate XXXVIII), namely—

(1) an outer or SUB-HIMALAYAN ZONE composed of sediments for the most part of Tertiary age;

(2) a central or HIMALAYAN ZONE, comprising most of the ranges known as the Lesser Himalaya together with the line of high peaks. This is composed of granite and other crystalline rocks and a great group of unfossiliferous sediments of unknown age; and

(3) a northern or TIBETAN ZONE, lying for the most part behind the line of high peaks (the axis of the Great Himalayan range) and composed of a series of highly fossiliferous sediments ranging in age from the Cambrian to the Tertiary epochs.

The following table shows the classification and the more important subdivisions:—

Table XL.

	Sub-Himalayan Zone.	*Himalayan Zone.*	*Tibetan Zone.*	*Approximate Foreign equivalents.*	
Aryan Group.	High level terraces of the chief Himalayan rivers; Karewas of Kashmir; Ossiferous beds of Ngari Khorsum.			Pleistocene.	Post-Tertiary.
	Siwalik series. { Upper Siwalik stage. Middle Siwalik stage. Lower Siwalik (Nahan) stage.			Pliocene.	Tertiary.
				Miocene.	
	Sirmur series. { Kasauli stage. Dagshai stage. Subathu stage.	Intrusive tourmaline-granite, biotite-granite and hornblende-granite.		Oligocene.	
			Nummulitic limestone of Zangskar and Ngari Khorsum, and volcanics of Lake Manasarowar; Indus Valley Tertiaries; upper part of Kampa system.	Eocene.	
			Chikkim series; Flysch of Ngari Khorsum; Giumal series: lower part of Kampa system.	Cretaceous.	Mesozoic.
	Tal series.		Spiti shales and Jurassic of Tibet. Kioto limestone. { Tagling stage.	Jurassic.	
			Kioto limestone. { Para stage. Trias of Hazara; Lilang system.	Trias.	
			Kuling system. { Productus shales. Calcareous sandstone. Conglomerates.	Permian.	Palæozoic.
	Gondwanas of Eastern Himalaya.		Fusuli[illegible] mestone of Afghanistan. Kanawar system { Po series { Zewan stage. Gangamopteris beds. } in Kashmir.	Carboniferous.	
Dravidian Group.			Kanawar system in Spiti. { Lipak series. { Panjal volcanics. } in Kashmir.		
			Chitral limestones.	Devonian.	
			Muth system. { Muth quartzite. Limestone with Silurian fossils. Red quartzite. Conglomerate in Spiti; Coral limestone in Kumaun.	Silurian.	
			Haimanta system. { Upper Haimanta. Middle Haimanta. Lower Haimanta.	Middle Cambrian, Lower and perhaps in part pre-Cambrian.	
Purana Group.		Panjal system in part; Infra-Trias of Hazara; Krol system; Carbonaceous system; Simla slates; Deoban limestone; Jaunsar system; Baxa series; Miju beds.		Algonkian.	
Archæan Group.		Daling series; old schists, gneisses and crystalline limestones.	Vaikrita system in part.	Archæan.	

33

THE SUB-HIMALAYAN ZONE.

Although it is customary in stratigraphical treatises to deal first with the oldest rock-groups, it will be more convenient in the present instance to take the three zones in their geographical sequence, describing them in the order in which they would be met with by the traveller passing from the plains of India to the highlands of Tibet. Whether his route lie through the tropical forests of the Darjeeling Terai, the sal-covered spurs above Kathgodam, the outer ridges and duns of the Siwalik range below Mussooree, or the sinuous tunnels of the Kalka-Simla Railway, he must always cross a band of conglomerates, sandstones and clays, which runs from end to end of the Himalaya along their outer margin, and is known to geologists as the Sub-Himalayan zone. Even should his destination be the valley of Kashmir, he must still cross the same zone in the Murree hills and through the deep and narrow gorges of the Jhelum.

Subdivisions of the component beds.

The rocks of this zone fall into two well-marked subdivisions, known as the Sirmur and Siwalik series, respectively: these, again, are subdivided as follows:—

Sub-Himalayan system	Siwalik series	Upper Siwalik	stage.
		Middle „	„
		Lower „ (Nahan)	„
	Sirmur series	Kasauli	stage.
		Dagshai	„
		Subathu	„

Sub-Himalayan system.

Siwalik series.

Siwalik series: Upper Siwaliks.

The upper, or Siwalik, series is the first rock-group met with in passing from the plains into the Himalayan foot-hills, and takes its name from the Siwalik hills, which are composed of the various members of this series. The uppermost stage consists of an immense thickness—many thousands of feet—of loosely aggregated conglomerates and soft earthy beds immediately underlying, but, as a rule, sharply marked off from, the extensive recent deposits still in process of formation along the foot of the Himalaya. Here and there, however, where the Siwalik beds have been subjected to comparatively little disturbance, no distinct line of division between them and the overlying recent deposits can be found, and, owing to the mutual similarity of composition, we are led to conclude that the recent deposits are the direct successors of the Upper Siwalik beds. Both are of subaërial origin, and both are the direct products of those forces of which the concrete embodiments are rain and rivers, and which are to-day at work, removing material from the mountains to lay it down again on the plains at their foot. To this process not only the recent deposits, but clearly also the Upper Siwaliks, owe their origin. It has further been found that, in the neighbourhood of the debouchures of the great rivers of the present day, the Siwalik deposits consist chiefly of coarse conglomerates, whereas, in the intervening areas soft earthy beds predominate.* It is clear, therefore, that, throughout the vast period of time necessary for the accumulation of these deposits, the distribution of the main drainage lines of the Himalaya was much as it is at the present day, and the more important Himalayan rivers are therefore of very great antiquity.

Middle Siwalik and Nahan stages.

The Upper Siwalik conglomerates are underlain by a great thickness of a soft, barely coherent, sand-rock,† lying upon a harder but otherwise very similar sandstone: these two subdivisions of the Siwalik series are known as the Middle and the Lower, respectively, the latter being also frequently known as the Nahan stage, from its being exposed and having been first studied at Nahan.‡ As already stated, the three stages forming the Siwalik series are all composed of sub-aërial deposits which bear internal evidence of a fluviatile origin. As might, therefore, be expected, fossils are rare, but the two uppermost stages have yielded locally large numbers of remains of mammals closely allied to species existing in the Himalayan foot-hills at the present day. These include bones and teeth of such animals as the elephant, rhinoceros, tiger, pig, ox and various species of deer.§ Such fossils are by no means of common occurrence, but the few localities which have hitherto been discovered have yielded them in some profusion. The same belt of Siwalik deposits is known to extend far to the west, through the Punjab into Sind, whilst similar beds, also highly fossiliferous, have been found in Burma. Although there is an extensive literature on the subject of the Siwalik fossils as a whole, little is known as to their exact vertical distribution or their respective horizons in the rocks in which they occur, and a wide field for detailed research still exists in this direction. On the whole, however, it is generally agreed that they are of the same age as the very similar fossils found in Europe and known to belong to the pliocene stage of the Tertiary system.

Siwalik Fossils.

Middle Siwaliks.

The beds below the Upper Siwalik conglomerates—the Middle Siwalik or sand-rock stage—are composed chiefly of soft sands of a "pepper and salt" colour; here and there they contain small masses of lignite, which have frequently led to expectations of coal; such expectations, however, have invariably proved fallacious, and in all cases the lignite deposits have been found to be merely isolated pockets of carbonised wood|| or, in a few instances, patches of drifted vegetable matter ¶ far too small to be of any economic value.

* *Manual of the Geology of India*, 2nd ed., 358 (1893); H. B. Medlicott, *Records, Geological Survey of India*, Vol. IX, 57 (1876).

† C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2 (1890).

‡ H. B. Medlicott: *Memoirs, Geological Survey of India*, Vol. III, pt. 2 (1864).

§ Falconer and Cautley: *Fauna antiqua sivalensis*; also *Palæontologia Indica*, ser. X.

|| H. B. Medlicott: *Memoirs, Geological Survey of India*, Vol. III, pt. 2, 14 (1864); C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2, 26 (1890); H. H. Hayden: *Records, Geological Survey of India*, Vol. XXX, 249 (1897).

¶ F. R. Mallet: *Memoirs, Geological Survey of India*. Vol. XI, 46 (1875).

Nahan stage.

The lowest, or Nahan, stage differs from the Middle Siwalik in its greater degree of induration and, at times also, in its colour, the prevailing tints being brownish and greenish-brown, although bluish-grey is not uncommon, especially on weathered surfaces; the safest criterion by which to distinguish the members of the two groups, one from the other, is the greater degree of hardness characteristic of the Nahan sandstone, which is capable of being dressed into blocks and used as a building material, whereas the sand-rock is much less coherent and crumbles away when struck with the hammer.

Lithological characters of the three stages.

Although the three stages of the Siwalik series may be denoted broadly as the conglomerate, sand-rock and sandstone stages, respectively, yet it must not be supposed that each of these rocks constitutes the whole of the formation of which it is characteristic; these are merely predominant types, and conglomerate is found also in the sand-rock stage, especially towards its base, as well as in the Nahan stage, whilst clay and loam are found throughout the whole series, purple and red clays being especially characteristic of the Nahan stage.

Main boundary fault.

Between the Siwalik series and all older beds with which they are found in contact there occurs one of the most peculiar, as it is one of the most constant, features of Himalayan tectonic geology. This is known as the "main boundary fault," which, probably throughout the whole length of the Himalaya, from Assam to at least as far as the Beas, occurs at the inner edge, and so forms the northern boundary, of the Siwalik series. This fault has many peculiar and interesting features: in the first place, it is not a simple fault, but is of the type known as "reversed," along which, in the process of folding, the older rocks have been thrust up over the younger, whilst, at the same time, the apparent order of superposition of the beds on one or on both sides of the fault may be exactly the reverse of the order in which they were originally deposited. Whatever be the ultimate causes to which the folding of the crust of the earth is due, they resolve themselves finally into tangential thrusts acting in opposite directions; the effect of this is to throw the crust into folds, which, at first gentle, gradually become more and more compressed until the pressure exceeds the breaking strain of the component rocks and fracture (faulting) results. This is most readily exemplified by means of diagrams; on plate XXXIX, figures 1 to 3 represent successive stages in the compression and folding of a series of stratified rocks, from their simple wave-like beginnings up to the reversed and broken flexure which is the key to almost all the complicated puzzles of Himalayan structure, not only in the geologically young Sub-Himalayan area but also throughout the whole of the mountain masses between India and Tibet, as well as in the ranges of Afghanistan.

Character of the faults.

If, now, we turn to the actual conditions of the rocks of the Sub-Himalayan zone, we find this type of structure clearly shown in the beautiful sections traced by Mr. Middlemiss in the area between the debouchure of the Ganges and Nepal. Plate XXXIX, figures 4 to 6, which are reproductions of Mr. Middlemiss' sections,* show not only one of these reversed fault but a whole series of them (figure 6), each separating one rock formation from another and occurring not only among the members of the Siwalik series, but also through the older beds of the unfossiliferous and metamorphic zone of the Lesser Himalayan ranges. It will be noticed that each of these fractures has taken place along the middle limb of the fold, *i.e.*, along the part lying between an anticlinal crest and its complementary synclinal trough, and that on either side of the fault the normal order of superposition of the beds has, in many cases, been reversed, the younger now appearing to underlie and dip beneath the older; this is a characteristic and constant feature in the relation of the beds of the Siwalik series to all older beds and also, to a great extent, to one another.

Main boundary fault an original limit of deposition.

A second point of importance in connection with the main boundary fault lies in the fact that the Siwalik deposits never overstep this boundary line and are never found among the higher hills beyond, but are restricted to the zone fringing the foot of the hills. The main boundary must, therefore, mark an original limit of deposition of the Siwalik series. Furthermore, Mr. Middlemiss has inferred that the reversed faults lying to the south of the main boundary are also to a certain extent original limits of deposition for the beds lying immediately to the south of each, and that they consequently mark the approximate position of the mountain-foot as it was at the time of their formation. They were thus "not contemporaneous, but successional," each having been produced or at least completed at the end of the period during which the beds immediately to the south of it were deposited.† The detailed reasoning and careful observation which have led to the above conclusions and which we owe, first, to the genius of the late Mr. H. B. Medlicott, and subsequently to the skill and industry of Mr. C. S. Middlemiss, are too extensive and of too technical a nature to be dealt with here, but those who wish to pursue the matter further are referred to the original papers.‡ An admirable summary, by Mr. R. D. Oldham, of the whole question will be found in the second edition of the "Manual of the Geology of India," pp. 467 to 471.

Mode of accumulation of the Siwaliks.

Turning now to the Siwalik series as a whole, we find it to consist of an enormous thickness—averaging over 16,000 feet—of deposits, which, in spite of local unconformities, are undoubtedly one great conformable and connected formation,§ which has been deposited sub-aërially by streams and rivers|| along the outer margin of the Himalaya. The deposition of such a great thickness of material must have occupied a vast period of time, during which the area over which they were being laid down was steadily sinking. The cause of this persistent movement of subsidence is still a matter of controversy, and no

* *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2 (1890).

† C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2, 118, 119 (1890).

‡ H. B. Medlicott: *Memoirs, Geological Survey of India*, Vol. III, pt. 2 (1864); C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2 (1890).

§ C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2, 29 (1890).

|| *Manual of the Geology of India, 2nd edition*, 358 (1893).

theory has been generally accepted, although that put forward by the Rev. O. Fisher had until recently many supporters. This has already been ably dealt with by Mr. Oldham,* whose modification of the theory seemed to satisfy all the requirements of the case. The theory is based on the hypothesis that the crust of the earth is comparatively thin, and rests upon a zone of material which is either fluid or has the properties of a fluid. As this inner portion contracts owing to loss of heat, the crust is left unsupported and, not being strong enough to bear the strain due to its own weight, will "yield along lines of weakness" and be "thickened both upwards and downwards" from a zone at certain depths below the surface. Above this zone, which has been termed the "neutral zone," "the material will, on the whole, be forced upwards and below it downwards." Mr. Fisher has most ingeniously explained not only the rise of the Tibet plateau but also the overfolding of the outer border of the Himalaya and the subsidence of the submontane tracts, whilst Mr. Oldham's amplification of the argument affords a complete explanation of all the observed phenomena.†

Rev. O. Fisher's theory.

Of late, however, physicists have begun to question the validity of Mr. Fisher's premises and Major Dutton's theory of isostasy (see above, page 48) is now more generally accepted. Major Dutton assumes that, owing to the removal, by rain and rivers, of material from the mountains and its deposition on the plains at their foot, isostatic equilibrium has been disturbed and can be restored only by the rise of the denuded area and the subsidence of that portion over which the material has been deposited; we thus have an explanation of the manner in which these vast sub-aërial deposits may have accumulated in areas which have for a long period of time been steadily subsiding.

Dutton's theory of isostasy.

Sirmur series.

The Sirmur series is, with one exception, not known to occur to the east of the Jumna, but is extensively developed in the outer portion of the Lesser Himalaya to the west of that river. It has been subdivided into the three stages already noted (*supra*, page 209). Of these, the uppermost, or Kasauli, stage consists chiefly of sandstone, with subordinate beds of clay: the sandstone is grey or greenish in colour, at times hard, but, as a rule, rather soft and coarse, the upper beds being not unlike the sandstones of the Nahan stage. The apparent absence of marine fossils, the presence of remains of land plants, and the general similarity of the beds of the Kasauli stage to those of the lower beds of the Siwalik series leave little room for doubt that the Kasauli sandstone is of fresh-water origin. The stage takes its name from the hill station of Kasauli, where it is well exposed.

Kasauli stage.

The underlying Dagshai stage consists chiefly of grey or purple sandstone with beds of bright red or purple homogeneous clay. Both at Dagshai and on the ridge to the north of that station the beds are

Dagshai stage.

* *Manual of the Geology of India*, 2nd edition, 471—477 (1893).

† *Ibid*, 473.

well exposed and readily recognisable in the road and railway cuttings. The only fossils found are worm-tracks and obscure markings ascribed to fucoids. It appears probable that these beds were deposited in lagoons or salt-water lakes: they thus constitute an intermediate stage between the overlying Kasauli beds of fresh-water origin and the underlying Subathu stage, which is definitely marine.

Subathu stage.

The Subathu stage—so named from the hill station of Subathu—consists chiefly of "greenish-grey and red gypseous shales, with some subordinate lenticular bands of impure limestone and sandstone, "the latter principally found near the top" of the stage.* At the base there is a peculiar ferruginous bed which bears a strong resemblance to the laterite so well known in the Indian peninsula. Fossils are common throughout the rocks of this stage, especially in the neighbourhood of Subathu.† The only forms that need be mentioned here are *Nummulites*, the presence of which leads to the inference that the Subathu stage corresponds to the eocene of Europe.

Near the base of this stage at Subathu, there is a seam of coal, which, however, is too impure and too crushed to be of any economic value.‡

Distribution of the Sirmur series:

The Sirmur series was first critically examined and described by Mr. Medlicott (*op. cit.*) in the Simla region; it was subsequently traced by him westwards into Jammu § and thence linked up with the similar rocks of Murree and the Jhelum valley.||

in Jammu;

The Sirmur series of Jammu is similar to that of the Simla region, with the exception that the coal seams of the Subathu stage are here more extensive, and are underlain by thick beds of ironstone.¶

in the Murree Hills.

In the Murree hills nummulitic limestone and shales represent the Subathu stage, whilst the two upper stages (Dagshai and Kasauli) are represented by the formation known as the Murree beds, the identity of part of which with the Kasauli stage has been proved by the occurrence in the Murree hills of fossil plants similar to those found in the Kasauli stage in the Simla region.** Similar fossils have also been found in the valley of the Ravi,†† which thus serves as a connecting link between the Murree and Simla regions.

Age of the series.

The whole of the Sirmur series is one perfectly continuous and conformable group of deposits, there being a gradual transition, first, from the Subathu stage up into the Dagshai stage and thence from that into the Kasauli stage. The evidence afforded by fossils enables us to correlate the

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* *Manual of the Geology of India*, 2nd edition, 350 (1893).

† H. B. Medlicott, *Memoirs, Geological Survey of India*, Vol. III, pt. 2 (1864).

‡ *Manual of the Geology of India*, 2nd edition, 350 (1893).

§ *Records, Geological Survey of India*, Vol. IX, 53 (1876).

|| A. B. Wynne: *Records, Geological Survey of India*, Vol. VII, 64 (1874); O. Feistmantel: *Records, Geological Survey of India*, Vol. XV, 51 (1882).

¶ R. R. Simpson: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 4 (1904).

** O. Feismantel: *Records, Geological Survey of India*, Vol. XV, 51 (1882).

†† H. B. Medlicott: *Records, Geological Survey of India*, Vol. IX, 52 (1876).

Subathu stage with the eocene stage of the Tertiary system of Europe * and the Kasauli stage with the lower miocene.

Its eastern development.

It has already been pointed out that, to the east of the Jumna, the Sirmur series is only known to occur in one area. To the east of the debouchure of the Ganges and along the inner boundary of the Siwalik series, there is found a most complicated group of beds, amongst which the typical beds of the Subathu stage have been recognised not only by their lithological characters but also by their fossils.†

Relation of Sirmur series to older rocks.

Where the Sirmur series has been found in contact with older beds, the junction between the two has always been found to be either a faulted or an unconformable one. Nevertheless, from a tectonic point of view, this series is more nearly associated with the old, frequently metamorphosed, beds of the central zone of unfossiliferous sediments, amongst which its component members have been intimately infolded, than with the younger Siwalik series and it extends beyond the strictly Sub-Himalayan hills into the ranges of the Lesser Himalaya, whilst, except in the western parts of the Himalayan area, it is marked off from the Siwalik series by the sharp line of the "main boundary." In all except its purely structural relations, however, it differs widely in every respect from the old unfossiliferous rocks of the Himalayan zone.

Tal series and Himalayan Gondwanas.

Before passing on to deal with the component parts of this latter zone, we must refer briefly to certain pre-Sirmur beds which are, from a stratigraphical point of view, more nearly related to this younger series than to the members of the older Himalayan zone. These include a small patch of beds immediately underlying the Subathu stage in western Garhwal to the east of the Ganges, and certain coal-bearing beds found along the southern foot of the Himalaya to the east of the Nepal Terai. The first of these is known as the "Tal series," and the latter comprise a small fragment of the well-known Gondwana system of Peninsular India.

Tal series (Plate XLII).

The Tal series was first noticed by Mr. H. B. Medlicott in the valleys of the Tal and Bedasni rivers, affluents of the Ganges in western Garhwal,‡ and was subsequently traced for some distance in an easterly direction by Mr. C. S. Middlemiss.§ It comprises two subdivisions: a lower composed of sandstone, some conglomerate and a black carbonacecus shale containing plant remains, and an upper, indigo-coloured, calcareous grit, at times becoming a sandy limestone, full of broken marine fossils. On normal sections, this series lies immediately below the nummulitic beds of the Subathu stage, and is therefore older,

* D'Archiac and Haime: *Groupe nummulitique de l'Inde.*

† C. S. Middlemiss: *Records, Geological Survey of India,* Vol. XX, 33 (1887), *Memoris, Geological Survey of India,* Vol. XXIV, pt. 2 (1890).

‡ *Memoirs, Geological Survey of India,* Vol. III, pt. 2, 69 (1864).

§ *Records, Geological Survey of India,* Vol. XX, 33 (1887).

whilst the fossils, which are unfortunately too badly preserved for complete determination, indicate that it may possibly be referable to some part of the Jurassic system or at least to some member of the Mesozoic group of Europe. It is to be hoped, however, that fossils in a better state of preservation may yet be found in this area, and thus enable us to ascertain the exact age of this series, which is unique in comprising the only fossiliferous marine beds of pre-Tertiary age known to occur in close association with the unfossiliferous series of the Himalayan zone.

Gondwanas in the Eastern Himalaya.

Along the southern foot of the Eastern Himalaya, from the Balasan river, which debouches at a few miles to the east of the Nepal frontier up to the Dikrang river in the Daphla hills on the Assam border, a band of highly crushed coal-bearing rocks has been found, first by Lieutenant-Colonel Godwin-Austen* in the extreme east, and subsequently by Mr. F. R. Mallet † in the Darjeeling Terai and the Duars, by Mr. G. E. Pilgrim‡ in the foot-hills of Bhutan, and by Mr. T. D. LaTouche§ in the Aka hills. The rocks of this series consist of sandstone, shale and coal, which, owing to the intense crushing to which they have been subjected during the building up of the Himalaya, have been locally changed to quartzites, slates and carbonaceous schists. The coal beds, being the softest, have suffered most, and have been rendered so friable that they crumble into powder with the least handling; at the same time what were once probably continuous beds have been squeezed out into lenticular patches; these characteristics detract largely from the economic value of the coal-seams, and have rendered futile all attempts at mining enterprise. A number of fossils have been found in these rocks in the Darjeeling area and include such well-known genera as *Vertebraria* and *Glossopteris*,|| plants eminently characteristic of the coal-measures of Bengal. On the whole, the fossils, as well as the lithological characters of the rocks in which they occur, offer conclusive proof that these Himalayan beds represent the Damuda series of the Lower Gondwana system. The importance and interest of this group of beds are obvious, since they afford evidence of the north-easterly extension of the old Gondwana continent.

Distribution of the Gondwanas.

How far this belt of Damuda rocks is continuous along the foot of the Eastern Himalaya, it is at present impossible to say; but since it has been met with at most points at which the lower hills have been visited between the eastern frontier of Nepal and the Dikrang river, it is highly probable that its continuity is practically uninterrupted, whilst it may not improbably extend still further towards the east. The whole of the Eastern Himalaya, however, from the Sankos river to the gorge of the Brahmaputra is practically a *terra incognita*, in which much work of absorbing interest still remains for the geographer as well as for the geologist. Towards the west also these beds may possibly extend into Nepal, but of this there is no evidence. The only part of the country regarding which we have any

* *Journ. As. Soc. Bengal*, Vol. XLIV, pt. 2, 35 (1875).

† *Memoirs, Geological Survey of India*, Vol. XI, 14 (1875).

‡ *Records, Geological Survey of India*, Vol. XXXIV, 24 (1906).

§ *Records, Geological Survey of India*, Vol. XVIII, 122 (1885).

|| F. R. Mallet: *Memoirs, Geological Survey of India*, Vol. XI, 30 (1875.).

information is the strip bordering the road to Katmandu, along which Mr. Medlicott found the Siwalik series well developed, but could not definitely identify any part of the section seen by him as being of Gondwana age.* No trace of the latter system has been found anywhere along the foot of the Himalaya to the west of Nepal, the only other extra-peninsular area in which plant-beds of Gondwana age have been identified being the valley of Kashmir (see below, p. 244).

* *Records, Geological Survey of India,* Vol. VIII, 93 (1875)

34

THE HIMALAYAN ZONE.

Distribution and subdivision.

The next great group of rocks, which occupies what is known as the Himalayan zone, forms the bulk of the ranges constituting the Himalaya proper, and stretches from end to end of this mountain chain. To visitors to the hill stations it is the most familiar, yet at the same time the least understood, of all the Himalayan rock-groups and its classification still constitutes the greatest and most insoluble of all problems of Himalayan geology. It falls broadly into two subdivisions, (1) metamorphics, composed of granite, gneiss and crystalline schists and (2) a series of fragmental rocks of undoubtedly sedimentary origin, such as slates, quartzites, conglomerates and limestones, which, although frequently, to all appearance, eminently suited for the preservation of fossils, have not yet yielded to the most careful and repeated search a single trace of any undoubted organic remains.

The absence of fossils throughout the Himalayan zone renders it impossible to correlate, with any degree of certainty, the various rocks of one area with those of another since all attempts at such correlation can be based only on the individual peculiarities of the rocks themselves, that is to say, on their lithological characters, a method which, in the case of stratified rocks of undoubted sedimentary origin, is always more or less unreliable and not infrequently misleading, especially in areas in which disturbance and metamorphism are so pronounced as in the central zone of the Himalaya. The result of this is that, with rare exceptions, it has been impossible to recognise with certainty the petrographical elements of one area in those of another, and a large number of apparently independent rock-groups have consequently been established, each under a purely local name, thus giving rise to a confusing variety of subdivisions, no two of which can be definitely correlated the one with the other. Of these the best known are the "Simla slates" and "Carbonaceous system" in the Simla hills and Mussooree, the "Jaunsar system" in Jaunsar-Bawar, the "Purple slates," "Deoban limestone" and "Vaikrita system" of Garhwal and Kumaun, the "Baxa" and "Daling" series in the Darjeeling Himalaya and the slates and schists of the Miju ranges between North-Eastern Assam and Tibet.

Granite and Crystalline Schists.

Crystalline belt.

In striking contrast with the amount of detailed attention that has been paid to the unfossiliferous sediments of the Himalayan zone, the metamorphosed schists and other crystalline rocks have, with one exception, been most strangely neglected. This has no doubt been largely due to the fact that the crystalline rocks, as a rule, lie in that "no man's land" between the sedimentary Himalayan systems and the fossiliferous beds of the Tibetan zone, and have thus, owing to lack of time and opportunity, failed to receive attention at the hands of the respective investigators of these two belts of rocks. The one exception referred to is that of the gneissose granite of the Himalaya, which was most exhaustively studied by the late Lieutenant-General C. A. McMahon, whose work is a monument of patient investigation and a brilliant example of the great assistance that can be rendered by a non-professional worker in the field of Indian geological research. Of the many valuable results of General McMahon's work, the most important of all was the conclusive proof of the intrusive origin of the granite, which had hitherto been regarded as a metamorphic rock of probably sedimentary origin, and, under the name of the "central gneiss,"* had been described as the oldest of all Himalayan rocks, whereas he was able to show that it was in reality one of the youngest members of the Himalayan and Tibetan zones, into which it had been intruded, and with which it had been intimately infolded, whilst to it is due much of the metamorphism of the rocks amongst which it occurs. The period at which the intrusion of the Himalayan granite took place is not definitely known, but is usually regarded as approximately coincident with the disturbances to which the origin of the Himalaya is ascribed and which occurred towards the end of the eocene division of the Tertiary period.

Gneissose granite.

Age of the granite.

Fragments of granite have been found among the pebbles of the conglomerates in the old "Panjal" rocks of Kashmir (see below, p. 242) and in the "Kuling system" in Spiti (*infra*, p. 234); it is therefore evident that granite must have formed part of the land surface from which the materials that make up these beds were derived and must consequently have been older than Carboniferous, which is the latest date that can be attributed to the Panjals (*infra*, p. 245). It will be seen subsequently that at this period the Himalaya did not exist and this old granite must therefore be excluded from the term "Himalayan."

Pre-Carboniferous granite of Spiti and Kashmir.

Three other granites are found in the Himalayan region. The best known of these is characterised by the presence of biotite (black mica) and the absence of the mineral hornblende. It forms almost all the high peaks of the great Himalayan range (*supra*, p. 44) and is the form commonly understood by the term "Himalayan granite." Associated with it is another granite characterised by the presence of black tourmaline (schörl), plagioclase felspar and beryl; this rock occurs in the form of bands intruded into the biotite-granite and is therefore younger than the latter; the difference in age between the two, however, is probably not great, the tourmaline-granite being perhaps merely the residual portion of the magma which still remained molten after the separation of the biotite-granite, in which case they may be regarded as merely representing two stages of a single phase of intrusion.

Biotite-granite.

Schörl-granite.

* F. Stoliczka: *Memoirs, Geological Survey of India*, Vol. V (1866).

The remaining granite differs markedly in mineralogical characters from both of the foregoing and is especially characterised by the presence of hornblende and sphene. It was found to be common in the valleys of the Brahmaputra and Kyi Chu in the neighbourhood of Lhasa* and has also been noticed in the Upper Indus valley in Ladak, in Astor, in Gilgit† and again in the Hindu Kush in Afghanistan. In Tibet it was regarded as possibly a form of the common biotite-granite of the Himalaya modified by the absorption of lime from the rocks into which it hed been intruded; but the type has now been found to persist over such a wide area that this explanation of its origin seems hardly satisfactory, and it should perhaps be regarded as a definite petrological type. The age of the hornblende-granite is not known with certainty; it has been shown by General McMahon to be older than the typical biotite-granite and was found in Tibet to be either later Cretaceous or post-Cretaceous. There is, therefore, no great difference in age between these granites and all three may possibly have been derived, by a process of differentiation, from the same magma, the hornblende-granite solidifying first, the biotite-granite next, and the tourmaline-granite last of all. The result of this is that each of the two older is penetrated by veins of the younger.

Hornblende-granite.

It has already been pointed out (*supra*, p. 44) that the axis of the great Himalayan range, the line of highest peaks, lies on a continuous zone of granite and associated crystalline rocks: this belt extends for some distance on either side of the axis and separates the old Himalayan sedimentary systems from the Tibetan zone to the north, at the same time sending out ramifications in all directions into both. Thus the granite extends down into Chamba on the west, to the Chur peak between Simla and Mussooree, far south into Nepal, Darjeeling and the Chumbi valley, and probably composes much of the mountains of Bhutan and the unknown regions further to the east.

Extension of the biotite-granite.

The associated crystalline rocks can, to a certain extent, be proved to be merely the metamorphosed representatives of the adjacent sedimentary systems. This is especially the case in the western part of the Himalayan belt, as, for instance, in the valley of the Sutlej in Kanawar, where the kyanite-schists and garnetiferous mica-schists bordering on the fossiliferous system of the Tibetan zone are seen to pass horizontally into comparatively unaltered beds which belong structurally to the Haimanta system ‡ (see below, p. 232).

Nature and origin of the crystalline schists;

Further to the east, in Kumaun and Garhwal, a schistose series has been described under the name of the Vaikrita system,§ part of which is probably of similar origin. Still further eastwards, in Northern Sikkim and the Assam Himalaya, this relationship between the granite and contiguous sedimentary beds is still traceable, but such metamorphism as can be ascribed with certainty to the granite extends to but

their distribution: in Kumaun (Vaikrita system);

in Sikkim and Assam;

* H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 2 (1907).

† C. A. McMahon: *Quarterly Journal, Geological Society*, Vol. LVI, 340 (1900).

‡ H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1, 9 (1904).

§ C. L. Griesbach: *Memoirs, Geological Survey of India*, Vol. XXIII, 41, 159 (1891).

a short distance from the intrusive masses of this rock, and we are not justified in assuming that such rocks as compose the crystalline complex of the Upper Tista valley are the result of a single effort of contact-metamorphism. These include such types as pyroxene-granulite, graphitic biotite-gneiss and spinel-bearing crystalline limestone, all of which occur in the valley of the La-Chen river in Sikkim,* whilst pyroxene-gneisses have also been recently found by Mr. L. L. Fermor, of the Geological Survey, in the neighbourhood of the Pindari glacier in the Almora district of Kumaun† and presumably, therefore, amongst the rocks constituting the Vaikrita system.

in Nepal.

Between these two areas, crystalline limestone and other metamorphic rocks are known to occur in the valley of Nepal,‡ and may possibly be the representatives of the rocks of the La-Chen valley in Sikkim. Crystalline limestones have also recently been brought by Mr. Claude White from Bhutan.

Origin and relationships of the crystalline schists.

Thus we may regard the crystalline belt as composed of three elements, *viz.*, intrusive granite, metamorphic schists due probably to the action of the granite on the rocks into which it has been intruded and which it has partially absorbed, and, lastly, a series of old gneisses, schists, granulites and crystalline limestones, of which the advanced state of metamorphism cannot be attributed merely to the Himalayan granite. These latter rocks, in fact, bear a marked resemblance to certain Peninsular types which are found in Madras, Burma, Ceylon, the Central Provinces § and Rajputana, and which are referred to the Archæan, the oldest of all the Indian rock-groups. Far to the west, in North-Eastern Afghanistan, the Siah Koh and the mountain ranges to the south and west of Kabul are either completely formed of similar types or have a foundation of these old rocks upon which younger fossiliferous beds have been unconformably deposited. In the intermediate areas crystalline schists are found in Hazara,|| Gilgit and Kashmir,¶ and, though in part merely altered representatives of sedimentary beds, probably also include members of the Archæan group.

Thus it is difficult to escape from the conclusion that the axis of the Himalayan chain and of the associated ranges to the west is in part made up of true representatives of the oldest known group of rocks, and that these are merely the northerly extension of the similar rocks of the Indian Peninsula.

Sedimentary Systems.

Sedimentary rocks of the Himalayan zone.

Throughout the whole of the Himalaya the crystalline axis is always separated by a belt of unfossiliferous sedimentary deposits from the band of Sub-Himalayan rocks which skirts the outer foot of the

* H. H. Hayden : *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 2 (1907).

† *Ibid.*

‡ H. B. Medlicott : *Records, Geological Survey of India*, Vol. VIII, 96 (1875).

§ The pyroxene gneiss found by Mr. Fermor near the Pindari glacier is said to be indistinguishable from similar rocks from the Central Provinces.

|| C. S. Middlemiss : *Memoirs, Geological Survey of India*, Vol. XXVI, 46 (1896).

¶ R. Lydekker : *Memoirs, Geological Survey of India*, Vol. XXII, 265 (1883).

mountains. On the west, in Kangra district, in the Simla hills, and thence as far as the Nepal frontier, this belt occupies the greater part of the Lesser Himalayan ranges; to the east of Nepal, however, the crystalline rocks approach nearer to the plains and the width of the sedimentary belt is reduced (Plate XXXVIII). In the western areas it consists, as already pointed out, of a number of apparently unrelated groups denoted by local names, such as the "Jaunsar system," "Carbonaceous system," "Deoban limestone," "Purple slate and breccia series" and the "Massive limestone." In the east its component members are known as the "Daling" and the "Baxa" series, respectively.

Jaunsar system.

Of the systems of the western area the Jaunsar is regarded as the oldest and is said to lie unconformably on the beds of the crystalline belt.* In eastern Sirmur the lowest member of the system is composed of slate and limestone, overlain by quartzite. Elsewhere the lower beds are not seen, and the quartzite lies directly on the crystalline rocks. Above the quartzites is a series of beds of trap, ashes and lava-flows, locally replaced partially by slate and limestone. In the Bangahal valley and again in northern Jaunsar a peculiar rock, composed of large boulders set in a fine-grained matrix, occurs in the lower beds of this system; it bears a curious resemblance to the so-called "boulder-slate" of the Blaini series (see below, p. 223) and, like it, has been attributed to the action of floating ice, large boulders having presumably been thus carried out to sea, or, at any rate, into tranquil water in which fine-grained deposits were at the same time being laid down. This system has not been definitely recognised out of Jaunsar and eastern Sirmur, but it may be represented by a series of purple slates and volcanic breccia found in western Garhwal to the east of the Ganges† and throughout the hills around Naini Tal.‡

Deoban limestone.

The Jaunsar system in Jaunsar-Bawar is overlain unconformably by a massive grey limestone series, which has been named the Deoban limestone after the peak of that name north of Chakrata. The same limestone overlies the purple slate series of western Garhwal and Naini Tal (Plate XLI) and a somewhat similar rock has been observed to the south-west of the Chur peak between Mussooree and Simla, in the Shali peak to the north-east of Simla and again in Kulu.

Simla slates and Carbonaceous system.

The systems next to be described comprise the most widely distributed and most readily recognised of all the subdivisions of the great complex of unfossiliferous sediments composing the Himalayan group. They are known as the Simla slates and the Carbonaceous system, and have been studied in considerable detail first by Mr. H. B. Medlicott§ and subsequently by Lieutenant-General C. A. McMahon|| and Mr. R. D. Oldham.¶ The area in which they were first

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* R. D. Oldham: *Records, Geological Survey of India*, Vol. XXI, 131 (1888).

† C. S. Middlemiss: *Records, Geological Survey of India*, Vol. XX, 26 (1887).

‡ C. S. Middlemiss: *Records, Geological Survey of India*, Vol. XXIII, 214 (1890).

§ *Memoirs, Geological Survey of India*, Vol. III (1865).

|| *Records, Geological Survey of India*, Vol. X, 204 (1877), XIV, 305 (1881) XV, 34 (1882), XVI, 35 (1883).

¶ *Records, Geological Survey of India*, Vol. XX, 143 (1887).

examined and on which their description was based is that lying between the inner edge of the Sirmur series, to the north of Dagshai, and Simla, but they are believed to extend thence both eastwards and westwards to beyond Mussooree on the one side and into the Chamba-Dalhousie region on the other.

Simla series.

The lowest member of the group consists of a series of slate and quartzite, well exposed throughout the ridges and valleys to the east of Simla, and seen all along the road from Sanjauli Bazar to Mashobra as well as on the outer slope of Elysium hill and the spurs below the Mall on the north-eastern side of Jako (Plate XL); to the visitor to Simla the slate is no doubt most familiar on the backs of coolies toiling up the steep "khud" sides and plodding laboriously along the Mall.

Blaini series.

The next overlying subdivision is that known as the Blaini series, so called from the Blaini river below Solan, where it was first studied by Mr. Medlicott. This is the most characteristic and readily recognised member of the Carbonaceous system and has served as a means of correlating various exposures in widely separated areas throughout the Lesser Himalayan ranges. It consists essentially of a bed of slate—presumably originally deposited as a fine mud or silt—through which are scattered sometimes pebbles of white quartz, sometimes large boulders of quartzite and other rocks. The large size of these boulders and the extremely fine-grained nature of the matrix in which they lie has led to a comparison of the Blaini "boulder-slate" with the "till" or "boulder clay," a characteristic deposit among the pleistocene or glacial beds of Europe, and which was formed by the instrumentality of floating ice during the Great Ice Age. Were the till to undergo severe pressure, such as the beds of the Himalayan zone have time and again been subjected to, the result would undoubtedly be a rock very like the Blaini boulder-slate for which a glacial origin has consequently also been inferred.*

The upper part of the Blaini series consists of a thin band of limestone, sometimes blue but typically pink or buff in colour. Occasionally this bed is absent, but in the Simla area it is almost invariably to be found above the boulder-slate. A conspicuous outcrop of the limestone occurs at Simla in the steep bank above the Mall, just beyond the Lakkar Bazar, whilst the boulder-slate is particularly well exposed at the Sanjauli corner beyond the Mayo Institute (Plate XL).

Carbonaceous shale.

Above the Blaini series is a bed of black carbonaceous shale, which, owing to its colour, has frequently been mistaken by the inexperienced for coal, and has led to many a vain expectation of the discovery of this mineral in Simla on the hill-side above the "Ladies' Mile."

Boileauganj series.

This is overlain by a thick series of quartzite and schist, known as the Boileauganj series in the Simla area, where it forms the greater part of Jako above the Mall and underlies most of the town.† Its

* *Manual of the Geology of India*, 2nd edition, 133 (1893). The name "tillite" has recently been introduced for indurated boulder-clays of glacial origin and pre-pleistocene age.

† R. D. Oldham: *Records, Geological Survey of India*, Vol. XX, 143 (1887).

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thickness is very variable, ranging from only about 20 feet on the Krol mountain near Solan to perhaps a thousand at Simla.

The carbonaceous shale and overlying quartzite and schist (Boileauganj series) were grouped together by Mr. Medlicott, who named them the "Infra-Krol" series, on account of the fact that at the Krol mountain they underlie a thick band of limestone which caps both the Krol and the Boj, and which he, therefore, named the "Krol limestone." At Simla the Boileauganj series is overlain also by limestone, but with it are associated beds of carbonaceous shale and igneous rocks, including a garnetiferous hornblende-schist, which is found on the summit of Prospect hill; these igneous beds have been regarded as altered volcanic ashes, but their origin is very obscure. In other localities beds of basalt have been found interbedded with the upper members of the Carbonaceous system.

Krol series.

To the east, in Jaunsar, a thick series of quartzite, which has been named the "Bawar quartzite," has been observed in the Tons and Pabar valleys; it is overlain by volcanic beds, followed by carbonaceous slates and limestones, and has been taken to represent the Boileauganj quartzite and overlying beds of the Simla area.

Carbonaceous system in Jaunsar.

Also, in Jaunsar, but not in direct contact with the above series, there is a thick group of quartzite, slate, limestone, conglomerate and boulder-beds, lying unconformably on the Deoban limestone. These are known as the Mandhali series, and have been correlated, owing to the presence of boulder-beds, with the Blaini series of Simla. A very similar series occurs on the eastern flanks of the Chur mountain, where it is overlain by carbonaceous slates and a thick formation of quartzite and schist exactly like the Boileauganj series; this has been regarded as fairly conclusive evidence in favour of correlating the Bawars and Mandhalis with the lithologically similar series of the Carbonaceous system.

Mandhali series of Jaunsar.

Beyond the Simla area, towards the west, beds regarded as the representatives of the Blaini series have been found in Chamba; further to the west, in Kashmir, Mr. Lydekker has described a boulder-bed belonging to his Panjal system* as the exact counterpart of the Blaini rock, whilst certain conglomerates and limestones so far off even as Chitral have been referred to the same horizon.†

Supposed representatives of the Blaini series: in Kashmir and Chitral;

The rocks described as the Panjal system in Kashmir consist of a thick series of deposits composed of quartzite, slate and conglomerate (boulder-beds) below, capped by great masses of volcanic beds, frequently amygdaloidal, which represent old lava-flows. These are exposed on the Pir Panjal range, from which they take their name; a good section or part of them is seen along the cart-road, on the left bank of the Jhelum between Uri and Baramula; they also form the hills on which Gulmarg stands. The upper or volcanic part of the system composes most of the hills sur-

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* *Memoirs, Geological Survey of India*, Vol. XXII (1883).

† C. A. McMahon: *Quarterly Journal, Geological Society*, Vol. LVI, 337 (1900), *Geological Magazine*, Dec. IV, Vol. IX, 7 (1902).

rounding the Kashmir valley on its northern and north-western sides from Baramula to Vihi, and is particularly well seen on the Gilgit road between Bandipur and Tragbal and in the immediate neighbourhood of Srinagar. In an easterly direction the Panjal beds are said to extend to Chamba,* where they include the beds supposed to represent the Blaini series of Simla.

in Hazara.

Still further westwards, in Hazara, a series of conglomerate and sandstone has been described by Mr. Middlemiss under the name of "Infra-Trias," and has been correlated by him also with the Blaini series of the Lesser Himalaya† (Plate XLIX).

Age and correlation of the Blaini series.

We thus see that the unfossiliferous sedimentary belt is composed of a patch-work of more or less isolated groups of beds, no two of which can, with absolute certainty, be identified one with the other. For the most part they consist of perfectly ordinary sediments such as have been formed at all times during the earth's history, at least since its surface was divisible into land and water, and are still forming round the coasts and in the seas of the present day. Consequently, so far as these deposits are concerned, correlation depends on the manner of association of the respective deposits; thus, quartzites overlain by carbonaceous shales and limestones in one area are correlated with a similar sequence in another. This method of correlation by lithological characters is unfortunately open to many objections and cannot be relied on except over very limited areas. Where, however, a peculiar and uncommon form of deposit occurs in two neighbouring areas, we are on safer ground in correlating the one with the other, and it is chiefly this method that has been employed throughout the Himalayan unfossiliferous belt. The Blaini boulder-slate is generally admitted to be of glacial origin,‡ and as boulder-beds of this character, now known as "tillites," are by no means of common occurrence, but have been formed under very special conditions, which are known to have recurred only at rare intervals in the history of the earth, the Blaini rock has been regarded as the key to the solution of the mutual relationships of the respective members of the sedimentary rocks of the Himalayan zone and, with the exception of the supposed boulder-slate of the Jaunsar system, all similar beds in this belt have been referred to the Blaini series. Nor has this procedure been restricted to the rocks of the Lesser Himalaya; it has been extended to certain supposed boulder-beds found in Spiti, in the Panjal system in Kashmir, in the Infra-Trias of Hazara and even so far afield as Chitral. All these have, by one observer or the other, been referred to the Blaini horizon, and this again has been correlated with the well-known Talchir boulder-bed, which is of undoubted glacial origin and which occurs below fossiliferous deposits of known age in the Salt Range and at the base of the Gondwana system of Peninsular India. The Blaini boulder-slate and its supposed representatives in other parts of the Himalaya have, therefore, all been referred to the Talchir horizon, that is to say, to about the Middle Carboniferous epoch of the European geological

* R. Lydekker : *Memoirs, Geological Survey of India*, Vol. XXII (1883).

† *Memoirs, Geological Survey of India*, Vol. XXVI, 22 (1896).

‡ T. H. Holland: *Records, Geological Survey of India*, Vol. XXXVII, 129 (1908).

time-scale. This method of endeavouring to fix the age of the Blaini boulder-slate and its supposed representatives is a perfectly legitimate one, and the conclusions arrived at have until quite recently been accepted as offering a not improbable solution; unfortunately, however, the beds in Spiti, which have been identified with the Blaini rock, have now been found to be perfectly ordinary conglomerates with only a superficial resemblance to tillite, whilst they have also been proved by means of fossils to belong to a horizon considerably younger than the Talchirs.* Again, the conglomerates of the Panjal system of Kashmir, as described by Mr. Lydekker,† occur at some considerable distance below the top of that system, and recent work near Srinagar has shown that the uppermost beds of the Panjal system, the traps, are probably older than the Talchir boulder-bed;‡ consequently the Panjal conglomerates must be older still.§ Since, therefore, the correlation of the Blaini boulder-slate with the conglomerates of Spiti and Kashmir, which are comparatively near the Simla area, have proved erroneous, we must regard with suspicion any attempt to refer to this horizon beds in areas so far off as Hazara and Chitral. It must be admitted, however, that the wide distribution of the Talchir tillite, which has been identified both in Australia and South Africa, would justify its extension to the Simla area, but it must be remembered that in all other areas it is found associated with fossiliferous rocks of known age, and it is therefore extremely difficult to account for the absence of fossils in the Blaini series; this might no doubt be attributed to the disturbance and crushing to which the Himalayan group as a whole has been subjected, were it not for the fact that beds no less crushed and altered have been found in other areas to retain their fossils in a recognisable state, whereas the rocks of the Himalayan zone, although often apparently eminently suited for the preservation of fossils, have not yielded so much as a trace of any structure that can be definitely pronounced to be of organic origin, much less any recognisable fossils. We are, therefore, compelled to conclude that these rocks are truly unfossiliferous and to give up further attempts to correlate them with the fossiliferous beds of known age constituting the Tibetan zone to the north. There has consequently of late been a general tendency to look elsewhere for the representatives of this great unfossiliferous group. Attention has been drawn to this point by the Director of the Geological Survey in a "General Report" on the work of his Department; Sir Thomas Holland|| writes —

> The fossiliferous character of the strata lying on the northern (Tibetan) flanks of the crystalline axis stands in remarkable contrast to the unfossiliferous character of the beds which form the southern or Lower Himalayan zone. The persistence of the northern fossiliferous zone eastwards as

* H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, 51, 109 (1904).

† *Memoirs, Geological Survey of India* Vol. XXII, 216 (1883).

‡ H. H. Hayden: *Records, Geological Survey of India*, Vol. XXXVI, 23 (1907).

§ It seems not improbable that the Panjal system may include more than one set of conglomerates, namely, one of upper Cambrian or lower Silurian (Muth) age (*infra* p. 233), and another which occurs at the base of the Permian; both of these are found in Spiti and have each been referred to the Blaini boulder-slate. If both of these occur in Kashmir, there are grounds for suspecting that they may have been regarded as one and the same. This, however, cannot be settled until Kashmir has been surveyed in detail.

|| *Records, Geological Survey of India*, XXXII, 156 (1905).

far as Sikkim, now established, naturally accentuates this contrast, and increases the suspicion, which has recently been growing amongst the members of the Geological Survey, that the Lower Himalayan rocks, like those of Simla, Kumaun and Bhutan, are members of very ancient systems of sediments, all or in part pre-Cambrian, nothing other, in fact, than northerly extensions of the Vindhyan, Cuddapah and similar old systems of the Peninsula, which have been caught, like the much younger Gondwana beds of Darjeeling and Assam, in the great earth-folds that have produced the Himalayan range. That one, two or more stratigraphical stages on the south could be unfossiliferous whilst their equivalents on the north are fossiliferous might be possible; that such an accident could be carried through every geological epoch from Cambrian to Cretaceous is so highly unlikely, that we are driven to regard the ingenious and elaborate systems of lithological correspondences, which have been propounded to distribute the strata of the Lower Himalayan zone over the standard fossiliferous scale, as so much misdirected, though well intended, mental energy.

That this solution is a nearer approximation to the truth is becoming yearly more and more apparent. It has already been pointed out (*supra*, page 221) that rocks exactly resembling Archæan types of the Indian Peninsula and Burma have been found in Sikkim, Kumaun and Afghanistan, and it is not unreasonable to suppose that they will also be discovered in the intermediate areas; furthermore, the Daling series of Sikkim and the metamorphic and crystalline rocks of the Miju ranges at the extreme eastern end of the Himalaya have also been referred to well-known Peninsular types * and we are thus led to correlate the Himalayan group with the old unfossiliferous and metamorphic beds comprised in the Archæan and Purana groups† of the extra-Himalayan areas, which include such systems as the Vindhyans, Cuddapahs, Dharwars and that embracing the old gneissose rocks of Rajputana, the Central Provinces, Madras and Burma and so to regard this unfossiliferous belt as a northerly extension of what has been one of the most permanent, as it is one of the oldest, continental areas of the globe.

The Tethys.

The presence, immediately to the north of this zone, of an extensive series of fossiliferous marine sediments, further points to the conclusion that here lay the southern shores of the Tethys, the sea which extended over most of Asia during Palæozoic and Mesozoic times. Its old littoral deposits can still be traced among the beds of the Tibetan zone and prove that much of the present Himalaya was a land surface even in early Cambrian times (see below, page 250); and the unconformities and overlaps found at various horizons in the Palæozoic systems are indications of the vicissitudes through which this part of the ancient continent has passed.

Exception may perhaps be taken to the correlation of the unfossiliferous Himalayan zone with the Archæan and Purana groups of Peninsular India on the ground of the absence from the latter area of any known glacial deposits of pre-Gondwana age resembling the Blaini boulder-slate. A somewhat similar rock, however, has been recorded as occurring among the Purana rocks of Rewa.‡ Certainly no great weight

* J. M. Maclaren: *Records, Geological Survey of India*, Vol. XXXI, 181 (1904).

† See table showing classification of Himalayan systems: *supra* p. 208.

‡ *Memoirs, Geological Survey of India*, Vol. XXXI, 132 (1901).

can be attached to this observation, since definite proofs of glacial origin, such as striation and facetting of the included pebbles, have not been obtained. It nevertheless indicates the possibility of a pre-Talchir glacial epoch on the Indian Peninsula. In this connection attention may be drawn to the extraordinary resemblance, amounting indeed almost to identity, of some of the old pre-Cambrian groups of rocks of India to those of South Africa: thus the Dharwar system is very similar to the Malmesbury series of Africa. In much later times the Gondwanas of India find their exact equivalents in the Karroo system of the Cape, whilst similar mutual resemblances can be traced between the Cretaceous deposits of the two areas. The intimate relationship of India to South Africa in later Palæozoic and Mesozoic times has long been known, * but it is only quite recently that the more extensive geological surveys of South Africa have revealed the close resemblance between the older rock-groups of the two areas and have shown that from earliest times until comparatively recently the geological histories of the two areas have been strikingly similar. Many points of resemblance also exist between the geology of Australia and that of the Indian Peninsula and the recent discovery of boulder-beds of undoubted glacial origin below the Cambrian rocks of South Africa,† China‡ and (?) Australia§ render it by no means improbable that glacial conditions existed also in India in pre-Cambrian times and left their record in the form of the Blaini boulder-slate.

Daling series.

In the eastern Himalaya, the unfossiliferous rocks are represented by the Daling and Baxa series. The former consists of green and grey silky slate, quartzite and, occasionally, beds of hornblende schist. These beds are much crushed and contorted, and frequently contain small deposits of copper-ore, which have long been mined in primitive fashion by the natives of the Darjeeling district. The series occupies the lower hills between the crystalline rocks of Darjeeling and the Damudas of the foot-hills (Plate XXXVIII, fig. 3), and extends up along the Tista valley into Sikkim; thence it runs eastwards into Bhutan and probably continues through the unknown ranges on the north of Assam.||

Baxa series.

In the foot-hills of Bhutan another set of rocks, composed chiefly of dolomitic limestone and quartzite and known as the Baxa series, from the hill-station of Baxa, is found between the Damudas and the Dalings. Neither of these series has yielded any fossils, nor have they any special lithological features in common with individual members of the subdivisions into which the unfossiliferous rocks of other parts of the Himalaya have been grouped. Like these latter, however, they are now referred to the pre-Cambrian systems of the

* *Manual of the Geology of India*, 1st edition, Vol. I (1879).

† A. W. Rogers in *10th Annual Report of the Geol. Commission of the Cape of Good Hope*, 162 (1905).

‡ Bailey Willis, Eliot Blackwelder and R. H. Sargent: *Research in China*, pt. 1, 267 (1907).

§ Rev. W. Howchin: *Quarterly Journal, Geological Society*, Vol. LXIV, 234 (1908). The age of the South Australian tillite here referred to is regarded by Dr. Howchin as Cambrian, but all Australian geologists are not agreed upon this point, some considering it to be part of the Permo-Carboniferous boulder-bed and so homotaxial with our Talchir tillite.

|| F. R. Mallet: *Memoirs, Geological Survey of India*, Vol. XI, 39 (1875); P. N. Bose: *Records, Geological Survey of India*, Vol. XXIV, 217 (1891).

Indian Peninsula, of which they probably constitute merely an outlying portion. The metalliferous Dalings in some respects resemble the Dharwars, whilst the rocks of the Baxa series may find their nearest relatives among the members of the Cuddapah system.

Both the Daling and the Baxa series always appear to overlie the crushed representatives of the Damuda series and also the beds of the Sub-Himalayan zone, which fringe the southern mountain-foot. For this reason they were formerly regarded as possibly younger than the Damudas, but we now know that one of the most persistent features of the tectonic geology of the Sub-Himalayan zone is the manner in which the younger formations appear to dip below and underlie the older beds in the higher hills, a feature which we have seen to be due to recumbent folds and reversed faults; and when we find that each higher member is more metamorphosed and more crushed than that below, we may safely assume that the apparent sequence is the reverse of the true one and that, as in the case of the Tal series and associated rocks in western Garhwal, the Daling is in reality older than the Baxa series and the latter older than the Damudas.

35

THE TIBETAN ZONE.

The most northerly of the three zones of the Himalaya embraces not only the northern part of this mountain range, but extends far into Tibet and comprises one of the most complete representations of the geological record to be found in the world, ranging, as it does, from almost the earliest period of which there have yet been obtained any unequivocal organic remains down to the Tertiary epoch. Between these extreme limits not a single period remains unrepresented, for, although there may be local gaps in one area, these are bridged over in another; and as a book may be restored in its entirety from a number of incomplete copies, so the geological record may, with the exception of a few pages at the beginning and a few at the end, be pieced together from the editions lying open in the mountains of Kumaun, Spiti and Kashmir.

Distribution of the zone.

Throughout the Himalaya, this northern, or Tibetan, zone is met with almost everywhere immediately behind the crystalline axis—the line of high peaks—of the great Himalayan range. It embraces the Ladak and Zangskar ranges with their intervening troughs, and extends far to the north, probably at least to the great lake basin of Tibet and possibly as far as the Kuen Lun range. It consists of a vast thickness—more than 20,000 feet—of sediments almost entirely of marine origin and represented by such rocks as slate, sandstone, conglomerate and limestone. Along its southern border it is in contact with the Himalayan granite, which throws out branches ramifying through and metamorphosing the component members of the sedimentary zone.

Early stratigraphical work in the Himalaya.

Fossils had long been known to occur to the north of the great Himalayan range, the sacred "saligram" * of the Hindus having been identified as an ammonite related to those found in the Jurassic beds of Europe, and as early as the year 1831, the presence of genera common in the European Palæozoic and Mesozoic systems had been recorded in the Himalaya.† No systematic work, however, was undertaken till some years later, when General Sir R. Strachey visited the Kumaun Himalaya and Ngari Khorsum‡ and laid the

* "Saligram" are ammonites brought into India chiefly from the Jurassic shales of Kumaun, Ngari Khorsum and the uplands of Tibet on the northern frontier of Nepal. They are to be found in Hindu temples in India, and are also worn as charms. Among the Buddhists of Tibet they are also regarded as having magical properties and are used in certain mystic rites. Sarat Chandra Das also draws attention to the presence of fossils among the offerings to the gods in Densa-til monastery near Samye on the Brahmaputra [*Journey to Lhasa and Central Tibet*, edited by W. W. Rockhill, p. 299 (1904)].

† *Gleanings in Science*, Vol. III, 30 (1831).

‡ Spelt Nari Khorsam in previous parts, but the more correct form has now been substituted. We have experienced great difficulty in dealing with Tibetan names, since no phonetic system has yet been universally adopted. In the case of Indian names, we have decided, for the sake of consistency, to adopt the orthography of the Imperial Gazetteer, but, in dealing with names of Tibetan origin, we feel that this course would lead to needless perpetuation of error and have decided to employ the nearest possible approximation to the correct pronounciation. Thus, according to recognised standards of transliteration, the name Ngari Khorsum is written in Tibetan (m)Nga(h)-ri(s) (h)Khor-(g)sum; the letters in brackets, being silent letters, may be elided, thus leaving the name as pronouounced—Nga-ri Khor-sum. In the case of Zangskar, we also follow the Tibetan spelling in preference to the form "Zaskar" employed in the Imperial Gazetteer; the Tibetan form is Zangs (d)kar, which, in Central Tibet, would be pronounced Zang-kar, but in Ladak Zangskar. This is very near the form Zanskar sanctioned by long usage, which, however, has latterly been discarded for Zaskar, presumably the nearestapproximation to the Tibetan word that the Kashmiri is capable of. [H. H. H.]

foundations of Himalayan stratigraphical geology. He was followed by Dr. F. Stoliczka, whose description and subdivision of the fossiliferous rocks of Spiti*—a valley lying to the north of Kulu—long served as the basis for the classification of the sedimentary rocks of the Tibetan zone. Simultaneously the work of Lieutenant-Colonel Godwin-Austen † and of Verchère‡ proved the extension of this zone into Kashmir, and the subsequent surveys of Kumaun, Ngari Khorsum and Spiti by Mr. C. L. Griesbach§ and of Kashmir by Mr. R. Lydekker,|| both confirmed and amplified the results of Stoliczka's earlier traverses, whilst the publications of the Geological Survey Department bear witness to the amount of attention that the Tibetan zone has received in recent years.¶ Although much still remains to be done, and we can hardly claim yet to have advanced beyond the threshold of Himalayan stratigraphical investigation, nevertheless we have obtained sufficient evidence to reveal the striking fact that, throughout almost the whole period covered by that branch of geology known as "Historical Geology"—that is to say, that portion of the geological time-scale determined by the remains of living organisms—what is now the northern slope of the great Himalayan range lay beneath the waters of a sea, which extended over Tibet and stretched at one time to China and at another to the Mediterranean. Throughout almost the whole of this period, the sea-floor continued steadily to subside and thus rendered possible the deposition on it of those thousands of feet of sediments which have now been raised once more into dry land and form part of the highest mountain range in the world. This great series of fossiliferous sediments falls into a number of natural subdivisions which are not capable of exact adjustment to those of the European scale. Thus the clear line of division which is found in Europe between the Palæozoic and Mesozoic groups does not exist in the Himalaya, where beds of Permian age pass upwards by perfect gradation into others with Lower Triassic fossils. There is no break in the continuity of the deposits, and it is consequently impossible to define exactly where Palæozoic ends and Mesozoic begins. Similarly, a well-marked break in the Indian deposits may be bridged over by a perfectly continuous sequence in the rocks of Europe, and it has now been found impracticable to apply to the one region the nomenclature of the other. Hence the natural groups of the Himalayan sequence must for the most part be recognised as individual units, characterised by names of their own and referable only approximately to European equivalents.

Correlation of the systems of the Tibetan zone with those of Europe.

The most marked break in the Indian stratigraphical sequence occurs at the base of the Talchir boulder-bed, and this has been adopted by Sir Thomas Holland as a datum line for the classification of all the post-Purana rocks, the beds found below this break being included in his

Classification of the deposits of the Tibetan zone.

* *Memoirs, Geological Survey of India*, Vol. V (1865).
† *Quarterly Journal, Geological Society*, Vol. XX (1864), XXI (1865), XXII (1866).
‡ *Journal, Asiatic Society of Bengal*, Vol. XXXV (1866). XXXVI (1867).
§ *Memoirs, Geological Survey of India*, Vol. XXIII (1891).
|| *Memoirs, Geological Survey of India*, Vol. XXII (1883).
¶ *Pal. Indica*, Series XV, Vols. I to V.

"Dravidian group" and those above it in the "Aryan group."* These two divisions are clearly marked off from one another in the Salt Range and also in Kashmir, but there is some difficulty in demarcating them exactly in other parts of the Himalaya; and in the present state of our knowledge of Himalayan stratigraphy the dividing line between the two cannot be rigidly laid down.

The following table shows the subdivisions recognised in the rocks of the Tibetan zone :—

TABLE XLI.†

<table>
<tr><th></th><th colspan="3">System or subdivision.</th><th>Approximate European equivalent.</th></tr>
<tr><td rowspan="8">ARYAN GROUP.</td><td colspan="3">KAREWAS of Kashmir ; OSSIFEROUS BEDS of Ngari Khorsum
Stratigraphical break.</td><td>Pleistocene.</td></tr>
<tr><td colspan="3">NUMMULITIC LIMESTONE of Ngari Khorsum ; INDUS VALLEY TERTIARIES.</td><td>Tertiary.</td></tr>
<tr><td colspan="3">KAMPA SYSTEM</td><td rowspan="2">Cretaceous.</td></tr>
<tr><td colspan="3">FLYSCH of Ngari Khorsum ; CHIKKIM SERIES ; GIUMAL SERIES.</td></tr>
<tr><td colspan="3">SPITI SHALES ; JURASSIC of Southern Tibet.
KIOTO LIMESTONE.</td><td>Jurassic.</td></tr>
<tr><td colspan="3">LILANG SYSTEM.</td><td>Trias.</td></tr>
<tr><td colspan="3">KULING SYSTEM.</td><td>Permian.</td></tr>
<tr><td>(in Kashmir)
ZEWAN STAGE.
GANGAMOPTERIS BEDS.
Stratigraphical break.</td><td rowspan="2">(in Spiti)
Stratigraphical break.
PO SERIES } KANAWAR SYSTEM.
LIPAK SERIES }</td><td rowspan="2">(in Kumaun)
Strati-graph-ical break.</td><td>Carboniferous.</td></tr>
<tr><td rowspan="4">DRAVIDIAN GROUP.</td><td>PANJAL VOLCANICS.</td><td>Devonian.</td></tr>
<tr><td colspan="3">MUTH SYSTEM.</td><td>Silurian.</td></tr>
<tr><td colspan="3">Stratigraphical break.</td><td rowspan="2">Cambrian and possibly in part Pre-Cambrian.</td></tr>
<tr><td colspan="3">HAIMANTA SYSTEM.</td></tr>
</table>

TIBETAN ZONE IN SPITI AND KUMAUN (PLATES XLIII, XLIV, XLV).

Haimanta system.

Haimanta system.

The Haimanta system was the name given by Mr. C. L. Griesbach‡ to a series of conglomerates, quartzites and slates found in the Kumaun and Garhwal Himalaya and immediately overlying the crystalline schists of the Vaikrita system. The passage from the one system into the other is often quite gradual and no hard and fast line can be drawn between the two. This is no doubt due to the fact that the Vaikrita system consists partly of sedimentary beds which have been metamorphosed by the Himalayan

* T. H. Holland: *Trans. Min. and Geol. Inst. of India*, Vol. I, 48 (1906).

† See page 272.

‡ *Memoirs, Geological Survey of India*, Vol. XXIII (1891).

granite and which are in all probability merely the altered representatives of the lowest members of the Haimanta system (see above, page 220). The greatest development of this system is found in the Kumaun and Garhwal Himalaya, but it is also seen in the mountains to the north of Kulu, in Spiti and in Lahaul. In Spiti, the uppermost beds have yielded trilobites similar to those found in the rocks of the Cambrian system in other parts of the world.*

Muth system.

Coral limestone and conglomerate.

The beds of the Haimanta system are overlain by a group of beds named by Stoliczka the "Muth series." In Kumaun and Garhwal the lowest member is a dark coral limestone with imperfect fossils, said to be of Ordovician age; this subdivision is not found in Spiti, the slates with Cambrian trilobites being overlain unconformably by a conglomerate composed of pebbles of the underlying rocks. The next bed, both in the eastern and western sections, is a red quartzite, the colour of which is very persistent and serves as an unfailing guide to the recognition of this subdivision; it contains no determinable fossils, but is overlain by limestone with corals—including the very characteristic species *Halysites catenularia*—trilobites and brachiopods, such as occur in the Silurian rocks of Europe. Above this is a remarkable band of white quartzite, which is a constant feature in Himalayan sections of this part of the fossiliferous series. It is known as the Muth quartzite, from the village of Muth in Spiti. At its base are some thin bands of darker quartzite containing a brachiopod [*Pentamerus* (?) *oblongus*] probably identical with a species common in the upper part of the Gothlandian of Europe. No fossils have been found in the main mass of the quartzite, which may be of either Gothlandian or Devonian age and probably represents a part of each system.

Red quartzite.

Fossiliferous limestone.

Muth quartzite.

Kanawar system.

In parts of Spiti, but not in the more easterly sections of Kumaun and Garhwal, the Muth quartzite passes up into a thick series of limestone and shale containing at the base fossils which are possibly of Devonian age, but in its upper beds a rich fauna characteristic of the lower Carboniferous (Mountain Limestone) of Europe. This is overlain by about 2,000 feet of shale and quartzite containing two important fossiliferous horizons, the lower of which has yielded plant remains and the upper is characterised by great numbers of *Bryozoa*, amongst which the genus *Fenestella* is particularly common: this bed has consequently been named the "Fenestella shales."† It corresponds in age with the Upper Carboniferous of Europe. These two groups of beds, the limestone series and the shale and quartzite, have only been found

Lipak series.

Po series: Fenestella shales.

* H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1 (1904).

† *Ibid.*

completely developed in Spiti and Kanawar, being absent from Garhwal and Kumaun. The lower series is very well exposed in the valley of the Lipak river near Lio, a village on the right bank of the Spiti river just above its confluence with the Sutlej; it has consequently been named the Lipak series, whilst the upper beds, the shales and quartzites, are known as the "Po series," after the village of Po in lower Spiti. For convenience of reference the two may be grouped together under the name "Kanawar system."

The top of the Po series, which corresponds approximately with the end of the Carboniferous period in Europe, marks an important epoch in the stratigraphical history of the Spiti and Kumaun Himalaya. The shales and quartzites pass upwards into conglomerates composed of rolled boulders of limestone, slate, quartzite and granite derived from the erosion of the various older rocks, such as the Po quartzites, Lipak limestones and members of the Haimanta system. It is thus clear that before the deposition of this conglomerate parts of the sea-floor, on which the older systems had been laid down, were raised up to form dry land, which then underwent erosion. Similar conditions prevailed throughout Garhwal and Kumaun and may have extended even further east, but the whole of the Nepal, Bhutan and Assam Himalaya is still unsurveyed and we know practically nothing of the geological conditions to the east of Kumaun. A group of beds, which has been described as the Dothak series,* at the lower end of the Phari plain, may possibly cover a part of this period, whilst fossils of approximately the same age as those of the Fenestella shales have been found in rolled boulders in the gorge of the Subansiri in Assam† and thus afford evidence of the presence of fossiliferous beds somewhere in the catchment area of that river, but their relations to such older and younger beds as may be present are completely unknown.

Break in continuity of deposits above the Kanawar system.

Dothak series in Tibet.

In the Kumaun and Garhwal Himalaya the whole of the Po series, as well as the Lipak series, is wanting, and the overlying beds rest usually on an eroded surface of the Muth quartzite or, more rarely, on the underlying limestone. In Spiti and Kanawar extensive erosion took place throughout the greater part of the area before the deposition of the conglomerate which occurs above the Po series, but at both the upper and lower ends of the Spiti valley, the Lipak series and the Po series have been preserved.

Absence of Kanawar system from Kumaun.

Kuling system.

The next overlying series was first observed in Spiti by Stoliczka, who named it the Kuling series.‡ It consists of conglomerate at the base overlain by calcareous

* H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, part 2 (1907).

† J. M. Maclaren: *Records, Geological Survey of India*, Vol. XXXI, 186 (1904): C. Diener: *ibid*, Vol. XXXII. 189 (1905).

‡ *Memoirs, Geological Survey of India*, Vol. V, pt. 1 (1865).

sandstone which is covered in turn by a bed of black shale—about 150 feet thick—known as the "Productus shales"* on account of the predominance in it of brachiopods, which were originally referred to that genus. In Kumaun and Garhwal the presence of the conglomerate and overlying calcareous sandstone has not been recorded, but the Productus shales appear to lie directly on one or other horizon of the older systems. The fossils of the Productus shales are numerous and well preserved, and this horizon, together with the underlying sandstone and conglomerate, is regarded as approximately equivalent to the Permian system of Europe.

Productus shales.

Lilang system.

The next overlying beds show a distinct change both in the character of the component rocks as well as in the fauna that they contain; for whereas the predominant elements of the Kuling system are shallow-water coastal deposits, such as conglomerate, sandstone and shale, containing the remains of brachiopods, the next group of beds consists chiefly of limestone, deposited for the most part in deeper water beyond the reach of the sand and mud derived from the neighbouring land. The fauna, too, comprises chiefly ammonites, with only a comparatively small percentage of brachiopods. The change, though rapid, is by no means abrupt; marine conditions still prevailed, but the sea-bottom slowly subsided and what was formerly a comparatively shallow-water area now became deeper and further removed from the shore. There was no interruption of continuity of deposition on the sea-floor nor any *sudden* change in the character of the deposits. It is consequently impossible in the Himalaya to draw any hard line between the top of the Palæozoic group and the base of the Mesozoic, the passage from one to the other being perfectly gradual. The Productus shales pass up into an alternating series of thin bands of shale interbedded with equally thin bands of impure limestone; as the series is followed upwards, the calcareous element increases and the shale disappears and thence there extends to a vertical thickness of over 6,000 feet a perfectly uninterrupted group of deposits of which the predominant rock is limestone, with subordinate bands of shale and sandstone. This vast series of marine sediments comprises representatives of all the members of the Mesozoic group of Europe, which can be readily identified by means of the numerous fossils that they contain. The most important subdivision, both in point of thickness as well as of fossil contents, is the Lilang system, which is over 3,000 feet thick in Spiti and rather less in the Kumaun and Garhwal Himalaya. The base of this system is regarded as lying immediately above the Productus shales and beneath a thin band of limestone known as the Otoceras zone, so called from the prevailing genus of ammonite found in it. The lower beds of the Lilang system correspond to the Lower Trias of Europe and possibly in part to the uppermost subdivision of the Permian system. They consist of thin bands of limestone and shale, passing upwards into a thick bed of nodular limestone. Part of this latter bed, together with a series of bands

* *Memoirs, Geological Survey of India*, Vol. XXIII, 66 (1891); XXXVI, pt. 1 (1904).

of limestone separated by thin partings of shale, represents the Muschelkalk of Europe, whilst the remainder of the Middle Trias, the Ladinic stage of Europe, is represented by shale and limestone containing the characteristic European fossil *Daonella lommeli*. Above this, again, are representatives of the carnic and juvavic stages of the Upper Trias (for correlation see below, p. 239).

Kioto Limestone.

From Spiti eastwards as far as the western frontier of Nepal, the Zangskar range is usually capped by a great mass of limestone, over 2,000 feet in thickness, which is for the most part unfossiliferous, but the uppermost beds contain a rich Jurassic fauna, whilst those at the base contain bivalves (*Megalodon* and *Dicerocardium*) characteristic of the Upper Trias. The upper part was named by Stoliczka the "Tagling limestone" and the lower the "Para limestone," of which the Tagling was intended to represent the Jurassic, and the Para the Triassic, part. Like most of the other Himalayan formations, however, this limestone mass cannot be subdivided according to the European scale; it is a well-charcterised stratigraphical unit in which it is impossible to say where the Triassic part ends and the Jurassic begins. It is therefore necessary to have a single name for it, and in recent publications of the Geological Survey it has been referred to as the "Grey Limestone," * in which term was included the whole limestone mass between the top of the Quartzite series of the Lilang system and the base of the Spiti shales. Unfortunately the term "Grey limestone" had already been applied to a subdivision of the Nummulitic series in Hazara † and to employ it also for the limestone of Spiti and Kumaun would lead to confusion. The latter might appropriately be called the "Kioto limestone," as it is well seen in the cliffs behind Kioto in upper Spiti. Of its two subdivisions the name Para stage is restricted to the beds containing *Megalodon* and latterly known as the "Megalodon limestone," ‡ whilst the Tagling stage includes all the rest.

Kioto Limestone.

All the subordinate stages of the European Trias have been recognised by their fossils, but the perfect continuity from base to summit of the stratigraphical sequence of the Mesozoic group in the Himalaya, where a single mountain-side not infrequently affords a complete section from the Productus shales to the top of the Spiti shales, renders it impossible to define the exact limits corresponding to those of the stages of the European Trias. The classification of the Himalayan sequence is, therefore, based on the natural subdivisions of its component beds which, according to their fossil contents, can be approximately referred to their European equivalents. Such correlation is facilitated by the large number of characteristic European species, particularly of ammonites, found also in the Himalayan Trias. The general resemblance of the fauna of the Trias of the Himalaya to that of the Alps is indeed so great as to lead to the

* A. von Krafft: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 3 (1902); C. Diener: *Pal. Indica*, ser. XV, Vol. V, No. 3 (1908).

† C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXVI (1896).

‡ H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1 (1904); C. Diener: *op. cit.*

conclusion that during the Triassic epoch, the sea, known as the Tethys, which extended over much of Asia, was continuous with that in which the Trias of the Alps was being laid down, and that thus intercommunication took place between these two areas.

Spiti shales.

Spiti shales.

In Spiti, as well as in the Garhwal and Kumaun Himalaya, the steep limestone cliffs (Kioto Limestone) of the Zangskar range are usually capped by undulating downs covered with black friable shales. These are known as the Spiti shales and have yielded large numbers of ammonites and belemnites of Upper Jurassic type.*

Giumal and Chikkim series.

Giumal and Chikkim series.

Here and there, resting on the Spiti shales, lie beds of sandstone, occasionally capped by limestone and shale ; these are known as the Giumal sandstone, Chikkim limestone, and Chikkim shales, respectively, and have been so named after the villages of Giumal and Chikkim in Spiti ; they have yielded few fossils, but such as have been found are of Cretaceous age.†

CLASSIFICATION OF THE ARYAN AND DRAVIDIAN SYSTEMS OF THE TIBETAN ZONE IN SPITI AND KUMAUN.

The above short description of the Palæozoic and Mesozoic rocks of the Tibetan zone is based on their development in Spiti and in the mountains of Kumaun and Garhwal, in which areas they have been studied in greater detail than elsewhere, whilst the sequence from the base of the Haimantas to the Chikkim shale is the most complete and continuous yet observed in any part of the Himalayan region. Even in these areas, however, much still remains to be done, especially in the direction of a detailed study and subdivision of the Kioto Limestone which embraces the uppermost Trias and the greater part of the Jurassic system.

End of marine and beginning of continental phase in the Himalayan area.

The change from limestone to Spiti shales and Giumal sandstone marks the beginning of a new phase in the geological history of the Himalaya and Tibet. The Tethys gradually began to recede, its southern shores crept slowly northwards and areas, which, throughout almost the whole of the Triassic and lower Jurassic periods, had lain beneath a clear and tranquil sea, were now brought within reach first of mud and silt and then of sand and grit carried down by rivers from the south. Gradually the sea retreated until the northern ranges of the Himalaya and the whole of Tibet became a continental area. During the progress of this change, however,

* F. Stoliczka : *Memoirs, Geological Survey of India,* Vol. V. (1865) ; V. Uhlig : *Pal. Indica,* ser. XV, Vol. IV (1903).

† F. Stoliczka : *op. cit.*

deposition continued for some time in Ladak, Ngari Khorsum and Central Tibet; the deposits thus formed are of lower Tertiary age and are partially marine and partially of fresh-water or estuarine origin. The former are found in Tibet and in Zangskar and the latter in the Indus valley in Kashmir. In Zangskar these Tertiary beds are represented by a mass of nummulitic limestone found at an elevation of 18,500 feet on the peaks above the Singhgi La,* whilst, further east, nummulitic limestone is said by Mr. Griesbach to overlie the Cretaceous beds in Ngari Khorsum, to the north-east of the Niti Pass.† The Tertiary rocks of the Upper Indus valley and of the more easterly portions of Tibet will be referred to subsequently (*infra*, p. 245).

None of these beds are younger than eocene, the oldest subdivision of the Tertiary system, and they thus furnish us with an approximate date for the close of the marine, and the opening of the continental, phase in the history of the Indo-Tibetan area; this date may be placed in the latter part of the eocene period of the Tertiary epoch. The crustal disturbances which then took place, resulting in the rise of the land and retreat and disappearance of the sea, were accompanied by great volcanic activity, evidences of which are now to be seen in the lava-flows associated with the Tertiary deposits and in the dykes of intrusive rock found cutting through all the older sedimentary deposits.

The annexed table shows the detailed classification of the Aryan and Dravidian rocks of Spiti and Kumaun.‡

THE "EXOTIC BLOCKS" OF MALLA JOHAR (PLATE XLVI).

Before passing on to discuss the development and distribution of the Palæozoic and Mesozoic beds in other parts of the Himalaya, it is necessary to refer to a very peculiar group of detached blocks of limestone and other rocks found in the extreme north of Kumaun on the Indo-Tibetan frontier and beyond in Ngari Khorsum (Hundes). The culminating ridge of the Zangskar range in Malla Johar and the northern slopes of the same range at Chitichun in Ngari Khorsum are composed chiefly of Spiti shales overlain by a sandstone formation (the equivalent of the Giumal sandstone of Spiti) which passes upwards into a series of sandstone and shale (probably of Cretaceous age) exactly resembling the European "Flysch." Overlying these and resting sometimes on the Spiti shales and sometimes on the flysch, and inextricably mixed with, and embedded in, masses of andesite and other basic volcanic rocks, are innumerable blocks of sedimentary rock, varying in size from mere pebbles to masses of many thousand cubic yards in volume. Blocks of limestone, sandstone, Spiti shale and flysch lie scattered through the volcanics

* T. D. LaTouche: *Records, Geological Survey of India*, Vol. XXI, 160 (1888).

† *Memoirs, Geological Survey of India*, Vol. XXIII (1891).

‡ A. von Krafft: *General Report, Geological Survey of India*, 1899-1900 (1901); H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1 (1904); C. Diener: *Pal. Indica*, ser. XV, Vol. V, No. 3 (1903).

TABLE XLII.

Group	System	Sedimentary rocks of the Tibetan Zone in Spiti and Kumaun.	Approximate European Equivalents.	
ARYAN GROUP.		Nummulitic limestone and Volcanics of Kumaun and Ngari Khorsum.	*Eocene.*	
		"Flysch" of Kumaun and Ngari Khorsum. "Chikkim shales." "Chikkim limestone." "Giumal sandstone."	CRETACEOUS.	
		"Spiti shales."	JURASSIC.	
	KIOTO LIME-STONE.	"Tagling stage." "Para stage."	*Rhætic and Dachsteinkalk*	TRIAS.
	LILANG SYSTEM.	"Quartzite series" with *Spirigera maniensis* (Krafft). "Monotis shales" with *Monotis salinaria* (Schlotheim). "Coral limestone" with many corals and *Spiriferina griesbachi* (Bittner).	*Juvavic.*	
		"Juvavites beds" with *Juvavites angulatus* (Diener). "Tropites beds" with *Tropites cf. subbullatus* (Mojsisovics). "Grey shales" with *Joannites cymbiformis* (Wulfen). "Halobia beds" with *Halobia cf. comata* (Bittner).	*Carnic.*	
		"Daonella limestone" with *Daonella indica* (Bittner). "Daonella shales" with *Daonella lommeli* (Wissman).	*Ladinic.*	
		"Muschelkalk;" limestone with *Ptychites rugifer* (Oppel). "Nodular limestone."	*Muschel-kalk.*	
		"Hedenstræmia beds" with *Hedenstræmia mojsisovicsi* (Diener). "Meekoceras zone" with *Meekoceras varaha* (Diener). "Ophiceras zone" with *Ophiceras sakuntala* (Diener).	*Lower Trias.*	
		"Otoceras zone" with *Otoceras woodwardi* (Griesbach).	?	?
	KULING SYSTEM.	"Productus shales" with *Xenaspis* and *Cyclolobus* above and *Marginifera himalayensis* (Diener) below. "Calcareous sandstone" with *Spirifer fasciger* (Keyserling) and *Spirifer marcoui* (Waagen). Conglomerate, grit and sandstone.	PERMIAN.	
	KANA-WAR SYSTEM.	"Po series" including "Fenestella shales" with *Protoretepora ampla* (Lonsdale).	CARBONIF-EROUS.	
DRAVIDIAN GROUP.		"Lipak series;" chiefly limestone with *Syringothyris cuspidata* (Martin) above and *Atrypa aspera* (Schlotheim) below.	DEVONIAN.	
	MUTH SYSTEM.	"Muth quartzite" with *Pentamerus cf. oblongus* (Sowerby) at base. Limestones with Trilobites, Brachiopods and Corals (including *Halysites catenularia* Lamarck). "Red quartzite." Conglomerate in Spiti and coral limestone in Kumaun.	SILURIAN.	
	HAI-MANTA SYSTEM.	Slate, quartzite and limestone with trilobites. Blue and black slate (weathering bright red), with carbonaceous shales. Slate and quartzite. Conglomerate in Kumaun,—absent from Spiti.	CAMBRIAN and (?) PRE-CAMBRIAN.	

with no trace of regularity or arrangement, whilst the jumble becomes the more confused when the fossiliferous character of certain of the blocks reveals the striking fact that almost every stratigraphical horizon from Permian to uppermost Cretaceous finds its representative in one or other individual block. Unfossiliferous blocks prevail, but those which contain fossils have yielded specimens both sufficiently numerous and sufficiently well preserved to leave no room for doubt as to the particular horizon to which each belongs. When, however, we compare them with the corresponding horizons of the typical Palæozoic and Mesozoic sequence of Spiti and Kumaun, they are found to show a very marked difference both in their physical character and in the fauna that they contain. Thus the curious fact is revealed that in one and the same area, and almost in contact with one another, there are two distinct facies of Permian, Triassic and Jurassic rocks, the one being the typical Spiti-Kumaun facies and the other that of the exotic blocks. The latter, therefore, cannot be merely fragments of the underlying beds which have been brought into their present anomalous position on the top of beds younger than themselves by a simple process of faulting to which the origin of certain of the European "Klippenzüge" or "blocs exotiques" has been ascribed; but they must have been transported from some other area, where the upper Palæozoic and Mesozoic facies is different to that of the typical Tibetan zone. Such an area may possibly be found to lie to the north, in Ngari Khorsum, which is still a *terra incognita*, but perhaps contains the solution of one of the most interesting problems of Indian stratigraphical geology.

Mode of origin of the exotic blocks.

The invariable association of these exotic blocks with great masses of lava and other volcanic rocks of sub-aërial origin affords a clue to the manner in which they have been transported to their present position. During the great outburst of volcanic activity which took place throughout the northern parts of the Himalaya and in western Tibet in early Tertiary times, these blocks were torn by the disruptive forces from their parent mass and carried on the lava-flows far to the south of their original home.*

The Tibetan zone in the Eastern Himalaya (Plate xlvii).

We shall now try to follow the Tibetan zone from the typical areas of Spiti and Kumaun into other parts of the Himalaya. We have already seen that in these two districts the only points of difference in the oldest (Dravidian) group of the fossiliferous rocks is the absence from Spiti of the Lower Haimanta conglomerate and of the coral limestone which occurs at the base of the Muth system in Kumaun† and the presence in lower Spiti of an extensive series of beds, the Kanawar system,‡ which has not been found in any part of Kumaun.

* A. von Krafft: *Memoirs, Geological Survey of India*, Vol. XXXII. pt. 3 (1902). For other literature on the subject of the Exotic blocks see *Records, Geological Survey of India*, Vol. XXVI, 19 (1893), *Denkschr. d. k. Akad. Wien.*, LXII, 533 (1895); *Memoirs, Geological Survey of India*, Vol. XXVIII, 1 (1895); *Pal Indica*, ser. XV, Vol. I, pt. 3 (1897); Vol. II, pt. 3.

† *Memoirs, Geological Survey of India*, Vol. XXIII (1891); XXXVI, pt. 1 (1904).

‡ *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1 (1904).

The development of the Aryan group is almost identical in the two areas, but in Kumaun the Lilang system is not quite so thick as in Spiti. As the Tibetan zone is followed south-eastwards towards Nepal, this thinning out of the Lilang system (Trias) is very marked, the total thickness in Byans being only 2,000 feet as compared with over 3,000 feet in Spiti. East of Kumaun practically nothing is known of the Tibetan zone until we reach the northern frontier of Sikkim, where there is a very extensive development of Jurassic beds, which appear to cover almost the whole of this part of Tibet from Sikkim and Bhutan on the south to beyond Lhasa. The limestones of the Lhonak range, north of Kinchinjunga, and a small group of limestones at the south-eastern edge of the Phari plain, probably represent parts of the Trias and the Lias of Europe, and the hills which run from Kam-pa Dzong to Tuna contain an interesting group of limestone and shales (Kam-pa system) of Cretaceous and Lower Tertiary age.* The fossiliferous boulders of Permo-Carboniferous age, found near the mouth of the Subansiri river in Assam, have already been referred to (*supra*, p. 234).

Thus we see that little is known of the Tibetan zone to the east of Kumaun, but it is highly probable that Mesozoic rocks (chiefly Spiti shales and other Jurassic beds) run continuously eastwards along the northern frontiers of Nepal and Bhutan, possibly even as far as the gorge of the Brahmaputra.

Kashmir and the Western Himalaya (Plate xlviii).

Returning once more to our central area and proceeding north-westward and westward from Spiti, we find an extensive development of the Tibetan zone in Kashmir. In the year 1883 Lydekker published an account of the geology of Kashmir and adjoining territories,† based on his own surveys and upon the work of previous observers, amongst whom the names of Drew,‡ Godwin-Austen,§ Verchère ‖ and Stoliczka ¶ are conspicuous. This work was completed before detailed surveys of Spiti and Kumaun had been carried out and his classification of the rock-groups of Kashmir is on broader lines than that since adopted for the latter areas. He recognised four main systems in the rocks of Kashmir, *viz.* (1) "Tertiary," (2) "Zanskar," (3) "Panjal," and (4) "Crystalline and Metamorphic."

Crystalline rocks;

The crystalline and metamorphic rocks, which consist of granite, gneiss and schist, cover the greater part of Northern Kashmir, including Baltistan, and run west-wards through Chilas and Gilgit into the mountains of Afghanistan. Towards the east they run through northern Ladak and probably continue thence through Western Tibet (Rudok) and Chumurti into the mountainous regions north of lake Manasarowar and the head-waters of the

* *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 2 (1907).

† *Memoirs, Geological Survey of India*, Vol. XXII (1883).

‡ *The Jummoo and Kashmir territories* (1875).

§ *Quarterly Journal, Geological Society*, Vol. XV, 221 (1859), XX, 383 (1864), XXI, 492 (1865), XXII, 29 (1866), *Journal, Royal Geographical Society*, XXXI, 30 (1859).

‖ *Journal, Asiatic Society of Bengal*, Vol. XXXV, pt. 2 (1866), XXXVI, pt. 2 (1867).

¶ *Memoirs, Geological Survey of India*, Vol. V, pt. 1 (1865), pt. 3 (1866).

Brahmaputra. In Eastern Kashmir they constitute much of the district of Zangskar, sending out a narrow arm south-eastwards through Lahaul to join the similar rocks of the great Himalayan range between Kulu and Spiti, and thus merging into the crystalline axis of the Himalaya.

In south-west Kashmir a narrow strip of crystalline rocks runs along the Pir Panjal range, forming a narrow tongue protruding from the wider crystalline area of Chamba and the Dhauladhar range, which, again, is an offshoot from the crystalline axis of the Himalaya.

The prevailing type amongst the rocks of this series both in Zangskar and in the Pir Panjal is the characteristic Himalayan biotite-granite, and these two crystalline areas are the result of the bifurcation of the hitherto unbroken central zone of the Himalaya. The crystalline zone, which crosses the Sutlej, as a single broad band, from east to west, splits up in Kangra district into two branches, one of which, following the range between Kulu and Spiti, runs through Lahaul into Zangskar, where it ends in the Nun Kun peaks. The other branch, still maintaining much the same trend, passes through the Dhauladhar range into the Pir Panjal, where it thins out to a narrow strip, separated only by a band, of insignificant width, of pre-Tertiary rocks from the Sub-Himalayan zone of Jammu and the Murree hills.

their distribution.

Between these two branches of the crystalline zone lies a broad area of sedimentary rocks belonging to Lydekker's "Panjal" and "Zanskar" systems, which correspond approximately with the Dravidian and Aryan groups, whilst along the north-east of the Zangskar branch runs the direct continuation of the Tibetan zone of Spiti. Throughout Kashmir the sedimentary beds continue north-westwards until they meet the great crystalline complex of Baltistan, Gilgit and Chilas.

"Panjal" system;

The outermost strip of sedimentary beds, which lies between the Sub-Himalayan zone of Jammu and Murree and the crystalline axis of the Pir Panjal range, has been included by Mr. Lydekker partly in his "Zanskar" system and partly in the "Panjal" system, which latter takes its name from the Pir Panjal range.

The "Panjal" system includes a great variety of rocks, all apparently devoid of fossils and consisting of slates, conglomerates and great masses of trap, representing old lava-flows; the slates and conglomerates prevail in the lower part of the system and the traps in the upper. The system completely surrounds the Srinagar valley and extends thence southwards along the edge of the crystalline zone of Zangskar. On the opposite side of the latter it runs north-west and south-west and is directly continuous with the Tibetan zone of Spiti. Small patches of the same system also occur at the lakes of Pangong and at Changchenmo near the frontier of Tibet.

in Eastern Kashmir;

The "Panjal" rocks of the western or Srinagar area differ from those of the eastern part of Kashmir; the upper division of the former is composed of great beds of trap, whereas this volcanic element is wanting in the latter area. No detailed subdivision of the system was attempted by Mr. Lydekker, who correlated the whole of the Panjals with the Dravidian rocks of the Tibetan zone, that is to say, with the whole rock series extending from the base of the Haimantas to the base of the Kuling system. Such correlation may be correct for Eastern Kashmir, where the sedimentary rocks on the north-east of the Zangskar crystallines are the direct continuation of the Tibetan zone of Spiti.

In Chamba and the Pir anjal.

In the western area, however, it is highly probable that the "Panjal" system, as found in Chamba and the Pir Panjal range, includes also members of the Himalayan zone of the Simla region, the beds of the latter area being probably continuous through Kangra and Chamba to the Pir Panjal, and also being represented in Jammu by the limestone formation known as the "Great Limestone," on which the Tertiary beds of the Sub-Himalayan zone rest unconformably.* Hence, in Western Kashmir, the "Panjal" system probably embraces representatives not only of the Dravidian members of the Tibetan zone, but also of the pre-Cambrian rocks of the Himalayan zone. Mr. Lydekker made no attempt to discriminate between these two, since he believed them to be one and the same, and a detailed survey must be made of Western Kashmir before the representatives of the two zones can be separated and compared.

Age of the volcanics of the Panjal system.

The only fossils hitherto found in the Panjal rocks of Western Kashmir occur in a band of limestone, which is interstratified with beds of volcanic ash in the upper or trappean division of the "Panjal" system in the hills around Imsalwara (Ambersilwara) about 20 miles to the north of Baramula. The fossils are mostly encrinites and brachiopods, but only very badly preserved specimens have been found. This fossiliferous bed, the age of which may be Devonian or Lower Carboniferous, is at present unique in the "Panjal" system and is well worth the attention of travellers in Kashmir.

"Zanskar" system.

Above the "Panjal" system is a thick series of beds of which the prevailing rock is limestone, with some quartzites and shales near the base. This is Lydekker's "Zanskar" system, which he subdivided into three series, known as the Kuling, supra-Kuling and Chikkim series respectively. The Kuling series he regarded as the equivalent of the Productus shales (originally named by Stoliczka the "Kuling shales") of Spiti: the supra-Kuling series, which is composed chiefly of limestone, is the equivalent of the beds between the Otoceras zone (base of the Lilang system) and the base of the Chikkim limestone of Spiti, whilst the name, Chikkim series, was applied to the representatives in Kashmir of the Chikkim limestone and Chikkim shales.

The sedimentary rocks of Kashmir, although highly fossiliferous in certain localities, are, as a rule, much poorer in fossils than those of Spiti and Kumaun; this, combined with the fact that time did not permit him to carry out his work on the detailed

* H. B. Medlicott: *Records, Geological Survey of India*, Vol. IX, 49 (1876): R. R. Simpson: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 4 (1904).

scale that has since been possible in Spiti and Kumaun, led Lydekker to work on broad lines and to rely largely on the physical characters of the rocks as a guide to their correlation with one another and with those of adjacent areas. Consequently all the slates, conglomerates and traps were referred to one system, the "Panjal," and all important groups of limestone to the overlying system, the "Zanskar."

Correlation with Tibetan zone in Spiti and Kumaun.

In order to correlate the "Panjal" and "Zanskar" systems with the fossiliferous groups of the Tibetan zone, we must turn first to that part of Kashmir which adjoins Spiti. Here we find that the sedimentary beds of the Tibetan zone run continuously from the one area to the other; although interrupted for a time by the crystalline area of Zangskar, the same zone can be followed north-westwards to Vihi, Dras, Tilail and Gurais, where, however, owing partly to lack of fossils but even more to the fact that no detailed survey of these areas has yet been made, only a few of the subdivisions of the typical Spiti sequence have been recognised. The most interesting, and now the best known, of the above areas is Vihi. Here the massive hills of trap, which extend along the northern edge of the Srinagar plain and constitute the uppermost member of the "Panjal" system, are overlain by shales and limestones. Immediately behind the village of Zewan, and again near the foot of the hills to the north-west of Khunmu, are the two most famous localities for fossils in all Kashmir. Immediately overlying the trap are bands of chert and shale, in the latter of which have been found remains of fishes and plants; these are of the greatest interest and importance, for the plants belong to the genus *Gangamopteris*, a form specially characteristic of the lower Gondwana beds of the Indian Peninsula; above the shale are the famous Zewan beds, which contain fossils identical with those of the Fenestella shales of Spiti. Overlying these, both at Khunmu and at the opposite side of the Vihi plain, are the Productus shales with their typical fossils, and above these, again, are limestones with Lower Triassic fossils similar to those of Spiti and Kumaun.* Thus, here, we have a link not only between the "Zanskar" system of Kashmir and the typical Tibetan zone, but also between both of these and the Gondwana system of the Peninsula.

Upper Palæozoic unconformity.

We have seen that, in Spiti and Kumaun, there is an unconformable break between the beds below the Productus shales and all older deposits, thus indicating a period of disturbance which set in after the deposition of the Fenestella shales, when much of the old sea-floor was raised up to form dry land and was worn away by atmospheric agencies before it again sank beneath the waves. In Vihi there is no trace of this unconformity or break in the sequence between the Zewan beds—the equivalent of the Fenestella shales—and the Productus shales; marine conditions here continued uninterruptedly; and whilst the more easterly areas were being raised up and denuded, this part of Kashmir remained continuously beneath the sea. On the other hand, the presence of terrestrial plants in the deposits below the Zewan beds and overlying the Panjal traps proves that the area in which

* H. H. Hayden: *Records, Geological Survey of India*, Vol. XXXVI, 23 (1907); A. C. Seward: *Pal. Indica*, New Series, Vol. II, No. 2 (1905), *Records, Geological Survey of India*, Vol. XXXVI, 57 (1907).

these deposits now occur was either the estuary of a river, or, if covered by the sea, was at least very near the coast, whilst the Panjal traps may represent lava-flows over the surface of the neighbouring land. Fossils similar to those of the Zewan beds have also been found at Barus on the right bank of the Jhelum, Pahlgam in the Lidar valley and at several points in the hills at the south-eastern end of the Kashmir valley. Recently, too, similar fossils have been found on the Golabgarh Pass in the Pir Panjal range.

The lower part of the " Zanskar " system thus corresponds to the Lower Trias (Lower Lilang system) Productus shales and Fenestella shales of the Tibetan zone, and at the same time includes at its base beds which are correlated with the lower Gondwanas of the Indian Peninsula. The age of the Fenestella shales, and consequently of the Zewan beds, being upper Carboniferous, the underlying plant beds belong either to the middle or upper division of the same system and the Panjal traps, being older still, may be of either lower or middle Carboniferous age. Hence we see that, during the earlier part of the Carboniferous epoch, when the Lipak series of Spiti was being laid down under the sea, Eastern Kashmir was at least partly a land surface, studded with volcanoes from which were poured out the lavas which are now represented by the Panjal traps.* From the sea, which lay to the north-east, an arm ran out to Imsalwara, where fossiliferous limestones were laid down among beds of trap and ash. The shore probably lay along the northern side of the Kashmir valley either as a continuous land surface or a chain of volcanic islands and was connected through Chamba with the old continental area of the Himalayan zone. Towards the end of the Carboniferous epoch subsidence set in and the land gradually became submerged and was covered, first by estuarine muds in which remains of the land flora became imbedded, and, subsequently, by the Zewan beds with their marine fossils. Thenceforward marine conditions appear to have prevailed throughout the whole of the Triassic and Jurassic epochs, when Kashmir was part of the floor of the Eurasian sea, the Tethys.

Panjal volcanic period.

Although the subdivision of the Himalaya into three zones, the Sub-Himalayan, Himalayan and Tibetan, which is so well marked eastwards of the Beas, is not so clearly defined in Kashmir where the crystalline rocks invade both the Tibetan and Himalayan zones and where the respective members of the two latter have not been satisfactorily distinguished one from the other, yet the outer, or Sub-Himalayan, zone is clearly marked off and can be traced through Jammu into the Murree hills and the gorges of the Jhelum. This zone of Tertiary rocks has already been described above (p. 214), but there remains a group of beds also of Tertiary age, to which reference has been made in connection with the Tibetan zone. These are the Indus valley Tertiaries, which extend as a long narrow strip in the valley of that river from eastern Ladak to Kargil. They are apparently quite unconnected with the Tertiaries of the Sub-Himalayan zone, and consist of conglomerates, sandstones and shales of fresh-water origin overlain by limestone with nummulites, which latter, it has already been seen, extends as far south as the Singhgi

Indus valley Tertiaries.

* See *Appendix*, p. 272, *infra*.

La in Zangskar (*supra*, page 238). With these Tertiary beds are associated great masses of volcanic rock, chiefly ashes and lava-flows.

Nummulitic limestone of Zangskar.

The deposition of the nummulitic limestone seems to have been the final chapter in the marine history of the Himalaya and Tibet. With the outburst of volcanic activity the present or continental phase became established, and what had, for a lapse of time which must be counted in millions of years, been more or less continuously the floor of a great sea was now gradually raised up to form the highest mountain range on the face of the globe.

HAZARA (PLATE XLIX).

Hazara.

With the exception of Hazara, very little is known of the geology of the great belt of mountains which extends westwards and north-westwards from Kashmir. We have already seen that in Kashmir the regularity of arrangement of the rocks, which to the east of the Beas fall readily into three zones, an outer or Sub-Himalayan, a central or Himalayan and an inner or Tibetan, has disappeared and although the outer zone of Tertiary rocks still persists through Jammu into the Murree hills, the Himalayan and Tibetan zones cannot at present be completely separated from one another. In Hazara the fusion of the three zones becomes even more complete ; the Sub-Himalayan is no longer separated from the Tibetan by the Himalayan and crystalline rocks, but the two are in direct contact and the lowest member of the Tertiary system is intimately infolded with the Tibetan facies of the Triassic, Jurassic and Cretaceous systems, whilst the latter are also found in association with a great series of unfossiliferous slates, which is regarded as the equivalent of the Himalayan zone as developed east of the Beas.

Change in the trend of the mountain ranges consequent on change of strikes of their component beds.

Concurrently with this change in the order of distribution of the three zones, the strike or trend of the rocks, which from Nepal to the Jhelum is on the whole S. E.-N.W., changes in Kashmir and bends round through E.-W. to N. E.-S. W. Consequent on this the mountain ranges also undergo a similar change of trend, and in Hazara run approximately from north-east to south-west. Nor is this bending of the ranges confined to the Himalayan chains, but is also reflected in the distant Salt Range of the Punjab.

The rock groups of Hazara.

The rocks of Hazara have been subdivided into seven series,* known as the Crystalline, the Slate series, the Infra-Trias, the Triassic, the Jurassic, the Cretaceous and the Tertiary. These form more or less parallel bands, with the youngest in the outer hills to the extreme south-east. The upper part of the Tertiary system of Hazara is merely the south-westerly continuation of the Murree beds ; the lower portion or nummulitic series, consists of limestone, shale and sandstone with a band of coal. This series covers the greater part of S. E. Hazara, but where it has been removed by denudation the underlying beds of the Mesozoic group have been exposed. These represent the Upper Triassic, Jurassic and Cretaceous systems and include formations such as the Spiti shales and Giumal sandstone, typical of the Tibetan zone.

* C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXVI (1896).

Infra-Trias and Slate series.

Beneath the Triassic beds is a series of rocks composed of limestone underlain by sandstone and shales which have a thick bed of conglomerate at their base. This is known as the Infra-Trias. It lies unconformably on a great group of unfossiliferous slates, the Slate series, which runs from north-east to south-west through the centre of Hazara. These slates, also known as the Attock slates, are probably the equivalent of the Simla slates of the Himalayan zone. The Infra-Trias series was regarded by Mr. Middlemiss as the equivalent of the Blaini series of Simla, and it is therefore probable that the Slate series and the Infra-Trias represent the old sedimentary beds of the Himalayan zone. Behind this, and forming most of north-western and northern Hazara, is a broad zone of granitic and crystalline rocks, the south-eastern portion of which consists of schists and gneisses, which may be partly Archæan but are to a great extent metamorphosed representatives of the Slate series and the Infra-Trias, which have been altered by contact with granite. The granite of this zone is the exact counterpart of the biotite-granite of the Himalaya, and we thus see in the crystalline zone the representatives of the Vaikrita system and the gneissose granite of the Himalayan zone. The great mountainous area lying between Northern Hazara and Northern Kashmir (Baltistan) on the one side and the Hindu Kush in longitude 70° on the other is still almost completely unsurveyed and deductions as to the geological conditions prevailing in that area can only be drawn from the few scattered observations which have been made in Gilgit and Chitral. The prevailing rocks appear to be granite and crystalline schists, but slates, quartzites and limestones, possibly representing the Dravidian members of the Tibetan zone,* occur in Hunza and Nagar, whilst beds of Devonian age have been found in the valley of the Kunar river in Chitral † and also on the Baroghil Pass ‡ between Chitral and Wakhan. These rocks appear to strike towards the north-east and may possibly be connected with the fossiliferous series of Palæozoic age found by Stoliczka in the Little Pamir and Yarkand, and thus serve as a link between the Tibetan zone of the Himalaya and the sedimentary rocks of the Tian Shan.

AFGHANISTAN.

Between Chitral and the Kabul province of Afghanistan there is a broad tract of country, the western continuation of the Hindu Kush, of which nothing is known in detail but which appears to be composed chiefly of crystalline and metamorphic rocks such as occur along the lower reaches of the Kabul river below Laghman. So far as the rest of Afghanistan is concerned, there appear to be two broad stratigraphical facies separated the one from the other by the Koh-i-Baba and Paghman ranges. The more southerly of these, which is found between Jalalabad and Kabul, comprises metamorphic rocks associated with ruby-bearing crystalline limestone—a series recalling the

* C. A. McMahon : *Quarterly Journal, Geological Society*, Vol. LVI, 337 (1900).
† C. A. McMahon and W. H. Hudleston : *Geological Magazine*, Dec. IV, Vol. IX, 3, 49 (1902).
‡ H. H. Hayden : *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1, 31 (1904).

Archæan beds of the Peninsula—and a younger marine group in many respects resembling part of the Tibetan zone of the Himalaya. The marine group lies with marked unconformity on the metamorphic beds and is composed of limestones, probably in part representing the Productus limestone of the Salt Range and its analogues in the Himalaya and partly embracing the Lilang system of the Tibetan zone. The northern facies, which is well seen in Bamian, Saighan and the country to the north of the Afghan Hindu Kush, consists of limestones of Palæozoic age overlain by a volcanic series possibly partly younger Palæozoic and partly of Triassic age. This is covered by an extensive system of fresh-water beds with coal seams, * and containing fossil plants of Jurassic age. Neither the volcanic series nor the overlying Jurassic beds resemble any of the Mesozoic systems of the Himalaya, but are, on the other hand, apparently identical with the Mesozoic beds of Russian Turkistan ;† hence during part of the Triassic and Jurassic peroids these two areas formed a continuous land surface, and probably constituted the south-western coast of the Tethys. Above the Jurassic plant-bearing series is a mass of red conglomerate and sandstone, which is, however, only locally preserved, having been as a rule removed by denudation before the deposition of the next overlying rock group, the upper Cretaceous limestone. The latter extends all over Northern Afghanistan and is almost always markedly unconformable to underlying beds, a feature which indicates a great extension of the Tethys in later Cretaceous times, when the whole of Northern Afghanistan once more became submerged. This marine phase, however, was of only short duration, for evidence of the drying up of the sea is found in the beds of gypsum and rock-salt occurring in the older Tertiary rocks. Subsequently land plants and land shells appear, and all the great valleys of Eastern Afghanistan are now filled with deposits of sand and boulders analogous to, and possibly contemporaneous with, the Siwalik series of the outer Himalaya.

* C. L. Griesbach : *Records, Geological Survey of India*, Vol. XX, 93 (1887).

† J. B. Mushketoff : *Turkistan* (1886, 1906) ; G. Romanowski : *Geology of Turkistan* (1880-1890).

36

PAST HISTORY OF THE HIMALAYAN AREA.

We may now attempt to sketch roughly the past geological history of the Himalayan area. Our knowledge of the nature and distribution of the Archæan rocks is as yet too scanty to permit of any attempt to reconstruct the conditions prevailing at any part of that period and our history opens at the time when a shallow sea lay over Central and Northern India and extended into the Himalayan region, covering most of the area now lying on the Indian side of the axis of the present Great Himalayan range. In this were deposited beds of conglomerate, shale, sandstone and limestone, the materials for which were derived from the degradation of the Archæan rocks, exposed in parts of what is now Peninsular India and also along the Tibetan edge of the Himalayan zone between Assam and Kashmir. The beds thus laid down are known as the Purana group in the Peninsular area * and include the Baxa, Jaunsar and Carbonaceous systems of the Himalaya. The connection of the one area with the other has still to be proved and the reference of the old unfossiliferous Himalayan sediments to the Purana group is consequently as yet only conjectural, but the conjecture has an air of probability which renders it for the moment the most suitable working hypothesis. Hence it is now generally believed that the Purana sea not only covered much of the Peninsula but also extended over what are known as the lesser ranges of the Himalaya. Whether it extended northwards beyond the Himalaya we are unable to say since the whole of the interior of Tibet is, geologically speaking, unknown, but there is evidence to show that land existed in the Himalaya at least during part of the Purana era, and the sea may therefore have been bounded on the north by a Tibetan continental area.

The Purana sea :

Recent work in China has revealed the presence there of a series of pre-Cambrian beds which may be the equivalents of our Indian Puranas, and the presence at or below the base of the Cambrian system of a boulder-bed of clearly glacial origin, gives us a possible clue to the true correlation of the Blaini boulder-slate of the Himalayan zone and suggests that the Purana sea extended to China.

its extension into China.

Two marked periods of volcanic disturbance have left their records in these pre-Cambrian beds of the central part of the Himalaya. The first occurred at the close of the Jaunsar period, when the lower beds of this system emerged from the sea and were covered by sheets of lava and volcanic ash. Again subsidence set in and the disturbed and eroded beds were once more submerged and were covered unconformably by a thick calcareous deposit, the Deoban limestone.

Volcanic disturbances in Purana times.

* T. H. Holland : *Trans. Mining and Geol. Inst. of India*, Vol. I, 48 (1906).

The second period of volcanic activity occurred during the deposition of the beds of the Carbonaceous system and is marked by bands of volcanic ash and basalt, which are found at several horizons in the system, thus showing that volcanoes were active in this area throughout a period of considerable duration.

The Dravidian era.

The next era of which we have a record in the Himalaya is that named by Sir Thomas Holland the *Dravidian*; it begins with the conglomerates and other shallow-water deposits of the Haimanta system and extends to the period of disturbance of upper Palæozoic age characterised by the Talchir boulder-bed of Peninsular India and the great outburst of volcanic activity in Kashmir.

Haimanta period.

The Haimanta, the oldest of the Dravidian systems, is characterised by deposits of detrital origin such as conglomerates, sandstones (quartzites) and slates, with only rare and insignificant beds of limestone at its upper limit. It is evident therefore that it was laid down in shallow water near a coast line and the absence of any post-Purana beds among the rocks of the Himalayan zone suggests that the present southern boundary of the Haimanta deposits marks approximately an original limit of deposition and consequently the southern shore of the sea in which the Haimantas were laid down. The relations of the Haimantas to the Purana rocks of the Himalayan zone have not yet been worked out and it is not known whether there is a gradual and conformable passage from the one into the other or whether the lower beds of the Haimantas are contemporaneous with the upper strata of the Puranas, nor is it possible to say at what period the Himalayan zone of Purana rocks first became a land-surface. The presence of rocks of the Haimanta system in Kumaun, Garhwal, Spiti and Kashmir proves that these areas at least were submerged, whilst during the latter part of the Haimanta period the sea extended also to the Salt Range of the Punjab where the Cambrian rocks contain a species of trilobite identical with one from the uppermost Haimantas of Spiti.* Westwards the same sea probably extended at least as far as the Hindu Kush and Afghanistan, but it was not connected with the Cambrian sea of Europe, for the fauna of the fossiliferous rocks of this age in the Himalaya has nothing in common with that of the European Cambrian. On the other hand, there are decided affinities between the Cambrian fossils of the Himalaya on the one hand and those of China and North America on the other, and this has been regarded as evidence of a sea connection between the Himalaya and America during late Haimanta (Middle Cambrian) times.

The latter part of the Haimanta period was marked by local disturbances in Spiti and probably also in Kashmir, and the presence of a conglomerate lying unconformably on the Middle Cambrian beds proves that the coast-line had moved temporarily northwards and the beds already deposited had emerged from the sea and undergone denudation. Normal conditions appear to have been soon restored throughout the Himalaya, but the absence from the Salt Range of any representatives of the post-Cambrian and pre-Talchir systems indicates that this range was now cut off from the Himalayan marine area and became a land-surface.

* F. Cowper Reed, quoted in *Records, Geological Survey of India*, Vol. XXXVI (1908).

Muth period.

The next geological epoch, the Muth, which approximately coincides with the Silurian (Ordovician and Gothlandian) of Europe, is remarkable for the great westerly extension of the Central Asian sea. The southern coast-line appears to have remained for a long period, at least until Lower Carboniferous times, much as it was after the Salt Range was cut off from the sea which covered the Himalayan area at the close of the Cambrian epoch, but the Tethys now encroached westwards and became linked up with the Palæozoic sea of Europe. Evidence of this is to be found in the character of the fossils of the representatives of the Upper Silurian, Devonian and Carboniferous systems in the Indian area, which bear a marked resemblance to those of the same systems in Europe, certain species being common to both areas. During the Devonian period the sea covered all the northern portion of the Himalayan area and extended eastwards into Burma, south-eastern Tibet and China. Westwards it appears to have extended through Kashmir, over what is now the Hindu Kush, into Afghanistan and northwards to the Pamir and the Tian Shan; its record is not very clear in the greater part of the Tibetan zone of the Himalaya, where fossils of Devonian age are scarce, having been found only at rare intervals, but there is no evidence of any break in the continuity of marine deposits between the beginning of the Muth (Silurian) period and the middle of the Carboniferous. The latter period, however, saw many changes along the southern coast of the Tethys and ushers in the next and latest era in the geological history of India, that named by Sir Thomas Holland the *Aryan*.

India now became definitely established as an integral part of that great continent of Gondwanaland, which extended to South Africa on the one side and Australia on the other and on which flourished the flora of *Glossopteris* and *Gangamopteris* familiar to us from the rocks of the Indian coal-fields. Below the beds in which these fossils occur, there is found in Australia, Africa and India a peculiar boulder-bed or tillite, which bears unmistakable evidence of having been deposited at a time when glacial conditions prevailed; the boulders found in it are facetted, polished and scratched whilst the rocks on which it lies are grooved and polished in a manner characteristic of the action of a glacier. This tillite, known as the Talchir boulder-bed, has not been proved to exist in the Himalaya, but is an important member of the stratigraphical series of the Salt Range, where its glacial origin has been proved beyond a doubt. On the Indian Peninsula it is usually regarded as of fresh-water origin, but in the Salt Range it is associated with marine beds, and would therefore appear to have been deposited in the sea. The materials of which the boulders are composed for the most part belong to a group of rocks now exposed in Rajputana, and it is therefore clear that, during the early Gondwana glacial period, Rajputana was a land-surface whence glaciers flowed northwards to deposit their imbedded boulders in the Salt Range sea, which was presumably a southern arm of the Tethys.

Panjal volcanic phase in Kashmir.

Whilst these changes were taking place in the Salt Range, Kashmir, which had formerly been covered by a shallow sea in which the shales and conglomerates of the Panjal system were deposited, had become the scene of great volcanic activity; masses of lava were poured out and, solidifying, formed what we now know as the Panjal traps. These have been regarded as of submarine origin, but the evidence of this is not convincing; ashes certainly fell into the sea, where they were interstratified with marine limestones, as at Imsalwara to the west of the Wular lake. Elsewhere the lavas may have been poured out over a land-surface, and it is possible that at this period Southern Kashmir was an archipelago of volcanic islands.

At the close of the volcanic phase the peculiar *Gangamopteris* flora of Gondwana-land had spread to Southern Kashmir, which must therefore have become connected with the mainland. But the sea soon encroached again and the plant-bearing Gangamopteris beds were covered by the Zewan beds, typical marine deposits with fossils of upper Carboniferous age. These again pass upwards into the Permian Productus shales which are overlain by the fossiliferous limestones of the Lower Lilang system (Lower Trias); from the Gangamopteris beds upwards to the Lilang system there is no sign of any important break in continuity of the deposits, and it would therefore appear that the close of the Panjal volcanic period marks the beginning of an era of subsidence and uninterrupted deposition, which lasted from the middle of the Carboniferous epoch until early Tertiary times, and throughout the whole of which Kashmir lay beneath the waters of the Tethys.

In other parts of the Himalaya there is no evidence of violent disturbance having taken place during the volcanic period of Kashmir; in Spiti there was slow, but steady rise of the sea-floor, resulting in a gradual northerly displacement of the coast-line, and what had formerly been an area of comparatively deep water was converted into a shallow coastal platform or possibly an estuary, in the sands and muds of which the remains of plants carried down from the land became embedded. But the remainder of the Carboniferous epoch was a period of some instability, and is marked by oscillations of the sea-level. These, however, were for some time comparatively trifling, but, at the close of the Carboniferous period, a steady rise of the land and northward retreat of the sea set in; almost the whole of the Himalaya to the east of Kashmir appears to have become a land-surface and remained such for a considerable length of time, long enough, in fact, for the removal by denudation of beds some thousands of feet in thickness. In parts of Spiti, in Kumaun, and in Garhwal, the whole of the deposits laid down during the Carboniferous and Devonian epochs, and even a great part of the Muth system, were removed before the land was resubmerged and the waters of the Tethys once more covered this part of the Himalaya.

Subsequent tectonic disturbances in Spiti and Kumaun.

It is interesting to note that these two periods of disturbance were not contemporaneous: that of Kashmir occurred at the end of the Dravidian era, while the Central Himalayan disturbance was of more recent date and is not reflected in any corresponding movement in Kashmir, having been probably of only local importance.

The earlier disturbance, however, belongs to a different category. It corresponded in time with the far-reaching changes which ushered in the Gondwana glacial epoch in India, Australia and South Africa. Recent work in Kashmir has led to the conclusion that these changes occurred

The world-wide extension of the earlier (Panjal) disturbance.

towards the middle of the Carboniferous period,* a time when marked changes in the distribution of land and sea began to take place in many parts of the world. Throughout Asia it is characterised by a great extension of the sea and the consequent overlap of marine deposits of Middle Carboniferous age upon older beds. Evidence of the former presence of this sea can be found in the Salt Range,† in S. E. Afghanistan and the neighbourhood of the Khyber,‡ in Baluchistan,§ in Northern and Western Afghanistan,|| Persia,¶ Kashmir,** the Central†† and Eastern Himalaya ;‡‡ eastward it extended into China and westward into Europe.§§

Of the northerly extension of the sea beyond the Indo-Tibetan frontier we as yet know nothing, but among the exotic blocks of Kumaun, already referred to (*supra*, p. 238), are masses of limestone containing a fauna similar to that of the Productus limestone of the Salt Range, and we therefore conclude that Ngari Khorsum at least was submerged at this period.

In this connection we may draw attention to the important and interesting work recently carried out in China by Messrs. Bailey Willis, E. Blackwelder, and R. H. Sargent, the results of which have been published by the Carnegie Institution of Washington.|| || In the second volume Mr. Willis discusses the distribution of land and sea in Eastern and Central Asia during past geological ages, and assumes that, throughout the whole of the Palæozoic era, Tibet was a continental area, which he designates *Isle Tibet*. Having regard to our present ignorance of the geology of the greater part of Tibet, we can offer no direct observations bearing on this question ; but if we turn to north-eastern Ladak, we find Palæozoic rocks exposed in the neighbourhood of Changchenmo and Pangong Lake, and if, as appears to be the case, the trend of these beds is the same as that of the rest of the Tibetan zone in Kashmir, Spiti and Kumaun, we should expect to find them well to the north of the head-waters of the Indus and the Brahmaputra in Western and Central Tibet. We are, therefore, inclined to believe that Palæozoic beds do occur in the great lake-basin of Central Tibet. They may possibly be hidden by the younger (Mesozoic) deposits to which we shall refer subsequently, but it may reasonably be expected that they will be found to crop out here and there, and thus prove that the sea in which the Dravidian (Palæozoic) rocks of the Tibetan zone were laid down was not, as has been assumed, merely a strait connecting Eastern and Western Asia, but extended northwards over a great part of Tibet.

Extension of the Dravidian Tethys over Tibet.

* *Records, Geological Survey of India*, Vol. XXXVI, 23 (1907).

† *Manual of the Geology of India*, 2nd edition, 123 (1893).

‡ H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXVIII, 108 (1900).

§ *General Report, Geological Survey of India*, for 1901-02, 31 (1902).

|| C. L. Griesbach: *Records, Geological Survey of India*, Vol. XX, 96 (1887).

¶ J. de Morgan: *Mission Scientifique en Perse*, III (1905).

** R. Lydekker: *Memoirs, Geological Survey of India*, Vol. XXII (1883).

†† H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1 (1904).

‡‡ C. Diener: *Records, Geological Survey of India*, Vol. XXXII, 189 (1905).

§§ Th. Tschernyschew: *Mem. Com. Geol., St. Petersburg*, XVI, No. 2 (1902), and *Records, Geological Survey of India*, Vol. XXXI, 111 (1904).

|| || *Research in China* (1907).

Extension of the Aryan Tethys.

Towards the close of the Palæozoic era, the Central Asian sea, which had extended from India to China on the one side and Europe on the other, gradually began to recede westwards, and in Triassic times much of China had become a land-surface. The sea, however, still lay over the Himalaya, and its connection with the European sea is proved by the large number of identical species of marine fossils found in the Triassic deposits of the Alps and the Himalaya. During the earlier part of the Triassic epoch the Salt Range formed part of the Tethys, which also covered Kashmir and Hazara, and appears to have extended into Eastern Afghanistan. Later on, connection with the whole of China, except the southern part, appears to have been cut off, and in Upper Triassic times the Salt Range also became a land-surface, but the sea extended from Eastern Afghanistan into Baluchistan, and also from Kashmir through the Pamir into Bokhara. These changes did not affect the Himalayan area and Kashmir, both of which remained submerged throughout the whole of the Mesozoic era.

Its vicissitudes during the Jurassic period.

During the Jurassic period great changes in the distribution of land and sea took place in Asia. The continental phase, indications of which are first to be found at the close of the Palæozoic era, became largely developed, and there arose on the north a great continent named by Suess "Angaraland,"* which was analogous to Gondwanaland on the south, and the site of which is now marked by a series of fresh-water beds and coal-seams, comparable to the Gondwanas of India. Communication between the Himalayan Tethys and the Mesozoic sea of Europe remained open, and the whole of Southern Tibet was submerged. At the same time the sea extended once more to the Salt Range and thence through Baluchistan and Southern Afghanistan to Persia. Northern Afghanistan, however, became dry land, on which flourished a flora similar to that of Angaraland at the same period. That the latter part of the Jurassic epoch was characterised by the gradual shallowing of the Himalayan and Tibetan sea is proved by the nature of the uppermost Jurassic deposits, the Spiti shales, which are composed of fine detrital sediments alternating here and there with beds of coarser material.

Great extension (transgression) of the sea during the Cretaceous period.

Similar conditions prevailed for the most part during early Cretaceous times, but in the latter part of the period a great extension of the sea took place and many areas that had previously been land became submerged. Connection, through Northern Africa and North-Western India (Baluchistan and Afghanistan), between the Mediterranean of Europe and the sea of Western India was now thoroughly established, and its progress is seen in the overlap of the upper Cretaceous beds over older formations which had been subjected to sub-aërial erosion during Jurassic and early Cretaceous times. The Cretaceous sea extended along the whole of the site of what we now term the Tibetan zone of sedimentary rocks and probably stretched far to the north over much of Tibet. Eastern Tibet and China, however, were now a continental area.

* *La Face de la Terre*, III, 27 (1902).

This "transgression" of the upper Cretaceous sea indicates a widely extended subsidence of the land, affecting north-western India, Afghanistan, Western Asia and probably much of Tibet. On the Indo-Tibetan frontier, however, there was no marked movement of subsidence, for the Cretaceous deposits of the Tibetan zone of the Himalaya are largely characterised by sediments such as are laid down in the neighbourhood of a coast-line. Associated with these on the southern frontier of Ngari Khorsum are beds of tuff, which indicate the presence of volcanoes at no great distance and prepare us for the volcanic disturbances that ushered in the great epoch of mountain-building which produced the mighty ranges of the Himalayan chain.

We have already seen that the Cretaceous sea lay over a great part of Tibet and extended as far south as the northern frontier of Sikkim. At the same time the Shillong Plateau was under water and was part of the floor of an ocean which extended along what is now the east coast of the Indian Peninsula but was then the submerged edge of Gondwanaland which, at the beginning of the Cretaceous period, still survived as a continent, though probably much reduced in size; this continent, however, appears to have begun to break up during the latter part of the period and in upper Cretaceous (senonian) times direct connection was established between the North African sea and the Pacific, through a strait separating India from Madagascar.

Possible connection between the Tethys and the Indian ocean.

It is possible that there may have also been a narrow and shallow arm of the sea running through that curious depression which is now filled by the Indo-Gangetic alluvium. That in early Tertiary times the western sea flowed over what is now the south-western foot of the Himalaya almost up to the meridian of Naini Tal is clear from the presence of nummulitic limestone all along that belt, and in the Tal beds there is some indication of a shallow arm having reached Garhwal at a much earlier period, probably sometime during the Jurassic epoch;* it would not, therefore, be surprising to find that the great upper Cretaceous transgression also affected this area. The absence of any Cretaceous rocks in this part of the Himalaya is certainly an argument against this supposition, but they may either have been completely removed by denudation at a subsequent period or may be merely hidden by the alluvium.

There is at present no evidence that the arm of the Pacific in which the Cretaceous beds of Burma and Assam were deposited was connected with the Tibetan sea; this can only be decided by exploration in the unsurveyed country around the head-waters of the Lohit Brahmaputra and the Irrawaddy. If there was no connection between the two oceans, the Eastern Himalaya must have been at this time either a narrow peninsula running out from the Chinese mainland or else an isthmus connecting that continental area with Gondwanaland.

Several periods of volcanic activity have left their records in the Himalayan area. Of these, two occurred during Purana times and a third at the middle of the Carboniferous period; another has been ascribed † to the upper Cretaceous epoch,

* C. S. Middlemiss: *Records, Geological Survey of India*, Vol. XX, 26 (1887).

† A von Krafft: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 3 (1902).

a period marked in the Peninsula by the great outpouring of lava which constitutes the Deccan trap. From this time onward there was a steady retreat of the sea from Tibet and the adjacent portions of the Himalaya; there were, no doubt, local oscillations of the coast-line as indicated, for instance, by the overlap of the nummulitic beds of Kashmir over older fresh-water deposits, but by the end of the eocene period, Tibet and the Himalaya had finally become dry land, and the western sea had been driven back to Sind and Baluchistan. This last phase in the marine history of the Himalayan area was accompanied throughout the whole Indo-Tibetan region* by great volcanic activity, which was no doubt intimately connected with the crustal disturbances to which the origin of the Himalaya is to be attributed. The igneous phase began with the intrusion of masses of granite into the sedimentary deposits of the Tibetan zone; subsequently there were outbursts of basic lavas which flowed over parts of Ladak, Ngari Khorsum and western Tibet, whilst dykes of basalt and allied rocks were formed by the injection of the basic magma into fissures both in the sedimentary beds and in the granite.

Periods of volcanic activity.

Volcanic activity seems to have been most intense in the neighbourhood of Lake Manasarowar, which has more than once been an area of special disturbance, and the comparatively recent change in the direction of flow of the upper Brahmaputra, to which attention has been drawn in a previous chapter (*supra*, p. 155), is an indication of elevation having occurred in this area at no very distant date in the past (*supra*, p. 178).

Although the volcano of Barren Island in the Bay of Bengal was active during the past century,† and other volcanoes in Eastern Persia on the immediate confines of Afghanistan are not yet extinct,‡ there is no indication of recent volcanic activity in the Himalayan region. In Central Tibet Mr. Littledale records a large number of volcanoes, none of which, however, appears to have been active at the time of his visit.§

SUMMARY.

If, now, we endeavour to summarise the geological history of the Himalayan area, we find that at the earliest time of which we have any record, it was part of the floor of the Purana sea, which stretched over much of what is now the Indian Peninsula; owing to elevation, this area subsequently became dry land and the sea retired to the north, where it remained throughout the whole period covered by historical geology from early Cambrian times until the middle of the Tertiary epoch; local oscillations occurred from time to time, the sea retreating northwards but again returning to cover the recently eroded land with marine deposits. Its southern shores, however, never

* A. von Krafft: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 3 (1902); H. H. Hayden: *Memoirs, Geological Survey of India*, XXXVI, pts. 1 and 2.

† F. R. Mallet: *Memoirs, Geological Survey of India*, Vol. XXI, pt. 4 (1885).

‡ E. Vredenburg, *Memoirs, Geological Survey of India*, Vol. XXXI, pt. 2 (1901).

§ St. G. R. Littledale: *Geographical Journal*, Vol. VII, 453 (1896). For numerous references to recent volcanoes in the Kuen Lun range see Suess, *La Face de la Terre*, III, 268 (1902).

seem to have moved very far one way or the other, and that part of the Himalayan area lying on the Indian side of the line of great peaks may be regarded as approximately the northern coast of Gondwanaland. It is probable, therefore, that since very early times the greater part of the Himalaya has been a land-surface.

Towards the end of the Mesozoic era the sea encroached both from the west and from the east and either completely or partly cut off the Himalayan area from Gondwanaland.

The general history of the Himalayan area may be tabulated as under :—

Purana era.

Much of Peninsular India and the Himalayan area covered by a sea which may have extended to China. Volcanic activity during Jaunsar and Carbonaceous periods. Blaini glacial epoch.

Dravidian era.

Emergence and conversion into dry land of Peninsular India and the southern parts of the Himalayan area.

Haimanta period.—Submergence of Salt Range area and Tibetan zone of Himalayan area—probably also Tibet—beneath a sea, which extended to China and possibly to North America.

Muth and Lower Kanawar periods.—Salt Range area became dry land but sea still spread over Tibetan zone eastwards to China and towards the end of the period westwards to the European ocean. Panjal volcanic period in Kashmir.

Aryan era.

Upper Kanawar and Kuling periods.—Gondwana glacial epoch in India, Africa and Australia. Extension of continental conditions to Kashmir, followed by resubmergence affecting Salt Range area, Kashmir and the whole Tibetan zone; local oscillations of land and sea in Spiti and Kumaun.

Lilang period.—Marine conditions completely established throughout Tibetan zone; re-emergence of Salt Range area. The Tethys covered much of Central Asia and was continuous with the Triassic sea of Europe.

Jurassic period.—Gradual rise of land and shallowing of Tethys throughout the Tibetan zone. North-East Afghanistan a land surface, probably a part of Angaraland.

Cretaceous period.—Further rise of land in Tibetan zone, with extension of sea ("transgression") to Afghanistan and Assam. Volcanic disturbances in Ngari Khorsum.

Tertiary epoch.—Period of mountain-building: final emergence of Himalaya and Tibet and disappearance of the Tethys. Volcanic activity during eocene period.

37

AGE OF THE HIMALAYA.

Post-Purana crustal movement.

There is no evidence to show that the Himalaya, as a great mountain range, are older than the latter part of the eocene period. There are undoubtedly signs of former periods of considerable folding; thus, the Purana rocks were folded and compressed during the earth-movements that resulted in the birth of Gondwanaland, but the Himalayan area then became the northern coast of the new continent and was not necessarily a mountain range. Towards the end of the Haimanta (Cambrian) period local folding again took place, for we find the (Ordovician) conglomerates of the Muth system in Spiti lying on the eroded edges of folded beds of Middle Cambrian age. After this, no tectonic movements of great intensity seem to have occurred until the last upheaval of the Himalaya and Tibet in Tertiary times. Movements there undoubtedly were, as, for instance, during the Carboniferous period when marine sediments were raised up, denuded and again depressed beneath the sea, but the parallelism to these older beds of the younger deposits subsequently laid down on them shows that the former underwent no contortion, but were merely subjected to a gentle uplift without violent crustal compression. Thus we have no evidence of mountain building in the Himalayan region before the Tertiary period. The movement which was so pronounced during this latter period probably began in late Cretaceous times and continued throughout the eocene and Middle Tertiary periods. That it was still active during the pliocene epoch is proved by the great series of overthrusts along the outer foot of the Himalaya, the origin and history of which have been so admirably traced out by Mr. C. S. Middlemiss.*

Upper Cambrian movement.

Eocene and oligocene disturbances.

Pliocene and post-pliocene disturbance.

The movements which affected the Siwalik (pliocene) deposits of the outer Himalaya were not confined to the neighbourhood of the Indo-Gangetic plain, but extended to such widely separated regions as Afghanistan and Ngari Khorsum. In the former area all the great river valleys of Eastern Afghanistan are filled with beds of sand-rock and conglomerate which are exactly similar to the Siwalik deposits of the Indian "duns," † and have, like them, undergone much folding and tilting. In Ngari Khorsum (Hundes) similar deposits were observed by Mr. Griesbach in the Nukchung valley,‡ and these also show signs of considerable disturbance. As the age of these deposits is pliocene, it is clear that even at the end of this epoch the crustal movement, to which the Himalaya owe their origin as a mountain range, was still active.

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* *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2 (1890).

† *Dun* is the Indian term for the narrow longitudinal valleys lying between the outer Siwalik ranges and the higher hills of the Lesser Himalayan ranges (*supra*, p. 85).

‡ *Memoirs, Geological Survey of India*, Vol. XXIII (1891).

In the next geological period, however, the Himalaya appear to have reached a stage of comparative quiescence. In the upper valley of the Sutlej in Ngari Khorsum there are vast deposits of boulders, sand and clay, in which occur remains of mammals * regarded by Mr. Lydekker as of pleistocene age.† The exact origin of these deposits has not been definitely ascertained, but they are now generally regarded as fluviatile, though possibly also in part lacustrine.‡ They lie unconformably on the tilted pliocene sandstones, but are themselves almost perfectly horizontal, thus showing that, since their deposition, no violent disturbance has affected this part of the Himalayan region.

Ossiferous beds of Ngari Khorsum

In the valley of Kashmir, very similar deposits occur, where they are known under the name of *Karewa*. These have been described from time to time by various observers as of lacustrine origin, but from a detailed study of them in recent years, Mr. R. D. Oldham has concluded that their mode of origin was similar to that of the alluvial deposits in process of formation in the same valley at the present day.§

and Karewas of Kashmir

If we are right in regarding the ossiferous deposits of Ngari Khorsum and the Karewas of Kashmir as of pleistocene age, we are led to infer that the general features of the Himalaya were at that period much as they are at the present day. We have already seen (*supra*, p. 210) that the main drainage lines date back as far as the pliocene epoch, and that the rivers which brought down the sand and boulders from the mountains to build up the Siwaliks of the duns and of Hundes were the direct ancestors of our modern Sutlej and Ganges.

indicate quiescence of Himalayan region since pleistocene times.

Of the topography of the Himalayan area before this period we as yet know practically nothing, but it is clear that the old coast-line of Gondwanaland cannot have been very far from the present southern boundary of the Tibetan zone of sediments, and detailed surveys will very possibly reveal the sites of pre-pliocene rivers, as indicated by the coastal or estuarine deposits laid down at their mouths. During the Palæozoic and much of the Mesozoic periods, when the Indian Peninsula and the zone of oldest rocks of the Himalaya formed part of Gondwanaland, rivers must have flowed northwards from India to the Tethys, and we have already noticed the evidence of the direction of drainage afforded by the pebbles of the Salt Range boulder-bed (*supra*, p. 251). In the distant future, when the geology of the Himalaya is known as intimately as that of England and parts of continental Europe at the present day, the presence of deposits like the Gangamopteris beds of Kashmir may enable us to locate, among the sedimentary beds of the Tibetan

Pre-pliocene drainage system.

* R. Strachey: *Quarterly Journal, Geological Society*, Vol. VII, 292 (1851); C. L. Griesbach: *Memoirs, Geological Survey of India*, Vol. XXIII (1891).

† *Records, Geological Survey of India*, Vol. XIV, 178 (1881).

‡ *Manual of the Geology of India*, 2nd edition, 422 (1893).

§ *Records, Geological Survey of India*, Vol. XXI, 157 (1888); T. H. Holland, *Records, Geological Survey of India*, Vol. XXXII, 152 (1905).

zone, the sites of some of the estuaries of this old drainage system, but all traces of its river-valleys through the central zone must have long since been removed by the subsequent processes of denudation, whilst the new drainage system, which has gradually arisen in a reverse direction, has replaced and obliterated the old.*

Indus valley an old structural depression.

Of the present river-valleys of the Himalaya, one at least can be shown to have existed as early as in the eocene period. In the Upper Indus valley in Kashmir are beds of either fresh-water or estuarine origin, which are of eocene age. They form a long and narrow strip in the present valley and mark the position of an old river-valley or of an estuary, which was apparently connected with the Tibetan portion of the Tethys.

Subsequent oscillations of the relative level of land and sea led to these fresh-water beds being covered by marine deposits containing nummulites, but the latest phase in the elevation of this area has resulted in the removal by denudation of the cap of younger beds and the old valley has been thus once more exposed to view. The presence of a valley along approximately the same line at two periods separated by such a great interval of time shows that its origin is not due to mere erosion, but must be attributed to structural causes, connected with the folding of the earth's crust, and producing a depression which was first outlined at least as long ago as the eocene period. This, again, is a further indication that the movements which finally resulted in the upheaval of the Himalaya were already operative at that period.

Recent movement as evidenced (1) by earthquakes:

Although the practically undisturbed condition of the pleistocene beds of Ngari Khorsum and of the Karewas of Kashmir leads us to suppose that there have been no violent disturbances in the Himalayan region since their deposition, many facts suggest that the apparent quiescence is only comparative and that movement tending to a further rise of the Himalaya is now in progress. That movement has not ceased is evident from the frequent earthquakes occurring in the Himalaya and Afghanistan, and such catastrophes as the Kashmir earthquake of 1885,† those of Shillong in 1897 ‡ and of Kangra in 1905 § forcibly remind us that the Himalayan region is by no means at rest.||

(2) by desiccation:

These, however, do not serve to give us any indication of the direction of movement, which we can at present deduce only indirectly from other phenomena. Amongst these may be mentioned the observations already referred to (*supra*, p. 204) in connection with the apparent progressive desiccation of the Tibetan lakes, a phenomenon which has been regarded as due to the rise of the Himalaya and consequent cutting off from Tibet of the moisture-laden monsoon winds. Evidence of such rise being now in progress is also to be found in the

* Since the above was written, a paper has been published by Mr. R. D. Oldham, on "The Valleys of the Himalayas," *Geographical Journal*, XXX, 512 (1907), in which he also refers to such a pre-existing drainage system.

† E. J. Jones : *Records, Geological Survey of India*, Vol. XVIII, 221 (1885).

‡ R. D. Oldham : *Memoirs, Geological Survey of India*, Vol. XXIX (1899), XXX (1901).

§ C. S. Middlemiss : *Records, Geological Survey of India*, Vol. XXXII, 258 (1905).

|| For a complete list of Indian earthquakes up to the end of the year 1869, see T. Oldham : *Memoirs, Geological Survey of India*, Vol. XIX, pt. 3 (1883).

present condition of the chief Himalayan rivers. The general tendency of a river rising in a mountainous region and flowing out on to a plain is to remove material from its upper reaches in the mountains, where its gradient is steep, and deposit it on the plains at their foot; as this process proceeds, the river gradually cuts down its channel, working most rapidly in the higher regions where its gradient is naturally steeper and less rapidly lower down. Where the gradient is steep and the current rapid, the water carries with it large quantities of material such as boulders, pebbles and sand; where, however, the current is less rapid in the lower reaches, its force is insufficient to carry the whole of its load and some or all of it is deposited. The tendency of the river is therefore to remove material from its upper reaches and deposit it in the lower, thus producing a flattening of its gradient throughout, in consequence of which the depositing section of the stream gradually creeps further and further back towards its head. If, during this process, the land round the head-waters of the stream undergoes a movement of elevation, the gradient and consequently the erosive power of the stream will be increased and the water begin to cut a channel through the deposits which had accumulated in the lower valleys. This phenomenon is known as the rejuvenation of a stream.

(3) by rejuvenation of the streams.

At the present day the great Himalayan rivers are not depositing in their lower reaches, except near the points at which they debouch from the mountains and consequently are not in that stage of equilibrium which characterises an old river. On the other hand, their valleys are cut through horizontal deposits of boulders and river-gravels, which can be seen to extend many hundreds of feet above the present stream-bed.* It is clear, therefore, that where the rivers are now in the active stage of abrading, they were once depositing streams and filled their rocky valleys with the sands and gravels through which they have since re-excavated their channels. They have, therefore, undergone rejuvenation presumably due to uplift of the highlands amongst which they rise.

When this uplift began, we are not yet in a position to say since we have at present no evidence of the age of most of these old river-deposits. It has already been pointed out that the ossiferous beds of Hundes are probably of pleistocene age, whilst the Karewas of Kashmir have been attributed to the same period; the other high-level alluvial deposits found in the Sutlej and the Indus may be of the same age or may be of later date, but we are justified in assuming that during the pleistocene epoch, and probably for some little time afterwards, little or no movement took place in the Himalaya, and the rivers gradually tended to assume a state of equilibrium, which, however, was subsequently disturbed by further elevation of the higher ranges and the Tibetan region, resulting in increase of gradient and consequent rejuvenation of the streams, and the present steep gradients of most of the Himalayan rivers lead us to conclude that uplift is either still in progress or has only quite recently ceased.

Date of this movement.

* H. B. Medlicott: *Records, Geological Survey of India*, Vol. IX, 55 (1876); R. Lydekker: *Memoirs, Geological Survey of India*, Vol. XXII (1883).

Similar evidence of recent elevation of the higher ranges of the Himalaya has been deduced by Mr. R. D. Oldham from the manner in which many of the southward-flowing streams are rapidly cutting back into the catchment areas and capturing the drainage of the Tibetan rivers on the north.* Striking examples of this are furnished by the Ganges,† the Tista‡ and the Sind river in Kashmir.§

Evidence of uplift afforded (1) by cutting back of streams;

A most instructive example of this rapid cutting back of the southward-flowing streams on the southern flanks of Kinchinjunga in Sikkim has been described by Prof. Garwood.|| Here the Rathong Chu ¶ and Praig Chu, feeders of the great Rangit, have cut back their heads so rapidly that they have actually truncated and captured what was formerly an important eastward-flowing tributary of the Tista. So rapid has been the work of these two streams that they have cut deep chasms or gorges across the old valley, with the result that the remnant of this former tributary of the Tista is now only a small stream, which "occupies a nearly level upland glen, three miles in length and some 2,000 feet above the floor of the Rathong Chu, and this elevation is maintained nearly to its mouth, whence it empties itself by precipitous cascades into the valley beneath." This rapid head erosion and "piracy" on the part of the Rathong Chu is ascribed to recent elevation of the Kinchinjunga massif lying to the north; such elevation would increase the gradient and consequently the erosive power of the Rathong Chu while not affecting that of the eastward-flowing stream, which would be merely tilted sideways.** Here we see that local uplift will account not only for the formation of a deep gorge on the flank of a range, but also to some extent for those curious side valleys which, as Prof. Garwood graphically expresses it, appear to be suspended in mid air high above the level of the main valley, which they join in a sheer precipice. The difference of level between these "hanging" valleys and the main stream is thus due partly to more rapid erosion of the channel of the latter, through a steepening of gradient attributable to uplift of the mountains at its head, but partly, in Prof. Garwood's opinion, to the recent occupation of the hanging valleys by glaciers which have protected them from the effects of river erosion.

(2) by "hanging valleys" in Sikkim:

Such uplift has also been regarded as a contributory cause of the deep and narrow gorges to be seen in so many of the Himalayan rivers. In a previous part (*supra*, p. 184), reference has already been made to these gorges and various possible modes of origin suggested. Two of these are of

(3) by gorges. Origin of gorges.

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* *Journal, Manchester Geographical Society*, Vol. IX, 112 (1893).

† *Ibid.*

‡ H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 2 (1907).

§ R. D. Oldham: *Records, Geological Survey of India*, Vol. XXXI, 142 (1904).

|| "The Geological Structure and Physical Features of Sikkim" in D. W. Freshfield's *Round Kangchenjunga*, 296 (1903).

¶ Chu=stream or river (Tibetan).

** *Op. cit.* 298; see also "Notes on a Map of the Glaciers of Kinchinjunga" by the same author in *Geographical Journal*, Vol. XX, 13 (1902).

special interest, and are regarded as embodying the main principles involved. They are—

(1) that the Himalayan drainage system had been established before the ranges, across which the rivers now cut, had become axes of special elevation, and that when elevation finally took place its rate was not so great as to interrupt the course of the river, which was therefore able to keep its channel open by abrasion across the rising range;

(2) that the old rivers have been dammed by the rising ranges and their valleys thus become lakes, the waters of which eventually overflowed and carved out gorges.

The first of these theories, which we owe to Mr. H. B. Medlicott,* has been applied with striking success by Mr. R. D. Oldham to the river-valleys of the Himalaya and neighbouring areas. In the comparatively young mountains of Baluchistan, which was still under the sea after the Himalaya had become dry land, he has followed out the earlier stages in the process of the formation of gorges and has subsequently extended these principles to the Himalaya themselves.† He has suggested that the present gorges of the Indus and the Brahmaputra lie along the alignment of valleys which were defined at the time when the upheaval of the Himalaya first began and when a pair of longitudinal valleys was established along the northern face of the rising mass, round the extremities of which the drainage escaped towards the south. This assumption is borne out by the observations of Mr. Medlicott, who has shown that the great Himalayan rivers are "antecedent" and that their debouchures in Siwalik times were where they are at the present day (*supra*, p. 210), whilst the nature of the Indus valley Tertiary deposits is evidence of the existence of a structural valley along the line of the Indus at a very early date (*supra*, p. 260).

The second theory has been advanced by Colonel Burrard to explain the origin of the gorge of the Brahmaputra.‡ He has suggested that an old river-valley, having become blocked by the rise of a mountain range, has been filled by a lake, the overflow from which has subsequently cut a channel resulting in the present gorge. Such a diversion of drainage has been shown by Mr. R. D. Oldham to have occurred in one instance in Baluchistan,§ but in this case there is no tendency for the new channel to become a gorge. The water, where it issued from a lake, would hold no sediment and would consequently have practically no abrasive power, hence, except in areas of extreme aridity, the sides of the outlet valley would be worn away by atmospheric denudation concurrently with the excavation of the new channel, and the valley would have gently sloping, rather than precipitous, sides.

There are several other difficulties in the way of the application of this process to the Himalayan gorges. In the first place, we should expect to find well-marked lake

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* *Manual of the Geology of India*. 1st edition. 676 (1879).

† *Geographical Journal*, Vol. III, 169 (1894).

‡ *Ann. Rep., Board of Scientific Advice for India*. 1905-06, p. 67; also *supra*, part III, p. 85.

§ *Records, Geological Survey of India*, Vol. XXV, 28 (1892).

deposits in the basins above the gorges. These, however, have nowhere been recognised; the previously accepted views of the lacustrine origin of the Karewas of Kashmir have been recently disputed,* whilst the description given by the late Sir Richard Strachey of the pleistocene deposits of the Upper Sutlej valley† points to an origin in part, if not entirely, fluviatile.

On the other hand, basins of this kind filled with fluviatile deposits, and in some cases even holding lakes, are commonly found above gorges in almost all parts of the world, but it can usually be shown that they are due to the obstruction caused by hard bands of rock running across the valley. Thus, in the case of the Sutlej, the stream after passing through the sedimentary beds of Hundes encounters the hard granite of the great Himalayan range; its rate of erosion is retarded, and, while slowly wearing its way down into a narrow trough in the hard rock, it works also laterally in the softer beds, and so produces a broad basin above, in which alluvial deposits accumulate, and a gorge or "narrows" below.‡ Thus the gorges have been developed concurrently with the open basins behind the ranges rather than after, and as a consequence of the damming of, these.

The two hypotheses above quoted are mutually conflicting, but so little is yet known of the actual conditions of the Himalayan rivers that it is desirable to keep both in view. One fact, however, is clear, namely, that until systematic observations have been made of most of the great Himalayan rivers on the lines of the admirable work of Mr. R. D. Oldham in the Sind valley in Kashmir§ and of Prof. Garwood in Sikkim,|| we can make no advance in India in this most fascinating branch of historical research, the history of the surface features of the earth.

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* *Supra*, p. 259; also Ellsworth Huntington: *The Pulse of Asia*, 22 (1907).

† *Quarterly Journal, Geological Society*, Vol. VII, 306 (1851).

‡ For details as to these processes see Sir A. Geikie: *The Scenery of Scotland* (1901); also Chamberlain and Salisbury: *Geology, Processes and their results* (1905).

§ *Records, Geological Survey of India*, XXXI, 142 (1904).

|| *Quarterly Journal, Geological Society*, Vol. LVIII, 703 (1902): *Geographical Journal*, XX, 13 (1902); *Appendix* to D. W. Freshfield's *Round Kangchenjunga* (1903).

38

ECONOMIC GEOLOGY OF THE HIMALAYA.

The Himalayan region is strikingly poor in minerals of economic value, there being only three industries which can be said to be established on a commercial basis; these are the salt and the slate quarries in Kangra district and the sapphire mines of Kashmir.

Salt.

The salt quarries are situated at Guma and Drang in Mandi State; they are at present only of local importance, the output in 1906 being about 3,600 tons.*

Slate.

The Kangra slate quarries, which are at Kanyara, have been worked with considerable success for some years past. The rock is not a true clay slate, but is sufficiently fissile for the production of slabs and roofing-slates.†

Sapphire.

The sapphire mines, which are situated near Padar in Kishtwar, were first opened nearly 30 years ago, but after being worked for a few years were closed on account of diminution of output.‡ Recently, however, the industry has been successfully revived, the output being valued at £1,327 in 1906§ and £3,144 in 1907.||

The other minerals found in the Himalayan region include: borax, coal, gold, gypsum, sulphur and ores of antimony, arsenic, copper, iron and lead.

Borax.

Borax is found in Ladak, where it is obtained as an efflorescence from the surface of the alluvium of the Puga valley. The superficial coating is scraped up and boiled with water in coppers; the resulting brine is then cooled in small pits, when the borax crystallises out. The production at Puga is quite insignificant, almost the whole supply of borax brought into India being imported from Central and Western Tibet.

Coal.

The chief occurrences of coal in the Himalaya are among the Gondwana rocks of the Darjeeling Terai and Assam Duars and in the Tertiary beds of Jammu in Kashmir.

As already pointed out (*supra*, p. 216), the Gondwana coal is usually too crushed to be of commercial value and such attempts as have hitherto been made to work it have not met with success.

The coal of Jammu occurs in a belt of Tertiary rocks to the north of the town of Jammu and comprises a number of fields known as the Ladda, Sangar Marg, Mehowgala, Siro valley, Kalakot and Lodhra coal-fields.

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* T. H. Holland: *Records, Geological Survey of India*, Vol. XXXII, 85 (1905); XXXVI, 80 (1907).

† T. H. Holland: *Records, Geological Survey of India*, Vol. XXXII, 114 (1905).

‡ T. D. LaTouche: *Records, Geological Survey of India*, Vol. XXIII, 59 (1890).

§ T. H. Holland: *Records, Geological Survey of India*, Vol. XXXVI, 79 (1907).

|| T. H. Holland: *Records, Geological Survey of India*, Vol. XXXVII, 82 (1908).

The seams are highly inclined and their thickness is very variable. The coal is much crushed and usually contains a high percentage of ash.* Experiments recently made, with a view to testing the suitability of the coal for the manufacture of briquettes, did not give favourable results and the prospects of the development of these fields as a profitable undertaking are not promising.†

Another small coal-field occurs further to the north-west in the Kotli tahsil at Dandli, but the prospects here are even less promising.‡ Coal also occurs in the Nummulitic series in Hazara, but its quality is poor and the thickness of the seams very variable.§

Reference has already been made to the small patches of lignite occurring in the sandstones of the Siwalik series in the Sub-Himalayan zone (*supra*, p. 210). These have often given rise to expectations, always foredoomed to disappointment, of the discovery of workable coal-seams.

Gold.

Gold is found in small quantities in the gravels of almost all the chief rivers of the Himalaya|| and its recovery provides occupation for the local inhabitants during the winter, when agricultural work is at a standstill.

In the Indus and its tributaries, and in the Sutlej, washing by means of primitive cradles is carried on to a considerable extent, but the results are at present too insignificant to raise this intermittent occupation to the status of a regular industry.

In the Eastern Himalaya, the gravels of the Brahmaputra and neighbouring rivers have long been known to be auriferous,¶ but so far no serious attempt has been made to exploit them on modern principles.

In Tibet, the gold fields of Rudok and Thok Jalung have been worked from very early antiquity and Herodotus' reference to the gold-digging ants, with the many ingenious commentaries to which it gave rise, is no doubt familiar to everyone.** The output of the Tibetan fields, however, is quite unknown, a circumstance to which the many stories of their fabulous wealth are no doubt to be attributed.

Gold is also found in Afghanistan, but what was formerly the most productive mine in the country, that of Kandahar, has long been closed owing to the miners having lost the vein.††

Gypsum.

Gypsum occurs in thick beds, as the product of the alteration of limestone, in lower Spiti, at a short distance above the junction of the Spiti and Sutlej rivers. Although the quantity available is very large and the quality high, the locality is too far from markets and too inaccessible to offer any prospects of remunerative exploitation of the deposits.‡‡

* R. R. Simpson: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 4 (1904).

† T. H. Holland: *Records, Geological Survey of India*, Vol. XXXII, 137 (1905).

‡ C. M. P. Wright: *Records, Geological Survey of India*, Vol. XXXIV, 37 (1906).

§ C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXVI (1896).

|| V. Ball: *Manual of the Geology of India*, pt. 3 (1881).

¶ J. M. Maclaren: *Records, Geological Survey of India*, Vol. XXXI, 205 (1904).

** For literature on the subject see *Manual of the Geology of India*, pt. 3, Art. *Gold* (1881).

†† C. L. Griesbach: *Memoirs, Geological Survey of India*, Vol. XVIII, pt. 1, 56 (1881).

‡‡ H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1, 101 (1904).

Sulphur.

Sulphur is found at Puga in Ladak, where it is deposited from hot springs. The quantity is small and the occurrence of little or no economic importance.*

Antimony.

Sulphide of antimony (stibnite) occurs in some quantity near the Shigri glacier in the valley of the Chandra river in Lahaul. The locality has long been known,† but no serious attempt had been made to work it until quite recently, when prospecting operations were undertaken and a mining lease obtained with a view to its exploitation. No information is as yet available as to the result of the operations.

Arsenic.

Orpiment, the yellow sulphide of arsenic, is found in Chitral, Hunza and Kumaun. In Chitral it has been mined for a long period, but the production has fallen off in recent years, having dropped from a little under thirty tons in 1904-05 to less than ten in 1905-1906.

Specimens have also been obtained from the Rishipjerab valley in Hunza and the Shankalpa glacier in Kumaun,‡ but the amount available in either locality is unknown.

Copper.

Copper-ore, chiefly in the form of the sulphide, chalcopyrite, is common in the schistose beds of the Daling series in Darjeeling district (*supra*, p. 228) and in Sikkim and in the similar rocks of the Himalayan zone in the Lesser Himalaya of Kumaun.

As a rule the lodes are patchy and irregular and no successful attempt has yet been made to exploit them on a large scale. Recently, however, the copper-ores of Sikkim have been attracting considerable attention, but no information is at present available as to the results of prospecting operations.

Iron.

Iron-ore is known to occur in some quantity in the lower hills in Kumaun,§ where numerous attempts have been made to establish a smelting industry on a commercial basis. All attempts failed however, presumably owing to the cost of transport of ore and fuel and there does not seem to be much prospect of a successful revival of the industry.

Iron-ore also occurs in Jammu State, where it underlies the coal measures, but has not been worked except locally and on a small scale.

Numerous other occurrences of iron-ore in the Himalayan region have been recorded, but none of these is at present of economic importance and they need not be enumerated here. Further information, however, will be found in the ***Manual of the Geology of India***, part 3 (1881).

Lead.

Galena, the sulphide of lead, is found at numerous places among the older rocks of the Lesser Himalaya,|| but it is not known to occur in sufficient quantity to warrant serious exploitation.

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* F. R. Mallet: *Memoirs, Geological Survey of India*, Vol. V, 164 (1866).

† F. R. Mallet: *Memoirs, Geological Survey of India*, Vol. V, 165 (1886).

‡ *Records, Geological Survey of India*, Vol. XXXV, 28 (1907).

§ T. H. Hughes: *Records, Geological Survey of India*, Vol. VII, 15 (1874).

|| V. Ball: *Manual of the Geology of India*, pt. 3, Art. *Lead* (1881).

APPENDIX.

A few addenda and notes of warning which should be read in conjunction with Parts I, II, III and IV.

Peak No. 60, Indus-Nagar Watershed No. 2.

Part I, page 4, table V.

The name "Indus—Nagar Watershed peak No. 2" has been allotted in Great Trigonometrical Survey Synoptical, Volume VII, to two peaks: on page 95-C there is a peak of this name in latitude 36° 0′ 13″·5 and longitude 74° 55′ 1″·5 of height 24,470. On page 135-C there is a peak of the same name in latitude 35° 51′ 40″·2 and longitude 75° 0′ 20″·7 and of height 21,390 feet. The origin of this duplication of names has been explained on the ground that the numbering of peaks was started afresh in each square degree, but whatever the explanation, a system under which the same name has come to be applied to two different peaks can in no way be defended. The Indus-Nagar Watershed peaks of pages 92-C and 95-C of Synoptical Volume VII will retain the names hitherto applied to them, whilst the Indus-Nagar Watershed peaks of pages 135-C and 136-C will be called in future Indus-Nagar Watershed peaks No. 7, No. 8, No. 9, and No. 10. Similarly in other cases, in which duplication of names have occurred, alterations will now be introduced.

On page 322 of the *Ice bound Heights of the Mustagh*, Mrs. Bullock Workman and Dr. Hunter Workman give their reasons for thinking that the Survey have miscalculated the position of the Indus-Nagar Watershed peak No. 2, height 24,470 feet. The two explorers ascended to a great height (23,394 feet), and thought at the time that they were climbing a flank of the Survey peak (height 24,470 feet). But when they came to construct their map, they found that the peak which they had ascended was 4 miles north by east of the Survey peak. They were convinced that their peak, which they have named Pyramid Peak, is higher than the Survey peak and they were

> "thus placed in the dilemma of considering either that the Survey had miscalculated the position of Peak 2, thus giving it a position four miles too far south, or that Pyramid Peak is another and higher peak not seen and triangulated by the Survey."

The maps of this high region are so inaccurate that they may be disregarded: it is useless to appeal to them. But the positions of peaks were fixed trigonometrically by the Survey, and are probably correct. The position of the Survey peak (24,470 feet) was determined from two independent triangles, and the discrepancy between the two values of position was only 7 feet. The height of this peak was determined from two different places and the two values obtained were 24,482 and 24,461 feet.

The evidence, therefore, is strong that the position of the Survey peak (24,470 feet) has been determined with fair accuracy and cannot be in error by 4 miles.

It is quite possible that a higher peak standing 4 miles behind it escaped observation. The uneven crest-line of the intervening ridge may have obscured the higher peak from one or two of the stations of observation and have left the lower peak visible. The original angle-books show that in 1862-63 Mr. Beverley observed an unnamed peak from his station of Chokh and found it to be 2 degrees east of the Indus-Nagar Watershed peak No. 2 This companion peak was, however, not seen from any other station and Mr. Beverley's observation from one station only could not be utilised.

Peak No. 66, Kuen Lun No. 1.

The height of this peak is uncertain. The position and height of the peak were derived from the observations of Surveyor Ram Singh, Rai Sahib, when he was working under Dr. Stein in 1900; the angle-book was in the handwriting of Dr. Stein himself. Ram Singh is an accurate observer, and his other observations taken at the same time as those of peak No. 66 have proved reliable. We had, however, some initial doubt whether to accept the peak No. 66 or not, because its position had been fixed from one triangle only and that a very acute one. But its height had been observed independently from two different stations, 4 miles apart, and whilst a value of 24,385 feet was obtained from one set of observations, a value of 24,227 feet was obtained from the other set. The agreement between these two values seemed to indicate that a very high peak was standing in this region, and peak No. 66 was admitted into our list on table V. The absence from Dr. Stein's letters and papers of all allusion to this apparently supreme peak of the Kuen Lun made us somewhat uneasy, and when Dr. Stein visited Dehra Dun in December 1908 upon his return from Chinese Turkistan, he was consulted. He expressed his conviction that no peak of 24,000 feet exists in the locality, in which peak No. 66 has been supposed to be standing. Dr. Stein has explored this locality, and could not have failed, he thinks, to have been struck by the appearance of so prominent a peak. He is of opinion that the observations upon which the existence of the peak has been based must be in error.

Part I, page 4, table V.

Tirich Mir.

This description of Tirich Mir is only true if the mountain is viewed from the side of Gilgit or Mastuj. From Chitral the higher flanks of Tirich Mir appear to be precipitous. During the summer it is seldom visible, being either enveloped in cloud or surmounted by a white "flag," which looks like cloud but is possibly fine snow being blown off the summit.

Part I, page 11.

Heights of peaks.

It has been suggested in a review in *Nature*, December 3rd, 1908, page 133, that the altitudes of peaks should be reduced to round numbers, that the height of Mount Everest, for instance, should be given as 29,000 instead of 29,002, and that of Kinchinjunga as 28,150 instead of 28,146. We think, however, that it is best to adhere to the present system, because a precise value of altitude is a ready means to the identification of a peak.

Part I, page 16, para. 1.

Gasherbrum.

In table XVIII, group XIV, column 6, the bracket should embrace the four Gasherbrum peaks only and not the peak of K^2.

Part I, page 40.

Kabru.

The name Kabru belongs rather to the high-level *ridge* itself than to the peak at either end of it.

Part I, chart VI.

The height, 21,970 feet, given to the peak at the western end of the Kabru ridge in the third panorama of chart VI is incorrect. The two Kabru peaks are very nearly of the same height, and are both about 24,000 feet: for Tanner's description of Kabru see page 8 of Part I. 21,970 feet is the height of Little Kabru, see Garwood's map attached to Douglas Freshfield's *Round Kangchenjunga.*

Singalila.

Referred to as "Singli" by Rai Bahadur Sarat Chandra Das, C.I.E.: *Journey to Lhasa and Central Tibet*, page 6.

Part I, pages 9, 20, 43;
Part II, pages 62, 77, 78, 89;
Part III, page 152.

Karo La.

See Rai Bahadur Sarat Chandra Das, C.I.E.: *Journey to Lhasa and Central Tibet*, page 173.

Part II, page 95.

Yamdrok Tso.

Part II, page 95; Part III, pages 156, 157, 189, 200, 202, 203, 204.

With regard to the name Palti (Yamdrok) see the note by W. W. Rockhill in *Journey to Lhasa and Central Tibet* by Rai Bahadur Sarat Chandra Das, C.I.E., page 188.

Sangpo.

Part II, pages 111, 112; Part III, pages 125, 127, 128, 157—160, 188.

The word Sangpo should have been written Tsangpo. In the Imperial Gazetteer of India, Volume I, pages 19, 27, Volume IV, page 499, it is written "Tsan-po."

Kuen Lun range.

Part II, page 103, footnote.

The warning given on page 103 of Part II is repeated here. In the frontispiece of Part I the axis of the Central Kuen Lun has been drawn too far north. In longitude 84° the axis should have been placed in latitude 36°. Chart XXXV repeats this mistake. Chart XXIII is correct.

Huang-Ho.

Part II, Chart XVII.

On this chart Huang should be Hoang.

The Hindu Kush.

Part III, page 123, para. 1.

It has been pointed out in a review in *Nature*, December 3rd, 1908, page 133, that our description of the Hindu Kush ranges on page 123 of Part III does not tally with figure 2 of chart XXI. The description on page 123 will be found to be in accord with the frontispiece to Part I. As was explained on page 101 of Part II, the figure 2 of chart XXI was purposely made to differ from the frontispiece in order to illustrate our uncertainties. In the two charts we have offered two different solutions of the problem. Whilst we agree with the reviewer in *Nature* as to the difficulties attending orographical analysis, we are of opinion that the uncertainties surrounding the Hindu Kush may prove to be due to the want of systematic surveys and may disappear when more accurate maps become available.

The Brahmaputra.

Part III, page 155.

The water-parting between the Brahmaputra and the Tibet Lake basin cannot be drawn with certainty. The position assigned to this water-parting on charts XXIII, XXX and XXXV is conjectural and is not based upon surveys. Until surveys of this region have been carried out, it will not be possible to indicate, except in a very rough way, the northern boundary of the basin of the Brahmaputra.

The warning given in the last paragraph of page 125 of Part III is thus very important. The second paragraph of page 95, Part II, contains the same warning.

The Kunar river.

Part III, page 155.

The angle, at which the Sor Laspur tributary joins the Kunar river at Mastuj, is deserving of attention. This tributary is shown on chart XXXIV of Part III.

Shigatze.

Part III, pages 155, 156, 158.

Spelling adopted from the map published with the Imperial Gazetteer. In the body of that work (Volume IV, page 119) it is written Shigatse, a modification of Shi-ga-tse, the form employed by Major W. F. O'Connor.

The brothers Strachey.

Part III, page 162, line 9.

Henry Strachey was alone in 1846; Richard Strachey did not visit Manasarowar till 1848. (*Geographical Journal*, Volume XV, 1900, and *Journal, Royal Geographical Society*, Volume XXI, 1851.)

Kurkulti Glacier.

Part III, page 196.

The Kurkulti Glacier flows into the Yasin river, and not into the Hunza as stated on page 196.

Panjal Volcanics.

Part IV, page 232, table XLI; page 245.

Since this table was drawn up, the work of Mr. C. S. Middlemiss in Kashmir has tended to show that the Panjal Volcanics are younger than the Lipak series.

GEOGRAPHICAL INDEX.

The values of latitude and longitude given in this index to the more important geographical names occurring in Parts I, II, III and IV, are intended only as rough aids to the localisation of places on maps: as many of these values have been derived from small scale maps, the index should not be utilised in scientific discussions or controversies. In certain cases, more especially in those of Tibetan lakes and of passes and glaciers, the values of latitude and longitude rest on doubtful evidence, and have been entered only to enable future explorers to correct our figures. In cases when two or more peaks bear the same name, mean values of latitude and longitude have been given in this index.

* The picture of Bandarpunch peak will be found facing page 39 of Part I.

* The picture of Nanga Parbat peak will be found facing page 39.
† See page 230 (footnote‡).

* The picture of Nojli Tower will be found facing page 30.

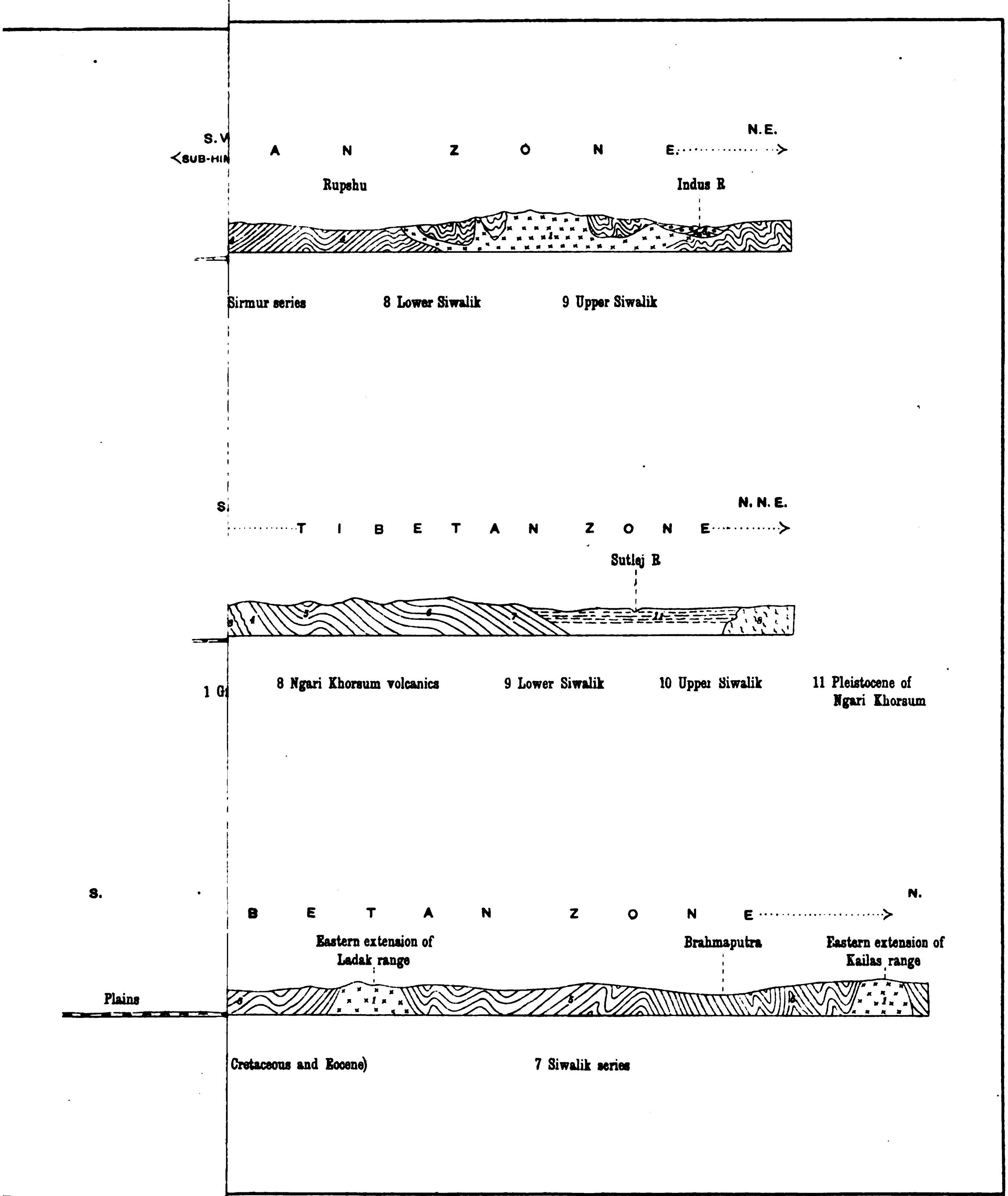
* See page 230 (footnote ‡).

N

INDEX OF SUBJECTS.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

PLATE XXXVIII



FOLDING IN THE SUB-HIMALAYAN ZONE

PLATE XXXIX

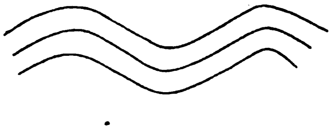


Fig. 1. Simple folding.

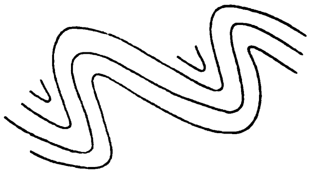


Fig. 2. Reversed folding.

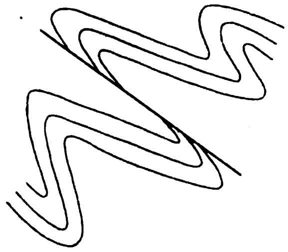


Fig. 3. Overthrust.

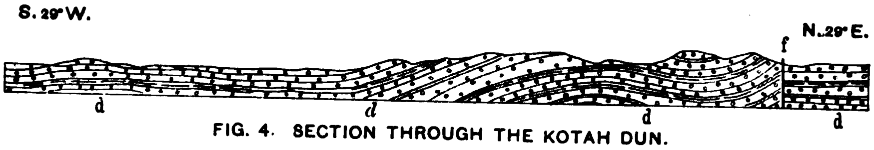


FIG. 4. SECTION THROUGH THE KOTAH DUN.

Scale 1 Inch = $1\frac{1}{8}$ Miles.

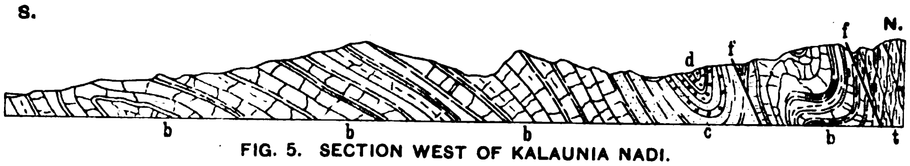


FIG. 5. SECTION WEST OF KALAUNIA NADI.

Scale 1 Inch = $1\frac{1}{8}$ Miles.

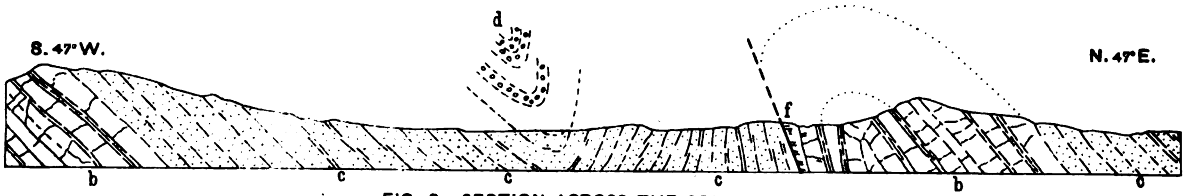


FIG. 6. SECTION ACROSS THE SONA NADI.

Scale 1 Inch = 1 Mile.

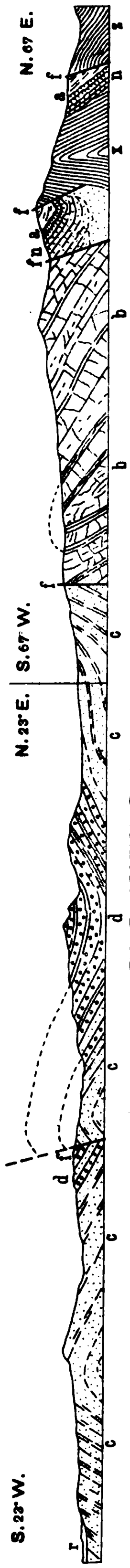


FIG. 7. SECTION EAST OF THE GANGES.

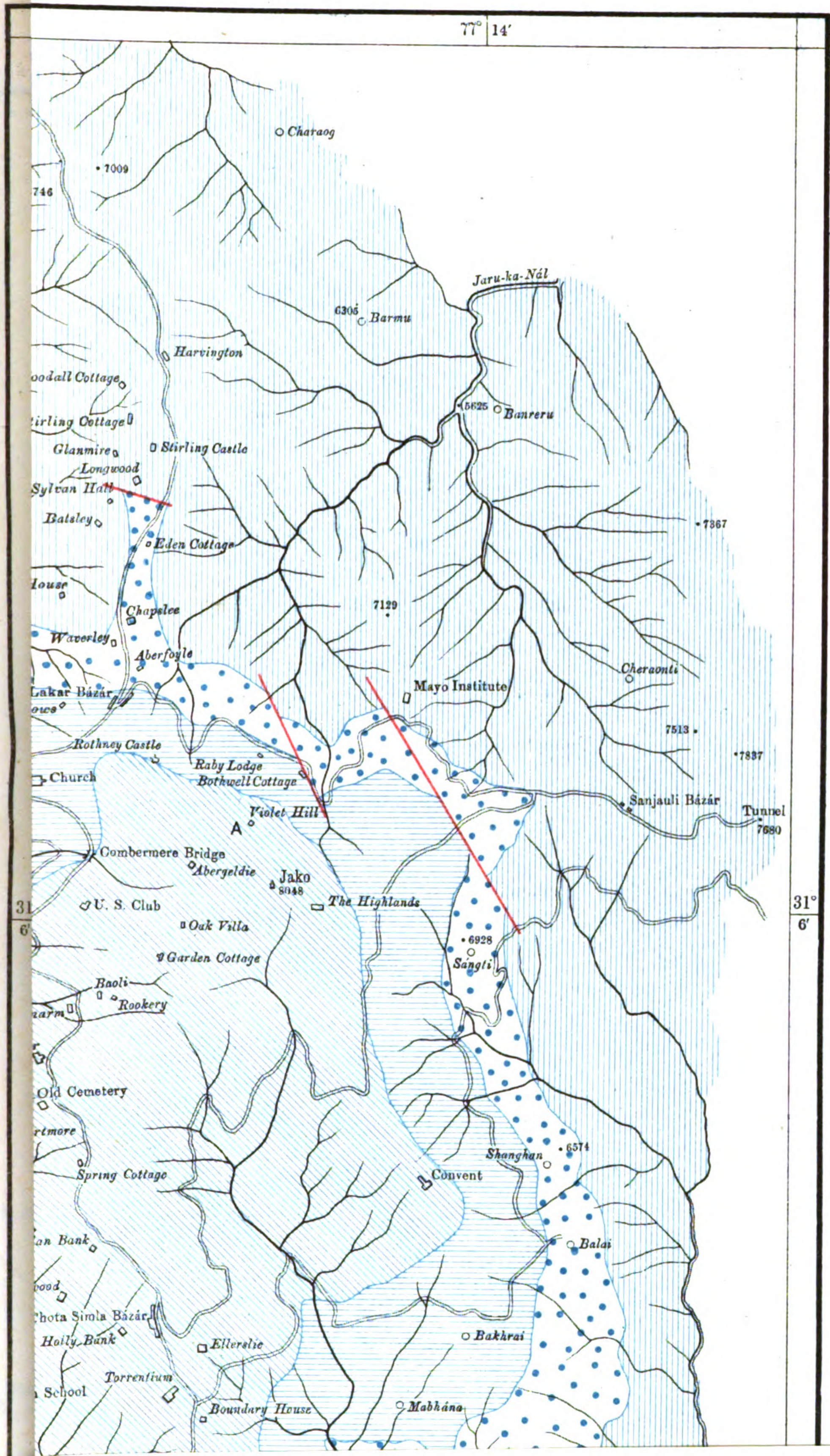
Scale 1 Inch = $1\frac{1}{8}$ Miles.

FIGS. 4 to 7. SECTIONS THROUGH THE SUB-HIMALAYA OF GARHWAL AND KUMAUN.

(*after C. S. Middlemiss. Mem., Geological Survey of India, XXIV, Pt. 2.*)

r = Recent.
d = U. Siwalik Conglomerate.
c = M. Siwalik sand rock.
b = L. Siwalik (Nahan) sandstone.
a = Nummulitic.
n = Tal series.
t = Trap.
x = Purple slate.
z = Crystalline schist.
f = Faults.

PLATE XL



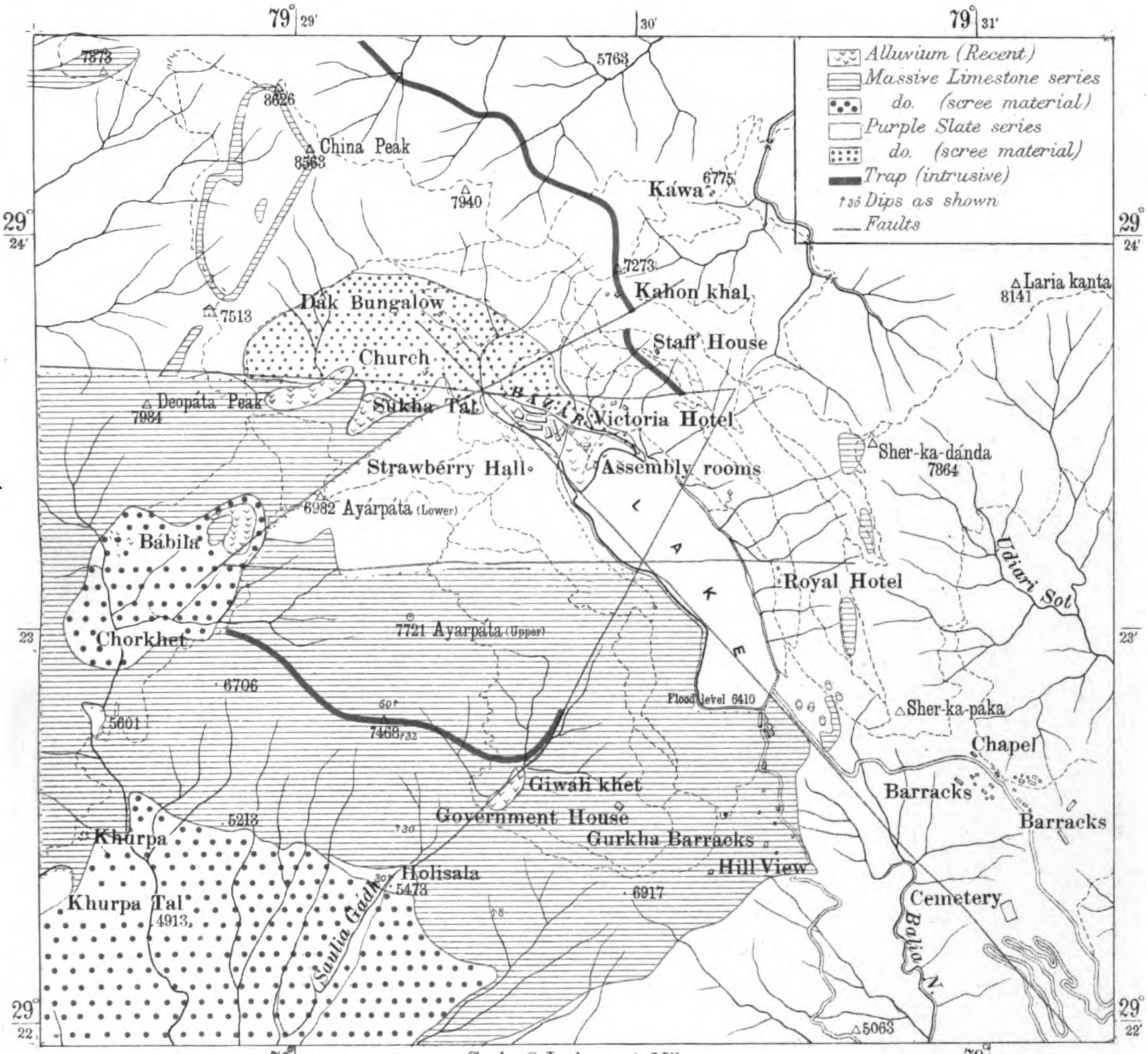
Helio. T. B. C.

GEOLOGICAL MAP AND SECTIONS OF

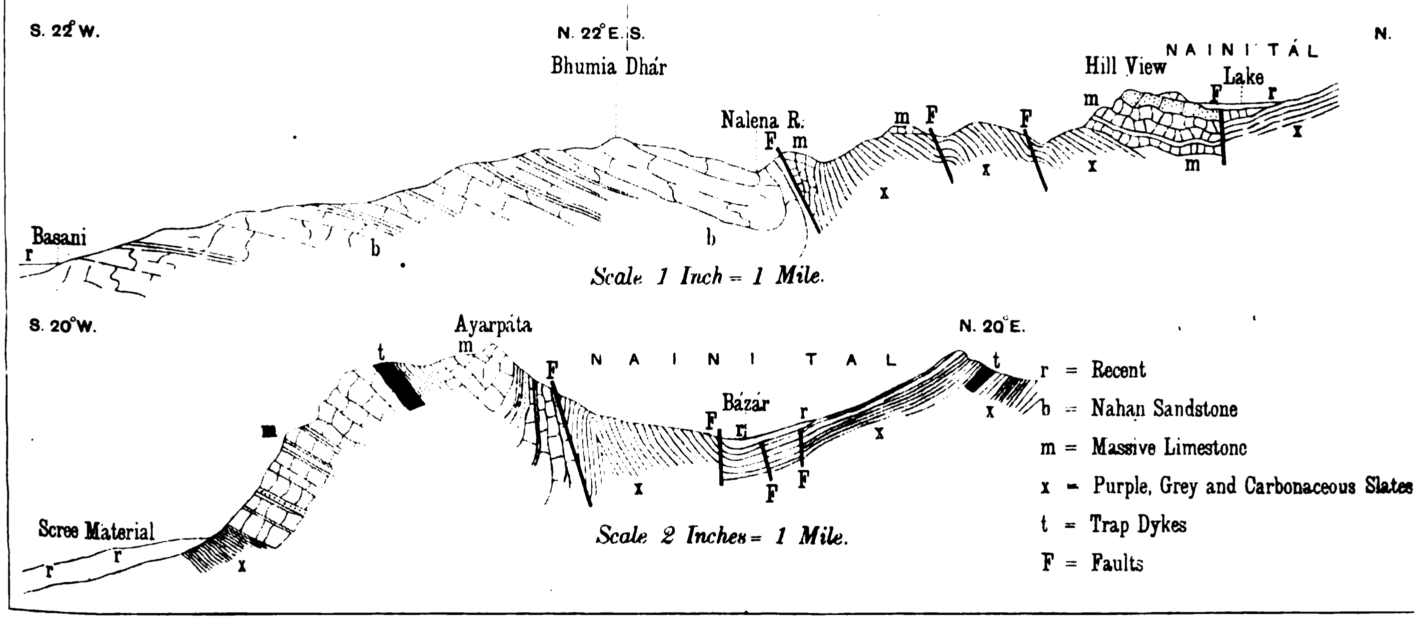
NAINI TÁL

(after C. S. Middlemiss: Rec., Geological Survey of India XXIII)

PLATE X



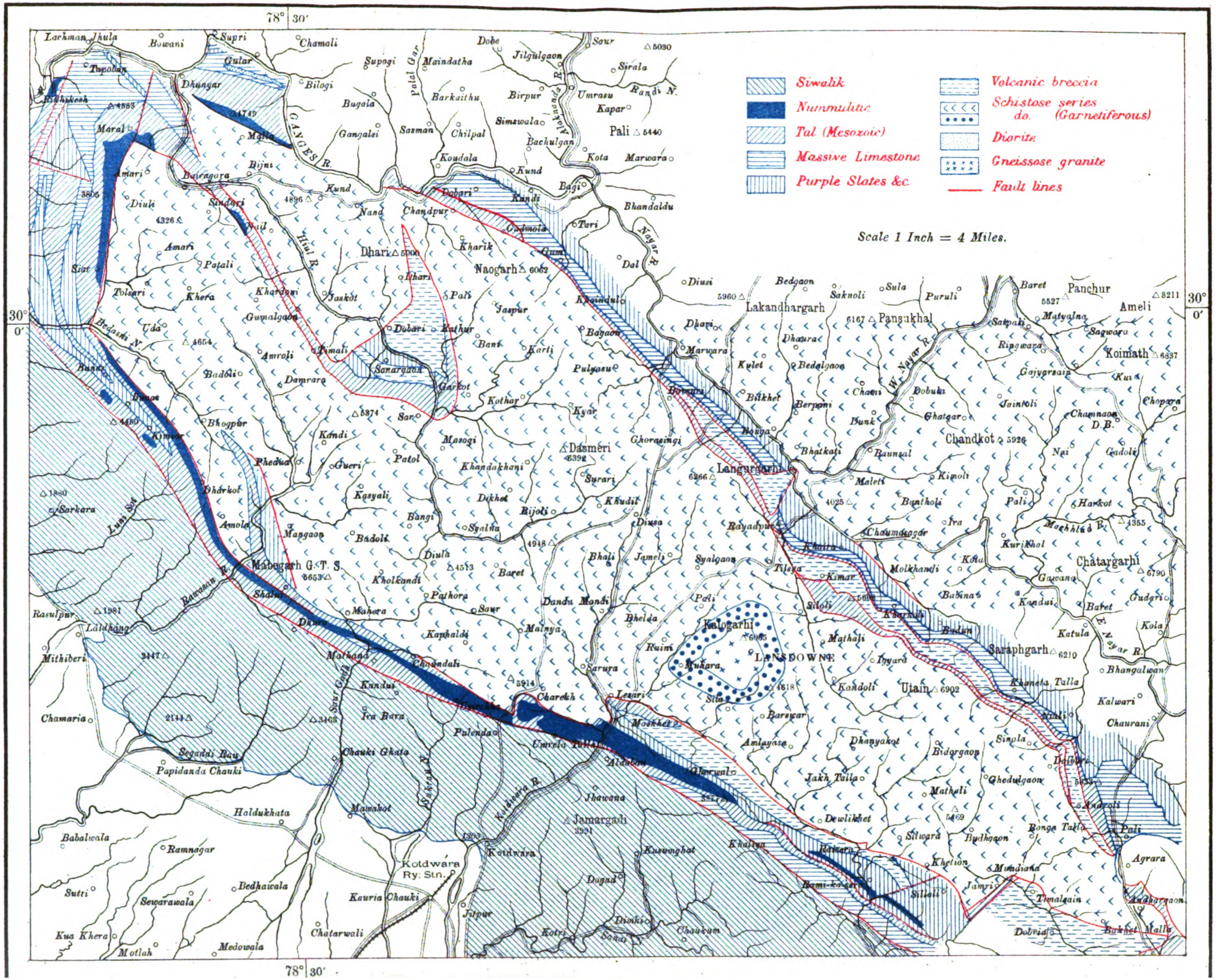
Scale 2 Inches = 1 Mile.



Helio. T. B. O. Dehra Dún

IN WESTERN GARHWAL

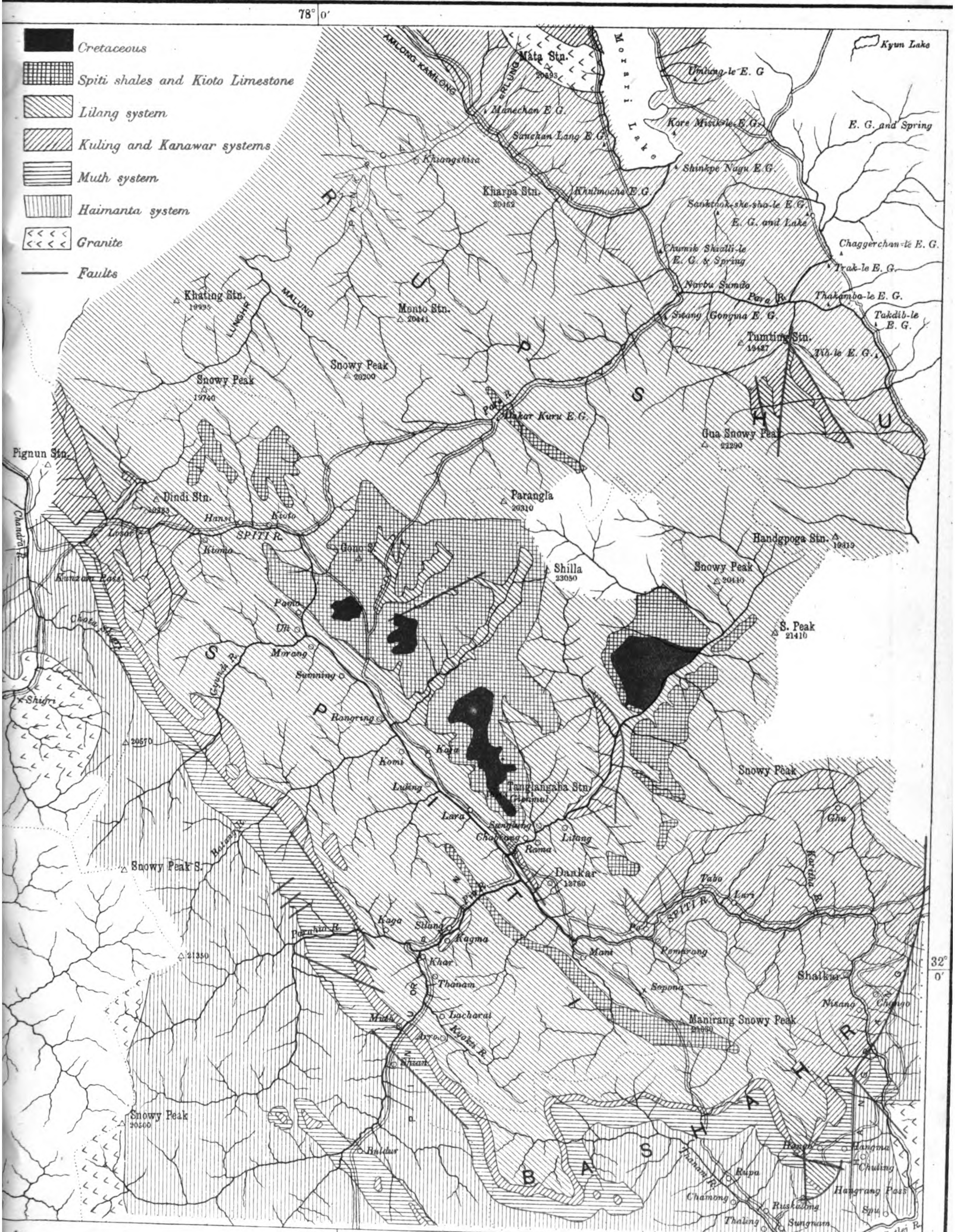
(after C. S. Middlemiss: Rec., Geological Survey of India, XX)



GEOLOGICAL MAP OF SPITI AND RUPSHU

(*after H. H. Hayden and A. von. Krafft: Mem., Geological Survey of India, XXXVI, pt. 1*)

PLATE XL

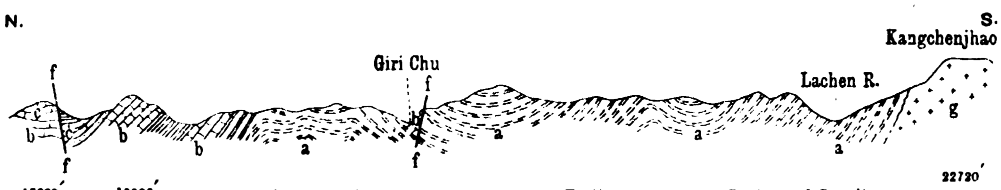


78° 0′ Scale 1 Inch = 8 Miles.

Helio T.B.O. Dehra Dun.

SECTIONS ACROSS THE
TIBETAN ZONE
IN SPITI, TIBET AND KUMAUN

PLATE XLIV



a. Jurassic. b. Cretaceous. c. Tertiary g. Gneiss and Granite.

FIG. 1. SECTION FROM KANGCHENJHAO TO KAMPA RIDGE, TIBET.

(after H. H. Hayden, Mem., Geological Survey of India, XXXVI, pt. 2)

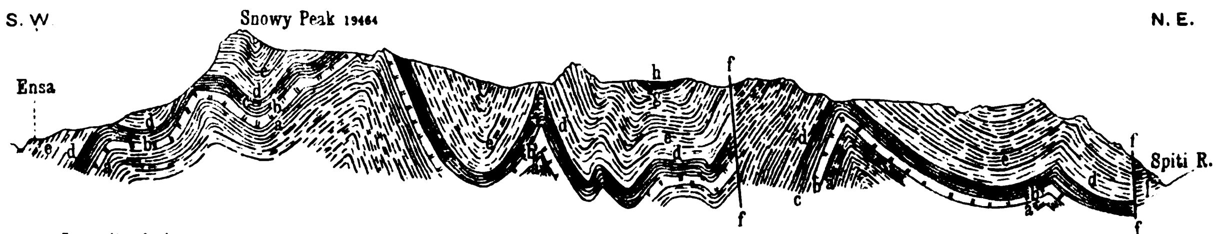
Scale 1 Inch = 4 Miles.

2. Haimanta system
3. Muth system
4. Productus shales.
5. Lilang system.

FIG. 2. SECTION BETWEEN THE EAST SLOPE OF THE BAMBADHURA AND THE DHAULI GANGA, KUMAUN.

(after C. L. Griesbach, Mem., Geological Survey of India, XXIII)

Scale 1 Inch = 2 Miles.



a. Juvavites beds.
b. Coral limestone.
c. Monotis shales.
d. Quartzite series.
e. Megalodon (Para) limestone
f. Faults
g. Jurassic (Tagling) limestone.
h. Spiti shales.
l. Daonella shales.

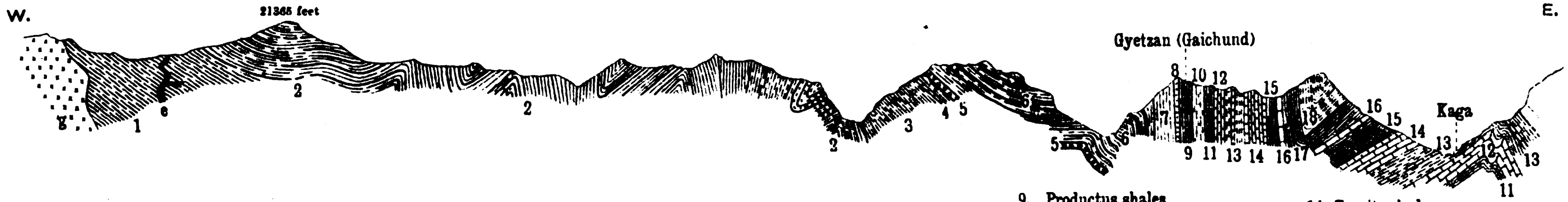
FIG. 3. SECTION FROM SPITI RIVER, ABOVE MANI, TO ENSA.

(after H. H. Hayden, Mem., Geological Survey of India, XXXVI, pt. 1.)

Scale 1 Inch = 2 Miles.

PLATE XLV

TIBETAN ZONE
IN SPITI, KUMAUN AND HAZÁRA

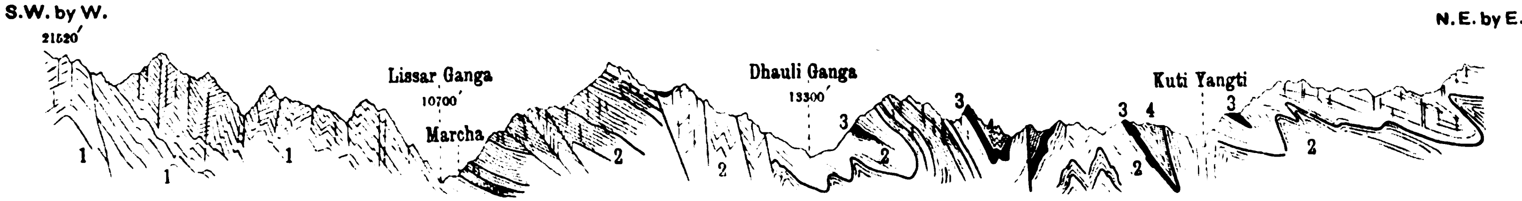


- g. Granite
- e. Epidiorite
- 1. Haimanta slates and quartzites, altered by contact with igneous rocks
- 2. Haimanta slates
- 3. Haimanta trilobite beds
- 4. Haimanta Dolomite
- 5. Muth Conglomerate
- 6. Red (lower silurian) quartzite
- 7. Muth limestone
- 8. Muth quartzite
- 9. Productus shales
- 10. Otoceras zone to muschelkalk
- 11. Daonella shales
- 12. Daonella limestone
- 13. Grey shales
- 14. Tropites beds
- 15. Juvavites beds
- 16. Coral limestone
- 17. Monotis shales
- 18. Quartzite series

FIG. 1.—SECTION ALONG THE PARAHIO RIVER, SPITI.

(after H. H. Hayden: Mem., Geological Survey of India, XXXVI, pt. 1)

Scale 1 Inch = 2 Miles.

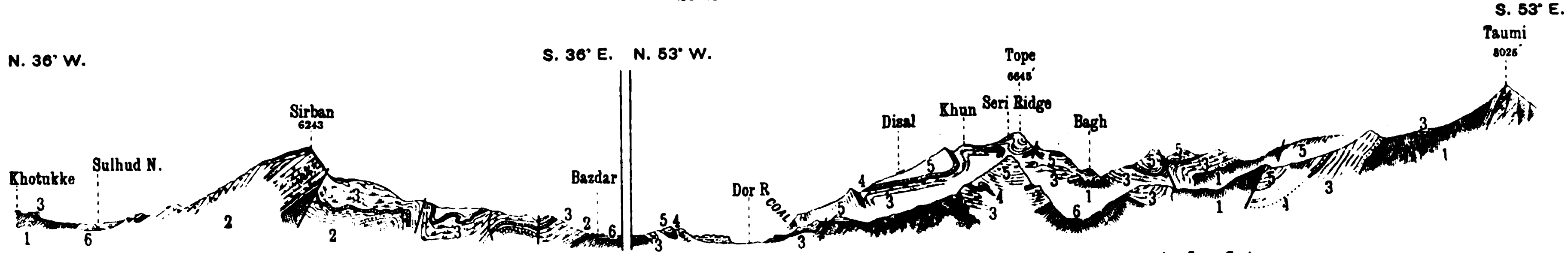


- 1. Haimanta system
- 2. Muth system
- 3. Productus shales
- 4. Lilang system

FIG. 2.—SECTION BETWEEN THE NAULPHU NIPCHUNG HEIGHTS AND THE RANGE WHICH DIVIDES THE KUTI YANGTI FROM HUNDES, SOUTH OF THE MANKSHANG.

(after C. L. Griesbach: Mem., Geological Survey of India, XXIII)

Scale 1 Inch = 3 Miles.



- 1. Slate series
- 2. Infra Trias
- 3. Trias
- 4. Jura-Cretaceous
- 5. Tertiary
- 6. River Gravels

FIG. 3.—SECTION IN HAZÁRA FROM SIRBAN TO TAUMI.

(after C. S. Middlemiss: Mem., Geological Survey of India, XXVI)

Scale 1 Inch = 1 Mile.

GEOLOGICAL MAP AND SECTIONS OF MALLA JOHÁR

(after A. von. Krafft: Mem., Geological Survey of India, XXXII, pt. 3)

PLATE XLVI

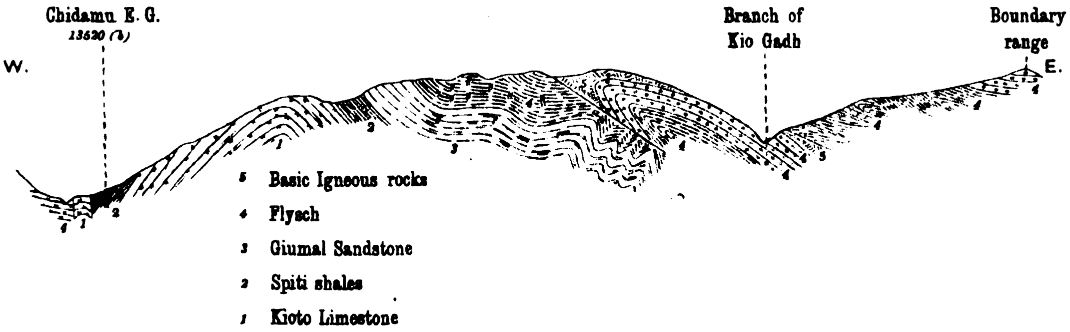


FIG. 2. SECTION THROUGH COUNTRY S. OF THE KIO GADH.

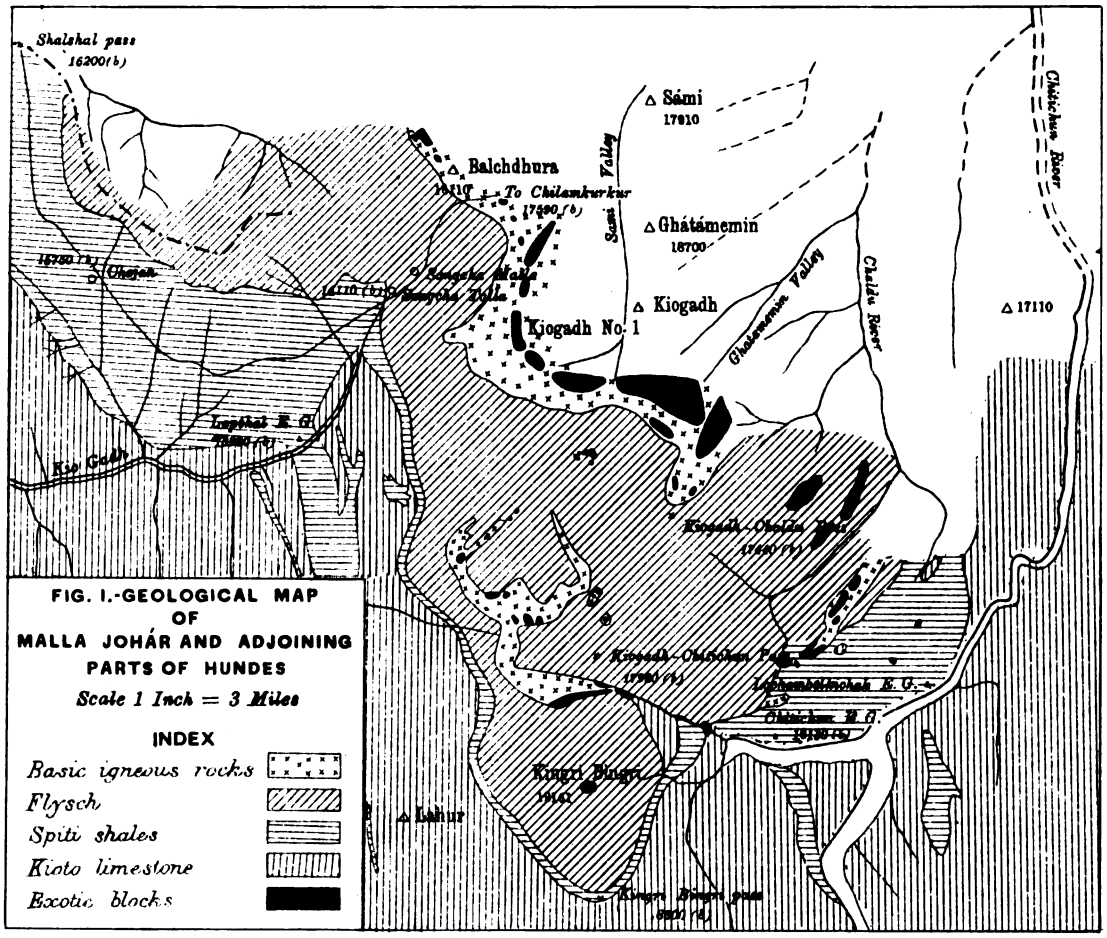


FIG. I.-GEOLOGICAL MAP OF MALLA JOHÁR AND ADJOINING PARTS OF HUNDES

Scale 1 Inch = 3 Miles

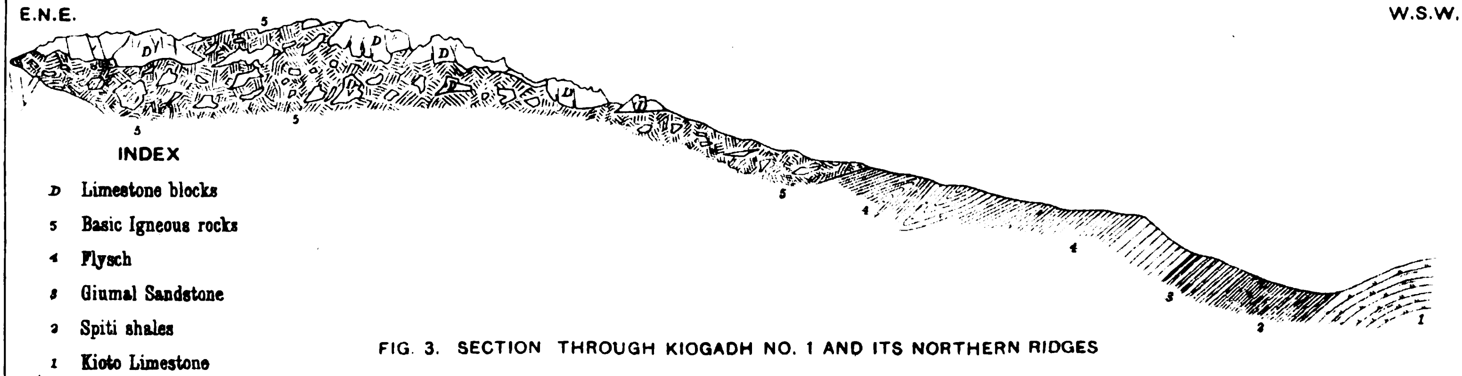


FIG. 3. SECTION THROUGH KIOGADH NO. 1 AND ITS NORTHERN RIDGES

GEOLOGICAL MAP OF THE PROVINCES OF TSANG AND Ü IN TIBET

(*after H.H. Hayden: Mem., Geological Survey of India, XXXVI, Pt. 2*)

PLATE XLVII

Helio T. B. O. Dehra Dún.

GEOLOGICAL MAP OF KASHMIR

(after R. Lydekker: Mem., Geological Survey of India, XXII.)

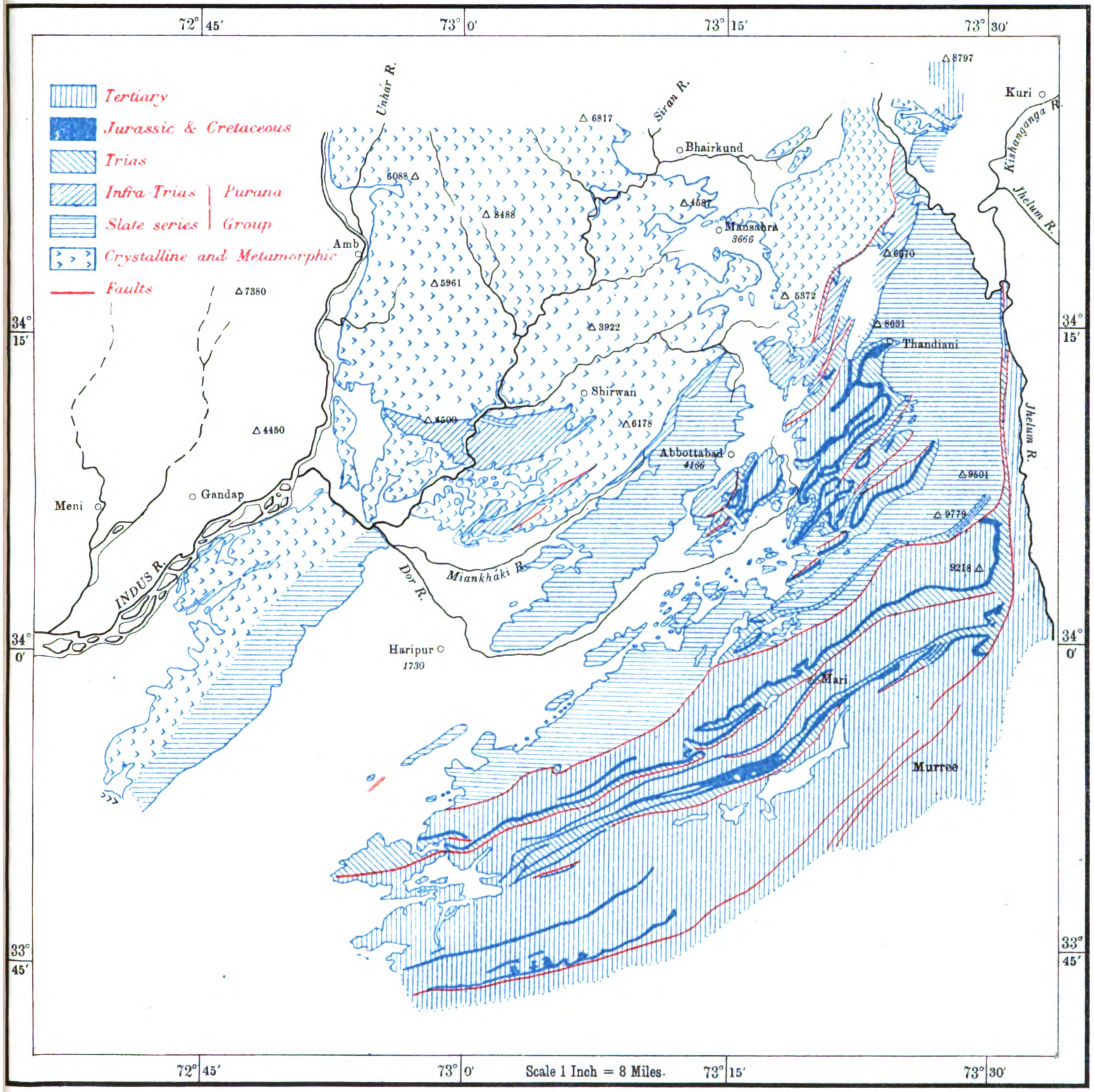
PLATE XLVIII

Helio T. B. O. Dehra Dún.

GEOLOGICAL MAP OF HAZÁRA

(after C. S. Middlemiss: Mem., Geological Survey of India, XXVI).

PLATE XLIX



Helio T.B.O. Dehra Dun.