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Part 1.—Annual report for 1873. On the geological structure of the hill ranges between the Indus valley in Ladak and Shah-i-Dula on the frontier of Yarkand territory. On some of the iron ores of Kumaon. On the raw materials for iron-smelting in the Raniganj field. On the habitat in India of the elastic sandstone, or so-called Itacolumyte. Geological notes on part of Northern Hazaribagh.

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Part 3.—Geological observations made on a visit to the Chaderkul, Thian Shan range. On the former extension of glaciers within the Kangra district. On the building and ornamental stones of India. Second note on the materials for iron manufacture in the Raniganj coal-field. Manganese ore in the Wardha coal-field.

Part 4.—The auriferous rocks of the Dhambal hills, Dharwar district. Remarks on certain considerations adduced by Falconer in support of the antiquity of the human race in India. Geological notes made on a visit to the coal recently discovered in the country of the Luni Pathans, south-east corner of Afghanistan. Note on the progress of geological investigation in the Godavari district, Madras Presidency. Notes upon the subsidiary materials for artificial fuel.

VOL. VIII, 1875.

Part 1.—Annual report for 1874. The Altum-Artush considered from a geological point of view. On the evidences of 'ground-ice' in tropical India, during the Talchir period. Trials of Raniganj fire-bricks.

Part 2. (*out of print*).—On the gold-fields of south-east Wynaad, Madras Presidency. Geological notes on the Khareean hills in the Upper Punjab. On water-bearing strata of the Surat district. Sketch of the geology of Scindia's territories.

Part 3.—The Shahpur coal-field, with notice of coal explorations in the Narbada region. Note on coal recently found near Moflong, Khasia Hills.

Part 4.—Note on the geology of Nepal. The Raigarh and Hingir coal-fields.

VOL. IX, 1876.

Part 1 (*out of print*).—Annual report for 1875. On the geology of Sind.

Part 2.—The retirement of Dr. Oldham. On the age of some fossil floras in India. Description of a cranium of Stegodon Ganesa, with notes on the sub-genus and allied forms. Note upon the Sub-Himalayan series in the Jamu (Jummoo) Hills.

Part 3.—On the age of some fossil floras in India. On the geological age of certain groups comprised in the Gondwana series of India, and on the evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. On the relations of the fossiliferous strata at Maleri and Kota, near Sironcha, C. P. On the fossil mammalian faunæ of India and Burma.

Part 4.—On the age of some fossil floras in India. On the osteology of Merycopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Occurrence of Plesiosaurus in India. On the geology of the Pir Panjal and neighbouring districts.

VOL. X, 1877.

Part 1.—Annual report for 1876. Geological notes on the Great Indian Desert between Sind and Rajputana. On the occurrence of the cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. On Estheria in the Gondwana formation. Notices of new and other vertebrata from Indian tertiary and secondary rocks. Description of a new Emydine from the upper tertiaries of the Northern Punjab. Observations on under-ground temperature.

Part 2.—On the rocks of the Lower Godavari. On the 'Atgarh Sandstones' near Cuttack. On fossil floras in India. Notices of new or rare mammals from the Siwaliks. On the Arvali series in North-eastern Rajputana. Borings for coal in India. On the geology of India.

Part 3.—On the tertiary zone and underlying rocks in the North-west Punjab. On fossil floras in India. On the occurrence of erratics in the Potwar. On recent coal explorations in the Darjiling district. Limestones in the neighbourhood of Barakar. On some forms of blowing-machine used by the smiths of Upper Assam. Analyses of Raniganj coals.

Part 4.—On the Geology of the Mahanadi basin and its vicinity. On the diamonds, gold, and lead ores of the Sambalpur district. Note on 'Eryon Comp. Barrovensis,' McCoy, from the Sripermatur group near Madras. On fossil floras in India. The Blaini group and the 'Central Gneiss' in the Simla Himalayas. Remarks on some statements in Mr. Wynne's paper on the tertiaries of the North-west Punjab. Note on the genera Chœromeryx and Rhagatherium.

VOL. XI, 1878.

Part 1.—Annual report for 1877. On the geology of the Upper Godavari basin, between the river Wardha and the Godavari, near the civil station of Sironcha. On the geology of Kashmir, Kishtwar, and Pangi. Notices of Siwalik mammals. The palæontological relations of the Gondwana system. On 'Remarks, &c., by Mr. Theobald upon erratics in the Punjab.'

Part 2.—On the Geology of Sind (second notice). On the origin of the Kumaun lakes. On a trip over the Milam Pass, Kumaun. The mud volcanoes of Ramri and Cheduba. On the mineral resources of Ramri, Cheduba, and the adjacent islands.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1905. [September.

NOTES ON AN ANTHRACOLITHIC FAUNA FROM THE MOUTH OF THE SUBANSIRI GORGE, ASSAM. BY PROF. C. DIENER, PH.D., *of the Vienna University*. (With Plate 8.)

A PAPER published by Mr. J. Malcolm Maclaren in the Records of the Geological Survey of India (Vol. XXXI, Pt. 4) gives a detailed report on the progress of his geological survey in N.-E. Assam. During his survey some fossils, supposed to be of permo-carboniferous age, were obtained by him in boulders in the Subansiri river at Derpai, near the mouth of the Subansiri gorge, North Lakhimpur, Assam. Provisional determinations of the fossils were made by Mr. G. H. Tipper.

The Subansiri valley being an impenetrable jungle occupied by hostile tribes, every fragment of evidence may be considered valuable until this almost unknown area is more thoroughly explored. In view of the interest connected with the problem of a relation between the coal-bearing Gondwanas of Assam and marine beds of Permo-Carboniferous (Anthracolithic) age,[1] Mr. T. H. Holland, Director of the Geological Survey of India, had Mr. Maclaren's fossils sent to me for examination, and asked me to determine them and to prepare a paper for the *Records*. I am greatly obliged to him for entrusting this interesting material to me.

[1] I prefer to use the term "Anthracolithic" under which I understand both the Carboniferous and Permian systems. The reasons for adopting this denomination introduced by W. Waagen, have been detailed in my memoir on the Anthracolithic fossils of Kashmir and Spiti. (*Palæont. Indica*, ser. XV, Himál. Foss., Vol. I, Pt. 2, p. 1).

The fossils were all obtained from a small number of boulders occurring in the bed of the Subansiri. From the differences in the matrix and the state of preservation of fossils the rock-specimens may be divided into two groups:—

(*a*) Matrix arenaceous and only slightly calcareous. The fossils are, as a rule, very badly preserved as weathered casts and subjected to considerable crushing.

(*b*) Matrix extremely hard, blue, argillaceous limestone nodules, recalling the limestone nodules in the Kuling shales of Lilang (Spiti) with *Cyclolobus div. sp.* They are rich in casts of *Chonetes carbonifera* Keyserl. Together with them other fossils occur, but, as a rule, their impressions only are preserved, the fossils themselves having been entirely destroyed. By making plaster-casts of the impressions, I have succeeded in obtaining several examples allowing a satisfactory determination.

The impressions of *Crinoidea* in one of the boulders are of a rather remarkable habit. The stems have been destroyed entirely, but a cast has been left of the interior canal in the shape of a long column, provided with numerous projecting annuli.

A.—FOSSILS FROM THE ARENACEOUS ROCKS.

PRODUCTUS CF. PUSTULOSUS, Phill. Fig. 1.

1836. *Productus pustulosus* Phillips, Geology of Yorkshire, Vol. II, p. 216, Pl. VII, fig. 15.

For a complete list of synonyms I refer to my memoir on the anthracolithic fossils of Kashmir and Spiti, *Palæontologia Indica*, ser. XV, Himál. Foss., Vol. I, Pt. 2, p. 34.

The impression of a dorsal valve, incomplete as it is, agrees closely with the dorsal valves of *Productus pustulosus*, as illustrated by Davidson on Pl. XLI of his monograph of British carboniferous Brachiopoda. The impression is slightly depressed in the middle, this depression corresponding to a small mesial fold in the cast, and is covered with numerous concentric wrinkles. The spaces between the concentric wrinkles are interrupted by numerous coarse pustules, which are often square-shaped and arranged irregularly.

PRODUCTUS DIV. SP. IND. Fig. 2.

There are numerous casts of *Producti* among Mr. Maclaren's fossils. They do not permit of a specific identification, but are valuable as evidences of the Anthracolithic age of the Subansiri fauna.

A large cast of a ventral valve reminds one of the group of *Productus Cora* d'Orb.

Three casts show the interior of dorsal valves, with the median septum, adductor and reniform impressions partly preserved. One of those casts has been illustrated in fig. 2.

SPIRIFER DIV. SP. IND.

The genus *Spirifer* is rather richly represented among the fossils from the mouth of the Subansiri gorge, but all specimens are fragmentary and only internal casts devoid of their shelly substance. Among them some transversely fusiform shapes with widely expanding wings have been noticed, reminding one of *Spirifer alatus* Schloth., or of *Sp. convolutus* Phill.

The cast of a large dorsal valve, measuring at least 115 mm. in width, shows strong and coarse ribs with distinctly triangular sections and sharp edges, and a strongly elevated mesial fold, which has been severely injured. It recalls *Spirifer convolutus* Phill., *Sp. trigonalis* Mart., or *Sp. vespertilio* Sow.

SPIRIFERINA SP. IND

A weathered fragment of a ventral valve reminds one of *Spiriferina Kentuckensis* Shum., or of *Sp. insculpta* Phill. It is greatly extended transversely and provided with rounded plications, which are crossed by numerous lamellæ of growth.

RETICULARIA CF. INÆQUILATERALIS (?) Gemmellaro.

1899. *Reticularia inæquilateralis* Gemmellaro, La fauna dei calcari con Fusulina della valle del F. Sosio, Fasc. IV, Pt. I, p. 336, Tav. XXXV, figs. 2-21. LXVI, fig. 13.

1903. *R. inæquilateralis* Diener, Himálayan Fossils, *Palæontologia Indica*, ser. XV, Vol. I, Pt. 5, p. 23, Pl. I, fig. 6.

A single cast without any trace of its shelly substance is provisionally and with much hesitation referred to *Reticularia inæquilateralis* as comparable on account of its remarkable similarity with this species.

That the cast belongs to the family of *Spiriferidæ* or rather to one of the subgenera of *Spirifer* distinguished by their smooth shells, is pretty certain. The general shape of the two valves, the presence of a large, slightly incurved beak in the ventral valve, the short hinge-line, and the indistinctly marked-off area with its deltoidal fissure are all characters agreeing with the group of *Spirifer lineatus* Mart.

With *Reticularia inæquilateralis* from the permian rocks of Sicily and of the Tibetan region of exotic blocks in the Himálayas, the present species agrees in the remarkably asymmetrical shape of the valves and in the position of the apex, which is shifted to the right, the specimen having been placed into its proper position, front margin upwards.

A mesial sinus is marked by a shallow impression in the ventral valve. Traces of concentric lines of growth have been noticed.

Whether this species of *Reticularia* really bears such close affinities to *R. inæquilateralis*, as I am inclined to suppose, cannot be decided. The fossils from the arenaceous boulders being very often crushed and deformed, its asymmetrical shape may, perhaps, be accidental only and due to pressure in the rocks.

DIELASMA SP. IND. AFF. URALICO Krotow. Fig. 8.

The fairly well preserved cast of a ventral valve reminds one very strongly of the Russian *Dielasma uralicum* Krotow (The Artinskian stage, Mem. Soc. of Naturalists Kasan, Imper. University, Vol. XIII, Pt. 5, 1885, p. 287, and Geologische Forschungen am westlichen Ural-Abhange in der Gebieten von Tscherdyn und Ssolikamssk, Mém. Comité géol. St. Pétersburg, 1888, Vol. VI, p. 429, Pl. I, figs. 33-36). It is strongly curved, bordered by straight lateral margins, which unite in the partly broken-off beak under a very sharp angle, and is provided with a high and regularly vaulted mesial elevation. This median elevation increases in width towards the front, where it terminates in a strongly protracted tongue. It is accompanied on each side by a flatly arched depression, above which the marginal region of the valve is slightly elevated.

The present cast differs from Krotow's type-specimen by larger dimensions, by a narrow mesial fold and by broader lateral wings. But those differences are of small importance only compared to the general agreement of the two shells. This Indian species is certainly most nearly allied to *Dielasma uralicum*, which for its peculiar characters is one of the most remarkable types of the genus.

Its affinity to the Russian form is much stronger than to *Dielasma La Touchei* Diener (Himálayan Fossils, Vol. I, Pt. 5, p. 111, Pl. V, figs. 7-9), from which it is easily distinguished by its different outlines. *Dielasma La Touchei* is nearly triangular, with a slightly emarginated front-line, the angles of which correspond to the greatest transverse diameter, whereas in the present cast the outline is trapezoidal and the greatest breadth occurs in the second fifth of the entire length of the shell.

The measurements of this cast are as follows :—

Length	of the ventral valve	. .	28 mm.
Breadth		. .	22 "
Thickness		. .	15 "

DIELASMA SP. IND. EX AFF. D. BIPLEX, Waagen. Fig. 7.

A cast of a ventral valve recalls in its outlines and in the presence of a median ridge the group of *Dielasma biplex* Waagen from the Productus limestone of the Salt Range (Productus limestone foss., Palæontologia Indica, ser. XIII, Vol. I, p. 349).

It cannot be identified with any of the species illustrated by Waagen on Pl. XXV of his memoir, but probably belongs to a new species. It is of larger size than *D. biplex*, a longitudinal diameter of 45 mm. corresponding to a transverse diameter of 32 mm. The mesial ridge is more strongly developed and originates in the apical region The greatest width occurs nearer to the front. The outline is distinctly pentagonal, with a biplicate front-line. By this character the present cast is easily distinguished from *Dielasma La Touchei* Diener, of which it reminds one in the development of a comparatively high and narrow mesial ridge.

DIELASMA SP. IND.

An imperfect cast suggests *Dielasma ficus* McCoy, but has its dorsal valve provided with a sharp mesial edge, from which the shell slopes obliquely towards the marginal region. The bad state of preservation does not allow of a decision as to whether this character is, indeed, a specific feature or only accidental.

B.—FOSSILS FROM THE HARD, BLUE, ARGILLACEOUS LIMESTONE NODULES.

CHONETES CF. CARBONIFERA Keyserling. Figs. 3-6.

1845. *Chonetes sarcinulata* Verneuil, Géologie de la Russie d'Europe II. Paléontologie, p. 272, Pl. XV, fig. 10.
1846. *Chonetes sarcinulata var. carbonifera* Keyserling, Reise in das Petschoraland, p. 215.

1876. *Chonetes variolata* Trautschold *ex parte*, Die Kalkbrüche von Miatschkows, II, p. 67; I. Pl. VII, figs. *a-c*.

1890. *Chonetes pseudovariolata* Nikitin, Dépôts carbonifères, et puits artésiens de la région de Mcscou, Mém. Comité Gécl. Pétersburg, Vol. V, No. 5, p. 27; Pl. II, figs. 1-3.

1898. *Chonetes pseudovariolata* v. Lóczy, Wissenschaftliche Ergebnisse der Reise des Grafen Béla Széchényi in Ostasien, Bd. III, Abt. IV, p. 73, Taf. III, figs. 8-12.

1902. *Chonetes carbonifera* Tschernyschew. Die obercarbonischer Brachiopoden des Ural and des Timan. Mém. Comité Géol. St. Pétersburg, Vol. XVI, No. 2, pp. 233, 595.

1903 (?) *Chonetes pseudovariolata* Schellwien in Futterer "Durch Asien" III, Bd., Abt. 3, p. 142. Taf. I, figs. 5-8.

This species is represented by numerous and fairly well preserved casts of both valves. They agree most closely with the Chinese specimens figured by L. v. Loczy and identified by him with *Chonetes pseudovariolata* Nikitin. All of them are of small size with rectangular outlines and rounded-off frontal corners.

The ventral valve is moderately inflated and not sinuated, but occasionally provided with a very flat mesial depression only. The dorsal valve is flatly concave.

The majority of my specimens are casts, with fragments of the shelly layer preserved. From plaster casts of impressions, however, a fairly good idea of the ornamentation of the shell may be got. The shell is covered with numerous and thin, thread-like, radiating striæ, which increase in number from the apex to the front by bifurcation. None of my casts is sufficiently well preserved to allow the presence of concentric striæ of growth to be noticed. The casts devoid of their shelly layer are covered with numerous grooves, arranged radially along the intercostal spaces.

The deep median septum of the ventral and the two converging hinge-plates of the dorsal valve are distinctly marked.

There is no species of *Chonetes*, to which the specimens from the Subansiri gorge show an equally close affinity as to *Chonetes carbonifera* Keyserl. The absence of a distinct sinus excludes an identification with *Ch. variolata* d'Orbigny (voyage dans l'Amérique méridionale, Vol. II, Paléont., p. 49, Pl. IV, figs. 10, 11) or with any of the Indian types of the group of *striatæ* hitherto described. With *Ch. granulifera* Owen (Meek in final report of the United States Geological Survey of Nebraska, p. 170, Pl. IV, fig. 9; Pl. VI, fig. 10: Pl. VIII, fig. 7, they cannot be identified, on account of the absence of strongly expanding rings. From *Ch platynota* White (in Wheeler's report on the United States Geographical Survey of the 100th meridian, Vol. IV, p. 121; Pl. IX, fig. 6) they differ by the curvature of their dorsal valve, which is distinctly concave, not flat or even convex, as in *Ch. platynota*. *Ch. dalmanoides* Nikitin is of much larger size. Among all the asinuated forms of *Chonetes striatæ* it is *Ch. carbonifera* with which the specimens from the Subansiri gorge agree most closely.

For this species, which is widely distributed throughout the upper carboniferous rocks of Europe and Asia, Count Keyserling's original name, *Chonetes carbonifera*, must be retained, as has been argued by Th. Tschernyschew.

MYALINA SP. IND. Fig. 11.

The plaster-cast of an impression of a right valve might at a first glance be mistaken for a *Mytilus*, nearly allied to a species from the Kuling shales of Spiti, which has been illustrated on Pl. VIII, fig. 4, of Vol. I, Pt. 5, of the "Himálayan Fossils" (Palæontologia Indica, ser. XV). But a closer examination revealed the presence of a moderately long hinge-line.

The generic separation of *Myalina* and *Mytilus* has been based on the character of the hinge-line by L. de Koninck (Description des animaux foss. du terr. carbon. de la Belgique, 1842, p. 125). It is short and very narrow in *Mytilus*, but elongated, thickened, and provided with longitudinal grooves in *Myalina*. Of all those characters of distinction enumerated by L. de Koninck only the length of the hinge-line is accessible to examination in my specimen, which, I think, must be classed with the genus *Myalina*. An identification with *Modiola* is excluded by the terminal position of the beak.

Myalina lamellosa de Kon. (Faune du calcaire carbonifere de la Belgique, Annales du Musée d'hist nat. de Bruxelles, T. XI, p. 169; Pl. XXIX, fig. 11) shows a distant similarity with the present species, but the gibbosity of the median part of its umbonal region is more distinctly developed.

MONOPTERIA SUBANSIRICA, nov. sp. Fig. 10.

Among Mr. Maclaren's materials there are a cast and an impression of the left valve of a very remarkable representative of the family of *Pteriidæ* Meek, distinguished by its large posterior wing and by the complete absence of an anterior one. *Pteriidæ* of this kind have been described as *Limoptera* by Hall (Palæontology of New-York, Vol. V, Pt. 1; Lamellibranchiata, p. 243), as *Monopteria* by Meek and Worthen (Geological Survey of Illinois, Pt. II, Palæontology, p. 340). The absence of the anterior wing in my specimens induces me to place them in the genus *Monopteria*, although they differ considerably from the prototype of that genus, *Monopteria gibbosa* Meek and Worthen (l. c., p. 340; Pl. XXVII, fig. 11) from the coal-measures of Illinois.

The plaster-cast of the impression allows a sufficiently good reconstruction of the left valve to justify the introduction of a new specific denomination. The differences in sculpture from *Monopteria gibbosa* are, perhaps, remarkable enough to be considered of subgeneric value, but my materials are too scanty for proposing a new subgeneric name.

Shell of equal height and length. Anterior margin truncate, posterior margin broadly rounded, uniting with the straight hinge-line in a right angle. Neutral margin passing into the posterior margin in a regular curve and meeting the anterior one in a blunt angle. From this angle a sharp edge runs to the beak, separating the vertical anterior part from the remainder of the shell. A second edge running from the beak towards the posterior margin is less distinctly defined.

Median portion of the shell elevated and gibbous along the umbonal slopes. Apex shifted to the anterior termination of the hinge-line, which corresponds to the greatest length of the valve.

Surface covered with numerous concentric lines of growth, which become obsolete along the anterior wall.

The measurements of the illustrated plaster-cast are as follows:—

Length } of the shell	19 mm.
Height } of the shell	19 „
Thickness of the left valve	5 „

LOXONEMA SP. IND. Fig. 12.

A turreted shell with deep sutures and S-shaped growth-lines is provisionally referred to this genus, but its fragmentary state renders it unfit for an exact determination. Neither the apical whorls nor the body-whorl have been preserved. The whorls are somewhat angular in the middle, but the growth-lines are not turned backwards along this angular band as along the slit-band of *Pleurotomaria* and its allies. The sutures are remarkably deep and take the shape of spiral furrows or channels as in *Loxonema Walcidiodorense* de Koninck

(Faune du calcaire carbonifère de la Belgique. Annales Musée Royal d'hist. nat. Bruxelles, T. V, 3ème ptie, p. 55; Pl. V, figs. 5, 6).

PLEUROTOMARIA SP. IND. AFF. PUNJABICA Waag. Fig. 13.

An impression of a *Pleurotomaria* reminds one of this species from the Productus limestone of the Salt Range (Salt Range Fossils, Palæont. Indica, ser. XIII, Vol. I, Productus Limestone Foss., p. 115; Pl. XI, figs. 3, 4) or of the examples of *Pleurotomaria* from the permian Productus (Kuling) shales of the Lissar valley, described and figured in "Himálayan Fossils," Vol. I, Pt. 5, p. 100; Pl. V, figs. 1—3).

The spire is a little less noticeably depressed, but consists of an equally small number of whorls. The profile of the body-whorl is not evenly rounded. The ridges bordering the narrow and angular slit-band are distinctly marked. The zone between the slit-band and the suture of the preceding whorl is covered with a small number of delicate spiral striæ. The lower part of the body-whorl is apparently smooth.

BELLEROPHON SP. IND. Fig. 14.

The cast of a small, bilaterally symmetrical shell, coiled in one plane, undoubtedly belongs to a species of *Bellerophon*. The globose shell is narrowly umbilicated on both sides and exhibits no trace of a slit-band.

FENESTELLA SP. IND. Fig. 15.

Traces of Bryozoa have been noticed in the condition of impressions left by the removal and decay of the polyzoarium. The delicate shape of the colony, with rectangular fenestrules and thin dissepiments reminds one of the *Fenestellæ* from the Zewan-beds of Kashmir and from the Fenestella-beds of Spiti, probably allied to *Fenestella plebeia* McCoy.

CONCLUSION.

Notwithstanding the unsatisfactory state of preservation of the materials from the mouth of the Subansiri gorge, their examination leads to the interesting result, that they contain a marine fauna of Anthracolithic age. This result fully confirms Mr. Holland's suggestion with regard to the relation between the Gondwanas and the marine Permo-Carboniferous strata in N.-E. Assam.[1]

[1] General Report, Geol. Surv. Ind. for 1903-04. *Records*, XXXII, p. 153.

The assemblage of forms does not leave a shadow of doubt about the Anthracolithic age of the Subansiri fauna. The large number of *Producti*, among which a species closely allied to a well-known European one (*Prod. pustulosus* Phill.), has been noticed, the presence of the widely distributed *Chonetes carbonifera* Keyserl., of a species of *Dielasma* nearly allied to *D. uralicum* Krotow, of a *Reticularia* of strongly inequilateral shape, are all characters of great stratigraphical importance. Their value is strengthened by the complete absence of any type which has hitherto been met with in strata of the lower Palæozoic systems.

The fauna is too poor in determinable fossils for me to say anything with regard to its correlation with either Carboniferous or Permian strata.

EXPLANATION OF PLATE 8.

Fig. 1. *Productus sp. cf. pustulosus* Phill. Impression of a dorsal valve.
" 2. *Productus sp. ind.* Cast of the interior of a dorsal valve, with adductor and reniform impressions and median septum.
" 3. *Chonetes cf. carbonifera* Keyserling. Dorsal valve with its test partly preserved.
" 4. *Chonetes cf. carbonifera.* Dorsal valve, with its test partly preserved.
" 5. " " " Fragment of a ventral valve, with its test partly preserved.
" 6. *Chonetes cf. carbonifera.* Cast of a ventral valve.
" 7. *Dielasma sp. ind. ex aff. biplex* Waagen. Fragmentary cast; *a* ventral view, *b* lateral view, *c* front view.
" 8. "*Dielasma*" *sp. ind. aff. uralicum* Krotow. Cast of a ventral valve; *a* ventral view, *b* lateral view, *c* front view.
" 9. *Reticularia cf. inæquilateralis* Gemmellaro. Cast; *a* ventral view, *b* dorsal view, *c* lateral view, *d* front view.
" 10. *Monopteria subansirica* Diener. Plaster-cast taken from the impression of a left valve.
" 11. *Myalina sp. ind.* Plaster-cast taken from the impression of a right valve.
" 12. *Loxonema sp. ind.* Cast, with fragments of the test adhering.
" 13. *Pleurotomaria sp. ind. aff. punjabica* Waagen. Plaster-cast taken from an impression.
" 14. *Bellerophon sp. ind.* Cast.
" 15. *Fenestella sp. ind.* Impression of the polyzoarium.

ON THE OCCURRENCE OF *ELEPHAS ANTIQUUS (NAMADICUS)* IN THE GODAVARI ALLUVIUM, WITH REMARKS ON THE SPECIES, ITS DISTRIBUTION AND THE AGE OF THE ASSOCIATED INDIAN DEPOSITS. BY GUY E. PILGRIM, B.SC., *Geological Survey of India.* (With Plates 9—13.)

Locality of the find.

IN February of last year, Mr. H. F. G. Beale, of the Public Works Department, informed the Geological Survey of the discovery of fossil bones at Nandúr Madméshwar (Lat. 20° 1′; Long. 74° 11′), which I was at once deputed to excavate. The locality is on the Godávari river and is about eight miles south of Niphád station on the G. I. P. Railway in the Nasik district of the Bombay Presidency.

The Godavari alluvium.

Great interest must attach to any discovery of fossil bones in the Godávari alluvium, as so few records of such exist. As compared with the alluvial deposits of the Narbada, which flows in a contrary direction, and enters the sea on the west coast of India, our knowledge of those of the Godávari is very limited, both as regards the fossil contents, and even as to the nature, thickness, and superficial extent of the alluvium itself. It may not therefore be out of place to touch upon these points in the course of this paper, as tending to throw some light upon the origin both of the Godávari and of the Narbada deposits.

Previous fossil discoveries in the Godavari alluvium.

That the fossil fauna of the Godávari beds is no less rich than that of other Indian river deposits, is proved by the reports we have in the past of exceptionally large "finds" of bones in them. In but few cases, however, has any trouble been taken to preserve the bones or turn the discovery to scientific account. At some time during the fifties, an elephant skull was found in the Godávari valley. No account of the discovery seems to have been published, and, so far as I know, the only authentic record of it is contained in a manuscript note by the late General Twemlow, the original discoverer. To this Dr. W. T. Blanford had access when he wrote his note on the Godávari gravels.[1] He considers that it is the same as

[1] Mem. Geol. Sur. Ind., VI, p. 232.

that referred to by Dr. Falconer in a paper read before the Geological Society of London,[1] when he mentioned the occurrence of *Elephas namadicus* "in richly fossiliferous fluviatile deposits of Southern India." Major-General Twemlow also seems to have been under the impression that the skull in question was examined and named by Dr. Falconer. We may therefore conclude that this Godávari elephant was identified by Falconer as *Elephas namadicus*, Falc. and Cautl. It was obtained from a place near Paitán, a town on the Upper Godávari, south of Aurangabád, (19° 45′; 75° 30′) on the left bank of the river, and had been washed out of a calcareous conglomerate, of which the bank consisted. The skull was sent to Sir Philip Egerton in England, but I have no knowledge of what eventually became of it. It appears to have been of immense size, as the tusk is said to have been 29 inches in circumference. The tusk of the animal which forms the subject of the present paper measures 25 inches in circumference at the base.

Ossiferous deposits of the Pem Ganga.

General Twemlow also met with very extensive deposits of mammalian bones in the valley of the Pem Ganga at Hingóli (19° 55′; 77° 2′), and is of opinion that these ossiferous gravels are widely spread throughout the valleys of the Godávari and the Pem Ganga.

In 1867 Mr. Fedden, of the Geological Survey of India, examined the whole area through which the Pem Ganga flows. He discovered a few bovine bones, but neither at Híngóli nor elsewhere did he come across any extensive fossil remains.

It appears from his observations that the gravels, though widely scattered, are not continuous, and while in some places they form the bed of the river, in others the Pem Ganga has cut down its channel into the Deccan Trap or even into the older crystalline rocks below.

The alluvial deposits at Nandur Madmeshwar.

Since 1867, however, no collections were made from these interesting deposits until February 1904. I shall therefore proceed to the details relating to this latest fossil find.

In the area which I was able to examine, most of the alluvial deposit lies on the left bank of the Godávari. The alluvial cliffs rise to a height of about 60 feet above the general level of the river-bed and are highest at a point about 1 mile farther up the river than Nandúr Madméshwar. It was here that I found, embedded in the

[1] Q. J. G. S., XXI, p. 381; Falconer Pal. Mem., II, p. 463.

gravels, in the very channel of the river, a magnificent skull of the ordinary Narbada elephant. These cliffs consist of conglomerates, gravels, and clays quite devoid of any stratification and showing evidences of a continuous period of deposition, marked only by such changes in the character of the deposit as might be expected in the history of most rivers. Calcareous concretions (*kankar*) were not observed in any portion of the deposit. The river-bed here was perhaps a quarter of a mile wide, but at the time of my visit most of it was entirely dry and the flow was kept up only in two or three channels. The broadest of these is shown in plate 9, and occupies the extreme right-hand margin of the river-bed. The falls shown are not more than 15 feet high, and are entirely of the Deccan Trap. In fact, all the rock within sight here is of the same nature, as is also the greater portion of the dry bed of the river. To the right of the river just here, there seems to be hardly any trace of alluvium, although lower down, opposite Nandúr Madméshwar, the right bank is alluvial. On the left of the river, however, the alluvial deposit stretches away some distance, but has been deeply carved out into innumerable small gullies showing to what an extent the forces of denudation have been acting. It would seem as if this alluvial deposit were confined to the immediate neighbourhood of the Godávari or of its main tributaries, one of which, the Kadva, I followed from the railway. At various places near its banks, the same network of deep channels had been cut out of the soft alluvial gravels, the existence of which I have noted on the Godávari. The smaller tributaries, however, had cut down into the Deccan Trap, and in many cases their sides consisted only of trap and soil arising from disintegration of trap. One is therefore led to the conclusion that the alluvium, though distributed over a wide area and accumulated locally to a considerable thickness, does not persist equally, and, except in the immediate neighbourhood of the depositing streams, is either superficial or altogether absent. It seems highly probable, however, that the alluvium of the Godávari valley as a whole, even if it be only superficial, is sufficient to merit a recognition on the geological map as distinct as that which has been accorded to the more northern rivers.

Extent of the Godavari alluvium.

Situation and excavation of the Elephant remains.

Immediately at the foot of the alluvial cliff above mentioned, the river flowed in three small adjacent channels, in one of which were the fossil remains. These channels were separated from one another by a hard calcareous, gravelly conglomerate, which, next to the bones, had become cemented into a refractory concrete material inseparable from the bone. The skull was almost entirely covered by water about three feet deep. On account of the alteration in the general level of the water being but slight for a considerable distance, it proved difficult to lower it at the required place, while the porous nature of the rock prevented the dams from being very effective. I supplemented the dams, however, by keeping a large gang of coolies continually baling, and in this way I was able to dry the spot sufficiently to extract all the fossil bones embedded there.

Throughout the operations I was much indebted to Mr. A. Hill, C.I.E., Executive Engineer at Nasik, for the assistance and implements which he kindly placed at my disposal.

The position of the animal, as found, was facing up stream. The cranium was resting on the vertical portion of its occiput, while the inferior part must have been subjected to the erosive action of the river for several years. Under these circumstances its imperfections are not surprising. A portion of a tusk lay detached a few feet in front of the cranium. Closely cemented to the cranium was the distal end of the femur, the head of the bone having evidently been jammed by some projecting part of the skull. About 4 feet behind the cranium, the pelvic bones were found. Through the kindness of Mr. H. M. Phipson, the Honorary Secretary of the Bombay Natural History Society, the proximal end of the femur and another portion of a tusk have been placed in our possession. Both of these had previously been obtained from the same spot by Mr. Beale and sent by him to Bombay. The whole of the remains are now deposited in the Geological Museum at Calcutta. Their reconstruction and present position in the Museum galleries will be dealt with later. That all of these belonged to a single individual no reasonable doubt can be entertained.

Other fossils from Nandur Madmeshwar.

In the gravels near the same spot was found a portion of the lower jaw of a *Hippopotamus*, containing the incisor and canine teeth. This specimen is unfortunately missing,[1] but there is little doubt that it belonged to the subgenus ***Tetraprotodon*** and may be assigned to the species *H.* ***palæindicus***, Falc. et Cautl. A single tooth has been

[1] It was stolen during the night from my collection of specimens at Nandúr Madméshwar, presumably by a villager, and subsequent enquiries failed to elicit any information with regard to it.

identified as that of *Equus namadicus*, Falc. et Cautl. Crocodile teeth were also found, and several shells of Mollusca which are identica with those that exist in the area at the present day.

Dimensions of the present individual.

The cranium and bones, which I am describing, and which represent the species *Elephas antiquus* (*namadicus*), Falc. et Cautl., belonged to an individual of remarkable size. It cannot have stood much less than 16 feet at the shoulder. The cranium, as found, is larger than any hitherto recorded. Individual bones have, however, been found both in India and in Europe, the original owners of which must have attained an equal or even a greater stature. The validity of the name *Elephas antiquus*, as applied to the Narbada elephant, will be referred to later. It will be more convenient to describe first the portions of the animal which the present find has put into our possession.

Description of the cranium.

The cranium.—The cranium either on one or both sides possesses all the essential features of the portion above the maxillaries and the foramen magnum. The occiput on the right side is complete, with the exception of a small region lying between the posterior depression and the vertical boss. On the left side this region is retained, but on the other hand the whole of the occiput external to the left vertical boss is broken away, together with portions of the parietal and frontal and the upper part of the temporal. The foramen magnum and the occipital condyles are missing. The frontal region and the nasals are perfect. The incisives are only partially preserved, the missing portions being indicated in the plate. It will, however, be observed that sufficient of them has been left bordering the nasal fossa, as well as in the distal region, to determine their shape and dimensions. The portions of the temporal fossa below the level of the external auditory meatus are broken away; on the left side the auditory opening cannot be observed, but on the right its position is distinctly indicated. The base of the zygomatic process of the temporal is preserved on the right side, and on both sides the orbit with the supra-orbital and post-orbital processes are well shown. The cranium, like all the bones, was surrounded by a very hard, unyielding calcareous conglomerate, in removing which the bones have lost some substance.

Other existing crania of *E. antiquus (namadicus)*.

The accompanying plates exhibit all the more important characters of the present cranium, and the most casual inspection of it can leave no doubt as to its identity with the crania from the Narbada beds, figured by Falconer in the *Antiqua Fauna Sivalensis,* Plates 12A, 12B, figs. 1-3, and Plate 24A, figs. 4, 4*a*, as *Elephas namadicus*. These are the two most complete crania which have been known up to now, and are preserved in the British Museum. One of them has small tusks and probably belonged to an adult female. The tusk sheaths are broken off almost immediately in front of the nasal foramen. The other, that of a young male, has large tusks, and shows also the characteristic divergence of the incisive alveoli. Five other crania exist in the Geological Museum at Calcutta. These are all exceedingly imperfect. Two of them, however, show the supra-orbital ridge, which, until Pohlig's extensive discoveries of *E. melitensis*, Falc., in the Grotto di Pontale von Carini in Sicily,[1] had been considered peculiar to the Indian species, if indeed there were not still some Palæontologists left, who favoured Professor Leith Adam's surmise that this peculiar frontal projection was a deformity or a distortion produced by compression after death. The present skull is that of a fully grown male.

It seems that the supra-orbital ridge grew forward with age, so that in young skulls there is a considerable interval between its margin and the extreme tip of the nasal process; in the large female skull in the British Museum this interval is sensibly diminished, while in this latest specimen, which represents the largest and presumably the most aged type with which we are acquainted, the supra-orbital ridge almost overhangs the nasal fossa, and the interval is reduced to its smallest dimensions.

Craniological material of the European varieties of *E. antiquus*.

The craniological material of *Elephas antiquus* (stem. sp.), though fairly extensive, is very imperfect. A comprehensive account of it is given by Pohlig[2] in his masterly monograph on *E. antiquus*.

The two most complete fragments are preserved, the one in Heidelberg which has been figured by Pohlig,[3] and the other in Florence photographed by Weithofer.[4] Nothing is present in these beyond the intermaxillaries and the basal portion of the cranium including the maxillæ and the basioccipitals.

The other varieties of *Elephas antiquus* are included under the

[1] Abh. d. k. Bayer. Akad., XVIII, p. 75.
[2] Act. Acad. C. L. C. G. Nat. Cur. LVII, 1892, p. 337, &c.
[3] id. Taf. B. figs. 5, 5*a*, p. 276.
[4] Beitr. z. Pal. Ost. Ung. Bd. VIII., 1891, Taf. II, fig. 2 & Taf. III, fig. 1.

various pygmy types found in Sicily, Malta, Crete and Cyprus, and described by their authors under the names *E. melitensis* Falc.,[1] *E. Falconeri* Busk,[2] *E. mnaidriensis* Leith Adams,[3] and *E. cypriotes* Bate.[4]

Comparison between the teeth of the races of *E. antiquus*.

Considering only the teeth and mandible of *E. antiquus* and of *E. namadicus*, Leith Adams[5] remarked that they seemed to him to be indistinguishable. This opinion of Leith Adams has been endorsed by many subsequent writers, among whom I need only mention Naumann, Weithofer, Pohlig and Lydekker.

There are three varieties of molars observable in *Elephas antiquus* :—

1. The broad-crowned variety with closely packed, faintly crenulated ridges with no definite angulations or central expansions. This is the usual type of molar found in *E. namadicus*.

2. The narrow-crowned variety with a central expansion of the enamel discs, annulation, and well-marked crenulation in the ridges.

3. A thick-plated variety presenting intermediate characters. This type is represented by the *Elephas priscus* of Goldfuss, and it often closely approaches the lozenge-shaped disc of *E. africanus*.

These same three varieties of molar are present in the dwarf Maltese fossil Elephants.

Comparison between the crania of the races of *E. antiquus*.

For a long time the similarity of the dentition of the pygmy Elephants to that of *E. antiquus* has caused many Palæontologists to class them as mere varieties of the latter, although no complete crania of either existed. It would seem to have been assumed by Lydekker and others that the crania, when found, would be of a different type to the Indian form and would possess no supraorbital ridge. So far is this from being the case, however, that all the skulls of the dwarf forms which Pohlig[6] has figured from the Grotto di Pontale von Carini in Sicily bear a striking resemblance to *Elephas namadicus*, and leave us no excuse for

[1] Parthenon 1862, p. 780, & Falconer Pal. Mem. II, p. 298.
[2] Trans. Zool. Soc., VI, 1867, p. 251.
[3] Trans. Zool. Soc., IX, 1874, pp. 112, 116.
[4] Proc. R. Soc., LXXI, 1903, p. 498, & Ann. Mag. of Nat. Hist., Vol. XIV, 1904, p. 162.
[5] Leith Adams, Br. Foss. Elephants, p. 67, 56.
[6] Abh. d. k. Bay. Akad. XVIII, p. 75.

separating the two forms specifically. The accompanying text-figure, taken from one of Pohlig's plates, brings out these resemblances in a remarkable degree. There is no doubt that future discoveries will prove that the original *E. antiquus* of Europe possesses the same craniological peculiarities as its Indian variety.

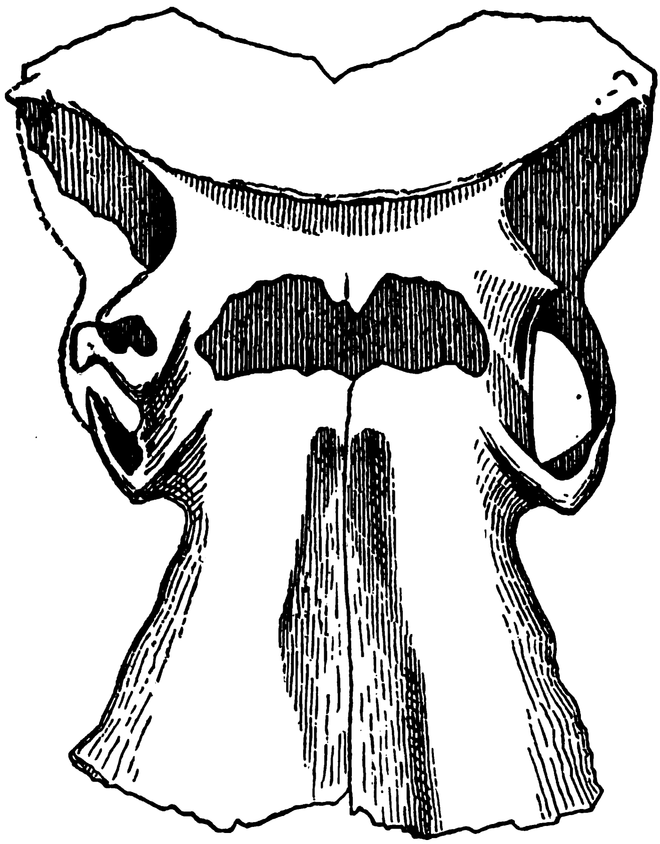


FIG. 1.—*E. antiquus* (*melitensis*) Falc. after Pohlig. [Fossile Elephantten aus Sicilien, Abh. d. k. Bay. Akad. XVIII. Taf. I, fig. 1.].

The crania of *E. antiquus* (stem. sp.), imperfect as they are, show the following points in common with the Indian variety and the pygmy types which serve to distinguish them from all other elephants:—

1. The extreme divergence of the incisive alveoli and the broad shallow depression which occupies their centre.

2. The great distance of the occipital fossa from the foramen magnum and the basal breadth and extreme depth of the fossa.

3. The strong convexity of the occiput in a horizontal direction, which pushes the zygomatic process of the temporal to the front in an unusual degree.

The crania of the Sicilian and of the Narbada elephants exhibit in addition the following points of likeness :—

4. The shortness and breadth of the brow and the widening out of the cranium from below upward.

5. The rhomboidal outline of the temporal fossa and its sharply-cut, acute-angled upper margin.

6. The presence of protuberances on either side of the occipital fossa.

7. The almost rectangular bend by which the occipital passes into the parietal, and the obtusely-angled junction between the parietal and frontal surfaces.

8. The well-marked frontal projection of the crown, which must have given an exceedingly beetling aspect to the living animal.

9. The approximately transversely oval contour of the cranium, when viewed in a direction at right angles to the plane of the occiput. It is much broader than high.

E. africanus also approaches them to some extent in regard to the 1st, 4th, 5th and 9th of the above characters. This is quite in accordance with the view that *E. africanus* is the living representative of an old ancestral form from which it took its origin along with *E. planifrons* Falc. & Cautl, *E. antiquus*, and possibly *E. meridionalis* Nesti. Pohlig[1] remarks that he can hardly recognize any essential differences between the portions of the cranium of *E. antiquus* (stem. sp.) known up to now and the London crania of *E. namadicus*. He calls attention to the differences in the molars and to the greater absolute dimensions of *E. antiquus* (stem. sp.). But as has been explained above, with the exception of the generally higher ridge formula, which prevails in the Indian variety, the molars of the latter are indistinguishable from the broad-crowned type of *E. antiquus*, while the present remains show that the advantages in point of size by no means lay with the European form. Pohlig considers that the suborbital foramen is larger and shorter in *E. namadicus*; that the occipital condyles do not attain such a colossal size; that the maxillary

[1] Act. Acad. C. L. C. G. Nat. Cur., LVII, p. 353.

zygomatic process lies somewhat higher; and that the profile line of the occiput appears to have formed a less obtuse angle with the extension of the sphenoidal portion. The importance of the last of these is, however, discounted by the equally obtuse angle exhibited in the corresponding region of the present cranium. In addition to this and the already mentioned excessive forward growth of the frontal ridge, the present cranium differs from the hitherto described crania of *E. namadicus* in the following particulars:—

The depth of the intermaxillary sinus at its proximal end is rather greater, and would seem to resemble the specimen of *E. antiquus* (*melitensis*) figured by Pohlig.[1]

As far as I can judge, the protuberances on either side of the occipital fossa are by no means so prominent as in the London cranium of *E. namadicus*, nor are the corresponding external depressions so marked.

The occipital fossa is extremely wide below and narrows to an unusual extent above, bearing some resemblance to a cranium from the Narbada described by Falconer.[2] The occiput itself is also exceptionally wide.

Below is a table giving the actual dimensions of the present cranium and of the London cranium figured in the Antiqua Fauna Sivalensis plates 12A, 12B, along with those of the Florence cranium of *E. antiquus* (stem sp.) and of the Palermo cranium of *E. antiquus* (*melitensis*).

Measurements of Crania in inches.

	E. ANTIQUUS (NAMADICUS).		E. antiquus (stem sp.) Florence.	E. antiquus (melitensis) Palermo.
	Calcutta.	London.		
Maximum length from occipital to tip of premaxillaries.	55·0	...	63·0	...
Maximum breadth at widest part of occiput.	42·4	30·0	...	19·7
Vertical height from occipital condyles to vertical plane.	23·7	15·5	...	...
Width of brow between temporal fossae at narrowest part.	27·4	20·0	...	10·2
Width of brow between centre of orbits .	25·0	20·0	...	...

[1] Abh. d. k. Bay. Akad. XVIII, plate III, fig. 2.
[2] Falconer, Pal. Mem. I, p. 115.

	E. ANTIQUUS (NAMADICUS).		E. antiquus (stem sp.) Florence.	E. antiquus (melitensis) Palermo.
	Calcutta.	London.		
Width between postorbital processes .	32·0	25·0	...	...
Vertical distance between plane of vertex and tip of nasal process.	11·5	8·2	...	3·5
Transverse extent of nasal opening .	20·0	15·0	...	...
Vertical height of nasal opening at sides.	5·6	5·3	...	...
Distance from anterior margin of nasal opening to tip of premaxillaries.	34·0	...	...	13·4
Distance from vertex to tip of premaxillaries.	50 +	...	...	...
Maximum width of premaxillaries at the distal end.	36·2	...	37·0	...
Maximum width of premaxillaries at orbital foramen.	19·8	...	18·9	..
Width of intermaxillary fossa at proximal end.	4·1	5·8	...	...
Width of intermaxillary fossa at distal end.	13·2	...	...	...
Vertical diameter of orbit . . .	9·5	6·2	...	...
Transverse diameter of orbit . .	5·0	...	...	...
Depth of occipital fossa from plane of vertical bosses.	12·5	7·5	...	...
Maximum width of occipital fossa below.	8·5	5·6	...	...
Minimum width of occipital fossa above.	3·1	4·8	...	...
From external auditory meatus to frontal margin of fossa at contraction.	15·7	13·3	...	...
From external auditory meatus to anterior margin of orbit.	17·5	14·0	...	...
From posterior plane of occiput to tips of nasals.	27·0	17·4	...	...
From posterior plane of occiput to anterior margin of orbit.	26·5	22·2	...	...
Width between margin of nasal opening and margin of orbit.	5·0	3·7	...	...
Width between margin of nasal opening and adjoining portion of temporal fossa.	4·5	4·1	...	...
Maximum diameter of tusk near origin .	8·0	...	...	...
Maximum circumference of tusk near origin.	25·0	...	...	..

Allied species.

E. antiquus may be classed with the short-crowned elephants, *E. africanus* Blum., *E. planifrons* Falc. et Cautl., and *E. meridionalis* Nesti. Corresponding with this character is the ratio between the length from the vertex to the extremity of the premaxillaries and the breadth of the cranium between the post-orbital processes.

E. africanus.

E. antiquus approaches nearest to *E. africanus* in the flattened shape of the vertex, in the shortness and breadth of brow, in the form of the temporal fossa and of the interjugal space, and in the obtusely angled junction between the frontal and occipital surfaces. It differs in the slope of the occipital surface, in the greater length and shallowness of the intermaxillary median fossa, in the convexity of the occiput, in the higher position of the maxillary zygomatic process, and in the shorter length and greater width of the sub-orbital foramen.

E. planifrons.

E. planifrons differs from *E. antiquus* in the extreme lowness of the vertex and of the occiput, the lower position of the maxillary zygomatic process, the extremely small dimensions of the nasal aperture, the excessive length and narrowness of the sub-orbital foramen, and in the small width and great depth of the intermaxillary fossa; this species stands, however, in a closer relation to *E. africanus*.

E. meridionalis.

E. meridionalis, though possessing the deep and large occipital fossa of *E. antiquus* and an excessive development of the occipital protuberances, differs essentially in the extreme narrowness and great concavity of the frontal region, in the trifling divergence of the incisive sheaths, the deeper intermaxillary fossa, in the narrowness and length of the sub-orbital foramen, and in the long and pointed shape of the temporal fossa.

It seems probable that all these species were developed from a common ancestor in a great Indo-Africo-European province in eocene or oligocene times and the subsequent disconnection, or partial disconnection, of these areas led to the differentiation of the individual types.

Improbability of the descent of *E. indicus* from *E. antiquus*.

Although there is no impossibility in the teeth of *E. indicus* Linn., being derived from those of *E. antiquus* (*namadicus*), the teeth of the former being of a more advanced type in the same direction, yet Mr. Lydekker[1] considers that such a descent would be most improbable, with which opinion I concur. Considering the long, high, narrow cranium of *E. indicus* Linn., with its pointed, concave vertex, it is inconceivable that the one form should have been derived from the other within the short period which we know to have elapsed between the latest remains of *E. antiquus* (*namadicus*) and the present day.

Description of the pelvis.

The pelvis.—The portions of the hip bones which I was fortunate enough to obtain are the following. That part of the pelvis lying between the two acetabula is complete with the exception of the lower part of the pubic symphysis; the bones are, however, fractured in various places. Of the two ossa innominata the left one is the better preserved. In it the acetabulum is perfect and is united to the internal region of the ilium; the external part of the latter is, however, missing. The ischium is broken off between the acetabulum and its own ascending ramus, so that the obturator foramen is incomplete. Of the right os innominatum only portions of the acetabulum and of the ilium are preserved besides the pubis as mentioned above. The central portions of the innominate bones across the pubic symphysis are figured in plate 13, fig. 1, and the upper part of the left ilium with its sacral margin in plate 13, fig. 2. These show the total width of the pelvic opening as well as the superior half of the obturator foramen. The remaining fragments have not been photographed.

The following are the measurements of the pelvis in inches:—

Distance between the inner margins of the two acetabula .	19·0 in.
Antero-posterior diameter of acetabulum	8·5 „
Transverse diameter of acetabulum	8·3 „
Breadth of pelvic opening	21·6 „
Breadth of obturator foramen	5·6 „
Girth of pubis at midshaft	13·0 „

It will be seen that, contrary to what is the case in the Indian elephant, the antero-posterior measurement of the acetabulum is slightly greater than the transverse one. The cotyloid fossa is narrower than in the recent species, and opens directly on to the outer border of the obturator foramen and not on to a flat surface.

[1] Pal. Ind., ser. X, Vol. I, p. 289.

Description of the femur.

The femur.—Both ends of the femur and a great portion of the shaft are in our possession. These are shown in Plate 13, figs. 3 and 4. The distal portion has been photographed end on, and the proximal portion lengthwise. It appears to be very similar both to those assigned to *E. namadicus* already in the Indian Museum, as well as to the one of *E. antiquus* figured by Leith Adams (Br. Foss. Elephants, Pl. XXII, fig. 5). The bone is long and slight. The patellar surface is broad and shallow. The intercondyloid space is not great. The neck is short and appears to be almost erect with very little inclination. The digital pit is shallow. The head seems to be rather oblique. The following are the measurements of the femur, the total length of which is estimated as having been about 69 inches:—

Length of fragment of femur from distal end to fragmented margin	40·0 in.
Length of fragment of femur from proximal end to fragmented margin	19·0 „
From distal end to narrowest portion . .	35·0 „
Maximum circumference of distal extremity around the tuberosities	34·0 „
Maximum diameter of distal extremity around the tuberosities	12·0 „
Minimum circumference of femur	20·5 „
Breadth of proximal end at great trochanter . .	19·0 „
Girth of ball of head	25·0 „

Restoration of the cranium.

I shall now add some brief explanations in reference to the mounting of the cranium and the photographs which have been taken of it, in connection with which I wish to acknowledge the assistance and the many useful suggestions which my colleagues Mr. E. Vredenburg and Mr. H. H. Hayden have kindly given me in the course of the erection and reconstruction of the specimen. The cranium, with certain plaster additions to it, stands in the vertebrate gallery of the Geological Museum, Calcutta, on a firm iron support, and the remaining bones of the skeleton are arranged near it. It was not deemed advisable to attempt any other restoration than that which was necessary to show the relation of the broken fragments to the main part of the cranium, and as to the correctness of which there could be no doubt. The tusks represented in the plates do not consist in any part of the original tusk, but are copied therefrom out of wood. In this way a more secure support has been obtained on which the pieces of bone and plaster are fastened. The white colour of the plaster in the plates shows sufficiently well how much of the specimen is restoration. It must however be remarked that in the course of transport as well as during the erection many losses and breakages have occurred. On this account an inspection of the plate may perhaps produce the impression that the information at my disposal for the restoration was less precise than is really the case; not only were the junctions between the fragments much more clearly defined originally, but also while clearing away the matrix the position of the parts was more apparent than it is at present. The photograph of the cranium in front view reproduced in Plate 11 was taken by Mr. E. Vredenburg with a telescopic lens at a distance of 18 yards, so as to prevent any distortion in the picture. As this method was impossible in the case of the side view owing to the position of the cranium in the Museum, Plate 12 was drawn in cylindrical projection, and as the orbital portion is much better preserved on the left side, this has been combined in the drawing with the remainder of the right-hand side of the cranium. Plate 10 represents a view of the cranium from the left before the restoration.

Contemporaneity of the Godavari and Narbada ossiferous deposits.

The question of the age of these deposits containing *E. antiquus* (*namadicus*) now demands some consideration. Comparing the fauna of the Godávari alluvium with that of the older Narbada deposits, we shall see that the only three mammalian species found in it up to now are identical with Narbada forms. Of these *E. antiquus* (*namadicus*) Falc. et Caut., and *Hippopotamus palæindicus* F. et C., are quite absent from the older deposits of the Siwalik beds, while *Equus namadicus* F. and C. comes up from below. We are therefore justified in regarding the two series of alluvia as of approximately the same age, and any conclusion we arrive at with respect to the Narbada deposits must apply equally to those of the Godávari. We must also extend this statement to include a great portion of the older Gangetic deposits, where in the valleys of the Jamna and Ganges near Allahabad have been found the following:—[1]

Semnopithecus sp.	*Sus* sp.
Elephas namadicus F. and C.	*Cervus* sp.
Mus sp.	*Bubalus palæindicus* F.
Hippopotamus palæindicus F. and C.	*Bos namadicus* F.
Equus sp.	*Antilope* sp.

[1] Q. J. G. S. XXI, p. 377; Falconer Pal. Mem., II, p. 640, and Rec. Geol. Surv. Ind., XXXI, p. 176.

The following is a list of the Narbada vertebrate fauna, which has hitherto been identified :—

The Narbada fauna.

Ursus namadicus F. and C.	*H. namadicus* F. and C.
Bubalus palæindicus F.	*Equus namadicus* F. and C.
Leptobos fraseri Rut.	*Rhinoceros unicornis* Linn.
Bos namadicus F.	*Elephas namadicus* F. and C.
Cervus duvaucelli Cuv.	*E. insignis* F. and C.
Sus sp.	*E. ganesa* F. and C.

Hippopotamus palæindicus F. and C.
Pangsura tectum Bell, and other reptilia.

Age of the Narbada ossiferous alluvium.

It will be remembered that Dr. Falconer designated these beds as pliocene at the same time as he concluded that the typical Siwaliks of the outer Himálayas, now classed as middle and upper Siwaliks, were miocene. The arguments for the pliocene age of the latter have been stated in the Manual of the Geology of India,[1] and are based on—

1. Their stratigraphical relation to the Mánchhar beds of Sind. The position of the latter immediately above the Gáj beds containing marine strata of miocene age, fixes their age as not older than the upper miocene. The beds of the original Siwalik area must therefore be pliocene.

2. The general facies of the fauna as compared with recent types and with the mammalian beds of the Mánchhars and Baluchistan; the latter have a distinctly older aspect.

Moreover, the immense thickness which has actually been proved for these middle and upper Siwaliks is evidence of a prolonged period of deposition; and the frequently observed occurrence of older as well as of more recent types confined to definite disconnected areas or to demonstrably different horizons in the series renders it probable that a very long period was required for the differentiation of such a diverse fauna. The Mánchhars as well as the ossiferous beds of Baluchistan are now classed with the Siwaliks, and the strong relationship which their fauna bears to that of the Pikermi and Samos deposits is quite recognized. Dr. W. T. Blanford, Mr. R. Lydekker and others class these beds in the lower pliocene,[2] which gives us a still

[1] Man. Geol. Ind., 1st. ed., ch. XXIV; 2nd ed., ch. XIV.

[2] Blanford, address to Br. Ass., 1884; Lydekker, Geog. Hist. of Mammals, 1896, p. 197; Geikie, Text book of Geol. II, p. 1296, 4th ed., 1904.

newer age for the middle and upper Siwaliks referred to above. Mr. Lydekker[1] in 1883 gave it as his opinion that the topmost beds of the Siwaliks, containing the newer types, *Camelus sivalensis, Bubalus palæindicus* and *Equus namadicus*, were probably upper pliocene or even pleistocene; his latest classification does not tend to invalidate this view.

The unconformity between the older alluvial deposits of the plain and the Siwaliks has been generally admitted[2]; the alluvial strata are nowhere inclined, and the deposit must in all cases have taken place subsequently to the great earth movements, which resulted in the upheaval of the outer Himálayas. These peninsular deposits must therefore be put at any rate into the pleistocene, and since the deposition could not have been continuous with that of the Siwaliks, there may be a considerable time break between the two series.

So much for stratigraphical evidence. The fossil molluscan fauna[3] of these beds does not contain any species, which is not identical with those at present living in the same area, although many species now living have not been found, while the relative proportion which the individual species bear to one another is different from that which prevails at the present day. As regards the vertebrate fauna there is no single genus which does not exist at the present day, although *Elephas* and *Hippopotamus* are in part represented by subgenera, which are now extinct. *Rhinoceros unicornis* is identical with the living species, while *Bubalus palæindicus* and *Cervus duvaucelli* are nearly allied respectively to the modern Indian buffalo and the barasingha. *Pangsura tectum* and possibly others of the *Reptilia* are also identical with forms which frequent the Indian rivers of to-day. *Elephas insignis, Elephas ganesa* and *Equus namadicus* have come up from the Siwaliks, and *Hippopotamus namadicus* may have originated from a Siwalik ancestor; *Hippopotamus palæindicus* belongs to a subgenus now only found in Africa. *Elephas namadicus* is identical with the European *E. antiquus*, while the phylogeny of *Ursus namadicus, Bos namadicus* and *Leptobos frazeri* is obscure. A fauna

[1] Pal. Ind., X, II, 96.

[2] Mr. Medlicott (Rec. G. S. I., VI, pt. 3, p. 52) states that the older alluvial clay of the Ganges rests on the denuded upturned surface of the upper Siwaliks at Hardwar. The topmost beds containing *Bubalus* and *Camelus* mentioned in the text are inclined, according to Falconer, at an angle of 20°, while at Bubhor strata with the same fossils are vertical (Rec. G. S. I., IX, p. 57).

[3] Mem. G. S. I., II, p. 284.

of such a type and with such recent affinities shows no inherent likelihood of having lived at a time approximating very closely to that of the Siwaliks, and we cannot reasonably assign to it a date earlier than pleistocene.

Geographical and geological distribution of *Elephas antiquus*.

In conclusion, it may be of interest to review briefly the various regions where remains of *Elephas antiquus* are found along with the geological horizons through which they are distributed. The case of *Elephas antiquus* is of special interest as it is a species which, by virtue of its powers of locomotion and its adaptability to varying environments, had a very wide geographical distribution and has been recorded from deposits ranging through a very considerable period.

India.

In the first place we have to notice that it is entirely absent from all the Siwalik strata, nor, as we have seen, is there any ancestral Siwalik type from which it might claim immediate descent. But as soon as we begin to examine the younger deposits of the Godávari, the Narbada and the Ganges, we at once find its remains in abundance. It has also been found in Burma,[1] China and Java, though *sparingly* so as compared with many other mammalia, which the researches of Owen,[2] Martin,[3] Koken[4] and Schlosser[5] have disclosed to us in the same countries. Naumann[6] has also recorded a tooth of *E. antiquus* from Japan. All these deposits are considered to be of younger date than those of Siwalik age.

Burma, China, and Java.

Japan.

Europe.

On the other hand *E. antiquus* is found widely distributed in the upper pliocene of Europe. It was essentially a southern type and its remains are found most

[1] Lydekker, Cat. Pleist. Vert. Ind. Mus., 1886, p. 14, and Foss. Mam., IV, p. 168.

[2] Owen, Fossil remains of Mammals found in China, Q. J. G. S., XXVI, 1870, p. 417.

[3] Martin, Fossile Saugethierreste von Java und Japan, Samm. d. Geol. Reichs. Mus., Lei. IV, 1886, 25.

[4] Koken, Ueber fossile Saugethiere aus China. Pal. Abhandl., III, 1886, 31.

[5] Schlosser, Die fossilen Saugethiere Chinas. Abhandl. d. k. Bay. Akad., XXII, 1903, p. 1.

[6] Palæontographica, XXVIII, 1881, p. 25, Taf. 6 and 7.

abundantly in Italy. Thence it extended both to northern Africa, which in upper pliocene times or later was united to the mainland of Europe, to England [1] and to Germany. It attains its maximum in the pleistocene deposits of the same countries, mingling with northern species, perhaps in the course of seasonal migrations according to the views expressed by Prof. Boyd Dawkins.[2]

Distribution of the stem species of *E. antiquus*.

The four dwarf races of *E. antiquus* are confined to four isolated areas centred respectively in the islands of Sicily, Malta, Crete and Cyprus. One can therefore hardly avoid the conclusion that the dwarfing of the type was due to its insulation in these areas under similar conditions of overcrowding and starvation. It may be remarked that additional evidence for this belief is afforded by the presence of pygmy species of Hippopotamus, *H. pentlandi* Meyer and *H. minutus* Blainv. in Sicily, Sardinia and Cyprus. These are both nearly allied to *H. major*, the large continental species. In Sicily Pohlig has also described a small race of red deer, which he considers indistinguishable from *Cervus elaphus* Linn., except in point of size. That the conditions of existence were somewhat abnormal is perhaps indicated by the presence of a gigantic dormouse, *Myoxus melitensis* Leith Adams. Remains of these animals Pohlig found in Sicily mingled with typical Pleistocene forms, *Bos primigenius* Boj., *Bison priscus* Boj. and *Hyæna spelæa* Gold. It seems likely therefore that the severance of these islands from the mainland, which resulted in the differentiation of this peculiar fauna, took place in early pleistocene times.

Distribution and origin of the dwarf races of *E. antiquus*.

The geographical and geological distribution of *Elephas antiquus* outlined above, suggests the probability that this is a species which originated in Europe and migrated thence to India and the Oriental regions.

Suggestions on the origin of the Indian variety of *E. antiquus*.

It may be that the causes to which we can ascribe such a migration are to be found in the increasing cold of the glacial period in Europe, and in the closure of a line of retreat southward into Africa.

[1] Remains of *E. antiquus* are found in the Norwich Crag, which is probably older than the topmost Siwaliks; according to Leith Adams molars of the species were obtained from the Red Crag.

[2] Q. J. G. S., XXVIII, p. 428, etc.

It may possibly be worth considering whether a similar migratory theory may not explain the resemblances of the later pleistocene and recent faunæ of India, to those of pleistocene Europe, and of Africa of the present day. Be that as it may, however, *E. antiquus* seems to have lived on in India long after its relatives had perished on the continent of Europe; still here too it died out, leaving no descendants to carry down its special characteristics to posterity, for, as we have seen, the present Indian elephant cannot claim kinship with it.

Summary.

The points to which special attention has been invited in this paper may be shortly summed up as follows:—

1. That the Godávari alluvial deposits are of approximately the same age as those of the Narbada.

2. That they must be considered as not *earlier* than lower pleistocene.

3. That their distribution is wider than would be inferred from the geological map.

4. That through the researches of Prof. Pohlig and others we have definite proof that the Narbada elephant is only a variety of *Elephas antiquus*.

5. That the distribution of *Elephas antiquus* strongly suggests a European origin for the species.

THE TRIASSIC FAUNA OF THE TROPITES-LIMESTONE OF BYANS. BY PROF. C. DIENER, PH.D., *of the Vienna University.*

IN Byans cephalopoda of upper Triassic age have been collected by C. L. Griesbach in a grey limestone in the upper valley of the Kali river near Kalapani. The credit for their correct interpretation is due to E. v. Mojsisovics, who was able to determine a small number of forms agreeing with, or very nearly allied to, species of the Alpine *Subbullatus*-beds of the upper carnic stage.[1]

A full description of the meagre fauna of the Tropites-limestone of Kalapani has been given by E. v. Mojsisovics in *Denkschriften Kais. Akad. d. Wissenschaften, Wien,* 1905, Bd. LXIII, and in the 3rd volume of "Himálayan Fossils" (*Palæontologia Indica,* ser. XV). Although the fossils were too badly preserved to permit a specific determination, the carnic type of the faunula showed itself so clearly in the association of genera, that he did not hesitate in correlating it with the fauna of the Alpine zone of *Tropites subbullatus.*

The genus *Tropites* being the chief leading fossil of this horizon, the name Tropites-limestone has been given and accepted generally in Indian literature.

Equivalents of the zone of *Tropites subbullatus* were not found in the sections closely examined by C. L. Griesbach, C. S. Middlemiss, and myself in 1892. Therefore, it seemed most desirable that the fossiliferous localities in Byans should be revisited and that larger collections of fossils should be made in the Tropites-limestone. Geological researches were made in Byans by F. H. Smith in the summer of 1899 and by A. v. Krafft in 1900, and large collections of cephalopoda from the Tropites-limestone were obtained from the following localities: Lilinthi, Tera Gádh, Kalapani on the Kali river, Nihal and Kuti on the Kuti Yangti river.

The following is a section through the lower, middle and part

[1] *E. v. Mojsisovics,* Vorlaeufige Bemerkungen ueber die Cephalopodenfaunen der Himalaya-Trias. Sitzgsber. kais. Akad. d. Wiss., Cl. 1. Abt., Mai 1892.

of the upper Trias, as observed in Byans by F. H. Smith and A. v. Krafft:

Noric stage	3. Black shales	1,000 feet
Carnic stage	2. Massive limestone Near top, *Tropites*, etc.	250 „
Ladinic „	70 feet above base, cephalopoda of upper Muschelkalk; immediately below, brachiopoda of the zone of *Spiriferina Stracheyi*.	
Muschelkalk		
Lower Trias	1. Chocolate limestone	150 „

According to A. v. Krafft, the fossiliferous horizon with *Tropites* is invariably found at the top of the massive grey limestone, which in its lower portion has yielded cephalopoda (*Gymnites Jollyanus*) and brachiopoda of the muschelkalk. The Tropites-limestone, occurring near the base of the black shales of noric age, does not exceed three feet in thickness and is the only upper Triassic horizon of Byans rich in ammonites, whereas all the other beds are practically unfossiliferous.

The beautiful materials collected by Smith and A. v. Krafft have been entrusted to me for examination by the Director of the Geological Survey of India. The full description of the fauna of the Tropites-limestone will form the first part of Vol. V of "Himálayan Fossils" (*Palæontologia Indica*, ser. XV). Although the manuscript has been finished and sent to Calcutta, considerable time must elapse before its publication. The remarkable interest connected with the results of my examination induces me, however, to give this short preliminary notice.

There are, altogether, 168 forms known to me from the Tropites-limestone of Byans, 155 species belonging to the order of *Ammonoidea*. The fauna of this horizon is therefore one of the richest Triassic faunas hitherto known. Its most characteristic feature consists in the overwhelming predominance of cephalopoda.

Among 155 species of ammonites 104 are peculiar to the Tropites-limestone of Byans, 51 are identical or probably identical with species from the Triassic Hallstatt-limestone of the Eastern Alps, or from the upper Triassic Halorites-limestone of the Himálayas. But among the new species the number of forms very nearly allied to European ones is much larger than the number of types which impart to the Indian Triassic province the character of a zoogeographical region of its own.

As faunistic elements peculiar to the Tropites-limestone of Byans, but unknown in the Mediterranean region, the following may be considered : *Trachypleuraspidites*, a sub-genus of *Dittmarites*, with remarkable morphological affinities to *Trachyceras ;* the sub-genus *Himavatites*, in which characters of *Acanthinites*, *Sagenites* and *Trachyceras* have been united ; the strange genus *Jellinekites* with three external keels, which are repeatedly interrupted by transitional constrictions ; the group of *Sirenites Vredenburgi*, distinguished from other congeneric species by its very delicate sculpture, thin, thread-like ribs and transversely elongated tubercles; the groups of *Drepanites Schucherti* and of *Clionites gracilis*, differing considerably from all congeneric forms of the Alpine region; the groups of *Tropiceltites arietitoides*, imitating liassic *Arietidæ* in its external characters, and of *Distichites ectolcitiformis*, a transitional shape between the two genera *Distichites* and *Ectolcites.*

The relations with upper Triassic faunæ of the Mediterranean region are most clearly indicated by the occurrence of numerous identical or closely allied forms in the two areas. But the assemblage of those species in the Tropites-limestone of Byans is very peculiar, and exhibits rather conflicting characters.

In Griesbach's small collection ten species of ammonites were noticed by E. v. Mojsisovics, all of them pointing to a correlation with the carnic stage of the Hallstatt limestone, especially with the zone of *Tropites subbullatus* (tuvalic sub-stage). In the rich materials collected by Smith and A. v. Krafft the *carnic* type of the fauna shows itself in the assemblage of the following genera : *Thisbites*, *Arpadites*, *Trachyceras*, *Protrachyceras*, *Jovites*, *Gonionotites*, *Eutomoceras*, *Anatropites*, *Carnites*, *Proarcestes*, *Pararcestes*, *Lobites.* There are altogether 27 species identical or probably identical with species of the carnic stage of the Salzkammergut. Among them 16 belong to the tuvalic, 8 to the julic sub-stage, 3 are common to both sub-stages. The majority of faunistic elements consequently points to the zone of *Tropites subbullatus.* Especially those groups of carnic elements, which give to the fauna its peculiar type and are conspicuous for their specific fecundity—*Tropites*, *Margarites*, *Anatomites*—are leading fossils of the tuvalic sub-stage of the Hallstatt limestone.

The species of ammonites bearing the stamp of a tuvalic age are contained in the following list:—

Tropites subbullatus v. Hauer.
" *cf. fusobullatus* Mojs.
" *cf. discobullatus* Mojs.
" *cf. Estellæ* Mojs.
" *cf. Paracelsi* Mojs.
Margarites Georgii Mojs.
" *cf. auctus* Dittm.
Polycyclus Henseli Oppel.
Sandlingites cf. Oribasus Dittm.
Sirenites Pamphagus Dittm.
" *Agriodus* Dittm.
Anasirenites cf. Menelaus Mojs.
Anatomites cf. Edgari Mojs.
" *cf. Thedori* Mojs.
" *cf. crasseplicatus* Mojs.
Arcestes bicornis Hauer.

The following species of the Tropites-limestone of Byans are leading fossils of the zone of *Trachyceras Aonoides* (julic sub-stage) in Europe:—

Arpadites Tassilo Mojs.
Isculites Heimi Mojs.
Anatomites cf. Fischeri Mojs.
Tropites Wodani Mojs.
Carnites cf. floridus Wulf.
Proarcestes Gaytani Klipst
Pararcestes cf. Sturi Mojs.
Lobites cf. ellipticus Hauer.

Protrachyceras is represented by two, *Trachyceras* by one species. In Europe these two genera make their appearance for the last time in the julic sub-stage, but have been found in the Tropites beds of California of undoubted tuvalic age by J. Perrin Smith (*Amer. Journ. Geol.*, II, p. 607, III, p. 377).

Three species of the Tropites-limestone, *Pinacoceras cf. rex* Mojs., *Eutomoceras sandlingense* Hau., *Margarites cf. circumspinatus* Mojs., are common to the julic and tuvalic sub-stages.

From this proportion of julic and tuvalic elements in the Tropites-limestone it is evident, that a greater number of relationships and analogies speaks in favour of a correlation with the tuvalic sub-stage.

There is, however, a second faunistic element equally distributed in the Tropites-limestone of Byans. This element consists of genera and species of ammonites characteristic of the *noric* stage of the Hallstatt limestone. The following species are identical with species from the noric stage of the Salzkammergut:—

Helictites cf. geniculatus Mojs.
„ *cf. subgeniculatus* Mojs.
Phormedites fasciatus Mojs.
Parathisbites cf. Hyrtli Mojs.
„ *cf. scaphitiformis* Hauer.
Distichites cf. Harpalos Dittm.
Sirenites Evae Mojs.
„ *cf. Argonautæ* Mojs.
„ *cf. Dianæ* Mojs.
Didymites tactus Mojs.
Pinacoceras parma Mojs.
„ *Metternichii* Hauer, *var.*
Arcestes dicerus Mojs.
Cladiscites cf. neortus Mojs.

To this list of noric types must be added 6 species of *Distichites* (*megacanthi*), 3 species of *Drepanites* and of *Didymites*, 4 species of *Ectolcites*, 2 species of *Stenarcestes*, 1 species each of *Dionites*, *Acanthinites* and *Daphnites*—genera which up to now have only been found in the noric stage of the Hallstatt limestone. It is especially the genus *Didymites*, restricted to the alaunic (middle noric) sub-stage in Europe, which is very richly represented in the Tropites-limestone at all localities from which collections have been made by Smith and A. v. Krafft.

The fauna of the Tropites-limestone of Byans has also close affinities to that of the Halorites limestone of the Central Himálayas (Bambanag section) of lower noric age. The following species are common to both horizons:—

Steinmannites Lubbocki Mojs.
Tibetites Ryalli Mojs.
Anatibetites Kelvini Mojs.
Paratibetites Adolphi Mojs.
„ *Bertrandi* Mojs.
„ *Geikiei* Mojs.
Parajuvavites Jacquini Mojs.
Pinacoceras parma Mojs.

As elements pointing to a close relation with the fauna of the Halorites beds must be mentioned moreover—

Paratibetites sp. aff. Tornquisti Mojs.
Halorites sp. aff. procyon Mojs.
Clionites sp. aff. Hughesii Mojs.
„ *sp. aff. aberrans* Mojs.
Sandlingites sp. aff. Archibaldi Mojs.
Bambanagites Kraffti nov. sp.

The representatives of *Tibetites* (including the two sub-genera *Anatibetites* and *Paratibetites*) are scarcely inferior to the genus *Tropites* in number of individuals.

The total number of species of ammonites with noric affinities in the Tropites-limestone of Byans is 49, or one-third of the entire number of species.

The above analysis shows that the cephalopod fauna of the Tropites-limestone of Byans has relations with *both the carnic and noric faunæ* of the Hallstatt limestone. Such an assemblage of forms has never been met with in any Triassic horizon of the Eastern Alps, where noric and carnic faunæ are invariably confined to entirely different horizons.

This strange association of faunistic elements in a single bed of three feet in thickness offers a problem, the explanation of which may be attempted from different points of view.

The easiest explanation would be to suggest that the two faunæ have been mixed together accidentally in the collections from different localities. Two deposits of equal lithological characters might easily be mistaken for a single horizon, although they contain two separate faunæ, if a careful examination of the fossils is not possible in the field. If each of the two faunæ of the Tropites-limestone were found concentrated in the collections of a single locality and not mixed there with the second fauna, we might take this explanation as the fittest.

A detailed examination of the lists of fossils from different localities has, however, convinced me that the noric and carnic faunæ do not occur at separate localities but are amalgamated in the Tropites-limestone at every locality from which collections have been made. Thus we are led to the conclusion that two faunæ, which in the Alpine Trias are known to characterise two horizons of different geological age, have in Byans been found mixed together in one single bed of three feet in thickness.

It must be especially remarked that A. v. Krafft, when surveying the Mesozoic territory of Byans, did not overlook the remarkable mixture of two different elements in the fauna of the Tropites-limestone. I quote the following passage from his diary:—

"Palæontologically the fauna of the Tropites-limestone is very remarkable. The genus *Tropites* being very common and *Tropites subbullatus* occurring among other species, the fauna must be nearly allied in age to that of the *subbullatus*-beds of the Salzkammergut. But with these upper carnic types forms occur which bear a strong resemblance to species from the limestone of the Sommeraukogel near Hallstatt, considered to be of noric age by E. v. Mojsisovics. No explanation of this fact can be attempted so far."

In the face of these facts it is impossible to maintain the suggestion that the noric and carnic faunæ contained in the Tropites-limestone of Byans have been mixed together accidentally in the collections from different localities.

It is a well-known fact that in the entire Alpine Trias there is no greater gap in the development of faunæ than between the noric and carnic stages. The question arises, whether the strange association of carnic and noric elements in the Tropites-limestone of Byans might not constitute a transitional fauna, bridging over the hiatus which exists between the carnic and noric stages of the eastern Alps. If this suggestion could be proved to be correct, the Tropites beds of Byans might be considered as passage beds from the tuvalic (upper carnic) into the lacic (lower noric) sub-stage.

This suggestion is, however, not confirmed by any facts. There is only an extremely small number of transitional forms connecting the two faunæ. As such connecting links might be considered *Placites polydactylus var. Oldhami* Mojs., a group of *Dittmarites* uniting characters of *D. Dorceus* Mojs. of carnic and of *D. Lilli* Guembel of noric age, *Buchites Emersoni* nov. sp., a representative of the carnic sub-genus *Buchites* but very nearly allied to the noric sub-genus *Phormedites*. But this is a very small number, whereas the overwhelming majority of ammonites in the Tropites-limestone are allied to either carnic or noric types, but do not constitute transitional forms between the two faunæ.

It has been stated that among the carnic elements of the fauna of the Tropites-limestone two groups can be distinguished, one with tuvalic, the other with julic affinities. In the noric elements of the fauna similar relations with the faunæ of the lacic and alaunic sub-stages are obvious. There is undoubtedly a preponderance of lacic affinities in them, but the affinity to the alaunic sub-stage is nevertheless sufficiently remarkable. This affinity is most clearly marked in the presence of *Didymites* and *Ectolcites,* two genera, which in the Alpine Trias are restricted exclusively to beds of alaunic age.

A fauna with so strange a mixture of julic, tuvalic, lacic and alaunic types, does certainly not exhibit a transitional character. It is widely different from the fauna of a passage-bed between the tuvalic and lacic sub-stages, in which we should expect an overwhelming preponderance of exclusively tuvalic and lacic species and of transitional links connecting them. The Tropites-limestone can consequently not be considered as a passage bed, but is a horizon distinguished by the mixture of two different faunæ.

This mixture of faunæ agrees in a remarkable manner with the association of Kelloway and Oxford ammonites in the Jurassic oolite of Balin (Galicia). As has been proved by Neumayr (*Abhandl., k. k. Geol. Reichsanst.,* Bd. V, 1871) the oolite of Balin contains in a very thin bed 66 species of ammonites of Kelloway and Oxford age, ranging from the zone of *Oppelia aspidoides* to the zone of *Quenstedtoceras Lamberti.* It would be in contradiction with our knowledge of the distribution of Jurassic ammonites to suppose, that two faunæ, which in all other parts of the world have been found confined to geologically different horizons, had lived together at the same period in the sea, in which the oolite of Balin was deposited. As in analogous cases the want of sediment seems to be the chief cause of the mixture of Kelloway and Oxford types at Balin.

Taking all this into consideration we are led to the conclusion that the Tropites-limestone is not only a homotaxial equivalent of the *Subbullatus*-zone of Europe, but also an equivalent of the lacic Halorites beds of Johár and Painkhánda, with which it has a considerable number of species in common. The intimate connection of carnic and noric faunæ in this thin bed of limestone might be explained by the small amount of sediment deposited during the tuvalic and lacic periods. With this suggestion the remarkable reduction in the thickness of all Triassic sediments in the Himálayas from Spiti to Byans would be well in accordance.

In Spiti the ladinic stage amounts to approximately 300 feet and is overlaid by strata of carnic age, 1,300 feet in thickness. In the Bambanag and Shalshal sections the ladinic stage dwindles down to such an insignificant extent, that Griesbach and myself failed to discover it in 1892, but the carnic stage is still represented by shales and limestones 800 feet in thickness. In Byans muschelkalk, ladinic and carnic stages are represented by a lithologically uniform mass of grey limestone of 200-250 feet in thickness. Counting 70 feet for the muschelkalk, the maximum thickness of the carnic stage cannot be more than 180 feet (800 in Johár, 1,300 in Spiti).

If we suppose that the sedimentation was nearly exhausted in the seas of the upper carnic and lacic periods, the entire result of sedimentation during those periods might have been a lithologically uniform bed of limestone, three feet in thickness. Then it would be impossible to separate carnic and noric fossils within this limestone. This is exactly the case we find in the Tropites-limestone of Byans, which contains in a single bed the faunæ of two different Triassic horizons.

ON THE OCCURRENCE OF AMBLYGONITE IN KASHMIR. BY F. R. MALLET, *late Superintendent, Geological Survey of India.*

IN 1881, or early in the following year, an important discovery of sapphires was accidentally made in the Zánskár Range of the Himálayas, and considerable quantities of the mineral, including many valuable gems, were subsequently obtained.[1] The yield, however, some years later, was steadily diminishing, in consequence of which the Kashmír Darbár, in 1887, applied to the Government of India for a Geologist to examine the mines, and Mr. T. D. LaTouche was detailed for the duty in question. It appears from the results of his investigations, which are given in *Records*, Vol. XXIII, p. 59, that the mines, or more correctly diggings, are situated at an elevation of over 13,000 feet, about two miles west-north-west from Sumjám, a village in the district of Pádar, in N. latitude 33° 25′ 30″, E. longitude 76° 28′ 10″.[2] Although most of the sapphires were obtained from loose débris fallen from the cliffs above, the original matrix of the gems, in which they were actually found *in situ*, was a (generally pegmatitic) granite that traverses the gneiss of the surrounding hills in numerous dykes, though the sapphires were only observed in some particular ones. Other accessory minerals observed were black tourmaline, euclase, kyanite, and garnet.

"Besides the corundum,"[3] LaTouche continues, "several other minerals, interesting from a scientific point of view, though not commercially valuable, are found in the granite of this region. For a determination of the species of most of these I am indebted to Mr. F. R. Mallet, late of the Geological Survey, who kindly examined them for me. These are the following:—1, green tourmaline; 2, cookeite; 3, spodumene; 4, prehnite; 5, copper carbonate; 6, beryl; 7, lazulite; 8, rock-crystal; concerning the third of these the author writes, "a few lilac-coloured crystalline blocks of this mineral,

[1] *Records*, Vol. XV (1882), p. 138, and Manual of the Geology of India, Part IV, p. 40.

[2] The village (with the name spelled Sunjám) is marked on Lydekker's geological map of Kashmír, *Mem. G. S. I.*, Vol. XXII.

[3] Sapphire.

which also[1] contains lithia, were found in a valley to the north of the Sapphire mines, between them and the place where the green tourmalines were found: none of these were found *in situ*." The green tourmaline was discovered about a mile from the ridge in which the sapphires occur.

As mentioned by LaTouche, I determined some of the above, but not the remainder, and amongst the latter was the mineral alluded to as spodumene. When retiring from the survey, however, I brought home a few Indian minerals, with the permission of Dr. King, the then Director, in the hope of being able to examine them at some future time, and amongst them was a piece of the mineral in question.

The physical and chemical characters of the specimen show that it is *amblygonite*, a mineral sometimes found in association with spodumene, and resembling it in containing alumina and lithia as the principal bases; but the acidic element is phosphoric instead of silicic.

The specimen is cleavable massive, with one fairly perfect cleavage, and another only faintly developed. Fragments suitable for goniometric measurement are obtainable with extreme difficulty. One excellent morsel, however, was found, with smooth planes yielding good reflections, and giving a measured cleavage angle of 104° 58′. The hardness is 6; the specific gravity 3·05; and the colour pale bluish gray to faint violet. The mineral is unusually transparent for amblygonite: thus the print of these *Records* could be easily read through a parallel-faced cleavage fragment nearly half a centimetre thick—the thickest obtainable without flaws. Solid inclusions are very rare or absent: some parts are free from inclusions of any kind, while in others there are numerous minute cavities, and some larger ones, which are partially filled with liquid. A few of the bubbles are moveable. Analysis showed that the principal constituents of the mineral are phosphorus pentoxide, alumina, and lithia, with minor proportions of soda, potash, fluorine, and water. It resembles the amblygonite of other localities by its occurrence in granite, and in its association with other lithia-minerals, represented in the present case by green lithia-tourmaline and cookeite.

The above is the only locality where amblygonite has been found within the limits of the Indian Empire, and I may add that none of the works on mineralogy I have consulted mention its occurrence in any part of Asia.

[1] *i.e.*, in common with the cookeite.

MISCELLANEOUS NOTES.

The Kangra Earthquake of 4th April, 1905.

AFTER a lapse of only eight years since the great earthquake of 1897, India has again been visited by another disaster of considerable magnitude, namely, the Kangra Earthquake of the 4th April, 1905, by which an unfortunate loss of human life occurred, estimated at 20,000. An investigation was immediately taken in hand by this Department among others, not only by sending officers personally to the affected parts, but by the issue of many thousand question-forms to local officials throughout the various Presidencies and Native States. The facts and information thus collected are now being arranged and sifted, and the first result will appear in the next issue of the "Records" as a preliminary account. Meanwhile, it may be summarily stated that the quake appears to have originated in a geotectonic movement taking place below an epifocal area some 160 miles long and extending in a north-west—south-east curve from the neighbourhood of Kangra to that of Mussoorie. It seems to have been connected with a reversed fault or series of related faults intimately bound up with the structural history of the Himalaya. This axial form of centrum must have had a distinct pitch to the south-east, whilst it emerged quite near the surface in the Kangra Valley and gave rise at that locality to a destructive intensity of 10 of the Rossi-Forel scale. On account of its increasing pitch towards the south-east, the intensity along the epifocal tract diminished to 9 in Kulu, and to about 8 near Mussoorie and Dehra Dun. In other words, the first few isoseismals close up round the north-west end of the centrum and widen out towards the south-east. The area of extensive damage to masonry buildings is only about 5,800 square miles as compared with 150,000 square miles in the Assam earthquake of 1897; whilst a further area of 27,000 square miles, surrounding the former, represents that of slight, but still frequently destructive damage to masonry buildings. On the other hand, the isoseismals of still more diminishing intensity expand out relatively, especially along the Indo-Gangetic alluvium; so that finally the total area over which the shock was sensibly felt works out not far below that of the 1897 quake, its western, southern and eastern limits being, respectively, Quetta, Surat, False Point, and Lakhimpur.

The unfelt earthquake, besides being recorded by the seismographs of Calcutta, Bombay, and Kodaikanal in India, was of world-wide effect, and has furnished long-distance traces to the instruments in Europe and Japan.

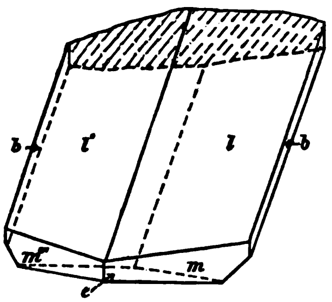
[C. S. MIDDLEMISS.]

An unusual form of Selenite from the Pachpadra Salt-Source, Jodhpur, Rajputana.

Selenite or Gypsum.

Some interesting samples of various substances obtained during the manufacture of salt from the brine obtained from brinewells at Pachpadra, and regarded as impurities, were forwarded by Mr. A. F. Ashton, Officiating Commissioner, Northern India Salt Revenue, Agra, to the Geological Survey Office for examination. One sample is impure Epsom salt and the remainder consist of selenite sometimes associated with common salt.

The most interesting of these specimens is locally called *anetha* and consists entirely of selenite crystals. These were sorted into three portions. The first (J. 843) consists of crystals of unusual habit. As will be seen from the accompanying figure, owing to the subordinate development of the faces *m* (110) and *b* (010), the pyramid faces *l* (111) become the most prominent and this, aided by the presence of the hemiorthodome *e* (103), causes the crystals to assume a flattened aspect roughly parallel to the negative hemi-pyramid (111).



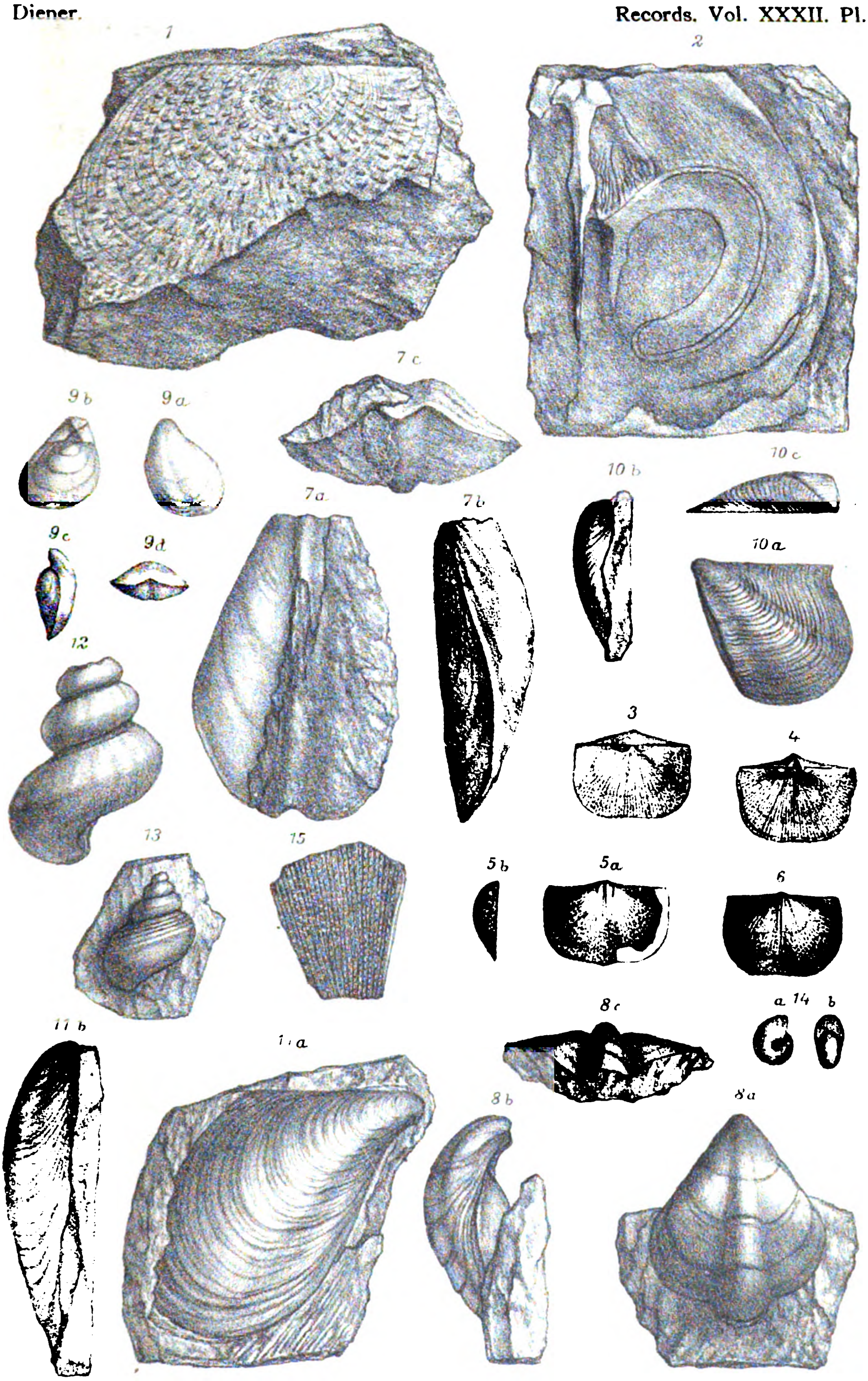
The face (*e*) is exceedingly roughly developed and is not always present. In colour they are usually creamy, more or less opaque, and often show zoning on the faces *l*, *l'* parallel to the edges *lm* and *lb*. The largest crystals measure about $\frac{3}{4}$ inch along the edge *ll'* and are $\frac{3}{16}$ to $\frac{1}{4}$ inch thick.

The second portion of these crystals (J. 844) consists of many small swallow-tail twins ranging up to $\frac{1}{2}$ and $\frac{3}{4}$ inch across the "tails," and having *a* (100) for twinning plane. They usually have the normal development of selenite crystals, *i.e.*, tabular parallel to *b*, but are occasionally of the preceding type.

The third portion (J. 845) consists of many more or less radiate aggregates of small crystals averaging $\frac{1}{4}$ to $\frac{1}{2}$ inch in length, some of the crystals showing the abnormal habit of J. 843, while some are twinned.

[L. L. FERMOR.]

G. I. C. P. O.—No. 474 D. C. Survey—20-10-05.—660—H. R.



A. *Swoboda, del.* *Alb. Berger print.*

ANTHRACOLITHIC FOSSILS FROM THE SUBANSIRI GORGE.

Photographed by G. E. Pilgrim. *Bemrose, Collo., Derby, Eng.*

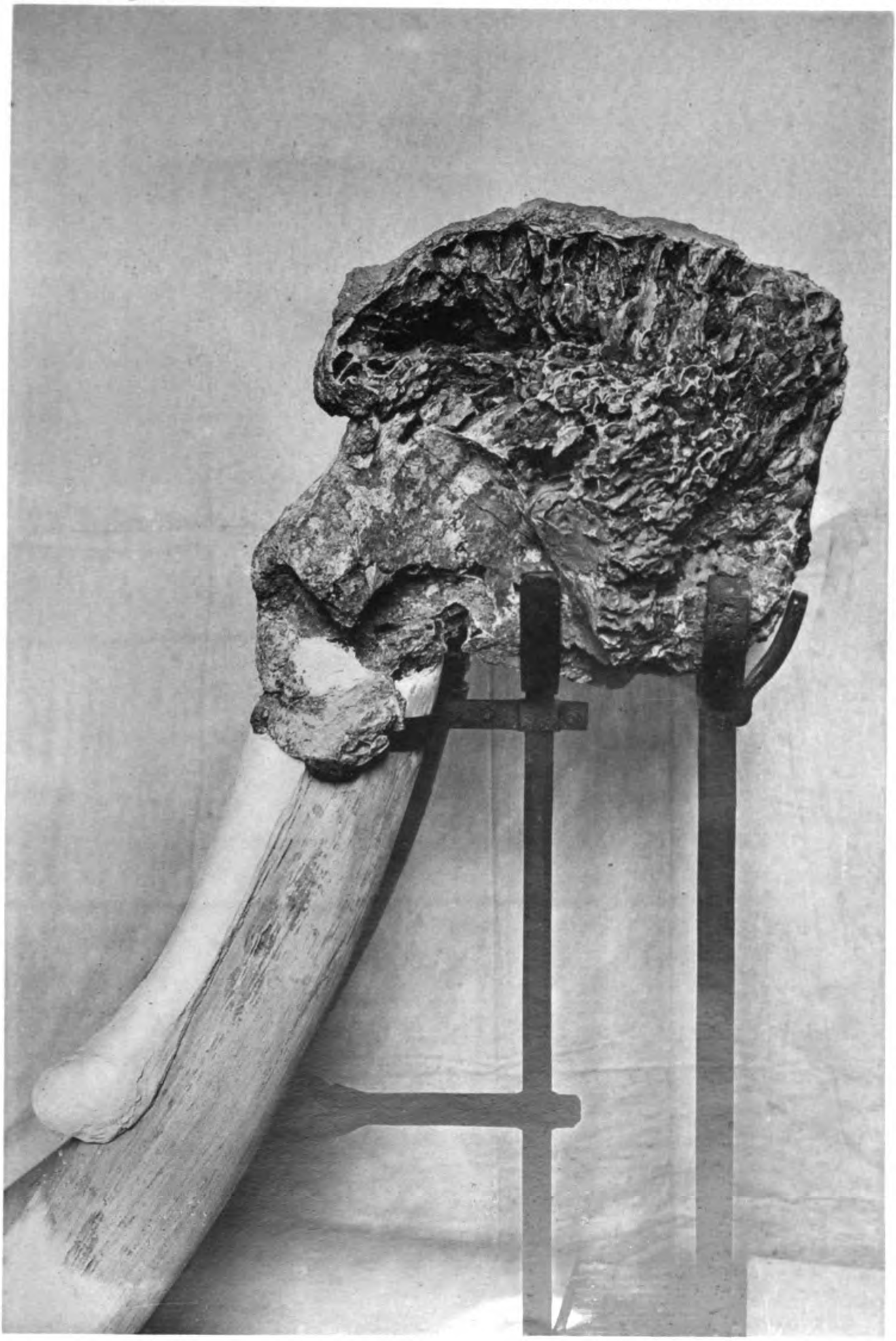
CHANNEL OF THE GODAVARI NEAR NANDUR MADMESHWAR.

G. E. Pilgrim.

Photographed by G. E. Pilgrim.

Bemrose, Collo., Derby, Eng.

CHANNEL OF THE GODAVARI NEAR NANDUR MADMESHWAR.



Photographed by H. H. Hayden. *Bemrose, Collo., Derby, Eng.*

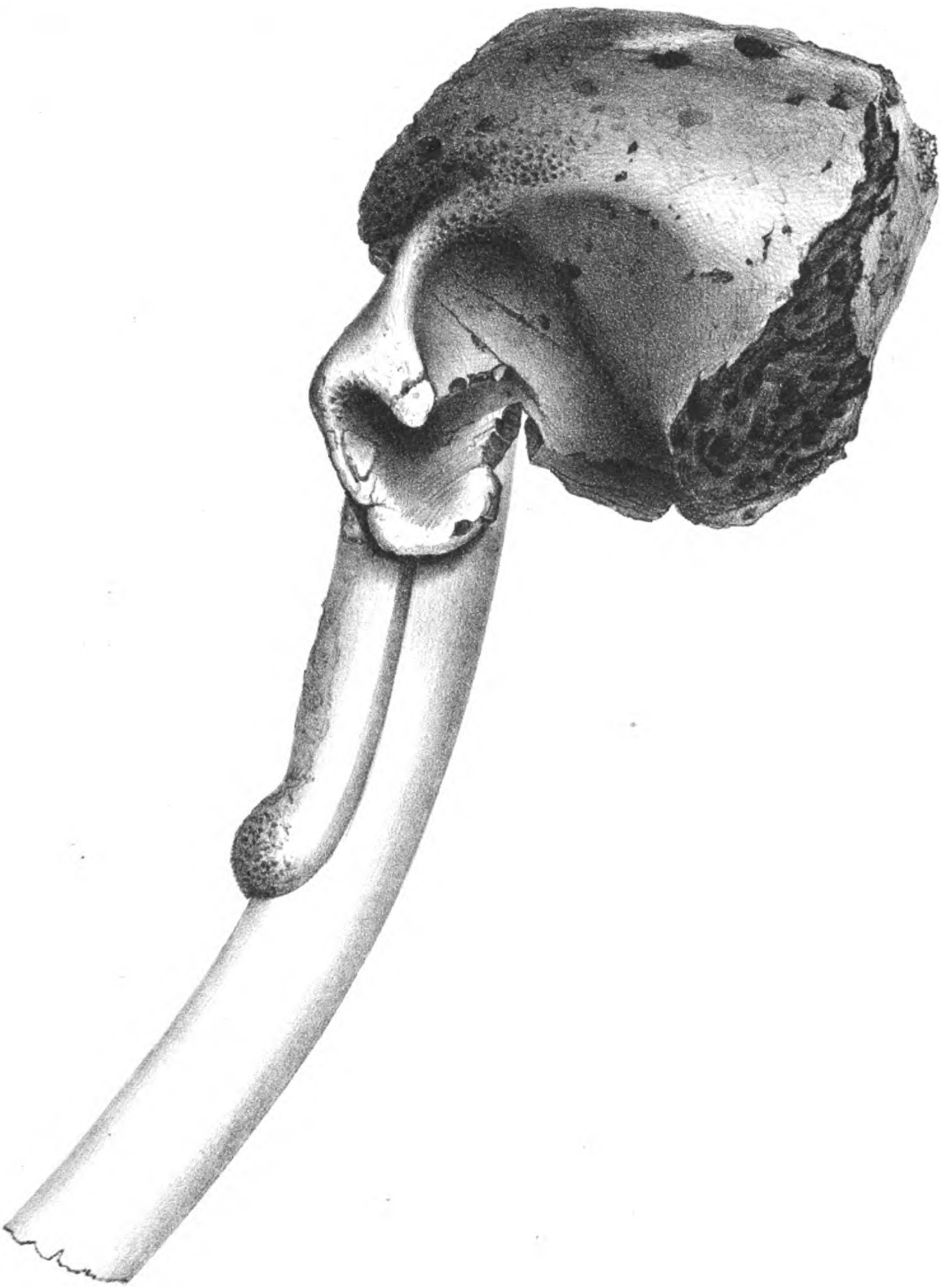
CRANIUM OF ELEPHAS ANTIQUUS (NAMADICUS).

Side view taken previous to restoration.

Photographed by E. Vredenburg. *Bemrose, Collo., Derby, Eng.*

CRANIUM OF ELEPHAS ANTIQUUS (NAMADICUS).

The scale is indicated by the foot-rule seen between the tusks.



Lith^d and Printed at the Geol. Surv. Office, Calcutta.

ELEPHAS ANTIQUUS (NAMADICUS)

GEOLOGICAL SURVEY OF INDIA

G. E. Pilgrim. Records, Vol. XXXII. Pl. 13

Fig. 1.

Fig. 4.

Fig. 2.

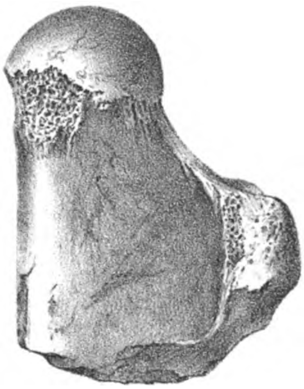


Fig. 3.

Fig. 1. Pelvic Girdle
Fig. 2. Upper portion of Ilium
Fig. 3. Proximal end of Femur
Fig. 4. Distal end of Femur

H. H. Hayden. Photo.

Lithd and Printed at the Geol. Surv. Office, Calcutta.

ELEPHAS ANTIQUUS (NAMADICUS)

Part 3.—Note on the progress of the gold industry in Wynaad, Nilgiri district. Notes on the representatives of the Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite form Sarawak.

Part 4.—On the geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Further notices of Siwalik mammalia. Notes on some Siwalik birds. Notes of a tour through Hangrang and Spiti. On a recent mud eruption in Ramri Island (Arakan). On Braunite, with Rhodonite, from near Nagpur, Central Provinces. Palæontological notes from the Satpura coal-basin. Statistics of coal importations into India.

Part 2.—On the Mohpani coal-field. On Pyrolusits with Psilomelane occurring at Gosalpur, Jabalpur district. A geological reconnaissance from the Indus at Kushalgarh to the Kurram at Thal on the Afghan frontier. Further notes on the geology of the Upper Punjab.

Part 3.—On the geological features of the northern part of Madura district, the Pudukota State, and the southern parts of the Tanjore and Trichinopoly districts included within the limits of sheet 80 of the Indian Atlas. Rough notes on the cretaceous fossils from Trichinopoly district, collected in 1877-78. Notes on the genus Sphenophyllum and other Equisetaceæ, with reference to the Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). On Mysorin and Atacamite from the Nellore district. On corundum from the Khasi Hills. On the Joga neighbourhood and old mines on the Nerbudda.

Part 4.—On the 'Attock Slates' and their probable geological position. On a marginal bone of an undescribed tortoise, from the Upper Siwaliks, near Nila, in the Potwar, Punjab. Sketch of the geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1.—Annual report for 1879. Additional notes on the geology of the Upper Godavari basin in the neighbourhood of Sironcha. Geology of Ladak and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Teeth of fossil fishes from Ramri Island and the Punjab. Note on the fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Notes on fossil plants from Kattywar, Shekh Budin, and Sirgujah. On volcanic foci of eruption in the Konkan.

Part 2.—Geological notes. Palæontological notes on the lower trias of the Himalayas. On the artesian wells at Pondicherry, and the possibility of finding such sources of water-supply at Madras.

Part 3.—The Kumaun lakes. On the discovery of a celt of palæolithic type in the Punjab. Palæontological notes from the Karharbari and South Rewah coal-fields. Further notes on the correlation of the Gondwana flora with other floras. Additional note on the artesian wells at Pondicherry. Salt in Rajputana. Record of gas and mud eruptions on the Arakan coast on 12th March 1879 and in June 1843.

Part 4.—On some pleistocene deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period. Useful minerals of the Arvali region. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The re-soils of Upper India. Note on the Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts, being fifth notice of the geology of Kashmir and neighbouring territories. Note on some Siwalik carnivora. The Siwalik group of the Sub-Himalayan region. On the South Rewah Gondwana basin. On the ferruginous beds associated with the basaltic rocks of north-eastern Ulster, in relation to Indian laterite. On some Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on the lower trias of the Himalayas.' On some mammalian fossils from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society.

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Part 2.—The Nahan-Siwalik unconformity in the North-western Himalaya. On some Gondwana vertebrates. On the ossiferous beds of Hundes in Tibet. Notes on mining records, and the mining record office of Great Britain; and the Coal and Metalliferous Mines Acts of 1872 (England). On cobaltite and danaite from the Khetri mines, Rajputana; with some remarks on Jaipurite (Syepoorite). On the occurrence of zinc ore (Smithsonite and Blende) with barytes, in the Karnul district, Madras. Notice of a mud eruption in the island of Cheduba.

Part 3.—Artesian borings in India. On oligoclase granite at Wangtu on the Sutlej, North-west Himalayas. On a fish-palate from the Siwaliks. Palæontological notes from the Hazaribagh and Lohardagga districts. Undescribed fossil carnivora from the Siwalik hills in the collection of the British Museum.

Part 4.—Remarks on the unification of geological nomenclature and cartography. On the geology of the Arvali region, central and eastern. On a specimen of native antimony obtained at Pulo Obin, near Singapore. On Turgite from the neighbourhood of Juggiapett, Kistnah district, and on zinc carbonate from Karnul, Madras. Note on the section from Dalhousie to Pangi, *viâ* the Sach Pass. On the South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1.—Annual report for 1881. Geology of North-west Kashmir and Khagan (being sixth notice of geology of Kashmir and neighbouring territories). On some Gondwana labyrinthodonts. On some Siwalik and Jamna mammals. The geology of Dalhousie, North-west Himalaya. On remains of palm leaves from the (tertiary) Murree and Kasauli beds in India. On Iridosmine from the Noa-Dibing river, Upper Assam, and on Platinum from Chutia Nagpur. On (1) a copper mine lately opened near Yongri hill, in the Darjiling district; (2) arsenical pyrites in the same neighbourhood; (3) kaolin at Darjiling (being 3rd appendix to a report on the geology and mineral resources of the Darjiling district and the Western Duars). Analyses of coal and fire-clay from the Makum coal-field, Upper Assam. Experiments on the coal of Pind Dadun Khan, Salt-range, with reference to the production of gas, made April 29th, 1881. Report on the proceedings and result of the International Geological Congress of Bologna.

Part 2.—General sketch of the geology of the Travancore State. The Warkilli beds and reported associated deposits at Quilon, in Travancore. Note on some Siwalik and Narbada fossils. On the Coal-bearing rocks of the valleys of the Upper Rer and the Mand rivers in Western Chutia Nagpur. On the Pench river coal-field in Chhindwara district, Central Provinces. On borings for coal at Engsein, British Burma. On sapphires recently discovered in the North-west Himalaya. Notice of a recent eruption from one of the mud volcanoes in Cheduba.

Part 3.—Note on the coal of Mach (Much) in the Bolan Pass, and of Sharag or Sharigh on the Harnai route between Sibi and Quetta. New faces observed on crystals of stilbite from the Western Ghâts, Bombay. On the traps of Darang and Mandi in the North-western Himalayas. Further note on the connexion between the Hazara and the Kashmir series. On the Umaria coal-field (South Rewah Gondwana basin). The Daranggiri coal-field, Garo Hills, Assam. On the outcrops of coal in the Myanoung division of the Henzada district.

Part 4.—On a traverse across some gold-fields of Mysore. Record of borings for coal at Beddadanol, Godavari district, in 1874. Note on the supposed occurrence of coal on the Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. On the genus Richthofenia, Kays (Anomia Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chamba. On the basalts of Bombay.

Part 2.—Synopsis of the fossil vertebrata of India. On the Bijori Labyrinthodont. On a skull of Hippotherium antilopinum. On the iron ores, and subsidiary materials for the manufacture of iron, in the north-eastern part of the Jabalpur district. On laterite and other manganese ore occurring at Gosulpore, Jabalpur district. Further notes on the Umaria coal-field.

Part 3.—On the microscopic structure of some Dalhousie rocks. On the lavas of Aden. On the probable occurrence of Siwalik strata in China and Japan. On the occurrence of Mastodon angustidens in India. On a traverse between Almora and Mussooree made in October 1882. On the cretaceous coal-measures at Borsora, in the Khasia Hills, near Laour, in Sylhet.

Part 4.—Palæontological notes from the Daltonganj and Hutar coal-fields in Chota Nagpur. On the altered basalts of the Dalhousie region in the North-western Himalayas. On the microscopic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and the Lower Himalayas. On a traverse through the Eastern Khasia, Jaintia, and North Cachar Hills. On native lead from Maulmain and chromite from the Andaman Islands. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice.—Irrigation from wells in the North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1.—Annual report for 1883. Considerations on the smooth-water anchorages or mud banks of Narrakal and Alleppy on the Travancore coast. Rough notes on Billa Surgam and other caves in the Kurnool district. On the geology of the Chuari and Sihunta parganas of Chamba. On the occurrence of the genus Lyttonia, Waagen, in the Kuling series of Kashmir.

Part 2.—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneissose granites. Report on the Choi coal exploration. On the re-discovery of certain localities for fossils in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The intertrappean beds in the Deccan and the Laramie group in western North America.

Part 3.—On the miscroscopic structure of some Arvali rocks. Section along the Indus from the Peshawar Valley to the Salt-range. On the selection of sites for borings in the Raigarh-Hingir coal-field (first notice). Note on lignite near Raipore, Central Provinces. The Turquoise mines of Nishâpûr, Khorassan. Notice of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan. Report on the Langrin coal-field, south-west Khasia Hills. Additional notes on the Umaria coal-field.

Part 4.—On the Geology of part of the Gangasulan pargana of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the North-west Himalayas. On the geology of the Takht-i-Suleiman. On the smooth-water anchorages of the Travancore coast. On auriferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Work at the Billa Surgam caves.

Vol. XVIII, 1885.

Part 1.—Annual report for 1884. On the country between the Singareni coal-field and the Kistna river. Geological sketch of the country between the Singareni coal-field and Hyderabad. On coal and limestone in the Doigrung river, near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2.—A fossiliferous series in the Lower Himalaya, Garhwal. On the probable age of the Mandhali series in the Lower Himalaya. On a second species of Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). On the Geology of Chamba. On the probability of obtaining water by means of artesian wells in the plains of Upper India. Further considerations upon artesian sources in the plains of Upper India. On the geology of the Aka Hills. On the alleged tendency of the Arakan mud volcanoes to burst into eruption most frequently during the rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3.—On the Geology of the Andaman Islands. On a third species of Merycopotamus. Some observations on percolation as affected by current. Notice of the Pirthalla and Chandpur meteorites. Report on the oil-wells and coal in the Thayetmyo district, British Burma. On some antimony deposits in the Maulmain district. On the Kashmir earthquake of 30th May 1885. On the Bengal earthquake of 14th July 1885.

Part 4.—Geological work in the Chhattisgarh division of the Central Provinces. On the Bengal earthquake of July 14th 1885. On the Kashmir earthquake of 30th May 1885. On the results of Mr. H. B. Foote's further excavations in the Billa Surgam caves. On the mineral hitherto known as Nepaulite. Notice of the Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1.—Annual report for 1885. On the International Geological Congress of Berlin. On some Palæozoic Fossils recently collected by Dr. H. Warth, in the Olive group of the Salt-range. On the correlation of the Indian and Australian coal-bearing beds. Afghan and Persian Field notes. On the section from Simla to Wangtu, and on the petrological character of the Amphibolites and Quartz Diorites of the Sutlej valley.

Part 2.—On the Geology of parts of Bellary and Anantapur districts. Geology of the Upper Dehing basin in the Singpho Hills. On the microscopic characters of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Karnul Caves. Memorandum on the prospects of finding coal in Western Rajputana. Note on the Olive group of the Salt-range. On the discussion regarding the boulder-beds of the Salt-range. On the Gondwana Homotaxis.

Part 3.—Geological sketch of the Vizagapatam district, Madras. Preliminary note on the geology of Northern Jesalmer. On the microscopic structure of some specimens of the Malani rocks of the Arvali region. On the Malanjkhandi copper-ore in the Balaghat district, C. P.

Part 4.—On the occurrence of petroleum in India. On the petroleum exploration at Khátan. Boring exploration in the Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3. Turkistan. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice of the Nammianthal aerolite. Analysis of gold dust from the Meza valley, Upper Burma.

Vol. XX, 1887.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1905. [November.

MEDLICOTT AND BLANFORD.

THE joint-authorship of the first Manual of Indian Geology has served to link together the names of Medlicott and Blanford in the minds of many scientific men, who were not aware of the close partnership which existed between these two great men from the time they joined the Indian Service just fifty years ago. Now both have passed away in the same year and in the order of seniority observed throughout their official careers. When the news of Mr. Medlicott's death reached India in April last, Dr. Blanford, as the one conspicuously most suitable, was asked to review his friend's services to science; but before the note printed below could be set up in type, or its receipt even acknowledged, the sad news arrived that its author too had gone: the last effort of a literary activity, hardly surpassed in the history of science, was thus spent characteristically on an appreciative memorial to a fellow-worker.

[T. H. HOLLAND.]

H. B. MEDLICOTT, M.A., F.R.S.

HENRY BENEDICT MEDLICOTT was born at Loughrea, County Galway, Ireland, on August 3rd, 1829. He was the second of three sons of the Rev. Samuel Medlicott, Rector of Loughrea, and of Charlotte, daughter of Colonel H. B. Dolphin, C.B. His elder brother, Joseph G. Medlicott, was also for several years on the staff of the Geological Survey of India. Henry Medlicott was educated in France, Guernsey, and Dublin, where he graduated at Trinity College and took the degree of A.B. in 1850, with diploma and honours in the School of Civil Engineering. He took the M.A. degree in 1870.

He was thus, from his early education, an excellent French scholar, and his acquaintance with the classical works of the great French geologists may be often traced in his writings.

In 1851 he joined the Geological Survey in Ireland, and in 1853 he was transferred to the English Survey, where, for a time, he worked with Mr. Aveline in Wiltshire. He was then engaged by Dr. Oldham for India, and joined the Geological Survey, then occupied in the Rájmahál Hills, at or near Bhagalpur, on March 24th, 1854. His brother, J. G. Medlicott, had joined the Survey a year or two earlier. Before, however, Henry Medlicott had commenced field work, he was appointed, in August 1854, by the Court of Directors of the East India Company, Professor of Geology in Rurki College, and he remained in this post till October 1862, when on some additions being made to the staff of the Geological Survey, he rejoined it as Deputy Superintendent for Bengal.

During his tenure of the Rurki Professorship, however, he did most important work in field geology. By an arrangement with Dr. Oldham he was allowed to occupy the field season in surveying, and thus he was enabled to examine part of the Nerbudda Valley and Bundelkhand in 1854-55 and in 1856-57, whilst in the other years he was engaged in working out the geology of the Lower Himálayas between the Ganges and the Rávi (Hardwar to Dalhousie) and of the Siwálik beds and their associates at the base of the mountains. In 1857 he served as a volunteer, with the garrison of Rurki, against the mutineers of the Bengal army, and on the close of the campaign was awarded the Indian Mutiny Medal for Special Service. An instance of the service rendered may be added here.

Rurki, during the outburst of the sepoy mutiny, was isolated, like most of the small garrisons in the Upper Provinces, where the natives of the villages were associated with the rebels. No European could possibly traverse the country in safety. News was received at Rurki, one day, of a Christian family who were held by the villagers as prisoners at a few miles' distance, and who were in imminent danger of being killed. It was arranged that Henry Medlicott and one other European companion should go out with an escort of sowars to endeavour to rescue these unfortunate people; but on the day before the attempt, the sowars showed signs of mutiny and were disarmed. Medlicott and his companion, whose name appears now impossible to trace, left in the morning, and by sheer pluck, at the risk of their lives, succeeded in bringing back the imprisoned people in safety, the villagers apparently being so astonished at two Europeans coming among them that they surrendered their prisoners. Only the outline of the story can be recovered: it was told to the present writer in 1866 by Colonel Baird Smith, who commanded the Rurki garrison in 1857.

After rejoining the staff of the Geological Survey in 1862, Mr. Medlicott was engaged for many years, first in one part of the country, then in another, generally by himself, though occasionally in charge of a party, in enquiring into economical problems or in investigating geological questions, and not infrequently in clearing up difficulties that had proved too serious for his predecessors. In 1862-63 he was in South Rewah; in 1863-64 in Behar; in 1864-65 he traversed Assam from the farthest eastern extremity of the province to the Khasi Hills; in 1865-66 he was in Central India and Rajputana. In other years he examined various tracts from the Jammu hills of Kashmir, the Satpura ranges of the Central Provinces and Chhattisgarh to the Garo Hills in Assam. Twice he officiated as Superintendent of the Survey during Dr. Oldham's absence on leave, once in 1870 for a short period, and in 1873-74 for seventeen months.

On April 1st, 1876, Mr. Medlicott succeeded Dr. Oldham as head of the Survey, and from that time the duties of his office kept him mainly in Calcutta. The title of Superintendent was altered to that of Director in 1885, but the change was confined to the title.

Dr. Oldham had been in weak health for some time before he retired, and he naturally left many arrears for his successor to carry out. Foremost among these was the preparation of a general account of Indian Geology. This had long been required: a mass of scattered papers and reports, not a few of which were in manuscript, represented about a quarter of a century's progress in the systematic examination of Indian Geology, and before those who had helped from the beginning had left India for good, it was essential that they should prepare a record of the work in which they had taken part, for the information of their successors. Moreover, until a general description of the country as a whole was compiled, it was impossible for any one, either in India or in Europe, without an enormous amount of labour, to gain a correct idea of its geological features. Henry Medlicott at once set to work at this general account, and dividing the chapters between Mr. Blanford and himself, brought it to a conclusion in 1879, and published the "Manual of the Geology of India." It is unnecessary to point out the great importance of this book, or the assistance it has afforded not merely to Indian geologists, but to those throughout the world.

This, however, is only one of the subjects to which the new Superintendent of the Survey devoted his attention. Of the effect of his superintendence on the work of the staff, a fair example may be furnished by the Survey publications. From 1877 the *Records* which, as describing recent work, are the best illustrations of Survey progress, doubled in size, and they certainly did not fall off in the importance of the contributions printed, either economic or scientific. Besides these, Mr. Medlicott edited, during his tenure of office, about ten volumes of the *Memoirs*, and numerous parts of the *Palæontologia Indica*, comprising Dr. Feistmantel's descriptions of Gondwána plant fossils, most of Mr. Lydekker's accounts of the Siwálik and other vertebrata, and the largest portion of Dr. Waagen's great work on the Salt Range fossils, and of the descriptions of Tertiary corals and echinoderms from Western India by Dr. Duncan and Mr. Percy Sladen. There was the same thorough progress in other directions, for instance, in the arrangement of the Museum and Survey offices. His work absorbed him entirely. Living almost the life of a hermit, and confining himself to his office, he devoted all his time to the Survey. He was a man of retiring disposition originally, not in the least from want of energy or courage, but because the social pursuits of men in general did not attract him; he had, in fact, something of the ascetic temperament.

After the completion of his 55th year in 1884, Mr. Medlicott was retained by the Government in his office until 1887. He retired on April 27th in that year, having served almost continuously for rather more than 33 years. He was only on leave for 6 months in 1865, less than 6 months in 1871, and again 6 months in 1884, or 18 months during the whole period of service.

After his retirement he lived very quietly at Clifton near Bristol and took but little part in scientific discussion, though always keenly interested in the progress of the Indian Survey. His time, as long as he remained in good health, was mainly devoted to philosophical problems, to which he had always been devotedly attached. He published two short pamphlets on "Agnosticism and Faith" in 1888, and on "The Evolution of Mind in Man" in 1892, and was engaged on a large work which has not been finished. A few years since a strain caused by bicycling led to serious symptoms, and although for a time a partial recovery was made, a relapse early in 1904 reduced him greatly. The end came quietly on April 6th, 1905, when he was seated in his study.

Medlicott joined the Geological Society of London in 1856 and received the Wollaston Medal in 1888, on his retirement from the Indian Service. He was elected a Fellow of the Royal Society in 1877. He was a Fellow of the Calcutta University, and from 1879 to 1881 he was President of the Asiatic Society of Bengal. He was also Honorary Fellow of several Foreign scientific societies, but he never made use of his titles, which he regarded as simply "official." It may be remarked that he carefully omitted the letters F.R.S. after his name in all his Survey publications, and even in the "Manual" he struck out the initials after his own name, whilst leaving them after his colleague's. Throughout his career, in fact, he appears almost unnecessarily to have disregarded the honours to which he was entitled for brilliant original work as well as good official service.

His policy as head of the Survey was to assist his colleagues, in every way, to publish the account of their observations in their own words. Occasionally the result was that their views drew upon the authors replies from other officers, who took different views, or from geologists who had another opinion on the subject. This was especially the case in palæontological questions, on which he never pretended to decide difficult points. He published both views. The policy adopted is perhaps not quite in accordance with official usage, but there can be no doubt that the result of Medlicott's principle was to bring out the facts in a discussion, and not unfrequently in a difficulty of high scientific and economic importance, as in the various disputes over the Gondwána flora. And not only did he obtain the help of the staff of the Survey in forwarding the progress of Indian Geology, but he succeeded in securing the valuable assistance of the late General McMahon and others, who contributed observations on subjects of high interest in the geological history of the Indian Empire. That he contributed no lengthy memoirs of his own was simply due to the fact that he regarded with horror any attempt to gain credit by others' work. Short notes and an annual report were for many years his sole contributions to the Survey publications. He was not a fluent writer, though he could write strongly and earnestly, never so strong as when he was dealing with attempts at injustice or plausible but misleading statements. He was absolutely fearless, and cared but little whose pet theory he was disputing, if the theory was in his opinion worthless.

It is difficult to appreciate Henry Medlicott's work in India without some acquaintance with the knowledge of the geology available when he entered the Service. So great a change has taken place in the half century that has elapsed since 1854, that it is scarcely possible to reconstruct the conditions under which geological surveying was carried out fifty years ago. There were no railroads and very few roads. Travelling was difficult and very slow. The early surveyors had often to make their own maps in the wilder parts of the country. Some idea of the geology known in the days before the Survey may be gained from Dr. H. J. Carter's Summary of the Geology of India between the Ganges, the Indus, and Cape Comorin, published in 1854, the year that Mr. Medlicott landed in India. In this remarkable work, to take only one instance out of many, Vindhyans and Gondwánas, both upper and lower, with limestones from every formation in India, from metamorphics to the Bágh beds and intertrappeans, are included in the "Oolitic Series." An equally remarkable confusion is shown by Greenough's Geological Map of India published about the same time.

Nothing had been done to clear up the nebulous condition of Indian Geology before 1854. Henry Medlicott's first season in India was signalised by the earliest and most important step in the classification of the Peninsular rocks. He and his brother, J. G. Medlicott, separated the Vindhyans north of the Nerbudda valley from the Gondwánas to the south. The name Vindhyan was given by Dr. Oldham, who, however, when announcing the discovery (*Journal, Asiatic Society, Bengal*, 1856, vol. XXV, p. 250, and more clearly *Memoirs, Geological Survey, India*, vol. II, p. 304), stated that the separation had been made by the Medlicotts before he visited the country. In the first memoir he wrote (vol. II of the *Memoirs*) Henry Medlicott reduced the whole mass of Vindhyans, infra-Vindhyans and Bijáwar rocks, that extend throughout Bundelkhand, to a sequence which has received no great subsequent alteration, the principal change, perhaps, being in the substitution of the term Lower Vindhyans for Sub-Kymores. This masterly paper, though published in a most imperfect condition, ill-arranged and not very clearly written, was not only the beginning of our accurate knowledge of the Vindhyan and infra-Vindhyan rocks, but a firm foundation on which much since has been built. From his earliest work to his latest, these wonderful azoic rocks of India were Mr. Medlicott's especial favourites, perhaps because all the knowledge of them was derived from purely physical observations, and not interfered with by organie remains, which in the younger Gondwánas have not always proved an accurate indication of the age of the beds or their relations to each other. Throughout the annual reports issued during his Directorship, point after point is brought forward tending to the correlation of these formations in various parts of India, and showing the relations between Kurnool and Cuddapah, Kaládgi, Gwalior, and many other similar rocks on the one hand, and the Vindhyan and Bijáwars on the other.

The next great work of his was the arranging of the rocks of the Lower Himálayas in the Simla and neighbouring areas, and of the Siwálik rocks and their associates at the base of the mountains, and of first sketching the history of the Himálayan range on a definite geological basis. The first named has been one of the most difficult questions in Indian Geology, and although the work was commenced in 1855, it cannot be regarded even now as nearly solved. The Tertiary Himálayan beds have, however, been fairly classified since Mr. Medlicott's memoir was published in 1864. The important observations made in this memoir are essentially physical. The demonstration that Himálayan elevation is shown, by the relations of the lower nummulitics to the older hill rocks, not to have begun before Tertiary times, and the beautiful illustration proving the permanence of the great river valleys by their coincidence with the maximum of conglomerates in the Siwáliks are amongst the observations that connect our first clear ideas of Himálayan elevation with Henry Medlicott's work.

It has been already noticed that not unfrequently Medlicott was occupied in clearing up difficulties that had been too great for his predecessors in the Survey. An illustration may be taken from the geology of the Khási Hills. A comparison of his observations as recorded in the VIIth volume of the *Memoirs*, should be made with the earlier account of the same area in the 1st volume. In the first account, amongst other differences, the bedded Sylhet traps (Mesozoic) are not distinguished from the ancient greenstone rocks of the inner hills, and the occurrence of fossiliferous Cretaceous rocks was not recognized; their fossils, then supposed to have been nummulitic, having been lost. The alterations that were made in the geology by Medlicott may be seen by comparing the map and section on Pl. VIII in vol. I, with the map and section at p. 154 in vol. VII. The earlier observations, it is true, were made in the monsoon, when, of course, the ground was not so well exposed. Again, the sketch map of the Satpura or Nerbudda coal area as corrected by Henry Medlicott in vol. X of the *Memoirs* may be compared with the earlier map published in vol. II. It was quite true that the principal discrepancy in this case is easily explained. J. G. Medlicott, who not merely geologically examined the country, but who also to a considerable extent surveyed the map, had practically completed the western portion containing the typical Mahadevas, without separating them from the underlying Damudas, when, in the early part of 1856, Dr. Oldham, the head of the Survey, went over the field, and almost at the end of the season, discovered that the Mahadeva was a separate series. The attempt to record this distinction on the map led to some confusion which was subsequently straightened by Medlicott.

Almost his only important geological paper published outside the Survey publications was that on "The Alps and the Himalayas, a Geological Comparison," issued in the *Quarterly Journal of the Geological Society* for 1868, vol. XXIV. This paper narrowly escaped rejection; it was postponed for a time, but finally published. Nor was this wonderful, for it attacks, and in no doubtful way, the conclusions of all the great Alpine geologists, von Hauer, Gümbel, Studer, Desor, and others, and there is no question that in the main Medlicott was right. Some of the views expressed by him required, and have since received, revision; but as an original description of mountain-building from uniformitarian views as opposed to catastrophic it is worth far more attention than it has received.

There can be no question of his uniformitarianism. One of his objections to some of his colleagues' work was to their use of faults to explain abrupt boundaries. It is, however, characteristic of his love of truth that when Mr. R. D. Oldham found that the typical Náhan-Siwálik section, to which Henry Medlicott had so long referred as an example of deposition against a pre-existing cliff, might be a fault after all, he revisited the section and in the simplest manner admitted that he had misunderstood it (*Records, Geological Survey, India,* XIV, 1881, p. 169). Only those who remembered the whole controversy about faults can have any idea of how great a blow to his theories this must have been, and there are few Directors of Surveys of whom it could be said that an error of so much importance was so frankly acknowledged.

On the large question, whether, for instance, the great lines terminating the Gondwána basins of Bengal, Orissa, and the Central Provinces are simple faults, or whether they represent the boundaries of the old river valleys to which the beds were limited, these boundaries having been subsequently slightly crushed and distorted, but not greatly faulted, is a question to which a complete answer has not yet been given. In some cases at least, for instance in the Mohpáni field of the Sátpuras, strong evidence was brought forward by Medlicott in favour of his views of his original limit, and even in the case of Rániganj, where unquestionably considerable faulting exists, the absence of outliers of the coal-bearing rocks south of the field is a difficulty in supposing that a simple great upthrow alone terminates the Gondwána area. Between the two authors of the Manual of Indian Geology there was a difference of opinion on this point, and it cannot be said that the question is finally decided.

The above may serve to recall a few of the services of Henry Medlicott to the Geological Survey and to India, and some of the discoveries which he made in science. It cannot do more than suggest the amount of labour that he devoted to his work. His memory should remain as a striking example of a thoroughly honest and capable geologist and as a worthy head of a scientific branch of the Indian Government Service.

[W. T. BLANFORD.]

W. T. BLANFORD, A.R.S.M., LL.D., C.I.E., F.R.S.

WILLIAM THOMAS BLANFORD was born in London on the 7th October 1832, and was educated at Brighton and in Paris. After a short interval of business life in Italy and London he matriculated in 1852 at the Royal School of Mines, London, where, with his younger brother, the late Henry F. Blanford, F.R.S., he had the privilege of training under a group of famous teachers in science—Lord Playfair, Sir Andrew Ramsay, Sir Warington Smyth, Edward Forbes, and T. H. Huxley under the directorship of Sir Henry De la Beche. The Blanford brothers successively headed the list of candidates at the final examinations, each in his year receiving the Duke of Cornwall and the Council scholarships. After further training at the Freiberg School of Mines, both brothers were appointed to the Geological Survey of India and joined at Calcutta in September 1855.

Henry Blanford some years later was transferred to organize the Meteorological Department, whilst his brother remained in the Geological Survey until his retirement from the service in 1882.

A simple extract from the annual distribution lists will show the wide experience obtained, and, to those who knew him, the great influence exercised by W. T. Blanford on Indian Geology:—1855-56, Orissa coalfields; 1856-57, Rájmahál hills; 1857-58, the Orissa coastal tracts; 1858-59, Ániganj coalfield, Trichinopoly, Nilgiris, Birbhum; 1860, Pegu; 1861, Upper Burma; 1862—65, various parts of the Bombay Presidency, Sind, and Central Provinces; 1866, Godávari area, Central Provinces; 1867-68, Abyssinia; 1869-70, Wardha valley, Central Provinces, Sikkim; 1870-71, Lower Godávari, Madras Presidency; 1871-72, Sind and Persia; 1874-75, Surát and Sind; 1876, Rájputána; 1877—1879, Calcutta; 1881-82, Baluchistán and Punjab.

During this period, when much of his time was occupied by purely official routine work and in travelling, at a time when neither railways nor roads were developed in India as they are now, Mr. Blanford published just 150 scientific papers, many of which were large memoirs, all descriptive of original work, not merely details of observation, but contributions to the philosophical aspects of geology and zoology which have made some of these papers classical works. His services to science were naturally recognised in Europe: in 1874 he was elected a Fellow of the Royal Society; in 1881, whilst representing India at the International Geological Congress at Bologna, he was elected a Vice-President of the Congress, and was decorated by the King of Italy with the Order of St. Maurice and St. Lazarus. He was also Vice-President of the Congress on three subsequent occasions—Berlin 1885, London 1888, and Paris 1900. On his retirement from the Indian Service in 1882, the Geological Society of London conferred on him the highest distinction at their disposal, the Wollaston medal. In 1884, he was selected President of the Geological section of the British Association at Montreal, and at the same time the McGill University conferred on him the honorary degree of LL.D. He was elected President of the Geological Society of London in 1888, served three times as Vice-President of the Royal Society, and on other occasions as Vice-President of the Zoological and the Royal Geographical Societies.

Although much of his time was taken up after his retirement with his duties as a member of Council or as an office-bearer in the various scientific societies of which he was such an active member, Dr. Blanford added another 24 papers to his enormous record of scientific work, these including three volumes of the Fauna of British India, and his well known memoir on the distribution of Indian vertebrates, for which he received the Royal medal of the Royal Society in 1901.

Those who enjoyed the inestimable privilege of his friendship will agree that Blanford's enormous record of published work was not greater than that which he freely contributed to friends in private correspondence. Amidst his duties at home he never failed to respond to a question or difficulty presented by the most junior member of his old Department: no section of Indian Geology appeared to be too small or local to be considered worthy of his earnest attention, and times without number, during the recollection of the writer, by private correspondence he has given his successors new lines for profitable research, pointed out, by his unique knowledge of literature and width of experience, the significance of new observations, and has frequently saved his less experienced juniors from the pitfalls of hasty deductions drawn from imperfect data in this country, where the paradoxical character of the Geology is as liable as its Sociology to exemplify in the new-comer the dangers of a little learning.

It would not be possible in a few pages to even enumerate the many ways in which Blanford influenced the lines of Indian Geology, as well as moulded the working principles of the science generally. But possibly the feature of his career of most interest to India was the way in which he brought his wonderfully wide range of information, and his well known ability to sift the value of apparently contradictory evidence, to bear on the tangled controversy with regard to the age of the Gondwána system. Dr. O. Feistmantel, the official Palæontologist of the Department, who was mainly a palæobotanist, following with conservative faithfulness the accepted principles of correlation with the European order of succession, enumerated the plant forms occurring in the different stages of the Gondwána beds, and by comparison of them with the types known in European systems, placed the lower (Talchir) limit of the Gondwánas on a level with the European Trias, whilst the uppermost beds in Cutch he correlated with the Lower Oolite [1]. Dr. Blanford, however, laid stress on the greater value of marine forms in the Cutch beds as indicating an age for the uppermost Gondwánas as young as the uppermost Jurassic of Europe, whilst as

[1] O. Feistmantel. *Rec. Geol. Surv. Ind.*, IX, 28 and 63, 1876.

regards the lowest stages he brought in indirect evidence obtained in Australia, where similar fossil plants having a Mesozoic facies were associated with, and even lying below, undoubtedly Palæozoic marine beds. He thus showed the accuracy of the opinions previously expressed by T. Oldham and H. F. Blanford with regard to the Palæozoic age of our productive coal measures.[1]

Following up this subject in his Presidential address to the Geological section of the British Association at Montreal in 1884, he summed up a mass of biological statistics to account for the apparent contradictions in the order of succession of plants and animals in the beds of intermediate position and age, demonstrating the truth of the prevision made fifteen years before by Huxley, that on isolated land-areas animals and plants have their own special rates of evolutionary development, and that it is only by the forms living in the ocean, under more uniformly distributed physical conditions and with greater freedom for migration, that approximate contemporaneity can be obtained in stratigraphical correlation.

Five years later, as President of the Geological Society of London, Dr. Blanford was able to assume without question the truth of the Gondwána proposition, and from it to draw conclusions affecting the much debated question of the permanence of oceanic depressions and continental plateaux. He then brought together in his inimitable way a mass of apparently isolated and unrelated data to show that, "not only is there clear proof that some land-areas lying within continental limits have at a comparatively recent date been submerged over 1,000 fathoms, whilst sea-bottoms now over 1,000 fathoms deep must have been land in part of the Tertiary era, but there are a mass of facts both geological and biological in favour of land-connection having formerly existed in certain cases across what are now broad and deep oceans."

Whether considered from the standpoint of a philosopher in his recognition of identity amidst apparent diversity in phenomena of independent branches of science, or regarded merely as a patient worker in the accumulation of descriptive detail, Dr. Blanford's record would place his name in the front rank of scientific workers. And to those who knew him the great range of his knowledge was no more remarkable than his unfailing generosity of disposition and courtesy of manner either to friend or opponent.

[T. H. HOLLAND.]

[1] W. T. Blanford. *Rec. Geol. Surv. Ind.* IX, 79, 1876.

As a Naturalist William Thomas Blanford has raised for himself a monument that will withstand the assaults of time, for it was patiently built of attested material upon a foundation of unique width. Whether as observer or writer, he will always be remembered as one of the foremost of those who brought Indian Zoology out of the region of chaos.

No one can be more wise than destiny; and by the nature of things the greater part of Blanford's zoological work was of a descriptive kind; but the imagination of an interpreter was constantly behind it.

Of this descriptive work, a very great part of which refers to collections made by himself, the earliest to appear in print (1860) was that on the Land and Fresh-water Mollusca of India and Eastern Asia. This was a subject in which, as a Geologist, he naturally had a particular and perennial interest, and the very last zoological paper that he wrote was one, describing some new Indian and Burmese species, published, just before his death, in the Proceedings of the Zoological Society.

Of his work in this field one of the most important results was a series entitled "Contributions to Indian Malacology," which appeared at intervals in the Journal of the Asiatic Society of Bengal between 1860 and 1880. Though chiefly of taxonomic value, these papers record numerous facts of anatomy, and are often animated by judicious observations upon such matters as geographical distribution, the interpretation of specific and varietal characters, the influence of environment, etc., all revealing the author's philosophic breadth of touch. That the final product of these critical investigations would form one of the volumes of his own "Fauna of British India" was an expectation that is, unhappily, unfulfilled.

While still busy in many other directions, Blanford, in 1867, made his first contribution to Indian Ornithology, the starting-point of a comprehensive series of papers, which, published from time to time during the following 27 years in various scientific journals, took finished shape in two of the four well-known volumes on Birds in the "Fauna of British India." In these two volumes all the birds except the Order of Passerines are included; and their treatment at the hands of an author who combined the qualifications of the expert, of the field-naturalist, and of the sportsman, appeals with equal appreciation to the trained Ornithologist and to that large company of educated people who take a general interest in living nature.

His connection, as Naturalist, with the Abyssinian Expedition of 1868, seems to have led Blanford to pay attention, among other things, to recent Reptiles and Amphibia; for between that year and 1881 he contributed to various scientific serials a number of papers in which many new species in these groups are described, chiefly from collections made during his own travels in north-western India, Baluchistan, and Persia, as well as in certain parts of the Peninsula. In respect of the reptilian fauna of the Indo-Persian desert region, Blanford came to be regarded as one of the leading authorities: here, as was generally the case, his knowledge of the fauna was part of a large organised knowledge of the country in its physical aspects and its geological history, acquired at first hand.

From 1868, too, dates Blanford's first published work on recent Mammals, another group of animals which he approached from many points of view. He was in working touch with Mammals for 35 years, and, as in the case of the Birds, his old experience was condensed into a volume in the "Fauna of British India"—another volume which is of the greatest use to the field-naturalist and amateur, without any detraction from its value as a standard scientific work.

In 1870 Blanford published his "Observations on the Geology and Zoology of Abyssinia," and in 1876 his "Zoology and Geology of Eastern Persia," the former dealing with land-vertebrates and mollusca, the latter with land-vertebrates alone. Both books are distinguished by that comprehensiveness, discernment, and balance, which characterize all their author's zoological work. His varied observations are digested: his materials are proportioned and attuned; and we get not merely a good description of a fauna, but also some notion of the manner in which the several differences of environment have affected its component parts.

Blanford's experience, grown ripe in bringing into order the results of 27 years of scientific survey of this and neighbouring countries, gave him such a unique position, that when, in 1883, he was chosen to organize an official work on the "Fauna of British India," it was felt that official and professional judgment were in complete accord.

Under his able editorship 18 volumes of this official serial have been published, and they include the whole of the Vertebrates and portions of 10 groups of Arthropods—chiefly Insects. Reference has already been made to Blanford's own contribution to the series—

the volume on Mammals, the first instalment of which appeared in 1888, and the two volumes on Birds, published in 1895 and 1898: these volumes, in their clearness and directness of style, in their moderation in matters of nomenclature and species-splitting, and in their freedom from all the delusions of faddism, are models of what a work of general reference should be.

The series is still far from complete; but to find a successor to carry it to a worthy conclusion—a successor possessing the ripe and varied knowledge, the fairness of mind, the tact, and the general wisdom of the first editor—will in truth be no easy task.

To those interested in the finer problems of zoology the most taking parts of Blanford's work are his essays on the geographical distribution of Indian animals. This subject, indeed, was at the back of all his systematic papers, and was separately treated by him, in a tentative way, as early as 1870. But in 1876 he published, in the "Annals and Magazine of Natural History," a critical and constructive paper, in which the elements of the Indian vertebrate fauna are segregated from a physiographical standpoint, their relations to the Ethiopian fauna are emphasized, and the argument that certain common elements suggest a vanished land-connection between South Africa and the Indian Peninsula is clearly stated.

Twenty-five years later the material accumulated in the compilation of the "Fauna of British India" was used by him for an exhaustive examination of this subject, and in 1901 he crowned his zoological work with an elaborate essay entitled "The Distribution of Vertebrate Animals in India, Ceylon, and Burma," which was published in the "Philosophical Transactions of the Royal Society."

In this fine monograph the entire land and fresh-water vertebrate fauna of the region is critically analysed by genera, and is split, by considerations of habitat, into definite geographical units: these, again, are recombined into subregions, the relations of which to each other, to neighbouring zoological regions, and to past geological land-connections and former geological climates being minutely and most effectively discussed.

It was characteristic of Blanford, in connection with this subject, upon which his profound knowledge of cognate branches of natural science entitled him to speak with authority, that his views were expressed with singular moderation. Though he was among the first to realize that modern zoological regions which ignore past geological changes *on the large scale* must be artificial, and, conversely, that instances of what are commonly regarded as anomalies of distribution may possibly afford corroborative evidence of those very changes, he allowed his opinions to mature before giving utterance to them.

No notice of Blanford as a Zoologist would be complete that failed to emphasize his telling personal influence, and his abundant sympathy with all who were in any way interested in the natural history of this country. It seemed to be natural to apply to Blanford, and natural to Blanford to sacrifice his time in order to help others. No man ever showed a warmer side to the amateur, or was so entirely free from the narrow prejudice of the professional. Of liberal intellect, of just and charitable temper, he was imbued with the true scientific spirit. In the annals of Indian Science—

"*Notus in fratres animi paterni,*
Illum aget penná metuente solvi
Fama superstes."

[A. W. ALCOCK.]

LIST OF SCIENTIFIC PAPERS BY W. T. BLANFORD.

1854. "On a section lately exposed in some Excavations at the West India Docks": Journ. Geol. Soc., x, pp. 433-435.

1856. (With Messrs. H. F. Blanford and Wm. Theobald,) "On the Geological Structure and Relations of the Talcheer Coalfield in the District of Cuttack": Mem. Geol. Surv. India, i, pp. 33-88.

1859. "Note on the Laterite of Orissa": Mem. Geol. Surv. India, i, pp. 280-294.

1860. "On the Rocks of the Damúda Group, and their Associates in Eastern and Central India, as illustrated by the Re-examination of the Ràniganj Field": Journ. As. Soc. Bengal, xxix, pp. 352-358.

1860-1. (With Mr. H. F. Blanford) "Contributions to Indian Malacology": Journ. As. Soc. Bengal, xxix, pp. 117-127, and xxx, pp. 347-367.

1861. "Note on the Geological Structure and Relations of the Ràniganj Coalfield, Bengal": Mem. Geol. Surv. India, iii, pp. 1-195.

1861. "Note on a species of *Plectopylis*, Benson, occurring in Southern India": Ann. Nat. Hist., vii, pp. 244-246.

1862. "Contributions to Indian Malacology, No. 3: Descriptions of new Operculated Land-Shells from Pegu, Arakan, and the Khasi Hills": Journ. As. Soc. Bengal, xxxi, pp. 135-144.

1862. "Account of a Visit to Puppádoung, an Extinct Volcano in Upper Burma": Journ. As. Soc. Bengal, xxxi, pp. 215-226; Rep. Brit. Assoc., pt. ii, pp. 69-70.

1863. "On Indian Species of Land-Shells belonging to the genera *Helix*, Linn., and *Nanina*, Gray": Ann. Nat. Hist., xi, pp. 81–86.

1863. "On the Animals of *Raphaulus*, *Spiraculum*, and other Tube-bearing Cyclostomacea": Ann. Nat. Hist., xii, pp. 55-58.

1863. "Descriptions of *Cremnobates Syhadrensis* and *Lithotis rupicola*, two new Generic Forms of Mollusca inhabiting Cliffs in the Western Ghats of India": Ann. Nat. Hist., xii, pp. 184–187.

1863. "Contributions to Indian Malacology, No. 4: Descriptions of New Land-Shells from Ava and other parts of Burmah": Journ. As. Soc. Bengal, xxxii, pp. 320–327.

1864. "On the Classification of the Cyclostomacea of Eastern Asia "Ann. Mag. Nat. Hist., xiii, pp. 441–465.

1865. "Contributions to Indian Malacology, No. 5: Descriptions of New Land-Shells from Arakan, Pegu, and Ava, with Notes on the Distribution of Described Species": Journ. As. Soc. Bengal, xxxiv, pt. 2, pp. 66–105.

1865. "On the Manner of Occurrence of the Reptilian Remains found in the Panchet Beds of the Rániganj Coalfield, and on the probable conditions existing at the time when these rocks were deposited" [1865]: Pal. Ind. (Pret. Vert.), i; 1865–85 (pt. 1), pp. i-iii.

1865. "On the Stratigraphy and Homotaxis of the Kota-Maledi (Maleri) Deposits" [1873]: Pal. Ind. (Pret. Vert.), i. 1865-85 (pt. 2), pp. 17 (*bis*)-23.

1866. "Contributions to Indian Malacology, No. 6: Descriptions of New Land-Shells from the Nilgiri and Anamullay Hills and other places in the Peninsula of India: Journ. As. Soc. Bengal, xxxv, pt. 2, pp. 31–42.

1866. "Contributions to Indian Malacology, No, 7: List of Species of *Unio* and *Anodonta* described as occurring in India, Ceylon, and Burma": Journ. As. Soc. Bengal, xxxv, pt. 2, pp. 134–155.

1866. "On *Opisthostoma*, H. Blanford, with the Description of a New Species from the Neighbourhood of Bombay, and of the Animal and Operculum (*O. Fairbanki*)": Proc. Zool. Soc., pp. 447–451.

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PRELIMINARY ACCOUNT OF THE KANGRA EARTHQUAKE OF 4TH APRIL 1905. BY C. S. MIDDLEMISS, B.A., F.G.S., *Superintendent, Geological Survey of India.* (With Plates 14 and 15.)

CONTENTS.

1.—INTRODUCTION.

Brief outline of the shock: its great range and importance.

AFTER a lapse of only eight years since the great earthquake of 1897, India has again suffered a similar, though somewhat less intense calamity, in the disastrous shocks of the 4th of April last. Whilst that of 1897 originated in Assam and Northern Bengal, the starting-point of the present earthquake was the Kángra district of the N. W. Himālaya. Beginning at an early hour of the morning, when many people were still asleep, the more violent phases of the shock dealt summary destruction to life and property in the neighbourhood of the Kángra valley and Dharmsála; accomplished very great damage and caused considerable loss of life in the hilly tracts of Mandi State and Kulu; did serious damage to Dehra Dun, Mussoorie, Chakráta, and other towns in the vicinity; and slight damage to the large towns of Lahore, Amritsar, Jullundur, Saháranpur, and others similarly placed with reference to the centre. Outside these points, again, in ever-widening closed curves, the earthquake was felt with continually diminishing intensity, until the limits of its appreciation by the unaided senses coincided roughly with part of an ellipse passing through the following localities:— Quetta, Surát, Ellichpur, False Point, and Lakhimpur. This curve, if continued, passes into the little-known and unreported-on regions of the higher Himālaya and Tibet; but it may be trusted to represent approximately the limit of sensible appreciability in that direction also, and to include a total area of about 1,625,000 square miles. Finally, outside these points (save for a few doubtful observations from isolated places) the record of the now greatly reduced vibrations is instrumental alone, but at the same time very complete. Not only did the seismological stations of India and the Far East—including those of Bombay, Kodaikanal, Calcutta, Batavia, New Zealand, and Japan—automatically register the earthquake, but so also did those of Europe and America, the records being unmistakably those of a very powerful shock. The earthquake must therefore be regarded as a notable one in the seismological history of the present and just concluded centuries, and, inasmuch as 20,000 human beings are estimated to have perished by it, it must also be ranked as one of the most disastrous of modern times.

Organization of its investigation.

Owing to the interruption of communications, it was not until the 6th of April that the full significance and magnitude of the shock became generally known in India, and steps could be taken by this Department for the proper scientific investigation of it. By that date, however, telegraphic warnings were issued by the Director of the Geological Survey to all District Engineers, Meteorological Observers, Telegraph Masters, Railway officials, and others, through their respective Departments, to record in writing the exact time and other details of the shock. These were followed by letters sent to the principal newspapers inviting volunteers all over India to answer a formulated set of questions, and to help in other ways by furnishing exact data. Question-forms were also printed, and in due course despatched, to all the provinces through the above channels, as well as to Political Officers and Residents of Native States. For the personal gathering of detailed observations of the effects of the earthquake in the more seriously disturbed tracts, the following officers of the Geological Survey were deputed: Mr. R. R. Simpson (followed later by Mr. K. A. K. Hallowes) to Dehra Dun, Mussoorie, and the neighbourhood lying S.-E. of Simla;

Mr. E. H. Pascoe to Lahore, Jullundur, and other large cities of the plains, and myself to the epicentral tracts of Kángra, Mandi, and Kulu, lying north-west of Simla. Mr. R. D. Oldham (late of the Geological Survey, and the compiler of the account of the Assam earthquake of 1897) has been asked to collect all information available from the extra-Indian instrumental records.

Basis of the present account.

The present account—which must only be considered as a preliminary one—has been compiled as quickly as possible on my return to head-quarters from the field. It, therefore, makes no pretensions to finality, except as regards the general features and effects of the shock. Besides expressing the results of my own field-work, it is based (1) on special reports sent in by my colleagues, Messrs. Simpson, Pascoe, and Hallowes; and (2) on the results of a necessarily brief examination of over a thousand earthquake-forms returned filled-in by official observers all over India, as well as by a considerable number of private individuals, to whom, collectively at present, the best thanks of the Department are here expressed for their generous response, which will be recorded in full detail in the final memoir. In addition to the above as sources of information, mention may be made of the principal newspapers of northern India, which spared no pains in reporting the earthquake in great detail, and whose early telegraphic accounts I found an excellent guide for prosecuting my own particular enquiries.

2.—GENERAL ACCOUNT OF THE SHOCK: ITS SUPERFICIAL ASPECTS.

Its suddenness.

All reports gathered from places near the earthquake centre agree as to the suddenness with which the great shock came, and the absence of anything of the nature of a crescendo. In this respect it presents a feature common to most earthquakes of the destructive class. To obtain a very connected account of its inception and progress from eye-witnesses in the more violently affected areas, has, however, been impossible—partly from the fact that many of those who would have been best fitted to speak were overwhelmed and lost their lives; partly because, on account of the early hour, many were still asleep, or only just preparing to rise; and partly because, out of those who escaped with their lives, so many were incapacitated by wounds, injuries or fright, that only a small minority remained who might have made useful observations had not they at once been fully occupied in aiding the wounded and rescuing those buried alive. The silent testimony of the long death-roll is, however, sufficiently convincing as to the rapid development of the shock, and the absence of any reasonably prolonged warnings conveyed by the preliminary tremors. In Kángra and the civil station of Dharmsála the proportion of killed to living is exceedingly high, and indicates a proportionately sudden attainment of the maximum vibrations. In Dharmsála cantonment the single-storied barracks and bazars were mostly evacuated just in time by the able-bodied, whereas double-storied buildings became either death-traps or scenes of extraordinary escapes. If one allows 3 seconds for the severity of the shock to awake and impress itself on any one situated in an upstairs room, 2 more seconds to prepare for flight, and 5 more to traverse rooms and passages and to descend a staircase to the means of exit, we might, I think from the evidence before us, limit the time for escape to, in all, about 10 seconds after the commencement of the earthquake. Many who were fortunately situated, or alone, probably accomplished this; but in a crowded double-storied barracks the outlets would become congested, and confusion cause further delay; whilst (as was certainly the case with households) the search for the various members, especially children, must have delayed the escape too long, and so the occupants were caught and overwhelmed by the falling débris. Of reliable witnesses whom I interviewed, no one of those living in upstairs rooms who must have extended the moments of grace beyond about 10 seconds were able to get clear of the house before the crash came; and their ultimate escape was due to their protection by the fortuitous falling of wood-work, beams, etc.

In other localities along the epicentral tract there is also a consensus of opinion as to the suddenness of the shock, whilst even at Lahore and the neighbouring cities of the alluvial plains it is described as jerky and abrupt, following on preliminary tremors to be reckoned in seconds only.

Preliminary tremors.

That there were preliminary tremors of very brief duration is, however, clear from the accounts of survivors in the Kángra valley and neighbourhood, as well as at more distant points. In some cases in Dharmsála these preliminary warnings are stated to have enabled persons to leave their dwellings just in time. Although 135 perished in the big Gurkha barracks, such tremors are nevertheless implied by the fact that scarcely any of them were found killed in their beds. One account from McLeodganj bazar states that these first effects were of the "nature of tremulous vibrations" and were likened to the "rustling of leaves in the wind." In Dehra Dun, also, minor preliminary vibrations are recorded which enabled those who were awake to reach the door. In Mussoorie, according to an eye-witness, preliminary tremors lasted from 15 to 20 seconds; and the same were noticed in Landour by several people. In Lahore preliminary shocks with intervals appear to have lasted for about 11 seconds before the arrival of the main shock.

The main shock.

Regarding the nature, duration, and direction of the main shock or shocks, there is considerable diversity of opinion expressed in the narratives of observers within the epicentral tract. This is probably due, not so much to personal bias, as to actually subsisting differences in the character of the shocks, especially so in widely-separated areas differently aligned with reference to the actual centre. A common description of the main destructive oscillatory movement applicable to the Kángra valley and Dharmsála, and based on such scanty information as is available, is that it consisted of a violent horizontal shock from north to south followed by an equally violent counter-shock from the opposite direction. A few observers noticed a third shock like a "downward sinking." There is preponderance of evidence in favour of the second shock being slightly the more violent, or at least the more destructive of the two, inasmuch as it was during it that "everything collapsed." The evidence is not clear as to the time intervening between the two shocks, but it seems to have been from one to four seconds. Sometimes the evidence appears to be distinctly contradictory, but it is highly probable, as already stated, that there were actual differences in often closely related localities. That these shocks really were brief and of powerful intensity, rather than long-continued and moderate, seems a generally correct deduction from the havoc wrought to many strongly and solidly-built structures, as well as from the testimony of survivors. The evidence from the former source will be considered later under a separate heading. As regards testimony, it seems certain that not only was it a physical impossibility at Dharmsála to keep one's feet whilst standing or walking, but also that people were "thrown to the ground." A similar violent effect is related at Pálampur, at least in double-storied buildings, whilst even as far away as Bajaura in Kulu, where the shock was considerably less intense, men clung to trees to steady themselves and some were sent "sprawling on all fours."

Kangra.

At Kángra the mortality was so terrible, especially among Europeans and officials, that no accounts have come to us through the usual channels—a sad fact which must be left to speak for itself as to the devastation wrought.

Dharmsala.

At Dharmsála cantonments Captain Muscroft first felt a tremor, called out to his companions, and escaped outside where he was "thrown to the ground as the house crashed down amidst the roar of the two shocks."[1] The Kotwáli bazar, Dharmsála civil hill, was shaken to pieces in a few seconds, tilted upwards, it is said, by the first shock, which ran down from the hills above, and then sent crashing to the ground by a second shock which came from the opposite direction almost instantaneously.[2] Mr. Naurojee Khujoorina (of Messrs. Framjee & Co.) was an eye-witness at McLeodganj bazar, Dharmsála civil hill, and he says that he rushed out at the first shock. He looked into the valley and saw native houses falling one after the other, and as the second shock came his house collapsed into a heap of ruins.[3] In his report to the Geological Survey the same observer describes three shocks, first a tremulous vibration with a minute's interval between it and the second shock. No sound was heard before, but a "rattling noise with a shrill high note" preceded the second shock. Captain C. Stansfeld, 7th Gurkha Rifles, in his report, describes two distinct shocks with 3 or 4 seconds' interval. The houses fell flat and not to any one direction, and he thinks without any oscillation. The first shock woke him, then a roar came from the north or north-east. He ran out of the house and was thrown to the ground south-east or east.

Palampur.

Mr. A. H. Machean, of Clachnacuddin Tea Estate, reports three shocks, the second longer and more violent than the first and from the north-east or east. The third seemed a sudden circular shock in which all the buildings collapsed, followed by a sudden jerk from north-east and back again.

Baijnath.

Mr. F. A. FitzGerald, of the Baijnáth Tea Estate, was standing before a window open towards the south, when, preceded by a terrific roar, the house began to shake.

[1] *Pioneer* of 17th April 1905.
[2] *Civil and Miltary Gazette* of 16th April 1905.
[3] *Pioneer* of 19th April 1905.

He rushed outside with difficulty. The shock appeared to come from south to north beginning with a tremulous vibration, which increased in intensity until he was nearly thrown off his feet. His houses partially collapsed, trees swayed to within a few feet of the ground, birds rose from the trees with deafening shrieks and a cat and dog ran away terrified.

Summing up the meagre narrative evidence for the main shock in the Kángra valley and Dharmsála neighbourhood, the following characteristics are plainly established :—

(1) The sound was a roar or crash.
(2) There were two or three violent shocks.
(3) People were thrown to the ground.
(4) Buildings fell almost instantaneously into utter ruin.
(5) There was very great mortality.

Mandi and Kulu.

In the less violently affected parts of Mandi State and in Kulu, where everything points to a greater depth of the focus, the evidence is still scanty, owing largely to the fewer inhabitants and the absence of large towns and military stations. Fortunately, we have been supplied with detailed accounts by Colonel R. H. F. Rennick (Indian Army, retired), and General Osborn, both residents of the Kulu valley, and present at Bajaura on the morning of the earthquake. Neither of these observers record a distinct breaking up of the main movement into separate shocks. General Osborn states that the brief preliminary tremor increased with a regular accelerating motion till it reached its climax of greatest violence, remained at that for a few seconds, and then diminished and died away as it had begun. Colonel Rennick was awakened by the approach of an underground sound of the nature of a dull rolling noise, which became a roar like a bombardment when the main shock was established. Both observers place the direction of the vibration as approximately north and south, but whereas General Osborn puts the duration at 1½ minutes, Colonel Rennick estimates it at fully 5 minutes. The former also thought the vibration a fairly regular to-and-fro motion, whereas the latter observed a vertical component in the shock, which made the house and other things dance like "peas on a drum." Considerable damage was done to buildings, the upper stories of even well-built houses being partially wrecked. The loss of life was also great. Landslips and earth-fissures were a prominent feature as is natural in a country of steeply-carved mountain-slopes and precipices. These will be referred to again later. Captain A. T. Banon's account of the effects in the Upper Kulu Valley agrees substantially with the above. In a second letter, dated 6th May, he gives some further interesting details of the earthquake effects in the higher valleys north of the Dhauladhar range.

Summing up, we have for Kulu:—

(1) A dull, rolling noise which became a roar.

(2) The shock was a single, continuous vibration, increasing and diminishing regularly.

(3) People had to cling to trees for support, or were sent sprawling.

(4) Buildings show considerable damage, amounting to ruin in some cases.

(5) There was considerable mortality.

Dehra Dun-Mussoorie area.

In Dehra Dun, Mussoorie, and the neighbourhood the chief vibrations appear to have been horizontal, and to be once more divisible into two or three main shocks, or maxima of oscillation, accompanied by a rocking motion causing trees to sway, and sufficient to disturb the balance of people standing or walking. Estimates of duration vary from 15 seconds to 2 minutes. A positive bit of exact information is afforded by Colonel S. B. Burrard, R.E., F.R.S., Superintendent, Trigonometrical Survey, at Dehra Dun, who considered that the horizontal vibrations had a frequency of 3 per second, as also by Lieutenant H. W. Kettlewell of Landour, who estimated them at 4 horizontal vibrations per second. Some observers at Mussoorie noted 3 distinct shocks with intervals of 2 or 3 seconds. The earthquake sound was a moaning, rushing, rumbling or rattling noise, just before and accompanying the shocks. The direction was north and south or N. E.—S. W. There can be no doubt from the recorded sensations of observers, as well as from the evidence of damage to buildings, that the intensity of the earthquake was generally less at these places than in the greater part of Kulu or in the Kángra valley.

Summing up for the Dehra Dun-Mussoorie area we have:—

(1) Moaning, rushing and rattling sounds.

(2) There were two or three discontinuous shocks.

(3) People standing or walking lost their balance.

(4) Buildings show serious damage, chiefly fissures and cracks.

(5) Loss of life insignificant.

Lahore and other cities of the plains.

At Lahore, Amritsar, Jullundur, Saháranpur, Rurki, and other cities on the alluvial plains, where the energy of the earthquake had already been so greatly reduced by diffusion, that the fall of even parts of high and unstable buildings was a rare occurrence, the shocks are still often described as jerky and abrupt, and as causing considerable alarm. There were two or three distinct shocks, the second (where two are mentioned) being the stronger. Rumbling sounds were generally heard, but they are not recorded from Lahore. There was no difficulty in standing with feet wide apart. Trees rustled as in a strong breeze, and books and light articles as well as cupolas from towers were projected from their supports. The direction of the shocks was either very complex or else there was more than one distant source of them.

More distant effects of the shock.

Outside the limits just indicated, the progress of the shock must for the present be followed in very brief outline. The sound phenomena gradually die away; damage to buildings and even cracks in walls cease; the effects become limited to shaking of bedsteads, rattling of doors and roofs, with the swinging of light articles, especially clothes suspended from pegs.

Next come very great areas where the shock, although felt distinctly, was a mere vibration; beyond that, again, others where it was scarcely felt at all, and where the evidence for the shock is very largely made up of observations of the movements of water in reservoirs.

3.—THE ISOSEISMALS.

Maps.

The accompanying two maps will show the disposition of the few isoseismals, or curves of approximately equal surface intensity, which it is considered prudent to insert in this preliminary account. In the full report, when all the earthquake forms and other sources of information have been estimated, it is hoped that the intervening lines may be added. Notwithstanding their present deficiencies, the curves express much of a very interesting nature, which it is the object of this section to roughly outline.

Scale of intensity used.

In drawing these curves the Rossi-Forel scale of intensity has been used, with the exception that isoseismals 1 and 2 must necessarily be differently interpreted at the present day, when great earthquakes are recorded by seismographs all over the world. Prof. Omori's intensity scale for destructive earthquakes, on the other hand, though very complete in the higher grades, allows place for two more isoseismals of still greater degrees of intensity than the Rossi-Forel No. 10. These latter were framed by their author to include surface intensities sufficient to destroy large iron bridges and railway lines, to shatter and convulse low cultivated lands, causing trees and vegetables to die, and to produce fault scarps at the surface—a degree of surface intensity not reached by the present earthquake. On this account, and because the lower isoseismals are less complete in Omori's than in the Rossi-Forel scale, the latter has been found more useful in the present instance. Only the outermost curve, No. 1, representing the limits of human sensibility, and the innermost four isoseismals, Nos. 7, 8, 9, and 10, representing the highest intensities, are here given, that of greatest intensity, No. 10, appearing to fit the position assigned to it fairly accurately.

Isoseismal No. 10.

The area of maximum intensity included within isoseismal 10 is roughly bounded by Dharmsála, Rehlu, Daulatpur, Bawarna, and Pálampur; and it includes of course the important town of Kángra, besides some smaller towns and hamlets. The size of the area is about 200 square miles; but on the east-south-east it fades away very gradually into the area of next intensity. With few exceptions, all or practically all buildings were found to be destroyed within this area; only the very strong, *e.g.*, the Dharmsála magazine and treasury, and a few pliable wooden structures and low huts escaping. Bazars such as those at Kángra and the Kotwáli bazar at Dharmsála, built mostly of sun-dried bricks and with slate or thatch roofs, were literally levelled to the ground. Many of the smaller scattered bazars of Dharmsála, Bawarna, Pálampur, etc., were nearly so levelled, and the same is true for the hamlets dotted about at intervening points. During my tour through area 10 of the epicentral tract, nothing impressed me so much in the valley area as the contrast between the expanse of ripening wheat fields, the trim tea-gardens, the well-kept roads, the avenues of trees and occasional wooded patches—all untouched by the earthquake—and the utter desolation presented by the mounds and rubbish heaps that alone marked the sites of former villages and towns. This contrast clearly indicates:—

(*a*) That the shock was of very great violence at the surface.

(*b*) That it was not, however, cataclysmic, thus giving a fairly precise upper limit for the surface energy over the area of greatest destruction.

Besides the usual roughly-built bazars and villages, the following were also ruined and mostly wrecked:—

(1) The stronger and massively-built temples of considerable antiquity, *e.g.*, the Golden Temple and others at Kángra, besides many small overturned temples and shrines.
(2) The ancient massive fort at Rehlu.
(3) Solidly-built court houses, police stations, jails, and barracks.
(4) Tea factories with their heavy machinery.
(5) Mission houses, and the English churches at Dharmsála and Pálampur.
(6) Many bungalows of various designs and strength.

Of all these, the roofs, towers, and generally all the walls were demolished, or with here and there mere remnants left. The degree of destruction to such solid masonry buildings was perhaps not so extreme as at Shillong during the 1897 quake—where scarcely a stone was left in position; but still it represents complete ruin with no alternative but entire rebuilding. There were, however, one or two notable exceptions in the hilly parts of Dharmsála: a particularly well-built bungalow, a few of the Gurkha lines, a portion of a bazar—all sheltered in hollows or bays along the hill-side—having marvellously escaped, sometimes without even a pane of glass being broken.

The damage to hill-sides by fissuring and slips is reserved for description to a section to follow, as such damage depends far more on the rock-structure and angle of slope, than on the actual intensity of the shock.

Isoseismal No. 9.

The next isoseismal, No. 9 of the scale, embraces the much larger area of about 1,600 square miles, surrounding No. 10 in a rough ellipse. The greater part of this area lies to the east-south-east of the 10 area with only a comparatively narrow band continuing round the north-west part of that area. On the west and south this isoseismal can be located with considerable accuracy as it cuts Sháhpur, Ránital, and Sujánpur; but further east-south-east by Mandi and Manglaur it is less well defined, the destructive effects within it dying away very gradually in that direction just as was the case within isoseismal 10. Its northern course also is somewhat vague where it cuts the uninhabited and little-trodden snowy ridge of the

Dhauladhár, passing thence to the Beas valley between Sultánpur and Naggar.

The destructive intensity within this area was found to vary considerably, but as regards the number of houses destroyed it averages about one-half. The western part of the area is geographically continuous with the area within No. 10, and it possesses a similar style of village architecture. To the east-south-east, however, the Kángra valley proper comes to an end, and a few parallel and lofty hill-ranges sweep round from the north, through which two chief passes, the Bubu and Dulchi, over 8,000 and 6,000 feet respectively, give entrance to the Kulu valley with its imposing and varied mountain scenery, its bazars built in many styles, and the quaint timber-bonded houses of the hill-people. Throughout this area the only approach to a constant type of building able to be used as a rough intensity measure, is to be found in the road-inspection and travellers' bungalows, which occur at regular stages along the various routes. These buildings were in most cases badly rent and broken, but not often entirely ruined, as were all buildings in area 10. They were, however, completely uninhabitable, and demanded reconstruction amounting nearly to entire rebuilding.

From the large portions still standing, the towns of Baijnáth, Guma, Mandi, Sultánpur, Bajaura, etc., were seen to compare favourably with the devastation wrought within isoseismal 10; but individually these towns show so many and such various stages of destruction according to purely local conditions, that their further description must be held over until the full report is written. Most of the small solidly stone-built Hindu temples within this area at Mandi, Baijnáth, Bajaura, Kulu, etc., successfully withstood the earthquake, as compared with those of area 10 which have mainly fallen.

The more steeply mountainous country beginning east of the Dhelu-Mandi road, and extending throughout the rest of this area, has given rise to many landslips, which severely damaged road communication and caused the Lárji lakes. They will be mentioned again later.

Isoseismal No. 8.

The next isoseismal, No. 8, may be split into two detached parts. The greater of these elliptically surrounds the 9 area, and in its southern curve cuts Telokenáth (Mangla Devi) near Kotluh, a point between Dera Gopipur and Jawálamukhi, Suket, and Rámpur; whilst in its northern curve it cuts less definitely a point between Naggar and Manáli, another a little east of Manikarn and a third at Gaora near Rámpur. Its area is about 2,150 square miles. The lesser part of the isoseismal embraces a small detached area of about 1,200 square miles including Mussoorie, Landour, and Dehra Dun, and takes an elliptical form with long axis parallel to the greater ellipse. The evidence for this separation and parallelism is considerably strong, being based on the reports of Messrs. Simpson and Hallowes in the Dehra-Mussoorie area, combined with local reports from other outside places along the same axis, namely, the Chor mountain, Náhan, Tiri, Srinagar (in Garhwál), Ránikhet, and Almora. It is only fair, however, to say that one strip of intervening ground between it and the Rámpur end of the greater area has not been examined and no local reports have been received from it. At the same time any connection that way seems to me highly improbable, and could it be proved by surface indications would even then be difficult of explanation.

The damage to buildings within these two ellipses was found to be still sufficiently pronounced to be apparent at a glance. In the northern area it took the form of a roof gone here, the end house of a row there, a hill-tower bulged or partially shattered, and so on. But there is no doubt that the intensity has become greatly weakened, especially near the boundary line. The road bungalows were found to be partially habitable, and obviously repairable without entire reconstruction. The accounts of Messrs. Simpson and Hallowes with regard to the area within the southern ellipse, indicate about the same grade of intensity, and are well illustrated by the record of damage to buildings at Dehra Dun, Mussoorie, Landour, etc. There, badly built and unstable structures have been seriously shattered, verandahs and house corners are out of plumb or partially shot away, cracks, amounting sometimes to rents and fissures, pervade most brick and stone buildings, and have sometimes necessitated extensive repairs and partial rebuilding.

From Chakráta accounts implying a similar or slightly inferior degree of damage have been received.

Isoseismal No. 7.

As just mentioned, the 8th isoseismal is coincident with a great, and universally marked, rapid decline in the visible intensity as expressed in house damage, so that on entering on the very large area circumscribed by isoseismal No. 7, we are manifestly getting away from the epicentral regions altogether, and into a tract where the power of the earthquake to carry destruction with it had very nearly ceased. Up to isoseismal

No. 8, the effects of the earthquake were found to be everywhere sufficiently dominant to command general attention. Beyond it the villages and towns presented an ordinary everyday appearance, and it was only on investigating things closely, by overhauling individual houses, that cracks, generally of small account, falls of plaster and of unstable light articles were still to be found subsisting. Nevertheless, the great alluvial plains away from the hills, and especially the larger towns and cities, undoubtedly did evince a slight amount of easily apparent damage that might at first sight be imputed to a slightly increased intensity in this direction. As instances may be cited the serious damage to the Town Hall, Railway Station, and market in Lahore; the practical universality of cracks in bungalows in Jullundur, the twisted and broken clock-tower at Amritsar, and the earth-fissures at Rurki. It seems probable, however, that the natural intensity at these localities has been really augmented in the above instances by the nature of the alluvial bed. It should also be remembered that very large towns such as Lahore, with their numerous and diverse architectural subjects, give a greater range for the law of probabilities to furnish us with some few remarkable effects.

The isoseismal surrounding the above area has been drawn passing slightly to the south of Jamu, cutting Sialkote and Lahore, passing between Jullundur and Ludhiána, and thence curving round by Muzuffarnagar and Bijnor. Its course on the north-east side of the epicentral tract is altogether problematical. It may be said to include an area of about 36,000 square miles where damage to buildings in the form of small cracks is very slight as a rule, sometimes almost entirely absent, and only very occasionally destructive. But in the terms of the Rossi-Forel scale, it nevertheless represents a degree of intensity sufficient to have caused general panic, coupled with overthrow of moveable objects. In using the above expressions it must be understood that percentages of damage and not actuals are meant. Now that our isoseismals are so large, and the affected area so immense, a very small percentage of destruction aggregates a great deal.

The remaining isoseismals.

The systematic description of the lower isoseismals will not be continued further in this short paper, because their delineation no longer depends on personal observation, but on the comparative estimation of a large number of individually recorded impressions furnished by the earthquake forms.

4.—THE ISOSEISMALS IN RELATION TO THE FOCUS.

Nature of the Focus.

Taking the isoseismals so far described in one general and comprehensive view, some noteworthy peculiarities may now be tabulated concerning them, and their bearing on the nature of the focus pointed out.

We may note:—

(1) The elongated epicentral tract enclosed within the last 3 isoseismals of highest intensity in the Kángra-Kulu area.

(2) The close approximation of their curves at the west-north-west end of that tract.

(3) Their widely-separated positions in an opposite direction, *viz.*, east-south-east.

(4) The small, isolated ellipse forming the southern part of isoseismal No. 8 in its course round the Mussoorie area.

With regard to (1) the elongated form of the Kángra-Kulu epicentral tract, it seems certainly to indicate that the original earthquake impulse proceeded from a centrum of the nature of a line or plane following beneath this longitudinally extended tract.

With regard to (2), it should be remarked that in travelling from Nurpur to Kángra, and from Haripur or Dera-Gopipur to Kángra, we cross in each instance through the grades of intensities from such as are marked by trivial cracks in the plaster and corners of walls to those of complete destruction to buildings, and all within the short radial distance of 8 or 9 miles. In other words, the surface intensity increases extremely rapidly in these directions and indicates a proportionately shallow depth for the position of the centrum in the vicinity.

With regard to (3)—which briefly expresses the fact that in travelling from the Kángra neighbourhood across the same isoseismals but in an east-south-east direction we must cover about 100 miles of continuous and slightly diminishing intensity—an exactly opposite conclusion is indicated, namely, the increasing depth of the centrum in that direction.

With regard to (4), the conditions imply a smaller separate centrum, following an axis parallel to that of the Kángra-Kulu area, once more rather nearer the surface, and of an actual focal intensity much less than that at the Kángra-Kulu centrum.

For the present we must be content to regard these two axial lines, lying within planes (probably of faulting), as being the main and subsidiary loci either of one universal and contemporaneous shock, or of two, or even a series, of separate but almost instantaneous shocks, following one another sympathetically along lines of great tension.

Depth of the focus.

In the earlier days of seismology, when the focus or centrum of an earthquake shock was conceived of as approximately a point from which one kind of elastic vibrations proceeded in a perfectly radial manner, a great deal of attention was bestowed on overthrown objects and on the direction and angles made by planes of fissuring in buildings, that is to say, the earthquake was treated as more ideal in its simplicity than has subsequently been shown to be the rule. In the present instance also, a large amount of data of the above kind has been laboriously accumulated on the chance that it might all tend to the localisation of a fixed centrum at a given depth. As it has turned out, the above data have generally given no uniformity of result, either as regards direction or depth. Very locally some of them point approximately to the nearest seat of disturbance; but taken as a whole they can only be interpreted in one of two ways. They must either be considered entirely untrustworthy owing to the secondary effects of different rocks, rock structures, and soils on the passage of the waves, or their diverse indications must be taken literally as pointing to innumerable foci having varying positions and depths. One other interpretation, which is a blending of the two previous ones, is to consider that the facts imply a complication of centra, or points of maximum impulse, distributed along a line of the kind found probable from a study of the isoseismal chart. This being so, we are once more driven to make use of the above chart as our chief guide in searching for further and more quantitative details about the exact position and depth of the originating disturbance. The method adopted by Major C. E. Dutton [1] recommends itself here by its reasonableness and general applicability.

On the assumption of a uniform medium, and that the intensity varies inversely as the square of the distance from the origin, Dutton shows that the variation of *surface* intensity along a horizontal line drawn from the epicentre is most rapid at a particular point which depends on the depth of the focus only, a point also where the intensity must be $\frac{2}{3}$ of the maximum intensity at the epicentre. The relation

[1] "Earthquakes in the light of the New Seismology," Chap. IX (1904).

between the two is exhibited by the formula $x = q \tan 30°$, where x is the horizontal distance of the place from the epicentre, and q the depth of the focus. If x is known, then $q = x\sqrt{3}$. In the diagram, fig. 1, A B represents the surface of the ground, O the centrum, and the vertical lines are proportional to the intensities at the several points on A B. The resulting curve is steepest at the point where it touches the $\frac{3}{4}$ intensity line.

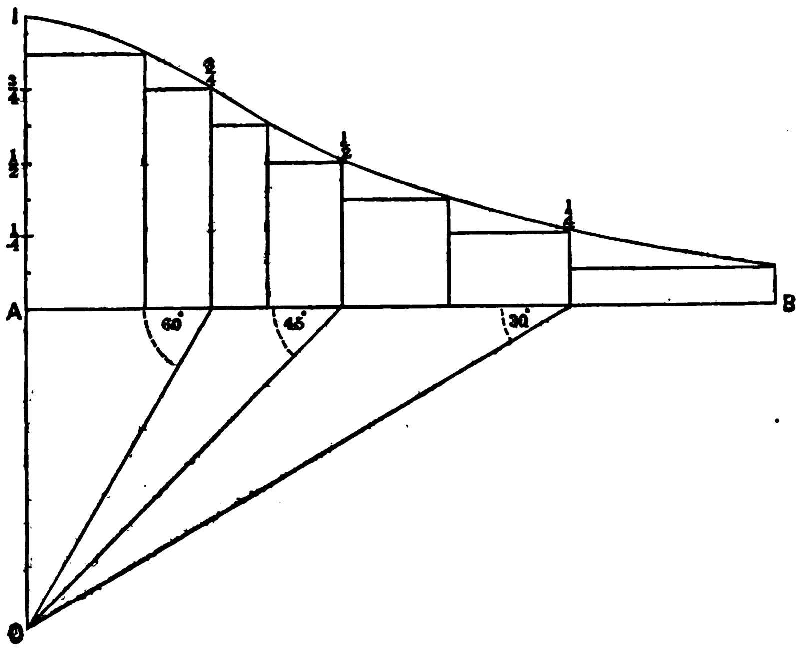

Fig. 1.

Now, it seems that we may apply this formula to the present earthquake by making sections across the epicentral tract at right angles to its long axis. The only difficulty is the recognising of that portion of the cross-section where the intensity declines or varies most rapidly. With regard to the Kángra end of the northern epicentral tract, there is no difficulty, as has already been shown, in making a selection of points situated near its W.N.W. end which must be correct within a few miles. From those points the distance to the epicentral line cannot be less than 7 or more than 12 miles. The centre, therefore, between Kángra and Dharmsála must lie at some depth greater than $7\sqrt{3}$ and less than $12\sqrt{3}$ miles, *i.e.*, between about 12 and 21 miles. Taking another cross-section over the tract from Naggar through Sultánpur, Mandi, and Suket, the horizontal measurements, though less exact, cannot be less than 12 or greater than 24 miles, and therefore the depth must lie between $12\sqrt{3}$ and $24\sqrt{3}$, or between 21 and 40 miles. The centrum thus deduced for this part of the earthquake-area can, therefore, be represented by a line or axis running from a point about midway between Kángra and Dharmsála in an E.S.E. direction towards Bajaura, a distance horizontally of 50 miles and at a depth of from $>12<24$ to $>21<40$ miles, the average being from 18 to about 30 miles, with a dip or pitch of 13½ degrees with the horizontal.

It will no doubt be thought by many that the above depths are possibly exaggerated, and in any case there is no doubt about their vagueness. Whilst freely admitting the possibility of serious refraction caused by change of rock-formation through which the shock must have been propagated, there are two general facts which point to at least a *considerable* depth for the part of the centrum below the Kulu area. One is the extremely large area over which the shock has undoubtedly been felt, and the other the only moderate violence at the surface. In other words, a shock of intensity 8 at the surface at Kulu, if of shallow origin, would not have been so powerful at that origin as to have been felt in such remote parts as the Bombay Presidency and Assam, nor would one of intensity 10 at Kángra unless it also were proportionately deep-seated.

With regard to the smaller subsidiary focus for the isolated Dehra-Mussoorie area, the fact that the latter is delineated by only one isoseismal, which has only been crossed by my colleagues at one point on its southern limb, and at a time when its isolation from the Kángra-Kulu epicentral tract was not suspected, renders impossible the application of Dutton's method of estimating the depth, inasmuch as there are no data for approximately determining the points of most rapid decline of intensity. On general grounds one would expect the depth of the centrum to be considerably less than at the Kulu end of the northern area.

5.—INTENSITY: ACCELERATION OF WAVE PARTICLE.

The foregoing isoseismal lines and their enclosed areas, it will be observed, have been mapped mainly according to the general effects produced by the earthquake on buildings. That no specific measurements have been made of the acceleration, amplitude, or period of the wave particle is a necessary misfortune in an area destitute of suitable seismographs. The common practice of drawing a certain amount of limiting values for these measurements from overthrown or projected natural bodies has also in this area had little scope, partly because of the general absence of suitable objects, and partly because of the extreme complexity of such cases as have occurred. The same causes which have tended to obscure the conclusions to be drawn from the direction of objects overthrown have also confused those deducible from the amount of that overthrow. For the present, I propose to mention only the following selected cases as evidence in this connection, because they appear to be less open to objections on the score of complexity than any others.

The old European cemetery at Kángra Bháwan lies in the middle of a flat plain, and at the time of my visit exposed a number of rectangular masonry pillars, overturned or broken with more regularity of direction than I have seen elsewhere (see fig. 2.) They comprise :—

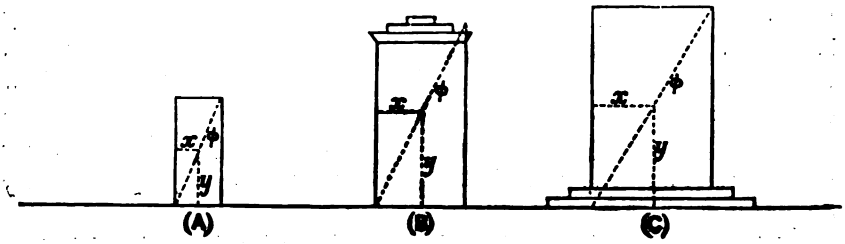

FIG. 2.

(A) Two small, rectangular upright tombs, 3 ft. high, by $1\frac{1}{8}$ ft. square. Fallen as a whole towards N.E.

(B) A pair of gate-pillars, of dressed stone and lime-mortar outside, with rubble within, 5 ft. high by $2\frac{1}{12}$ ft. square. Fallen as a whole, one towards E.25°N. and one towards W.20°S. (*i.e.*, nearly in opposite directions).

(C) A pair of pillar-like tombs, constructed like the gate-pillars, $5\frac{1}{2}$ ft. high by $3\frac{1}{3}$ ft. square. Not upset as a whole, but shattered above the base into fragments.

Using West's simplified formula for determining the acceleration of the wave particle, a formula which has stood the test of much experimental proof, we have :—

$$f = g\,\frac{x}{y}$$

where x = half diameter of the base and y = the height of the centre of gravity.

Then, in the three cases above, we have as follows:—

For (A) $f =$	$>$	$11\frac{2}{3}$	ft. per sec. per sec.
For (B) $f =$	about	13	„ „ „
For (C) $f =$	$<$	19	„ „ „

Since in the case of (A) both bodies were upset towards the direction of shock, and in the case of (B) one towards and one away from that direction, whilst in the case of (C) they were not upset at all, we may deduce a rate certainly between $11\frac{2}{3}$ and 19, and probably near 13 ft. per sec. per sec. for the acceleration of the wave particle at Kángra.

But, according to Prof. Omori,[1] the formula:—

$$2a = \frac{4x\,(x^2+y^2)}{3y^2}$$

where $2a$ is the double amplitude or range of motion of the overturning edge, will yield a limiting value for the amplitude of the earth vibrations in the case of short periods where the pillar is overturned towards the direction of impulse. Using it we obtain the result,

$$a = 9\tfrac{3}{4} \text{ inches,}$$

an amplitude which is large, but not excessive in the case of soft ground near the epicentre of a great earthquake.

Using this value for a in the general formula:—

$$f = \frac{4\pi^2 a}{t^2} = \frac{v^2}{a}$$

where t is the period of the wave and v the maximum velocity of the earth particle, we can obtain values of t and v. We thus have altogether:—

Acceleration	$f =$	13 ft. per sec. per sec.
Amplitude	$a =$	$9\frac{3}{4}$ inches.
Velocity	$v =$	$3\frac{1}{4}$ ft. per second.
Period	$t =$	$1\frac{4}{7}$ seconds.

On the other hand, by using Prof. Omori's second formula for the case of a pillar overturned in the forward direction when the period of motion is comparatively long, and applying it to the second of the pair of gate-pillars overturned away from the direction of shock, we get:—

$$v = \sqrt{\frac{8gy\,(1-\cos\phi)}{3\cos^2\phi}}$$

[1] *Seismological Journ. of Japan.* Vol. XVIII, p. 120, (1893).

where ϕ is the angle between a vertical side and the diagonal of the pillar. That is:—

$$v = 3{\cdot}87 \text{ ft. per second,}$$

a value which is sufficiently near the one previously obtained by the other method to be corroborative of it.

6.—TIME OF THE EARTHQUAKE: RATE OF PROPAGATION.

A few selected observations.

The remarks made by Mr. R. D. Oldham in his memoir on the Assam earthquake of 1897[1] as to the varying standards of time in India, and the varying accuracy with which they are kept for ordinary purposes apply equally today. Without an exhaustive statistical treatment of all the returns sent in, the only way to arrive at an approximately correct result is to take a selected few of them, which *primâ facie* seem the most reliable. Fortunately, with seismographs of the Milne type installed at Bombay, Kodaikanal, and Calcutta, there is the less need to weigh a large body of doubtful evidence. These selected few mark a great advance on the records available in 1897.

Beginning of shock fixed at 6h. 9m. 0s. a.m.

From the Kángra-Kulu epicentral area it may at once be said that we have no accurate details, and indeed very few at all. From the Dehra-Mussoorie area the automatic records of the Survey of India instruments have furnished times, which, however, are still a matter of enquiry as regards details.[2] From Simla the time of arrival of the shock is given as 6h. 9m. 30s. A.M. (Madras time). From towns about the nearness of Sialkote, Lahore, Amritsar, and Jullundur there is a general body of testimony derived from well-regulated clocks giving 6h. 10m. 0s. as the time of arrival of the first big shock. From Rawalpindi and Saharunpur the time is 6h. 11m. 0s. So that from the above times we may reasonably conclude that at the chief epicentral tract the time was about 6h. 9m. 0s. within a second or two of error.

Arrival of large waves at Bombay, Kodaikanal, and Calcutta.

Skipping the intervening areas for the present in this account, there are available from the Government Observatory, Bombay (Colaba), a number of detailed automatically-recorded times (provisional and subject to future correction in detail), from which I naturally

[1] Mem. G. S. I., Vol. XXIX, Chap. IV, (1899).

[2] Later information received points to a discrepancy with the times here recorded. The subject will be discussed in the forthcoming full report.

select those furnished by the seismograph, it being the instrument best qualified for the purpose. Neglecting the preliminary tremors, and confining our attention to the large movements which are most easily distinguishable in the seismograms, we find they began about 4 minutes after the preliminary tremors, the latter being given as 6h. 13m. 1½s. Thus the time of arrival of the large movements at Colaba was about 6h. 17m. os. At Kodaikanal and Calcutta(Alipur) Government Observatories the seismographs recorded the same phase at 6h. 21m. 48s. and 6h. 17m. os. respectively.

Rate of transit of large waves.

Now, assuming that these large movements as registered on the seismogram films represent the first arrival of the large waves which travelled along the surface of the earth (a generally accepted conclusion) and that they began at 6h. 9m. os. at the epicentre, we can tabulate the following distances, periods of transit and rates, thus:—

PLACE.	Distance in miles from centre of large epicentre.	Seconds during transit.	Deduced rate in miles per second.
Bombay (Colaba) . . .	950	480	1·98
Kodaikanal	1,497	768	1·95
Calcutta (Alipur) . . .	950	480	1·98

Agrees with average for 1897 earthquake.

It so happens that Colaba and Alipur are exactly the same distance from the central point of the larger epicentral area, a point fixed by a personal survey of the devastated region; and the agreement in the time and consequent rate is extremely satisfactory, and it may be further noted to agree to the second place of decimals with the mean value arrived at by Mr. R. D. Oldham for the 1897 earthquake. The Kodaikanal time and deduced rate come sufficiently near to be in every way corroborative. If, neglecting the time at the epicentre, we take the difference of the Kodaikanal time and that of either Alipur or Colaba, and also the difference of their distances from the known epicentre, we get 547 miles in 288 seconds, or a rate of 1·90 miles per sec., a rate which, if applied through the whole distance, would give a time of 6h. 8m. 40s. for the beginning of the shock.

Clocks stopped in Calcutta.

Besides the above time of 6h. 17m. os. recorded at Calcutta, we have further corroborative times afforded by Mud Point and Saugor Island, which agree in giving 6h. 17m. os. Other time evidence in Calcutta that may be mentioned here has been derived from the stoppage of clocks. At St. Xavier's College the electric clock stopped at 6h. 20m. os.; at Alipur Observatory the astronomical clock stopped at 6h. 19m. os., but it is important to remember that so far from the centre as Calcutta, where the shock was necessarily very weak, it is probable that these clocks did not stop all at once, and therefore that they considerably overstate the time.

Rate of transit deduced by Omori from Japan seismographs.

Prof. Omori in his note on the present earthquake seismogram as registered at Tokyo[1] and other places in Japan, deduces a rate of 3·3 kilometers per second for the surface transmission—this rate being obtained by considering the times of arrival of the 3rd phase of the principal portion of the wave along the minor and major arcs respectively of the great circle joining Tokyo and Kángra; together with the time of re-arrival of the former after making one complete circuit of the Earth. The length of time for that complete circuit was 3h. 15m. 4s. The value 3·3 kilometers or 2·05 miles per second differs from the value 1·98 by only ·07 of a mile and may be considered as further corroborative evidence regarding the rate of transmission of the shock.

7.—FORE-SHOCKS AND AFTER-SHOCKS.

Ongole earthquake of 2nd April.

The usual large number of attendant after-shocks have succeeded the great shock of the 4th April, but their discussion will be reserved for the present. As to fore-shocks, there is no evidence that any were felt in the disturbed area. It may be mentioned, however—although the occurrence is probably only a coincidence—that on the 2nd April a considerable earthquake shock was felt at Ongole, Markapur (Kurnool district) and Madras, and that after-shocks of it continued up to and subsequent to the 4th April. On geological grounds there is no reason for regarding the connection in time as anything but accidental, and it is

[1] Appendix to Pub. Earthquake Invest. Com. in Foreign Languages, No. 25 Tokyo, 1905).

only mentioned here because of the importance of anything that might possibly bear on the matter.

8.—GEOLOGICAL CONDITIONS IN RELATION TO THE EARTHQUAKE.

(1) As causes.
(2) As effects.

On the now generally accepted theory that great earthquakes are due to strains set up in the earth's crust by geotectonic movements, and to their sudden relief by slipping along a fault, it is of importance to consider the geological structure of the area. Although one can hardly hope to identify the particular local structural accident that constituted the earthquake, the matter is of such gravity to mankind that any hopeful suggestions should be recorded. The above is one aspect of the bearing of geology on the earthquake. Another aspect is the superficial and secondary effects of the earthquake consequent on the nature and disposition of the rocks at the surface. Taking these two aspects of the subject in order, and premising that the subject is very complex, the suggestions which follow are made with a full recognition of their hypothetical nature.

Inbaying of Tertiaries in Kangra Valley and Dehra Dun.

Neither the accompanying maps, nor any that could be conveniently used for such a great area, do anything like justice to the topography of the main and subsidiary epicentral tracts, which really are of a very varied and characteristic relief according to their geological composition. However, if Mr. Medlicott's map[1], or even the general geological maps of India on smaller scales be consulted for an outline view of the geology, there will be noticed a striking structural peculiarity at these two points of the Himālayan area, namely, the great inbaying of the younger Tertiary formation of the Sub-Himālaya towards the higher central regions of the mountains. The line of the "main boundary" fault separating these Tertiaries from the very old Himālayan rocks of that region may be observed to take a huge sweep inwards and eastwards from the Rávi River to Drang, and then to return almost in a N.—S. sweep by Mandi, Suket, and Sabāthu, and round the foot of the Simla mountain spurs. The Tertiaries then pursue a normal direction until the Dehra Dun area is reached, when there occurs another, but much smaller, inbaying of them towards the central area. Nowhere else along the Himālayan mountain-foot, as we know it, is there such

[1] Mem. G. S. I., Vol. III, 1864.

exceptional irregularity, unevenness one might say, in the disposition of these bordering bands of Tertiary strata (see fig. 3).

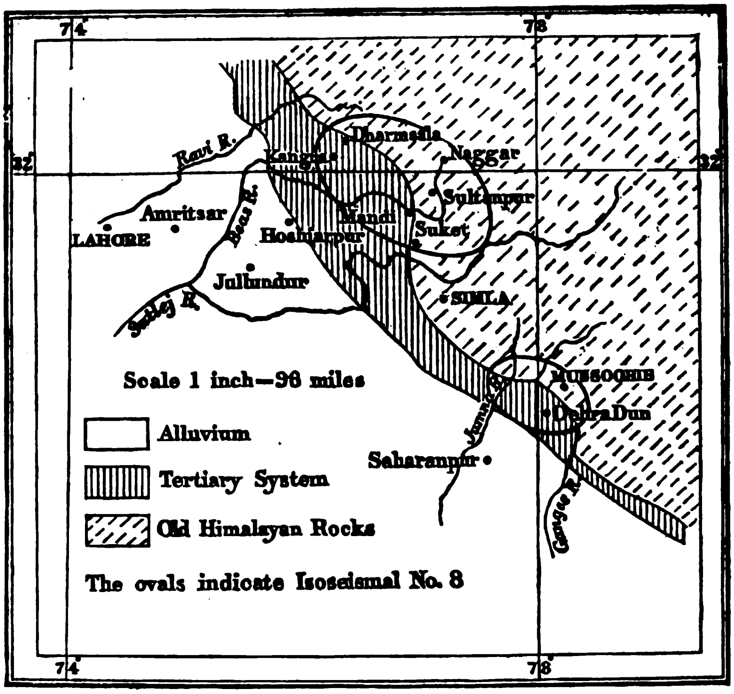

FIG. 3.

It probably implies a condition of special strain.

Now, the special function of all the folding and fold-faulting of the Sub-Himālayan tract that has gone on in Tertiary, post-Tertiary and possibly still more recent times has undoubtedly been to straighten out this mountain-foot into a very uniform curve—the great southwardly convex curve of the whole Himālayan chain. Therefore, areas which show any marked irregularities still left, such as those just pointed out, may well be in a peculiar condition of strain, extremely favourable to geotectonic movements, including faults.

This view is strengthened by the fact that already on the plainward edge of the Sub-Himālayan band considerable straightening has taken place, as is testified to by the long, straight strike-ridges behind Hoshiarpur and south-west of the Dehra Dun, respectively; whereas the areas in the angle of the inbayings show wavering irregularity of strike following the contours of the older Himālayan mass, succeeded by gently dipping areas forming longitudinal valleys, or, as at Dehra, the so-called "Dun."

Change of load by denudation and sedimentation.

Another source of such strain, and consequent tendency to movements, is undoubtedly provided by the steep slope from the Kángra valley at about 3,500 feet to the Dhauladhār ridge at about 16,000 feet, a horizontal distance of only 6 miles. With such a gradient the local interchange of load by denudation of the latter, coupled with deposition on the former, is inevitable; and that it has gone on for long ages is evident by the great debris fans and terraces of sand, clay, and enormous granite boulders that strew the valley-floor and also extend up the lower hill-spurs near Dharmsála. In a much less important degree the Dehra Dun presents some similar features.

It probably implies a further state of strain requiring re-adjustment.

From what we know of the isostasy of the earth's crust, especially along the Himālaya, such a continuously maintained change of loading cannot go on without re-adjustment. Such re-adjustment generally implies only folding and faulting with occasional insignificant earthquake shocks; but at the same time it carries with it the chance of a sudden change of strain enough to cause a great earthquake. As a matter of fact earthquakes in this area are said to be common, but generally non-destructive, whilst underground sounds of the nature of "Barisāl guns" have long been known.[1]

General instability of Himālayan Mountain-foot.

If the above structural peculiarities in the Kángra valley and Dehra Dun respectively, may be considered to have any influence in producing special lines of strain, then the major epicentre located at the former and the subsidiary epicentre at the latter place, carry out the same idea by possessing magnitudes proportional in size and intensity to the assumed causes. Should the particular local causes just outlined, however, be dismissed as fanciful, there can still be no doubt that the general tendency to instability of the Himālayan mountain-foot as a whole, consequent on rapid change of profile accompanied by

[1] Mentioned in a letter by Mr. C. Michie Smith, Government Astronomer, Madras. Mrs. W. S. Meyer, at "Townsend," Simla, about twelve days before the earthquake, also reports having heard rumbling sounds, not to be confounded with thunder, which the Meteorological Reporter to the Government of India reports as absent during the day on which the sounds were heard.

change of load, is an adequate cause in itself and one which is universally recognised by seismologists in all similar cases.

Geological conditions influencing surface-effects of the earthquake.

As to effects, that the earthquake, as felt disastrously and sensibly at the surface, was in many cases a very much modified product, depending largely on the nature of the stratified upper crust and on the surface-deposits, is abundantly clear for general and particular reasons. The subject is too vast, however, and also too full of unsolvable problems to do more than refer to it here very briefly. The following points are noteworthy:—

(1) All the surface valley deposits of alluvium, sand, gravel, and boulders appear to have been proportionately more heterogeneously shaken than solid rock.

(2) Of rock, the soft Tertiary sandstones have been thrown into more destructive vibrations than the older and more compacted strata.

(3) Narrow ridges with free ends (spurs) have been very much more shaken than broad areas and the flat hollows between the spurs.

(4) In the case of the more distant vibrations and tremors, the great alluvial tracts, and the flat-lying Vindhyans and Deccan trap with cotton-soil, have rendered such weak vibrations apparent, whilst the ancient and steeply-dipping Aravalis have resisted the shocks in a very noticeable way. As a consequence, there occurs an isolated area round about Udaipur, Dungarpur, Partábgarh, etc., from which no accounts of any shock have reached us. It is interesting to note that this area was similarly barren of results in the 1897 earthquake, although the shock was recorded both east and west of it.

9.—SPECIAL SURFACE-EFFECTS OF THE EARTHQUAKE.

(*a*) Earth-fissures: Rock and Land-slides.

Though serious all are of superficial origin.

In a short paper without illustrations it is difficult to convey a true impression of the size and importance of the secondary surface effects, relatively to the magnitudes (of mountain and valley) concerned. The danger of over- or under-stating is equally great. But it may at once be laid down that of all the ruptures of the hill-sides that have taken place with their accompaniments of rock-showers and soil-cap slides, none can be definitely regarded as having been caused by mass-movements of the solid rock from below upwards. Although the origin of the earthquake must be accepted without hesitation as due to just such a movement having taken place suddenly at a depth below the present surface, yet it nevertheless appears certain that the planes of such movement nowhere emerged at the actual surface of the ground producing changes of contour and drainage, or originating fault-cliffs, such as was a feature of the Assam earthquake of 1897 and the Japanese earthquake of 1891. The great majority, probably all, took place in a direction with gravity and not against it: all are secondary, and the expression simply of the shaking or vibrating of loose unstable material (whether in the form of soil, rock, crag or mountain-spur) followed by the descent of the disrupted masses to lower levels.

Chief causes are the crushed rock and steep hill-slopes.

Two causes have contributed to bring into special notice the rock and soil-cap slides in Kulu. One is the extremely fissile and sheared condition of the quartz-schists and epidiorites, which together with a considerable amount of much "mashed" limestone make up the principal rocks of the Kulu valley. The other is the extremely steep angle to which many of the slopes and precipices of the Beas river and its tributaries have been reduced by the continuous steady erosion of the river-bed. The Beas is much more gorge-like in its windings, especially near Lārji, than the majority of large rivers similarly situated in the Himālaya. It is no wonder, then, that when the earthquake came, such greatly splintered rock materials and such impending slopes—far above the limiting angles of safety—afforded ideal conditions for the production of landslips on a gigantic scale.

Kángra valley and neighbourhood.

A brief reference to actual examples must suffice here. In the immediate vicinity of Kángra and Dharmsála, where the hill-slopes are comparatively gentle for a mountainous district, though they steepen rapidly above Dharmsála, the appearance of fissures along many of the slopes, such as the Sessions House ridge at the former place, and the cantonment spur at Dharmsála, is a fair indication among other evidence of the greater intensity of the shock in that area. Special cases such as the narrowness of the ridge at McLeodganj bazar and at "Bryn," as also the peculiar lie and rock-composition of the Jail site (all on Dharmsála civil hill) have resulted in specially marked destruction, numberless fissures or, as at the Jail, an actual subsidence of the land in great blocks.

Palampur and Neogal gorge.

Above Pálampur, at the head of the Neogal gorge, one very noticeable rock-slide in the bare steep crystalline axis of the Dhauladhār range continued active for months after the earthquake. Each subsequent after-shock combined with the effects of melting snow dislodged further loose material, which, in its descent over precipices several thousand feet sheer into the bed of the gorge, gave rise to a dust-cloud of great volume that overtopped the great range and was visible for many miles away. It discoloured the snow-covered ridges far and near and was so continuous as to alarm the timid by its resemblance to a volcanic eruption. The nearer hill-spurs above Pálampur were also much damaged. In particular the fresh soil-cap, left whence snow had just retreated, showed that these slender ridges must have shaken like a quivering jelly and split up into fissures every few yards. Nearer Pālampur, again, and at other stream-outlets along the Dhauladhār, the shedding of the scarps of gravel terraces, and the skinning of the steep slopes carried away with them many miles of water-channels used for irrigating the lower parts of the Kángra valley.

Fojal Nullah.

A parallel instance to the Neogal Nullah dust-cloud is also afforded by the Fojal Nullah, about eight miles due west of Naggar in Kulu, where phenomena of the same kind, simulating volcanic action, took place, and where on the day of the earthquake the water joined the Beas river as a black torrent. Mr. W. H. Donald, Executive Engineer, Kulu, informs me that on the 24th May 1894 there was a previous rock-movement, or landslip, at the same place, accompanied by a flood and by a dust-cloud that continued for four months.

"Main-boundary" fault near Drang: Salt mines.

Near Guma and Drang the new cart-road from Pálampur to Mandi has been carried along the line of the main-boundary fault. The hill-sides for some way on both sides of the fault are much disfigured by cracks and landslips, but especially just along the junction, where not only are the rocks in that greatly-splintered and powdered condition usually presented in such places by the shearing and crushing that have gone on for geological ages, but also are rendered more unstable by reason of the local outcrops of easily soluble rock-salt. Much of the new road has been destroyed and many of the salt quarries blocked by rock-showers.

Dulchi and Bubu Passes.

The bridle-roads over the Dulchi and Bubu passes have also suffered in the same way, the latter, which enters a defile near the top, continuing blocked for many months.

Parbati River.

The Parbati river in Kulu, especially in its higher snow-fed tributaries, where precipices of white, much splintered quartz-schists abound, has been phenomenally prolific in rock-showers, which have often carried away with them pine forests as well as roads, and filled up the torrent-beds with streams of sliding debris.

Beas River at Larji.

At Larji, near where the confluence of the Beas with the Tirthan and Sainj streams takes place in profound gorges, the havoc wrought among the steeply-convex spurs is at first sight appalling. The Larji slips were still active when I was there, two months after the earthquake, and they showed signs of a probable great increase during the ensuing south-west monsoon. This river focus will indeed in my opinion give much trouble to communications for years to come.

Larji Lakes.

Both the Tirthan and the Sainj streams have been temporarily dammed up by the debris cones, some miles above Larji, forming lakes. The latter was still inaccessible when I was there, but I examined the Barwár lake, three miles up the Tirthan river. It is about three-fourths mile long in an S-shaped curve, and by reason of the rotten and much scarred precipices above, will be long before it attains a condition of rest. There seems to be no danger of the dam bursting, as a steady outflow had been established with a moderate gradient.

South-east of the Barwar lake damage to the hill-sides gradually diminishes. The northern ascent to the Jalori pass exhibits a few minor rock-slides and showers, and then there sets in comparative stability, especially in the wide open valley of the Sutlej near Luri. Near Mussoorie, however, a prominent rock-slide at the Kempte falls still shows the readiness of very steep slopes to give way under even the moderate shaking which this part of the area underwent.

(*b*) Miscellaneous Effects.

Springs.

A common accompaniment of earthquakes is the disturbance of lines of natural water-springs. The usual form which this takes is an increase in the volume of water discharged: a result easily seen to be due to the surface-shaking of the rocks causing a loosening of the joints or other fissures along which the water escapes.

Jawalamukhi springs.

The water-supply of Jawalamukhi, which has its source in springs, was about doubled; but the temple springs, with their natural inflammable gas, were not affected.

Boiling springs at Manikarn.

The boiling springs at Manikarn were slightly affected by the earthquake. One was checked altogether, and left a public bathing-place to run dry, whilst others within a short range shifted their channels. The character of the springs and their temperature (high enough to cook rice and other food-stuffs) remained unchanged.

Spring at Tipri.

Near Tipri, in the Parbati valley, a very small spring issuing from a rock-cleft flowed muddy for some months after the earthquake. Probably the continuance of after-shocks kept the water from clearing.

At Mackinnon's Brewery.

The springs at Mackinnon's Brewery, Mussoorie, increased their discharge by from 20 to 30 per cent.: a result accurately determined by Mr. Mackinnon. After 20th May the increase showed a gradual falling off until the end of June, when they resumed their normal flow.

Reservoirs: Canals.

The water in ordinary "tanks," or local reservoirs, was often visibly affected by the earthquake and thrown into waves or overflowed their edges, at localities where the shock was otherwise not felt. This was a common phenomenon round about Calcutta, at Ahmedabad, Bombay, and other places. In the case of tanks divided by partitions, the latter commonly burst. On many canals the water-wave due to the shock was also distinctly noted.

Earthquake "shadows."

Many cases of so-called earthquake "shadows" seem to have occurred, whereby a house, village or bridge sheltered behind and below a violently agitated hill or gravel cliff were spared the shock, which had locally exhausted itself in visible disruption of the sheltering mass. As examples may be mentioned "Woodside," a house in Dharmsála cantonment; part of Forsythganj bazar; the Gurkha lines east of the Magazine, and those north of the upper parade ground; and many road-bridges in the epi-central tract. The numerous small hamlets immediately north of Dharmsála, and divided from it by a deep ravine or by a saddle in the hills, were probably partly protected by being in shadow, partly by being on firmer rock, and partly by reflection of the wave from the main boundary fault. Several small villages and shops lying on the lower north slopes of a hill of soft tertiary sandstone, one or two miles east-south-east of Baijnáth, were also protected, apparently by being in shadow.

Instances of the opposite effect—the very violent movement of long narrow ridges—are too numerous to mention. Every house-site in Dharmsála and other towns, desirable for its good position, drainage, and view, became a most undesirable site from the standpoint of the earthquake.

Movements of bubbles in level tubes.

From Sind and Burma the long drawn-out distant undulations of the earthquake affected the bubbles in level tubes during survey operations, the movement at the former place indicating a surface tilt of about 30 seconds of arc both above and below the horizontal, in a north-east—south-west direction. No sensible motion was felt at those places, and the gentle oscillations of the bubbles embodied all the local energy that remained of this powerful earthquake after its wide sweep across the half of India.

10.—GEOGRAPHICAL INDEX.

Places within Isoseismal No. 10.

Name of town or village.	District.	Lat. N.—Long E.	Distance in miles from nearest point of main epicentre.
Bawárna . . .	Kángra . .	32° 3′—76°33′	All within a few miles.
Chari	Do. . .	32°12′—76°19′	
Daulatpur . . .	Do. . .	32° 3′—76°19′	
Dharamsála . . .	Do. . .	32°13′—76°24′	
Kángra	Do. . .	32° 6′—76°19′	
Nagrota . . .	Do. . .	32° 7′—76°26′	
Pálampur . . .	Do. . .	32° 7′—76°36′	
Rehlu	Do. . .	32°13′—76°16′	

Places between Isoseismals Nos. 9 and 10.

Name of town or village.	District.	Lat. N.—Long E.	Distance in miles from nearest point of main epicentre.
Baijnáth	Kángra . .	32° 3′—76°42′	About 4
Bajaura . . .	Do. . .	31°51′—77°13′	„ 10
Barwar (lake) . . .	Mandi . .	31°42′—77°19′	„ 17
Bhuin	Kangra . .	31°53′—77°13′	„ 9
Bubu (pass) . . .	Do. . .	31°57′—77° 3′	„ 6
Dhelu	Mandi . .	32° 0′—76°51′	„ 4
Drang	Do. . .	31°49′—77° 1′	„ 4
Dulchi (pass) . . .	Do. . .	31°50′—77° 9′	„ 5
Guma	Do. . .	31°58′—76°55′	„ 4

Places between Isoseismals Nos. 9 and 10.

Name of town or village.	District.	Lat. N.—Long. E.	Distance in miles from nearest point of main epicentre.
Jhatingri	Mandi . .	31°57′–76°57′	About 3
Kohad	Kángra . .	32° 5′—76°52′	" 9
Lárji	Do. . .	31°44′—77°17′	" 14
Mandi	Mandi . .	31°42′—77° 0′	" 10
Paprola	Kángra . .	32° 3′—76°42′	" 4
Ránitál	Do. . .	32° 1′—76°18′	" 10
Sháhpur	Do. . .	32°12′—76°15′	" 8
Sujánpur	Do. . .	31°50′—76°33′	" 14
Sultánpur . . .	Do. . .	31°57′—77°10′	" 10
Swar	Do. . .	32° 5′—76°55′	" 11

Places between Isoseismals Nos. 8 and 9.

(1) In Kángra—Kulu Area.

Name of town or village.	District.	Lat. N.—Long. E.	Distance in miles from nearest point of main epicentre.
Banjár	Kángra . .	31°38′—77°24′	About 24
Hamirpur . . .	Do. . .	31°41′—76°35′	" 22
Jalori (pass) . . .	Do. . .	31°32′—77°27′	" 30
Jari	Do. . .	32° 0′—77°18′	" 18
Jawalamukhi . . .	Do. . .	31°52′—76°23′	" 16
Jibhi	Do. . .	31°36′—77°25′	" 26
Kot	Do. . .	31°31′—77°29′	" 33
Mangfaur . . .	Do. . .	31°40′—77°22′	" 21

Places between Isoseismals Nos. 8 and 9.

Name of town or village.	District.	Lat. N.—Long. E.	Distance in miles from nearest point of main epicentre.
Manikarn	Kángra	32° 2′—77°25′	About 24
Nadaun	Do.	31°47′—76°24′	" 21
Naggar	Do.	32° 7′—77°14′	" 20
Plách	Do.	31°39′—77°24′	" 23
Suket	Suket	31°32′—76°58′	" 22
Telokenath	Kángra	32°14′—76° 8′	" 14

(2) *In Dehra Dun-Mussoorie Area.*

Name of town or village.	District.	Lat. N.—Long. E.	Distance in miles from epicentre.
Chakráta	Dehra Dun	30°43′—77°54′	All within a few miles.
Dehra Dun	Do.	30°19′—78° 5′	
Landour	Do.	30°27′—78° 7′	
Mussoorie	Do.	30°27′—78° 2′	
Rájpur	Do.	30°24′—78° 5′	

Places between Isoseismals Nos. 7 and 8.

Name of town or village.	District.	Lat. N.—Long. E.	Distance in miles from nearest point of main epicentre.
Amritsar	Amritsar	31°37′—74°58′	90
Bilaspur	Simla States	31°20′—76°49′	42
Chamba	Chamba	32°29′—76°10′	29
Chawai	Kángra	31°27′—77°30′	33

Places between Isoseismals Nos. 7 and 8.

Name of town or village.	District.	Lat. N.—Long E.	Distance in miles from nearest point of main epicentre.
Chini	Bushahr	31°32′—78°19′	72
Dagshai	Simla	30°53′—77° 6′	67
Dalhousie	Gurdaspur	32°32′—76° 0′	35
Dera Gopipur	Kángra	31°53′—76°16′	20
Gurdaspur	Gurdaspur	32° 3′—75°26′	53
Hardwar	Sahåranpur	29°57′—78°14′	144
Haripur	Kángra	32° 0′—76°13′	16
Hoshiarpur	Hoshiarpur	31°33′—75°58′	48
Jullundur	Jullundur	31°19′—75°38′	70
Kálka	Umbálla	30°50′—76°59′	70
Kapurthála	Kapurthála	31°24′—75°25′	77
Kasauli	Umbálla	30°53′—77° 1′	65
Kotgarh	Simla States	31°15′—77°34′	45
Lahore	Lahore	31°34′—74°21′	122
Luri	Simla States	31°20′—77°29′	42
Mozuffarnagar	Mozuffarnagar	29°28′—77°45′	170
Náhan	Sirmur	30°32′—77°21′	90
Najibabád	Bijnor	29°37′—78°20′	170
Nurpur	Kángra	32°18′—75°57′	26
Pathankot	Do.	32°17′—75°42′	39
Pauri	Brt. Garhwál	30° 9′—78°46′	141
Rurki	Sahåranpur	29°53′—77°57′	144
Sabáthu	Simla States	30°58′—77° 2′	61
Sahåranpur	Sahåranpur	29°58′—77°35′	129

Places between Isoseismals Nos. 7 and 8.

Name of town or village.	District.	Lat. N.—Long E.	Distance in miles from nearest point of main epicentre.
Sialkot	Sialkot . .	32°30′—74°34′	106
Simla	Simla . .	31° 6′—77°11′	58
Srinagar. . . .	Brt. Garhwál .	30°13′—78°46′	147
Tarn Taran . . .	Amritsar . .	31°26′—74°54′	96
Tiri	Garhwál . .	30°22′—78°32′	128
Umbála	Umballa . .	30°21′—76°52′	102

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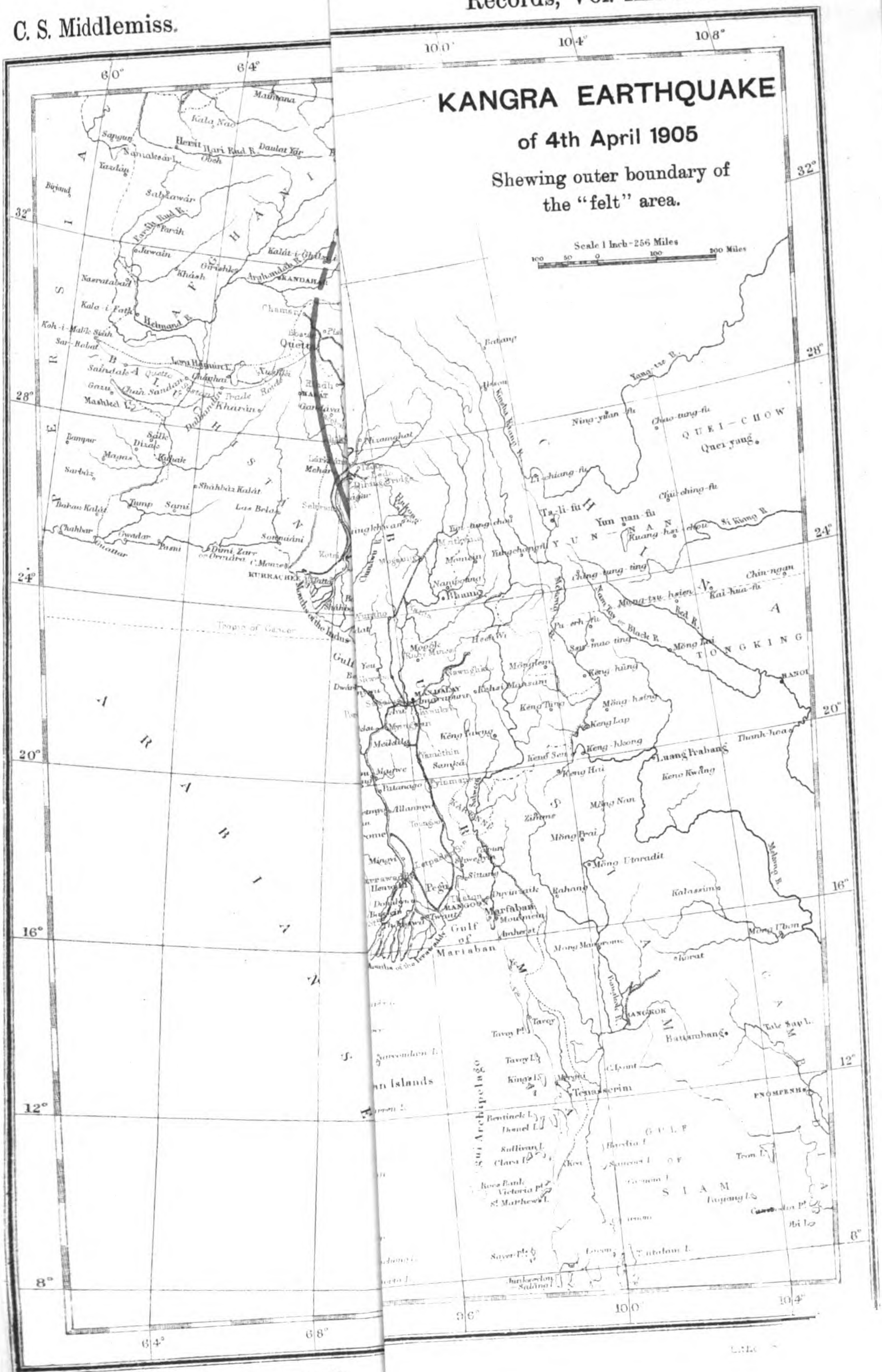

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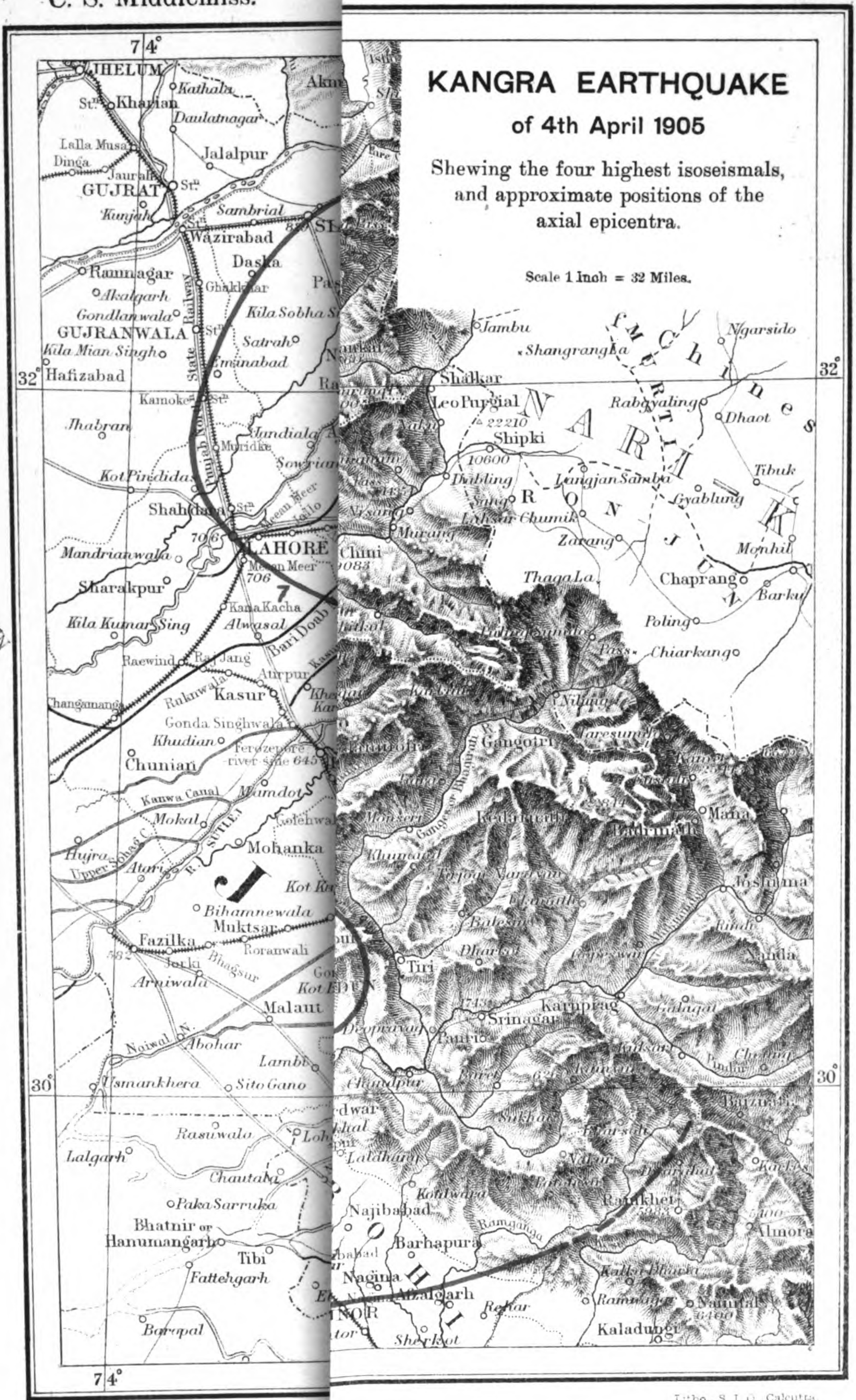

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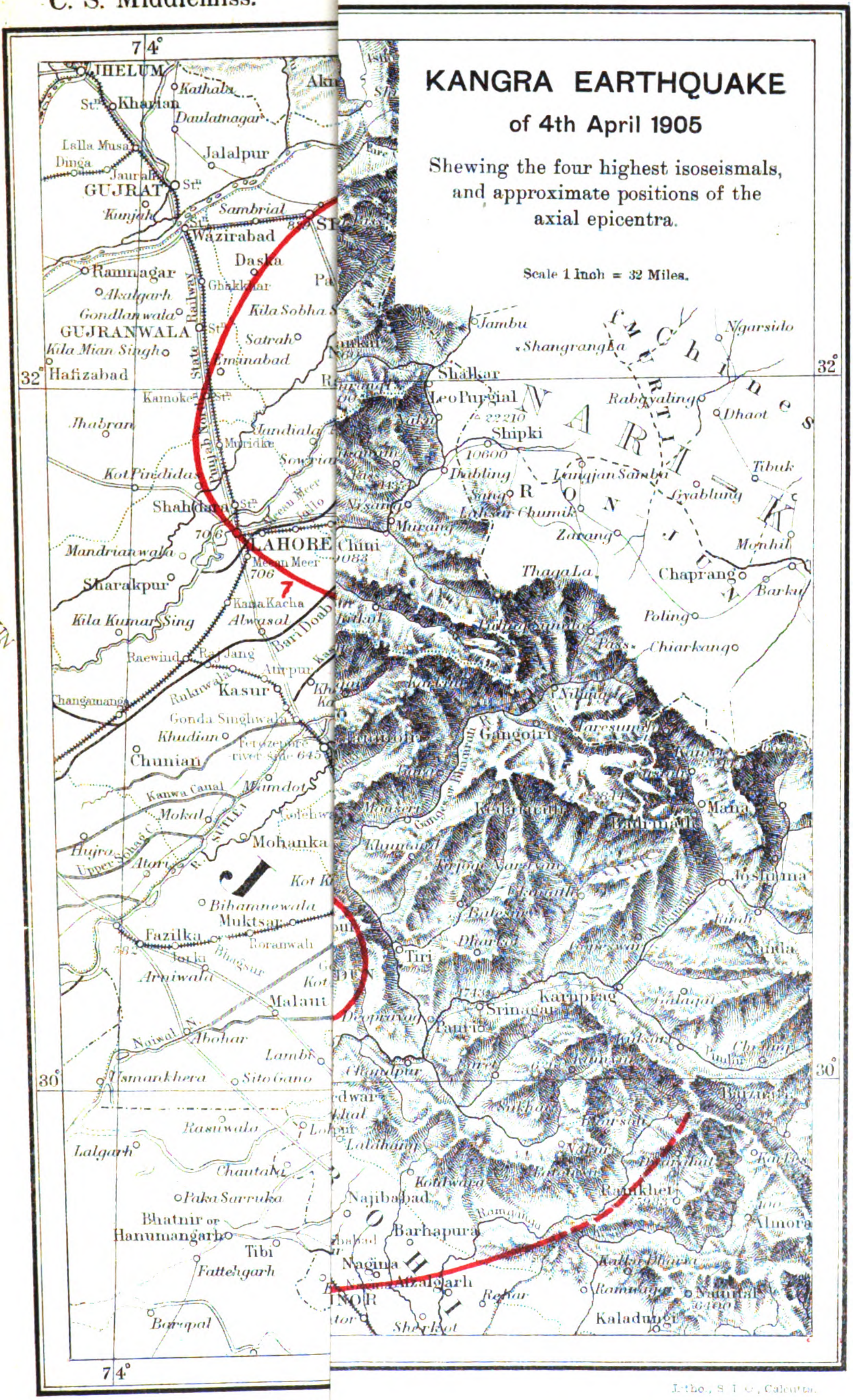

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