PHYSIOGRAPHIC RESULTS OF A RECENT SURVEY IN LITTLE TIBET

H. de Terra

Peabody Museum, Yale University

[With separate map, Pl. I, facing p. 40.]

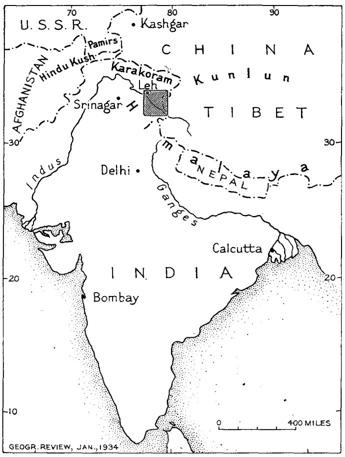


FIG. 1—The position of the region investigated: compare Plate I.

What makes eastern Ladak, or Little Tibet, so promising a field for exploration? Certainly it is not so much the spectacular scenery—for this lacks the great peaks, such as K_2 (28,250 feet), and the great snows and glaciers of the high Karakoram—as it is the central position occupied within the mountain belt between peninsular India and Central Asia. Geologically it is a key region lying between the southward-folded Himalaya and the northward-folded K'un-lun. Physiographically it forms a link between the high Karakoram in the northwest and the Tibetan ranges and plateau to the east. The youthfulness of the crustal disturbances and the recent enormous uplift of the ranges make the region a most promising field for an investigation into mountain building. These were some of the considerations that led to the organization of the Yale North India Expedition of 1932, an undertaking sponsored by Yale University. My choice of this particular mountain sector was determined also by the fact that I had become generally acquainted with Kashmir and Ladak in 1927–1928.

Epeirogenic upheavals in the southern Himalayas had been observed by Dainelli in 1913,[1] who estimated an 8000-foot rise of the Pir Panjal Range since the second half of the Pleistocene. My own observations confirm his view and lead me to conclude that young uplifts must have affected the entire Himalayan and Karakoram ranges. It was my plan to relate the study of land forms to that of their associated animal life, particularly the fresh-water life, and to investigate the limnological character of the great Himalayan rivers and of the high-altitude lakes with respect to their feasibility as a biological test for a geological process. Although the complexity of the problem calls for more data than this expedition was able to

[1] As described by F. De Filippi: The Italian Expedition to the Himalaya, Karakoram and Eastern Turkestan (1913–1914), London, 1932, p. 507.

gather in one year, it can be said that Mr. G. E. Hutchinson's[2] biological work has yielded important hints as to the ecologic status and relative age of the different limnologic facies in Kashmir and Ladak. A northern group, seemingly older than and different from the Kashmir and Indian fresh-water forms, was found to extend over the high upland along the Kashmir-Tibet boundary, with its remnants of an older relief and drainage pattern. Not only do relics of an older mammalian fauna (*Equus hemionus*, *Gazella picticaudata*, *Pantholops hodgsoni*) populate the last remnants of a gently rolling relief, but the fresh-water life as well seems to be related to Central Asian rather than to Indian forms. In order to contribute to our existing knowledge of the older Himalayan fauna, Mr. G. E. Lewis, of the Peabody Museum of Natural History of Yale University, was intrusted with collecting in the Tertiaries of the Himalayan foothills. His finds of fragmentary new anthropoid apes and of other mammals and my own discoveries in the Kashmir Valley of prehistoric implements with fragments of extinct species of elephants, fishes, and plants give new evidence as to the diversity and richness of life in the ancestral Himalayas. Such evidence points to surroundings that promoted rather than checked the evolution of a highly developed fauna. Prehistoric man, whose stone implements I traced from the Himalayan foothills across Kashmir to Baltistan, must have been benefited by the existence of large fresh-water lakes in the then less dissected mountains. The change in geographic conditions brought about by never-ending crustal movements even seems reflected in some of the older Indian mythologies, which probably hold the most ancient human traditions. And life older than man must have been most fatefully affected by the growth of the land, which ultimately evolved from a low mountainous and hilly country to the most elevated region on earth. To reveal the evidences for such an evolution as they are presented by the physiography is the general aim of this article.

The Topographic Survey

Attention must first be called to the map, Plate I, which presents the first detailed topographic work in the eastern portion of the area covered by the Survey of India Sheet No. 52 (1 : 1,000,000). Credit for this part of the program of the Yale North India Expedition[3] is due to the interest and encouragement of the American Geographical Society, and I wish especially to acknowledge the contribution of one of its

[2] G. E. Hutchinson: Limnological Studies at High Altitudes in Ladak, *Nature*, Vol. 132, 1933, p. 136.

[3] On the organization and personnel of the expedition see H. de Terra: Preliminary Report on the Yale North India Expedition, *Science*, Vol. 77 (N.S.), 1933, pp. 497–500; for a description of the route see *idem:* A Scientific Exploration of the Eastern Karakoram and Zanskar-Himalaya, *Himalayan Journ.*, Vol. 5, 1933, pp. 33–45. Leh was the starting point and terminus of the summer trip into western Tibet and the Karakoram Ranges (June to October, 1932).

FIG. 2—The north-to-south trending portion of the Chang-chenmo Range from the valley plain of Koh-lungpa. Note the salt lakes and glacier hidden beneath débris.

FIG. 3—Panorama of the northwestern portion of Lake Panggong from 3 miles south of Man at 17,100 feet.

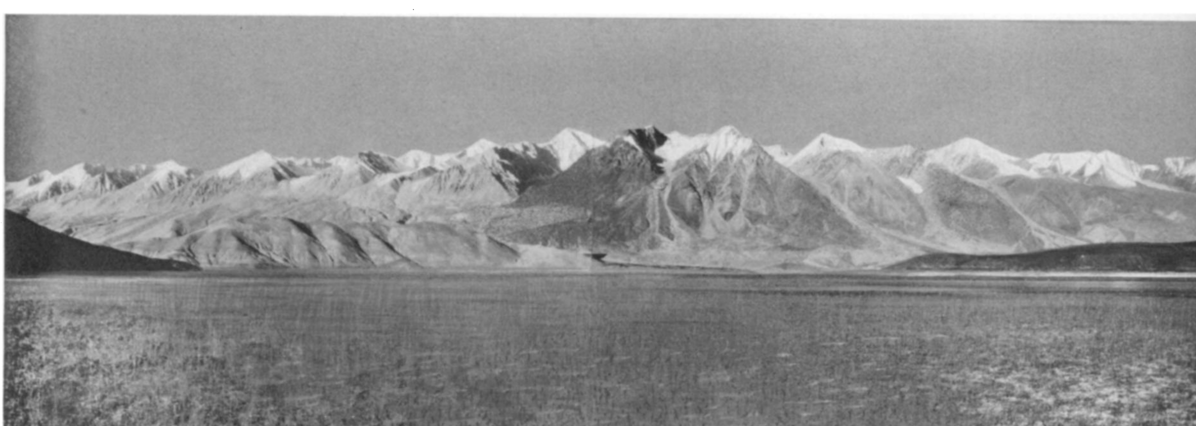


FIG. 4—The Panggong Range as seen from the northern shore of Lake Panggong opposite Man.

FIG. 2 (cont'd)—The summits are over 21,000 feet high. The view is from above camp Togarma at 17,226 feet (note the tents in the foreground).

FIG. 3 (cont'd)—The snowy crests of the Chang-chenmo Range constitute the background.

FIG. 5—Northern slope of the Zanskar Range south of Mahe, Ladak. Typical of the dissected mature relief of Rupshu at 16,600 to 17,000 feet.

members, whose generous support made it possible to engage a topographer and thus to provide a more substantial background for our other investigations.

The first topographic work in our region had been done as early as 1858, when Montgomerie of the Survey of India carried his triangulation series[4] into the upper Indus Valley. Godwin-Austen and Hayward (between 1861 and 1868) and various travelers, including Wellby (1896), Deasy (1898), Rawling (1903), and Hedin (1906), had provided data enough for the Survey of India to publish a set of maps on the scale of one inch to four miles. These maps showed the main triangulation points, but their broken contours indicated that the topography had been only roughly sketched. In many instances, as in the upper Chang-chenmo and Lingzi-tang, the hypothetical interpolations had led to gross errors; even the outline of Lake Panggong, which is much frequented by sportsmen, was inaccurate. Hedin's surveys in 1902 and 1907 were restricted to route maps and landscape sketching, the results of which were published in his great work,[5] of which the Survey of India made little use when newer editions of Tibetan and Kashmirian maps were issued. A boundary commission in 1924 and Trinkler's route map of 1927 did not add much information. Most welcome, therefore, was the willingness with which the Surveyor-General of India pledged his support for a detailed survey of part of this important borderland between Kashmir and Tibet. Through his courtesy a full surveying equipment was lent to us, and through his negotiations I was able to secure a most experienced mountain surveyor, the Khan Sahib Afraz Gul Khan, well known from his earlier surveys with Sir Aurel Stein, with Lieutenant Colonel Kenneth Mason, and with Mr. and Mrs. P. C. Visser. He plotted his plane-table sections for the proposed route before the actual fieldwork began, using the trigonometrical pamphlets of the Survey of India No. 52 F, G, H, J, K, L, N. He began his first sheet on the top of Digar La (Ladak Range) on July 22 and completed the last plane-table traverse on September 12, after having surveyed more than 4600 square miles. The slow progress of the expedition permitted the mapping to be carried out on the scale of two miles to one inch, with 100-foot contours. The total map comprises nine sheets and a special map of the morainic landscape at Man on Lake Panggong.

The main surveying instruments used were plane table, clinometer, rectangular magnetic compass, hypsometer, and, for leveling purposes, a Zeiss level with leveling staff. The plane-table fixings were based on the older trigonometric stations and points. Some new ones were

[4] J. T. Walker: Account of the Operations of the Great Trigonometrical Survey of India, Vol. 2, Dehra Dun, 1879; reference on pp. 16–17.

[5] Sven Hedin: Southern Tibet; text, 9 vols.; atlas, 4 vols.; Stockholm, 1916–1922.

computed, and in some places where the old stations were invisible a time survey was used, which was later checked by intersection with trigonometric points. There was an average control of 1.5 stations per day.

The weather was, with rare exceptions, perfect; the morning and late afternoon light never failed to bring out a relief of the most plastic expression. Evenings and days of rest and halt were used for inking in and determining heights, of which there were sometimes more than 500 on one sheet. The energy and tireless effort that the Khan Sahib put into this work deserve the greatest commendation, particularly when one realizes that most of his fieldwork was done at elevations of 16,000 to 19,000 feet.

Information concerning local names was gathered from local guides, who were engaged by the day or by the week. The original transcription of these Tibetan names was later corrected with the kind assistance of the Reverend J. Gergan of the Moravian Mission at Leh. The old maps were most incorrect in this respect, so a good transcription was consequently desirable. With the help of Mr. Hutchinson and of such books as A. H. Francke's "A History of Western Tibet" and Jaeschke's "Tibetan Grammar" a final check of the names was made.

My own geological fieldwork provided the regular survey with determinations of height by hypsometer and aneroid. The survey was equally valuable to the biologist, whose ecological and limnological studies required reliable data on heights of rivers, shore lines, terraces, etc. That the mapping resulted in a clearer conception of both geological and geomorphological features will become evident in the following discussion.

Structure of the Eastern Karakoram

From the high 18,000-foot passes of the Ladak Range the snowy ranges of the Zanskar-Himalayas to the southward and those of the southern and main Karakoram to the northward appear like giant waves following one another in perfect alignment (Fig. 6). The snowy crests of these ranges coincide generally with narrow belts of granite or gneissic rocks, the only exception to this rule being the range south of the Indus River, where the fossiliferous strata of the last great Himalayan sea (Lower Eocene) are folded to form peaks of 20,000 feet and more (Fig. 8). There also lies the thickest accumulation of ancient rock waste of the ancestral Karakoram—the Indus flysch, a 10,000-foot pile of detrital clastic sediments. This belt of softer but intensely folded strata is traversed by the largest drainage feature of the region—the Indus Valley, the natural boundary between the Himalayas and Karakoram. For 30 miles between

Spitok and Karu the river follows the plane of overlap—itself proof of a late Cretaceous uplift—between the basal beds of the flysch and the granite-gneiss of the Ladak Range. Newly discovered occurrences of similar flysch strata on the northern slope of the Ladak Range, near Chushul, and their overthrust here and along the Chang-chenmo by older rocks give proof of additional uplift in post-Eocene time, most likely between the Middle Oligocene and Lower Miocene.[6] The younger strata—the later Tertiary determined on lithologic grounds and the Pleistocene determined on fossil evidence—have been hardly disturbed in this region. Their formation took place subsequently to the folding processes.

These foldings determined the structural axes of the geologic formations that ultimately gave rise to the outer alignment of the various ranges. The northwest-southeast axis is dominant and continuous with that of the northwestern portion of the high Karakoram. But in the eastern part, from about longitude 78° 15′ E. on, the geologic backbone of this great mountain structure displays a most remarkable change in direction. For, whereas the granite axis of the range south of Chang-chenmo runs parallel to the course of this Tibetan river, it abruptly bends into a southeast-northwest direction where the Shayok breaks through its watershed (Fig. 6). The granite zone exposed on the Sassir La may be followed due southeast to where Hedin[7] and De Filippi[8] observed it again in the transverse gorge of the Shayok and thence to the headwaters of the Koh-lungpa. Its farther extension can now definitely be followed (Fig. 6) into Tibet, where it reappears in the form of monadnocks along the eightieth meridian south of Shum. The metamorphic schists and the younger calcareous formations north of the Chang-chenmo follow the example of the granite. South of Dapsang and around the Karakoram Pass they strike northwest-southeast, but as soon as they enter our region they are seen to take an eastward trend and to continue north of the lake basins of Panggong and Pangur. Particularly noteworthy is the similar behavior of the granite belt in the Ladak Range, which bends eastward near Nyoma on the Indus. Doubtless it continues in this direction as far as longitude 78° 50′ E., for Hedin[9] noted granite and diorite around the Tsaka La, extending north of the Indus as far as Gartok. Lydekker's map[10] indicated this bend of the granite belt, but, as it did not make a distinction between granite and metamorphic rocks, it gave the impression that the granite continues across the

---

[6] Previously (Geologische Forschungen im westlichen K'un-Lun und Karakorum-Himalaya (Wissenschaftliche Ergebnisse der Dr. Trinklerschen Zentralasien-Expedition, Vol. 2), Berlin, 1932) I was able to give evidence for only the older of the two foldings.

[7] *Op. cit.*, Vol. 5, Map A.

[8] *Op. cit.*, p. 288.

[9] *Op. cit.*, Vol. 4, pp. 198 ff.

[10] R. Lydekker: The Geology of the Kashmir and Chamba Territories, and the British District of Khagan, *Memoirs Geol. Survey of India*, Vol. 22, 1883.

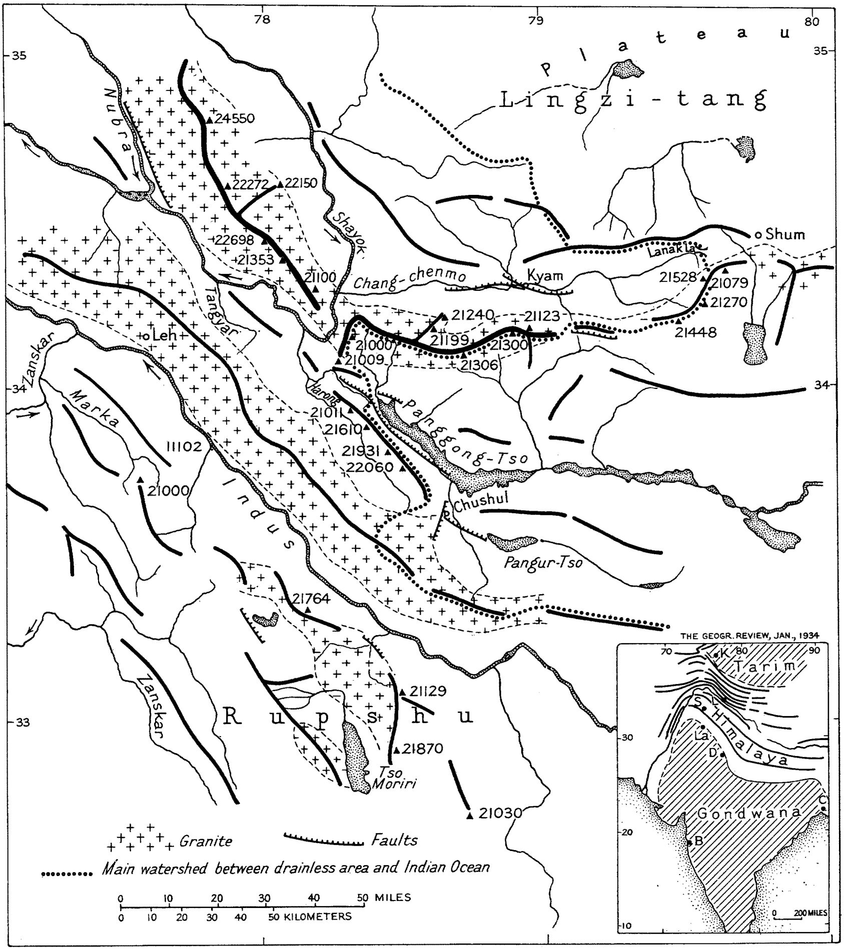


FIG. 6—Orographic sketch map of the eastern Karakoram and Zanskar-Himalaya in Ladak (Little Tibet). Scale 1 : 2,500,000.

Indus into Rupshu. In reality, the northeastern side of the transverse valley of the Indus is made up of crystalline schists similar to those that surround the Zanskar granite at Tso Moriri. The Indus therefore does not break entirely through the Ladak granite but only cuts into its southern slope.

The strict obedience of the crystalline axis to the change in strike of the flanking sedimentaries suggests that the granites, like those of the Alps, have been forced through orogenic pressure into the structural pattern that is the result of the major foldings. We must assume that this pressure came from the north, notwithstanding the fact that the general dip of the superficial folds and thrusts north of Panggong is distinctly southward. The bend in strike becomes apparent once more in the arrangement of the younger faults. In fact, Panggong affords a striking example of a graben. The fault defining the northern shore bends from northwest-southeast to west-east and farther on probably determines the Tibetan outline of the lake to its end. Major fault lines, indicated by thermal action, are exposed near Chushul and in the Chang-chenmo at Kyam, where they locally cut the west-east folds. These dislocations are so well defined that they may be followed through the entire Karakoram system. They determine the courses of the main drainage lines, such as those of the lower and upper Shayok and Nubra valleys.

None of these features described from the Karakoram can be reported with reasonable certainty from the Himalayan side of our area. Although the granites appear also in ill defined ranges and faulting is locally in evidence, no sign of a similar bend in geologic strike can be noticed. Very likely the Zanskar-Himalaya, as Burrard[11] indicated, continue southeastward until they join the great Himalayan range.

From the foregoing it becomes evident that this region was land ever since the Eocene estuary of the late Tethys sea ceased to exist. Of post-Eocene and pre-Pleistocene strata there are scattered remnants left on the undissected higher land forms. We meet them, for example, as an ancient basin around the Lanak La (Fig. 7). Their lithologic character and stratigraphic position suggest that they are denudation products of the pre-Pleistocene relief. They are probably late Miocene to Pliocene in age, certain facies appearing to be the equivalents of the Siwaliks of the fringing foothills of the Himalayas and similar ossiferous deposits in Hundes, southwestern Tibet. They must represent a period of river erosion to which the intricate structure of the Himalaya and Karakoram was subjected. To this period and to such agencies are ascribed the outlines of the present relief.

Orographic Trends: The Zanskar Range

Since Godwin-Austen's brilliant attempt[12] to demonstrate the eastern extension of the Karakoram system into Tibet no further progress has been made in this direction—a fact that Burrard[13] has mentioned with resignation. The new topographic work of our expedition, supported by former observations made during the Trinkler expedition, now permits us to recognize here four distinct orographic groups (Fig. 6). In addition, there is one range south of the Indus that, although known to earlier investigators (Cunningham and Godwin-Austen), deserves brief attention.

[11] S. G. Burrard and H. H. Hayden: A Sketch of the Geography and Geology of the Himalaya Mountains and Tibet, 4 parts, Calcutta, 1907–1908; reference in Part 2, p. 91.

[12] Presidential Address to the Geographical Section of the British Association, *Proc. Royal Geogr. Soc.*, Vol. 5 (N.S.), 1883, pp. 610–625.

[13] Burrard and Hayden, *op. cit.*, Part 2, p. 111.

This range, called Zaskar[14] by Burrard, is characterized by a line of higher peaks, all between 21,000 and 22,000 feet, which rise above a broad, often plateau-like but commonly dissected mountain range, the average elevation of which is about 19,500 feet. It is the northernmost range within the Himalayan system. In the region under discussion this Zanskar Range runs from southeast of Tso

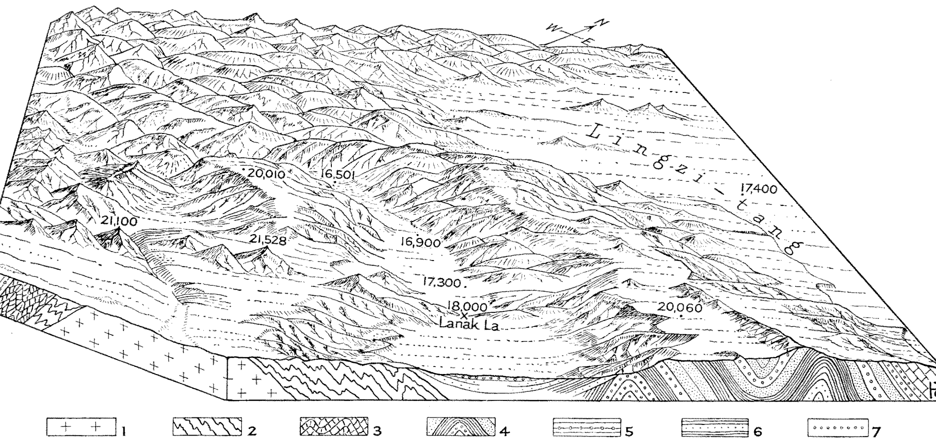


FIG. 7—Block diagram of the region around the upper Chang-chenmo Valley showing dissection of west Tibetan plateau. Numbers have reference: 1, Paleozoic Karakoram granite; 2, Paleozoic metamorphics; 3, Mesozoic limestones; 4, Carboniferous sandstones, shales, etc.; 5, arkosic red beds (Cretaceous-Eocene); 6, young Tertiary basin sediments. The vertical scale is exaggerated about five times.

Moriri across the lower Puga Valley to northeast of Lake Kar across the Taglang La (17,479 feet), south of Gya. From here on it strikes northwest to the junction of the Zanskar and Marka rivers. Apart from being characterized by higher snow peaks and locally extensive glaciation, it coincides to a large extent with the granite-gneiss belt of Rupshu. The latter feature helps to trace it farther northwestward, where I observed the same granite-gneiss near Kargil in Baltistan (about 76° E., 34° 35′ N.) at the bend of the Shingo River, whence it strikes southeastward, forming the prominent ridge south of the Wakka River. Its crystalline axis finally extends east of the Deosai, and it seems not unlikely that the Zanskar Range terminates only at the junction of the Gilgit and Indus rivers. Toward the southeast it may be definitely traced as far as geologic information permits, i.e. west of Hanle and possibly to the headwaters of the Sutlej. Minor changes in strike excepted, its orographic and geologic trend is northwest-southeast. Three shorter ranges, also locally glaciated but of lesser height (20,500 feet), accompany the Zanskar Range. The largest of these begins west of Tso Moriri in a belt of gneiss, which wedges out within a short distance, as Hayden[15] indicated.

[14] I prefer either Zanskar or Zangskar as used by Strachey in 1853, a transcription more in accordance with the Tibetan meaning "white copper."

[15] Burrard and Hayden, *op. cit.*, Part 4, geological map.

The Ladak Range

North of the Indus begins the Karakoram system, which is bordered to the north by the western K'un-lun and to the northwest by the Pamirs and Hindu-Kush. Its southernmost member is the Ladak Range named after Ladak ("Little Tibet or Maryul, the low country"). From the Shayok-Indus junction in the northwest it enters our region near Leh as a snowy range flanking the Indus Valley with an average height of 19,000 feet. It does not carry any prominent peaks and, seen from the south, presents a rather even skyline, like the edge of a plateau (Fig. 10). Southwest of Chushul it forms the watershed between the drainless lake basin of Panggong and the Indus. All maps show it to cross the Indus west of longitude 79° E., but its granite axis bends sharply west-east north of the very point where the Indus changes its course from northwest-southeast to southwest-northeast. The extension of the Ladak granite axis must therefore be looked for in the ridge east of Tsaka La, which extends into the Tibetan province of Rudok, south of the depression of Pangur and Nyak Tso.

The Panggong Range

Having crossed the Ladak Range on the Kaksang La, one descends toward Chushul and sees another snowy range rise very abruptly from the wide, lake-strewn valley plains. Seen from the shore of Lake Panggong, which reflects its jagged peaks, its deeply incised glacier troughs, and its steeply sloping spurs, it is most impressive (Fig. 4). It is no wonder Strachey[16] spoke of it as being higher than the other ranges, an impression warranted not so much by the number of high peaks as by the fact that this range is bordered by the deepest depressions, the Panggong and Harong valleys. For a distance of 35 miles between Tangtse and Chushul it contains no less than ten peaks exceeding 21,000 feet and one of 22,060 feet elevation, with double that number of glaciers on the northern side. The peaks are pinnacles reminiscent of the Aiguilles Rouges and Mont Blanc massifs in Switzerland, both of which have a gneissic composition. I shall call this the Panggong Range, after the native name of the whole lake district. Until the nomenclature of the Karakoram has been definitely settled, it seems advisable to designate the mountain ranges within this area by local names.[17] The Panggong Range, with diminished elevation, may be followed toward the northwest between Tangtse and Durbuk (Fig. 26), where it is cut by the river,

[16] H. Strachey: Physical Geography of Western Tibet, *Journ. Royal Geogr. Soc.*, Vol. 23, 1853, pp. 1–69; reference on p. 25.

[17] On this important question see "Mountain Names on the Indian Border," *Geogr. Journ.*, Vol. 74, 1929, pp. 274–277; Sir Sidney Burrard: The Mountains of the Karakoram: A Defence of the Existing Nomenclature, *ibid.*, pp. 277–284; "Himalayan Range Names," *ibid.*, Vol. 75, 1930, p. 35; Kenneth Mason: Nomenclature in the Karakoram, *ibid.*, Vol. 76, 1930, pp. 143–158.

and thence north of the Tangyar valley up to the Shayok-Tangyar junction. Its course is probably continued in the belt of gneisses and metamorphic schists found in the Shayok-Nubra watershed and south of the great Siachen glacier. Like the Ladak Range, its eastern extension is determined by a bend at Chushul, whence a west-east strike continues north of the Pangur Tso. Here it loses its grand alpine relief, as if it merged into the rolling highlands of Tibet.

The Chang-Chenmo Range

From the shore of Lake Panggong and still better from a commanding point at the glacier snout south of Man one sees on the horizon due northwest, north, and northeast a high snowy range, extending from Muglib to the Marsimik La and then eastward (Fig. 3). From this distance it appears to be almost unbroken, very jagged to the northwest, but with few peaks surmounting snow-clad ridges to the north and northeast. In its western portion as far as the Marsimik La I sought for the extension of the main or Muztagh-Karakoram,[18] which here coincides with the northernmost granite belt characterized by a number of high peaks and the longest glaciers. The recent surveys supported the opinion of Trinkler and myself in that they showed the existence of 15 peaks of more than 21,000 feet between longitudes 78° 15′ and 79° 40′ E. Of these the main culminations occur west of the Koh-lungpa (Koh massif), south of Pamzal (Pamzal massif), south of Kyam (Chang-chenmo massif), and south of Lanak La (Tartary massif). None of these reaches a height of more than 21,528 feet, and they rise from ridges partly snow clad, the average elevation of which may be about 20,000 feet. From Figure 6 it can be deduced that this range follows the granite belt of Marsimik La and that it finally joins with the granitic massif south of Shum. It should be called the Chang-chenmo Range, after both the name of the native district and that with which the people from Pobrang designate also the mountains on both flanks of the valley. Stolitzka and the early trigonometrical surveys applied the same name particularly to the southern side. We thus have a tradition to follow. Unlike the other orographic units in our region, this range displays a west-east trend throughout its length, with the exception of its westernmost part, where the Shayok has cut a short north-south-trending portion out of a formerly broader range (Fig. 6). Here we meet once more with this peculiar flexure affecting orographic and geologic axes alike—a trend which Godwin-Austen's map also represented. Its significance, however, must have escaped his notice, for he then bends his Mustakh Range southeastward, where only younger and softer rock formations and no alignment of higher peaks appear.

[18] H. de Terra, Geologische Forschungen, p. 4.

FIG. 8—Looking towards the Indus Valley and Zanskar-Himalaya from two miles north of Leh. Note terminal-moraine wall of last glaciation in foreground, low granite ridges in center and flysch strata in background, whence projects a series of spurs whose leveled tops indicate the old valley floor of the Indus.

FIG. 9—View from Lanak La to the plateau remnant (16,600 feet) north of Khyagar Tso. In the background is the Zanskar Range with its faceted spurs.

FIG. 10—The Indus Valley at Karu with the Ladak Range in the background (the dark spot at the right is the oasis of Karu 10,953 feet) and the Chimre Valley with flat-topped divide projecting from the snowycrest.

FIG. 11—The Ladak Range as seen from Shakya La (18,020 feet) toward Digar. High snow peaks of the Nubra-Shayok watershed are seen in the right background.

FIG. 12—Wide glacial trough valley of the upper Rimdi River, Chang-chenmo Range.

FIG. 13—A 21,249-foot peak south of Pamzal in Chang-chenmo Range. Note the terraces on the slope and the width of the Chang-chenmo Valley. Compare Figure 23.

FIG. 14—View from the foot of Lanak La toward the Tartary massif (21,528 feet). Note granite monadnock above plateau remnant (20,000 feet).

THE KARAKORAM-LINGZI-TANG RANGE

North of the Chang-chenmo Range we find another range distinctive from the morphologic point of view. It presents rounded or elongated ridges and divides practically without higher summits. Its position between the Lingzi-tang and the Chang-chenmo gives it a definite orographic character, which appears to become more prominent toward the west and northwest. Here, in a triangular group between the Kugrang, lower Chang-chenmo, and Shayok rivers, it displays a graceful curve of glaciated ridges following the great flexure of the entire mountain system. It is Godwin-Austen's Karakoram-Lingzi-tang Range,[19] which coincides with the first northern belt of young Paleozoic rocks and Mesozoic limestones.

THE REËNTRANT OF THE EASTERN KARAKORAM

Thus the four main ranges that constitute the eastern Karakoram bend from northwest-southeast to west-east approximately along the meridian of 78° 35′ E. Not only the Karakoram but the main Himalayan chain outside our area is subject to this reëntrant, which has only one counterpart within the same mountain belt—the great virgation of the Pamir, Hindu Kush, and Himalaya to which Suess[20] first called attention. Although different in character, the one being a grouping of divergent fold axes, the other a bending or simple reëntrant of a bundle of mountain folds, they both seem to reflect the peculiar northern outline of the old Gondwana mass to the south. Burrard[21] had already pointed to a parallelism between the Himalayan chain and the borders of the Indian tableland, but since then it has become possible[22] to reconstruct more of this northern outline of Gondwana.

[19] H. H. Godwin-Austen: The Mountain Systems of the Himalaya and Neighbouring Ranges of India, *Proc. Royal Geogr. Soc.*, Vol. 6 (N.S.), 1884, pp. 83–87 and map and sections.

[20] Eduard Suess: The Face of the Earth, Vol. 1, Oxford, 1904, p. 448; see also E. Trinkler: Das Problem der grossen Scharung in den Pamir-Gebieten, *Mitt. Geogr. Gesell. in München*, Vol. 16, 1923, pp. 1–12.

[21] Burrard and Hayden, *op. cit.*, Part 2, Chart 9.

[22] D. N. Wadia: The Syntaxis of the North-West Himalaya: Its Rocks, Tectonics, and Orogeny, *Records Geol. Survey of India*, Vol. 65, 1931, pp. 189–220.

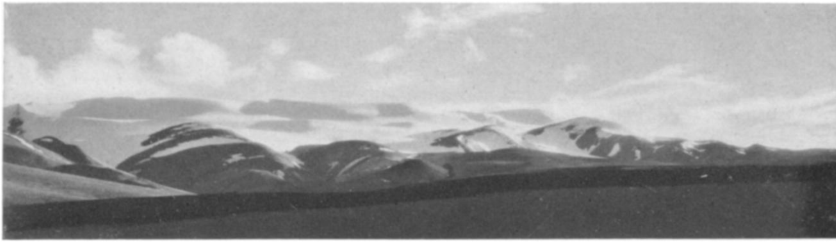


FIG. 15—A plateau glacier east of Lanak La, western Tibet.

The isostatic geoid of India as constructed by Major E. A. Glennie[23] gives two contours south of the Himalayas, the southern one, on a line Lahore-Delhi-Fyzābād, corresponding roughly with the hypothetical border line of Gondwana as it can be reconstructed from the distribution of ancient rocks. It shows the bend from a northwest-southeast to a west-east direction along the seventy-eighth meridian. It is the nick in the border of Gondwana about 500 miles south of the eastern Karakoram that is reflected in the reëntrant of the Karakoram ranges—an explanation fully supported by the general conformity of geologic strike and orographic trend.

This relationship permits us to draw further conclusions. First, it lends support to Von Schlagintweit's[24] old idea of the extension of the high Karakoram into the Panggong and Chang-chenmo districts, for the reëntrant is in itself proof of an eastern continuation. Secondly, it becomes evident that this mountain system cannot be an extension of Hedin's Trans-Himalaya, for the main Karakoram axis should consequently be expected to continue south of Arport Tso into central Tibet. Also, the Kailas Range of Burrard cannot possibly be linked with the Shayok-Nubra watershed and with our Panggong Range. The latter most likely continues south of the Shaman Tso, thus avoiding Mount Kailas, which, as Hedin has shown, is geologically different from, and younger than, the gneiss belt of Panggong-Nubra. Accordingly, the Ladak Range should eventually merge with the "Nain Singh Range."[25] The newly observed trend of the Karakoram system points to a more northerly extension than hitherto supposed, namely north of the great Tibetan lake district. Most likely its natural extension is the Tangla Range, which stands out as a dominant orographic feature of central Tibet. Geologically the Trans-Himalaya seems more related to the Himalayas proper than to the Karakoram, with which it has hardly anything in common. This becomes especially apparent with regard to the different ages of the granites in

[23] Gravity Anomalies and the Structure of the Earth's Crust, *Survey of India Professional Paper No. 27*, Dehra Dun, 1932, Chart VII. See a discussion of Glennie's hypothesis in "A Challenge to Isostasy" by Chester R. Longwell, *Geogr. Rev.*, Vol. 23, 1933, pp. 682–683.

[24] H. von Schlagintweit-Sakünlünski: Reisen in Indien und Hochasien, Vol. 3, Jena, 1872, map.

[25] H. Trotter: Account of the Pundit's Journey in Great Tibet from Leh in Ladákh to Lhása, and of His Return to India Viâ Assam, *Proc. Royal Geogr. Soc.*, Vol. 21, 1876–1877, pp. 325–350.

both ranges, which are, if Hennig's interpretation be correct,[26] of Tertiary age around Kailas, whereas my studies show that they are of Paleozoic origin in the Karakoram. *For these reasons I hold the Trans-Himalaya to be a separate orographic unit*, which on further exploration may prove to be cis-Himalayan rather than trans-Himalayan in character.

Salient Morphologic Features: The High Mountains

Most characteristic of the area under consideration are those highly elevated plateau remnants in the northeastern sector that are surmounted by still higher land forms. Two lower relief units—dissected mountains and deeper depressions such as main drainage lines and lake basins—reshaped by Pleistocene glaciation and subsequent erosion complete the picture.

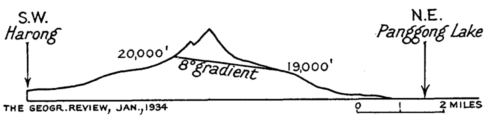


Fig. 16—Canting of snow line on Panggong Range.

In the first category are included the highest portions of the more important ranges discussed above—the Zanskar, Ladak, Panggong, Chang-chenmo, and Karakoram-Lingzi-tang ranges. Notwithstanding their great height, which is expressed by a mean summit level of 21,685 feet, they appear, with few local exceptions, not as sharp-wedged peaks but as serried summits that rise from broad shoulder-like mountains or ridges (Fig. 13). This feature differentiates them from the known Himalayan or high-Karakoram peaks. Where glaciation or proximity to deep erosion channels have not exerted their influence, the summits tend to form triangular or knob-like heights that show distinctly concave slopes. The high divides, mostly snow covered, from which these summits rise have precipitous flanks at 18,500 to 19,000 feet in the southern districts and at 19,500 to 20,000 feet in the plateau region around Lanak La. Apart from height, this relief unit is characterized by recent glaciation.

On its northeastern side the Panggong Range carries no less than 26 glaciers in a distance of 24 miles. Most of them are preferably described as "glacierets," for they do not exceed three miles in length (Fig. 17A). They begin in well defined cirques at an almost uniform level of about 19,000 feet. Bergschrunds are always in evidence, and the névé fields, in spite of their steepness, merge into the glaciers. Owing to a sharp break in the longitudinal profile of the high valley bottoms, some of the glacierets change abruptly from valleys into hanging glaciers of the pinnacled type. Toward the glacier snout appear *séracs*, some of which may be 20 feet high, while the snout itself is deeply cleft by crevasses, in which morainic débris accumulates to form esker-like masses. Terminal moraines are absent, for their

[26] Hedin, *op. cit.*, Vol. 5.

débris is quickly washed down the steep slopes, to accumulate in cones 1500 feet high (Fig. 4). Nivation, frost weathering, and solifluction combine to bring about rapid erosion in the summit region, to which must be added the effects of ice scooping and wedging. In spite of their smallness the Panggong glaciers advance to the lowest point (15,800 feet) at which recent glaciers were observed to exist in the area. This relative ice advance is doubtless due in part to the canting

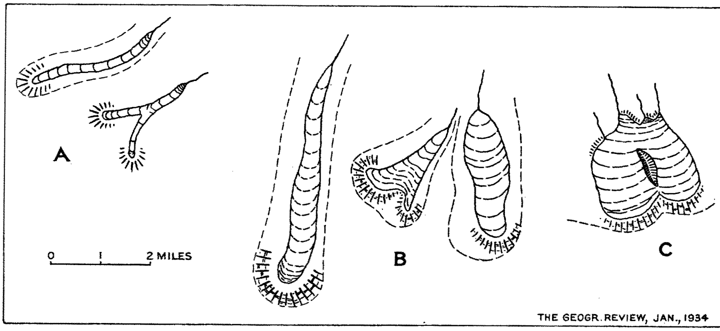


FIG. 17—Types of glaciers in the eastern Karakoram (100-foot contours on the glaciers). A, glacieret of Panggong Range; B, valley glacier of Chang-chenmo Range; C, Tibetan plateau (piedmont) glacier.

of the snow line (Fig. 16), apparently because of the greater precipitation and humidity on the lake side of the range. The northern exposure also promotes the existence of névé in shaded cirques, thereby supporting the advance of the narrow ice tongues. As regards secular or periodical changes, it must be admitted that, in the absence of terminal moraines and regular observations, no positive data are as yet available. A stone pyramid 660 feet below the snout of a glacier near Man (17,400 feet) may indicate a mark set up perhaps by H. von Schlagintweit in 1855[27] to locate the glacier front. Our surveyor was certain that this pyramid had not been erected as a trigonometrical station. It should be noted here that dead ice, so frequent around the glacier snouts of the high Karakoram,[28] does not exist here.

On the northern flank of the Chang-chenmo Range the glaciers are generally larger and longer (Fig. 18). They are valley glaciers of the alpine type, with broad névé fields projecting from peaks or ridges. In only one instance did I observe the "Turkestan glacier type" of Von Klebelsberg,[29] which derives from broken-down, regenerated névé masses at the foot of precipitous rock walls instead of from a regular névé field. Wherever longer glaciers (Fig. 17B) cross a break in the valley floor (i.e. the edge of plateau remnants) a change to hanging types can be noticed. Southern exposure leads to stronger

[27] *Op. cit.*, p. 171.

[28] Kenneth Mason: The Glaciers of the Karakoram and Neighbourhood, *Records Geol. Survey of India*, Vol. 63, 1930, pp. 214–278.

[29] R. von Klebelsberg: Beiträge zur Geologie Westturkestans, Innsbruck, 1922, p. 430.

FIG. 18—Peak, 21,190 feet, and glacier south of Pamzal in Changchenmo Range.

ablation and quicker deposition of débris, as is illustrated in the case of the upper Kohlungpa (Fig. 2).

Wider and flatter in appearance are the valley glaciers that flow from the high massifs (e.g. the Tartary massif and south of Shum) down to the open valley plains of western Tibet (Fig. 15). Locally they unite in the manner of piedmont glaciers to form small ice caps, 200–400 feet thick, with a steep ice front from which spring numerous rivulets (Fig. 17C). Some well defined valley glaciers show four successive terminal moraines, presumably indicating various stages of ice retreat in late Pleistocene or subrecent times. Usually accumulation is more noticeable than erosion, for the ice moves very slowly owing to the slightness of gradient of the valley floor. Such must also have been the case during the Ice Age, which has affected but little the land forms of the plateau region. The preglacial relief still continues to determine the phenomena of recent glaciation (Fig. 7).

Most surprising is the survival of dead ice in valleys bordering the Tibetan plateau. The Mitpal River one-half mile downstream from camp 34 crosses a large cake of unprotected valley névé, 3 feet thick, about 1500 feet long, and 600 feet wide (Fig. 19). The altitude is 15,900 feet (snow line at 20,000 feet), and the mass consists of coarse névé of granular texture and with well defined layers of dust separating strata one-eighth inch thick. Fans and streamers of talus on the sides of the valley indicate the repeated fall of avalanches. The névé must therefore have originated from the localized accumulation of snow to a depth sufficient to survive the following summers. We may assume that to this large mass were added the falls of winter, which, although melted away, protected the underlying older névé to some degree, especially as the latter acted as a local refrigerator. With night temperatures hardly ever rising above the freezing point, snowfalls beginning as early as August, and a soil frost-bound from October to May, such a process seems reasonable enough. Oddly, this same névé field was observed in 1848 by Strachey,[30] whose de-

[30] *Op. cit.*, p. 54.

FIG. 19—Valley névé in the Mitpal Valley at 15,900 feet.

scription made it equally thick but somewhat larger. The fact that a patch of névé could be maintained for 84 years in an open valley seems to argue against climatic oscillations of such magnitude as might otherwise be inferred from the changes of lake levels in the neighborhood.

The high mountains characteristically coincide with the distribution of the resistant rock formations (Fig. 6). In the case of the plateau border (Fig. 7) they appear as monadnocks surmounting the highest plateau level—a clear indication of preglacial planation. Of this the plateau remnants give indisputable evidence.

The Remnants of the Mature Relief

Plateau forms dominate in the northern corner of the area and also farther east of Lanak La, the frontier pass between Ladak and Kashmir. Figure 7 shows the high peaks of the Chang-chenmo Range rising out of remnants of a moderately rolling surface such as also appear, though less uniform, on the northern divide between the Lingzi-tang and the upper Chang-chenmo. From the facts that the plateau level is surmounted by monadnocks (Fig. 14) and that, on the other hand, it is characterized by wide basin-like valleys and fully graded rivers we conclude that this relief is in a state of late maturity. It is not a peneplain,[31] for, like all the other remnants of similar land forms in the Himalayas and Karakoram, this plateau carries residual summits, and it is interrupted by flat, unconsumed ridges and even, glaciated ranges (Fig. 25). However, when we connect the even levels about 20,000 feet with one another, we obtain a smooth reconstructed surface, with only a few snow peaks rising 1000 to 1500 feet above it and the Lingzi-tang as well as the main valleys appearing therein as slight depressions. Such seems to have been the earlier relief of western Tibet developed in the period that followed the last mountain folding. The wide planation that the level remnants imply

[31] Attention had been called to this by W. M. Davis in "Die erklärende Beschreibung der Landformen," Leipzig and Berlin, 1912, p. 271.

cut across complicated geological structures. At a later stage the drainage channels became choked with detritus, and fluvial sand and clays were deposited (Fig. 7). That the climate was rather humid is suggested by the lithologic character of the fluvial deposits and corroborated by the effectiveness of the lateral cutting by the ancient rivers. The valley floors, as terraces at 18,500 feet indicate, lay nearer to the level surface than they do nowadays, so that the maximum differences in height did not exceed 3000 feet. At that time the high intermontane basins of Lingzi-tang and Sumdjiling formed widened valley floors in this low relief, which deepened but little during the Pleistocene glaciation[32] and which must have broadened again under the subsequent aridity of a drainless region.

The region around Lanak La permits us to trace these old land forms toward the Karakoram. Figure 7 shows how the divide between the plateau and the middle course of the Chang-chenmo becomes more deeply dissected the farther we proceed toward the west and southwest. Here the plateau level is replaced by a summit level, the valley slopes steepen, and the valley floors narrow. Locally we find a clear superposition of plateau and terrace level (Fig. 13), and here also we notice a still lower level—between 16,000 and 17,000 feet. The latter, moreover, is not a local feature dependent on the lithology but is part of a widely extended surface form, which we meet again south of the Chang-chenmo Range. One can generally recognize an upper terrace level some 1200 feet above the present valley floors of the upper Mitpal, Koh, and Chagra rivers and just below the upper limit of recognized glacial erosion. This terrace presumably marks the older floor (level I of Fig. 21), which was much more profoundly modified than the plateau valleys because the more dissected preglacial relief lent itself to an intensive valley glaciation. It is noteworthy that many passes, such as Marsimik La (18,394 feet), that lie on the great watershed between the interior drainage basin and the Indus catchment area coincide with a similar high terrace level. The headwaters of the Koh and Mitpal rivers (Fig. 2) flow across very wide valley floors and are perfectly at grade. The Koh-lungpa, in fact, is reminiscent of the upper Chang-chenmo near Lanak La and seems like an outpost of the mature relief south of the main Karakoram range. Here are many other valleys of this kind (Fig. 3, center background), and the same floor level appears north of Lake Panggong (Fig. 21). Below this level lies a more dissected relief, with glacial troughs (Fig. 12) and exhibiting all the phenomena of glacial action.

The Panggong Range displays a most striking uniformity in the

---

[32] There is as yet no evidence in support of the uniform Pleistocene glaciation on the Tibetan plateau that Trinkler (Geographische Forschungen im westlichen Zentralasien und Karakorum-Himalaya (Wissenschaftliche Ergebnisse der Dr. Trinklerschen Zentralasien-Expedition, Vol. 1), Berlin, 1932, pp. 20 and 75) assumed. The ice cover must have been sporadic and quite unlike that of the neighboring ranges.

heights of the cirques, which seems to correspond with either the plateau or the topmost terrace level. The farther extension of such old surfaces becomes more evident in the less glaciated portions of the range, such as near Muglib or towards the Pangur Tso, where

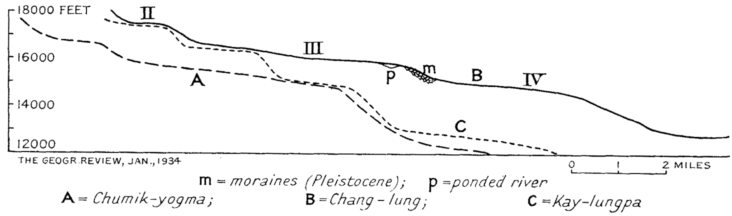


FIG. 20

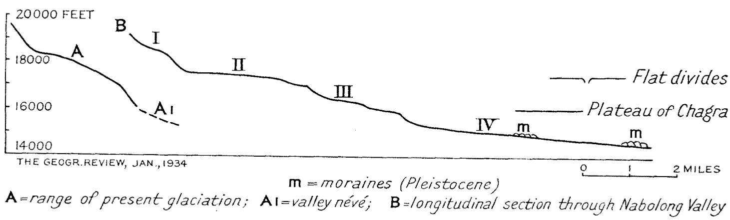


FIG. 21

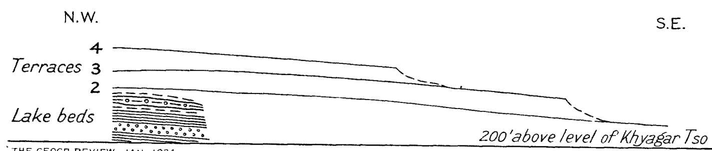


FIG. 22

FIG. 20—Longitudinal sections through present valley floors in the Ladak Range.

FIG. 21—Longitudinal section through the Nabolong Valley near Chagra. Smaller steps indicate halts of glacier retreat while larger ones are slopes between erosion levels.

FIG. 22—Tilting of young Pleistocene lake terraces and lake beds on west shore of Khyagar Tso, Rupshu. Vertical scale exaggerated ten times.

level-topped spurs are seen to project from both flanks of the Panggong Range at similar heights.

The Ladak Range on the south gives excellent examples of a preglacial mature relief. On its northern flank we see around the Kaksang Pass at 17,450 feet a rolling surface with valleys one to two miles in width separated from one another by low divides. Small rivulets locally dammed up or ponded meander through the morainic filling. Farther northwest one observes the same spectacle (Fig. 20)—the headwaters moving sluggishly around sand bars until they break through the terminal-moraine walls and fall at a rate of 1600 feet per mile through boulder-choked gorges down to the junction with a Shayok tributary. The southwestern slope of the same range exhibits a higher spur level at 18,430 feet and a lower one at about 16,700 feet, the former presumably the plateau level, and the other a dissected continuation of either level I or level II. Both old surfaces can be followed over a distance of almost 100 miles along the Indus Valley, where they seem best preserved around the Chang La (Fig. 10). Here they actually give the impression of greatly elevated plateau remnants, and their position above the glacial relief becomes once more apparent. Their former extension across the entire eastern Karakoram is, therefore, reasonably established.

If one takes into account a certain amount of glacial and postglacial erosion, the mean slope of the mature relief is hardly perceptible in this direction for a distance of 90 miles from the present edge of the west Tibetan plateau. The fact that no higher level than 16,700 feet is discernible on the southern flank of the Ladak Range might be explained by the stronger effects of Pleistocene glaciation and denudation along the Indus Valley. If this were the case, we should expect to find the equivalent morphologic units of the mature relief on the opposite side of the Indus, in the Zanskar and adjoining ranges. In reality, none of the remnants of this mature relief within the northern Himalayas ever reach the height of the west Tibetan plateau and its terrace level (I).

The most elevated plateau remnant in Rupshu—also known as "Chang-tang" (great plain)—lies between the Puga River and Lake Khyagar at an elevation of 16,600 feet (Fig. 9). A corresponding remnant occupies the northern slope of the Zanskar Range south of Mahe, at a slightly higher level—an average of 17,000 feet (Fig. 5). Such mature and late-mature forms make patches of rolling surfaces 200 square miles in extent. Their valleys show the effects of glaciation. Along the higher mountains we recognize rows of truncated spurs where the upper valleys have their outlets to the plateaus.[33] The area occupied by the mature relief is enormous, extending far into Tibet and thence south to the central crest of the Himalayas,[34] while toward the northwest we can follow it across Ladak into Baltistan.[35]

The question arises whether all these remnants of a late-mature relief belong to one uniform stage of erosion or whether they represent various phases. The existence of remnants of flat surfaces at two levels in the northern Himalayas, namely Nari Khorsum (15,000 feet) and Deosai (12,500 feet), the latter of which extends clear across the central Himalayas more than 80 miles southward to the Pir Panjal Range in Kashmir, indicates both an earlier and a later cycle of erosion. And such is also the case in the eastern Karakoram.

---

[33] On Pleistocene glaciation in Rupshu and neighboring regions see Giotto Dainelli: Studi sul glaciale (Relazioni Scientifiche della Spedizione Italiana De Filippi, nell'Himàlaia, Caracorùm e Turchestàn Cinese (1913–1914), Ser. 2, Vol. 3), text and atlas, Bologna, 1922.

[34] L. R. Wager: The Rise of the Himalaya, *Nature*, Vol. 132, 1933, p. 28.

[35] Karl Oestreich: Die Täler des nordwestlichen Himalaya, *Petermanns Mitt. Ergänzungsheft No. 155*, 1906.

Intermediate Mountain Groups and Lower Levels of Erosion

Apart from the graded lower slopes of the main ranges, there are mountainous regions where dissection, Pleistocene or recent, has led to a more youthful relief. Such are the Karakoram-Lingzi-tang Range and the regions south of Chushul, north of Lake Panggong, and around Tso Moriri. Here the effects of Pleistocene valley glaciation

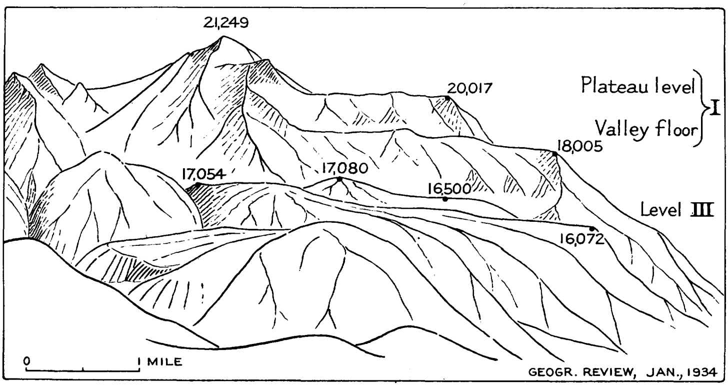


Fig. 23—Terraces on northern slope of Chang-chenmo Range near Pamzal. Altitudes by trigonmetrical determinations. Compare with Figure 13.

become dominant features. Along the lake basins or the larger rivers vigorous postglacial river action has cut V-shaped valleys or gorges on the floors of the wide flat valleys. But where the Indus drainage with its rejuvenating influence has not yet reached the more remote areas, as in the upper Chang-chenmo or Mitpal valleys, the change from a glacial to an arid subarctic climate (post-Pleistocene) has resulted in forms typical of drainless regions—wide, basin-like valleys with heavy accumulations of sediment (Figs. 7 and 25) and smaller basins with salt lakes. As formerly mentioned, these intermontane basins are features inherited from the young Tertiary relief, but their present shape is the result partly of glacial and partly of subrecent erosion.

Two features within this unit deserve special attention—the uniform appearance of the stepped stream profiles and their correlation with isolated occurrences of older surface forms. In the Chang-chenmo Range, for example, one notices on the northern slope (Figs. 13 and 23) at 16,500 feet a distinct terrace that might be taken for the shoulder of the greatest Pleistocene Chang-chenmo glacier. South of the same range, however, a similar level appears (Fig. 20) in all the valleys where younger erosion has not yet altered or destroyed the older land forms. A step in the valley gradient, sometimes of as much as 1000 feet, separates this level III from level II, its concave shape being often obscured by terminal-moraine walls. This feature repeats itself at a lower point where the moraine wall forms spectacular boulder "cascades," such as in the Nabolong Valley near Chagra (Figs. 20 and 21). Here the moraine wall encircles a lake on the upstream side, while downstream it falls abruptly to the next lower valley floor. Elsewhere (upper Chumik-yogma) the moraines have been washed away, and the step becomes visible in bed rock. This interrelation between valley step, terminal moraine, and lake is also a characteristic feature in the Ladak Range, where again a level between 16,000 and 17,000 feet and a lower one between 15,000 and 16,000 feet (IV) are uniformly developed (Fig. 20). As described in a former case (p. 31), the various valley levels may be followed across the intermediate country, where they give rise to even ridge levels or terraces. Not only do they occur in glaciated valleys but such surfaces continue over an entire mountain group. North of Panggong and especially around Chagra they shape the contours, appearing as broad spurs and flat divides (Fig. 24).

The steps in stream profile thus separate levels of former river action. Here they are not the result of successive stages of glaciation, as is the case in the alpine valleys of Europe and America. Their age relationship to the higher surface forms can be determined to a certain degree by interglacial lake deposits or by terminal moraines that cover the valley floors. By comparison with the interglacial strata from the Indus Valley and Panggong described by Dainelli[36] these lake deposits may reasonably be attributed to the last interglacial (Riss-Würm) age. At that time large bodies of fresh water formed all over the region. In the higher valleys these were dammed up, and plant-bearing clays were deposited in them. The flat valley floors must then have been already in existence; in fact, they must date back to an earlier interglacial period when river action was temporarily set free. The fact that a new level of erosion was formed that is distinctly independent of ice action leads to the assumption of an interglacial uplift. The terminal moraines of the last glaciation, lying on top of the lower level IV, point to a second phase of interglacial river action. In some instances it can be shown that this level was not entirely covered by ice. Another short uplift seems to have occurred, which produced the larger steps in the valley gradient.

Traces of similar surfaces of erosion lower than the highest Changtang level are frequently met with in the northern Himalayas. A high terrace at 15,600 feet is to be seen on both flanks of the range that lies south of the Indus between Kalatze and Leh. The Deosai plateau[37] is another level of this kind. In these regions later erosion has destroyed most of the older physiography so that it is almost impossible to assign any of the recognizable levels to definite periods

---

[36] *Op. cit.*

[37] Oestreich, *op. cit.*, pp. 81–89.

FIG. 24

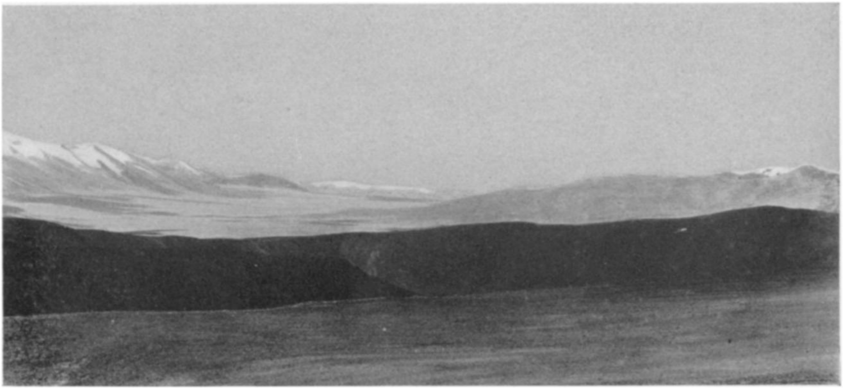


FIG. 25

FIG. 26

FIG. 24—Old relief north of Panggong near Chagra. Panggong Range in background.

FIG. 25—Old drainage channel of Chang-chenmo on the west Tibetan plateau, modified by Pleistocene glaciation and subsequent arid weathering in drainless region. View from ridge near Shum eastward.

FIG. 26—Former valley of the Shayok-Harong River between Tangtse and Durbuk. In background Panggong Range toward Shakya La.

within the Pleistocene or younger Tertiary. Their correlation with the terraces and plateau levels previously mentioned is made uncertain by the fact that the Zanskar Range has suffered from recent tilting through uplift. Proof of such post-Pleistocene movements is to be found in the tilting of lake deposits around Khyagar Tso in Rupshu (Fig. 22). Whatever the relationships of the individual erosion levels between the Himalaya and Karakoram may be, one important fact remains: both mountain ranges show residuals the highest of which antedate the glacial cycle of erosion. They are piedmont levels on a gigantic scale, ranging in altitude between 15,000 and 20,000 feet within the Karakoram and between 12,000 and 16,000 feet in the northwestern Himalaya. Although greatly altered by glaciation, Pleistocene and present, as well as by recent rejuvenation, such older land forms give the present physiography a definite set of inherited characteristics. Before further conclusions can be drawn, brief consideration must be given to the drainage of this older relief.

Main Drainage Channels of the Preglacial Relief

The more important rivers of the Karakoram, such as the Indus, Shayok, Nubra, and Chang-chenmo, follow the strike of the ranges, and their valleys lie on major fault lines. Where they have abandoned their former channels, these will be found to continue in the geological trend. In only one instance does the Shayok cut through the range at its great bend at about 78° 15′ E. The longitudinal drainage of the Karakoram, one of its salient physiographic features, contrasts with the transverse drainage of the southern and central Himalaya. The ancient character of this pattern becomes clearer as we try to eliminate its secondary attributes, such as transverse cutting or capturing by the Indus (Fig. 27).

Beginning with the Lingzi-tang in the north, various headwaters drain the eastern slope of the Karakoram-Lingzi-tang mountains west of Taldat (Fig. 6). They now end in lakes, but, as Trinkler has pointed out,[38] the headwater rivers must have been larger before the present arid cycle. Lingzi-tang and the Sumdjiling plain during part of the Pleistocene were occupied by a single lake and must previously have formed one continuous valley, in which a river flowed from west to east, leaving deposits (p. 32) that permit the tracing of its former course. Although it is obvious that the great width of these elevated plains (10–20 miles) is not exclusively the work of river action, it becomes evident that the former rivers meandered through wide valleys. The fact that Pleistocene and Tertiary lake and fluvial strata occur only along these longitudinal drainage lines indicates that the older drainage of western Tibet was directed from west to

[38] Geographische Forschungen, pp. 18 ff.

east, following the axes of the ranges at a period when the relief was late mature or old.

The Chang-chenmo also flowed across this surface. Its valley width, disproportionate to the shallow flood channel, suggests an old connection with the upper Shayok at a time when the latter had not yet cut through the main Karakoram range. This Shayok-Chang-chenmo stream faithfully followed the reëntrant of the ranges by bending eastward to continue across Lanak La into Tibet. Here its former easterly course can be detected likewise through the occurrence of preglacial fluvial deposits (Figs. 7 and 25). As in the case of the Lingzi-tang, this river left behind wide valley plains, remnants of which, according to Huntington,[39] have survived even the younger dissection in the upper Shayok region. The main tributaries were the Kugrang and Rimdi rivers, which still join the stream at acute angles in the original west to east direction. The former now constitutes the source of the Chang-chenmo.

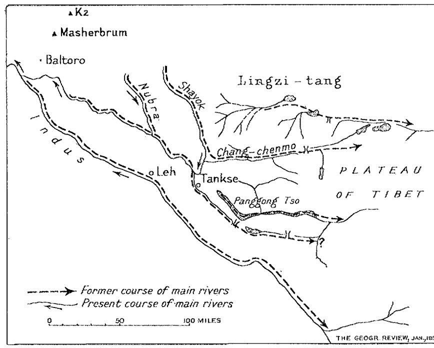


FIG. 27—Preglacial (young Tertiary) drainage pattern of eastern Karakoram.

The third main drainage channel lay in the great depression between the Chang-chenmo and Panggong ranges (Fig. 26). It followed the Nubra, Shayok, Tangtse, and Harong valleys and continued via Chushul-Pangur Tso to the Nyak Tso. The old valley floor is poorly preserved, but it may still be traced along the Harong Valley toward Pangur. Like the Shayok-Chang-chenmo, it drained the high culmination of the Karakoram (Fig. 27), first in a northwest-southeast direction (with the lower Shayok as a tributary), then west-east, parallel to the trend of the ranges. Near Tangtse (Fig. 26) its old course is visible in the large outlet of the Harong Valley, while the gorge toward Muglib is distinctly younger in origin. Possibly this stream pursued its course via the Tsaka La (15,268 feet), although I consider likelier an eastward course through the Pangur depression. That the Panggong basin ever contained a large preglacial stream is doubtful. Being of *graben* structure, it probably had its individual drainage, which followed the eastward slope into Tibet. During the Ice Age it was subject to powerful glaciation,[40] and its outlet during interglacial times led to Tangtse and to the Shayok Valley.

[39] Ellsworth Huntington: The Pulse of Asia, Boston and New York, 1907, pp. 78–79.

[40] Ellsworth Huntington: Pangong: A Glacial Lake in the Tibetan Plateau, *Journ. of Geol.*, Vol. 14, 1906, pp. 599–617.

The Indus belonged in part to a fourth ancient drainage line. Its source may have been in the headwaters region of the Hunza and Gilgit rivers near where the Karakoram bends westward to merge with the Hindu Kush. Oestreich[41] recognized that its old course must have developed on the Himalayan "peneplain-level"—a term that suggests association with our mature relief in Rupshu. The peculiar short deflection of its course that takes place east of Nyoma is not a transverse valley but merely a bend following the reëntrant of the Ladak Range. Its preglacial valley floor must have been at the level of the previously mentioned flat spurs, which now are 3000 to 4000 feet above the valley (Fig. 8).

The preglacial drainage of the Karakoram then consisted of several subsequent rivers, many of which can be traced across an eastward-sloping relief that was interrupted by subsequent valleys developed along the strike of softer strata.[42] These rivers presumably extended across Tibet, the present topography of which provides sufficient evidence of an old west-east drainage under structural control. The headwaters of the Indus may then have followed the depression that is at present occupied by the upper Tsang Po (Brahmaputra), thus forming a giant artery of this subsequent river system that may have drained off through the meridional valleys of eastern Tibet and Sechuan. Even now the catchment area of the Brahmaputra extends across the entire southern Tibetan plateau.[43] Oldham's hypothetical suggestion[44] that the longitudinal valleys of the northern Himalayas antedate the origin of the transverse drainage seems well supported. The initial drainage was directed from northwest to southeast and east and not from north to south, as Oestreich[45] had suggested. Neither antecedence nor superposition[46] can be claimed for any of the rivers under discussion. A definite solution of this problem, however, must be left to a later date when all the geological and biological results of the Yale North India Expedition are available. There is already some reason to believe that the biological studies of Mr. G. E. Hutchinson on the origin of the endemic freshwater fauna in eastern Ladak will lend weighty support to the foregoing conclusions.

From the existence of a widely extended relief of late maturity or old age in our area we may conclude that the Karakoram and the Himalayas could not have been greatly elevated during late Tertiary time. Their present position is due to uplift, and its three successive

---

[41] *Op. cit.*, p. 103.

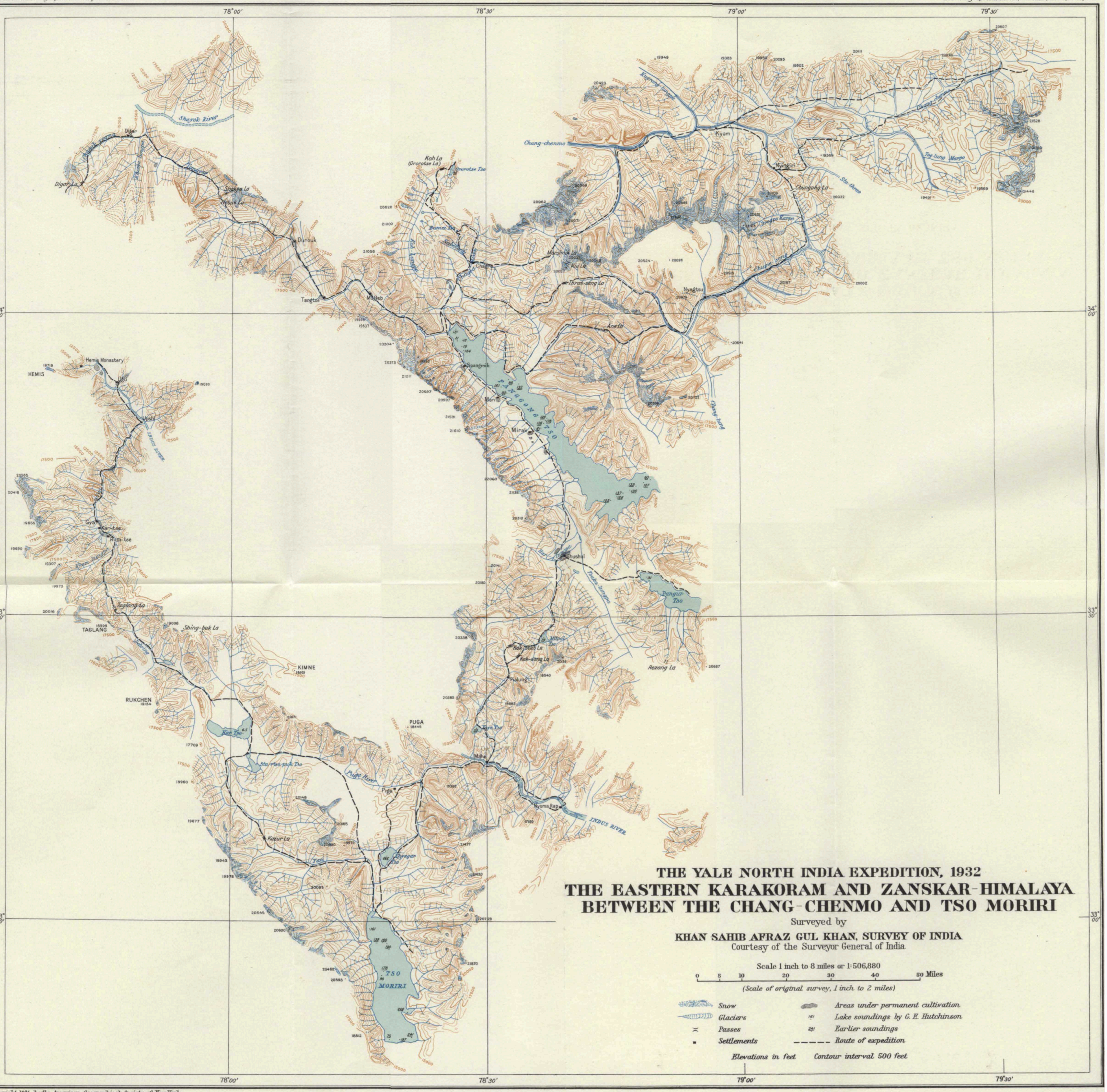
[42] Elsewhere (Geologische Forschungen, p. 118) I have called attention to the eastward pitch of the Karakoram axis of folding and the coincidence of its highest point of elevation with the virgation and topographic culmination around K2.

[43] Burrard and Hayden, *op. cit.*, Part 3, Chart 23.

[44] R. D. Oldham: A Manual of the Geology of India, 2nd edit., Calcutta, 1893, p. 463.

[45] *Op. cit.*, p. 105.

[46] *Ibid.*, p. 106.


THE YALE NORTH INDIA EXPEDITION, 1932
THE EASTERN KARAKORAM AND ZANSKAR-HIMALAYA
BETWEEN THE CHANG-CHENMO AND TSO MORIRI
Surveyed by
KHAN SAHIB AFRAZ GUL KHAN, SURVEY OF INDIA
Courtesy of the Surveyor General of India
Scale 1 inch to 8 miles or 1:506,880
0 5 10 20 30 40 50 Miles
(Scale of original survey, 1 inch to 2 miles)
Snow
Glaciers
Passes
Settlements
Areas under permanent cultivation
Lake soundings by G. E. Hutchinson
Earlier soundings
Route of expedition
Elevations in feet
Contour interval 500 feet
78°00'
78°30'
79°00'
79°30'
34° 00'
33° 30'
33° 00'
Shayok River
Digar La
Shakya La
Durbuk
Tangtse
Koh La
Chang-chenmo
Kyam
Chumesang Lo
Nyagtsu
Ane La
Spangmik
Man
Mirak
PANGONG TSO
Chushal
Pangur Tso
Rezang La
Hemis Monastery
HEMIS
Upshi
INDUS RIVER
Gya
Taglang La
TAGLANG
Shing-buk La
KIMNE
RUKCHEN
PUGA
Puga River
Puga
Mahe
Nyoma Rap
INDUS RIVER
Kazur La
TSO MORIRI

levels below the oldest valley floors of the plateau point, in conjunction with geological facts,[47] to repeated phases of epeirogenic upheaval.

The physiographic evolution of the relief may be summarized thus:

1. Young Tertiary relief of post-mature or old development. Monadnocks and lower ranges surmount an undulating surface (plateau level and old valley floors, level I).
2. Uplift and dissection followed by carving of mature forms at a lower level (II).
3. First Pleistocene ice advance remodels earlier relief.
4. During earlier interglacial period uplift and formation of level III, which was subsequently covered by deposits of later interglacial.
5. Maximum glaciation, most powerful in old drainage channels.
6. Later interglacial (Riss-Würm) and uplift. Establishment of level IV; period of large fresh-water lakes.
7. Last ice advance (Würm period).
8. Recent uplift and post-Pleistocene rejuvenation, particularly effective along the Indus drainage. Also local tilting of terraces and of lake deposits in the northern Himalayas (Rupshu).

The high elevation of the surveyed region and very likely that of the neighboring ranges are, therefore, due to late Tertiary and Pleistocene uplift and not to folding. Whether such uplifts resulted from isostatic adjustment, as Wager[48] seems to think, remains an open question until more detailed gravimetric surveys are available from both the Himalayas and the Karakoram.

[47] The Siwalik boulder conglomerate in the Himalayan foothills indicates a first uplift in the later Pliocene; unconformities between old and younger Pleistocene in Kashmir and the Punjab, a second movement. A third one is proved through unconformities between young Pleistocene and recent strata in Kashmir and Rupshu.

[48] *Op. cit.*