MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA

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THE TRIAS OF THE HIMÁLAYAS. *By* C. DIENER, PH.D.,
Professor of Palæontology at the University of Vienna

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CONTENTS.

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THE TRIAS OF THE HIMÁLAYAS. *By* C. DIENER, PH.D., *Professor of Palæontology at the University of Vienna.*

I.—INTRODUCTION.

In a note accompanying the description of the Muschelkalk in Spiti in the first part of the present volume by H. Hayden (page 72), and in a chapter treating with the correlation of the Mesozoic beds of Spiti with those of other parts of India and of Europe (page 88) it was proposed to devote a second part of this volume to a summary of the Trias of the Himálayas.

A paper treating with this subject, which had been left by the late Dr. A. v. Krafft in 1901, was entrusted to me for a careful revision by C. L. Griesbach, then Director of the Geological Survey of India. But the fragmentary character of the paper, consisting only of scattered and unarranged notes, induced me to postpone this task, until the palæontological descriptions of the new materials from the Triassic rocks of the Himálayas had been finished. The advisability of basing a summary of the Trias of the Himálaya on the results of an examination of the entire stratigraphical and fossil materials then available, was obvious.

This examination being now finished and the geological exploration of the Central Himálayas having come to a close for several seasons, a detailed paper on this subject is justified. This paper, however, can hardly be called a revision of A. v. Krafft's original notes, but is almost entirely my own work.

Fourteen years have elapsed since the publication of the results of the expedition of 1892, in which Griesbach, Middlemiss and I took part. Shortly afterwards the study of the sedimentary deposits of the Himálayas was resumed; areas formerly known only more or less superficially, were re-examined in greater detail and a very large amount of new fossil material has been obtained. Both the observations in the field, which are chiefly due to H. Hayden, A. von Krafft, La Touche, Smith, Noetling and Walker, and the subsequent examination of the collections have increased our knowledge considerably, particularly so with respect to the Trias. While formerly only the sections of Painkhanda (Shalshal cliff, Bambanag cliff) were known in any detail, we have now equally detailed accounts of those in Spiti and considerable additions have been made to our knowledge of those in Eastern Johar and Byans and in the region of the exotic blocks between Malla Johar and Hundes. It therefore seems possible now to make an attempt to correlate those four different areas.

Recent researches tend to show that the Trias, far from being developed uniformly throughout the length and breadth of the Himálayas, has some very marked geographical peculiarities. We can no longer characterise any individual section as a "type-section" of the Himálayan Trias. To do so would, indeed, be as incorrect as to speak of a particular section in the South-eastern Tirol or in the Salzkammergut as a type-section of the Alpine Trias.

In fact the Himálayan Trias clearly shows those changes of facies which are common to most sedimentary deposits of marine origin, and which, if not so rapid or abrupt as in the case of the Alpine Trias, are yet almost equally marked. This becomes especially evident from a comparison of the sections of Byans and Malla Johar with those of Spiti and Painkhanda.

My examination of the fossil collections made by Hayden and A. v. Krafft in Spiti and Malla Johar and my revision of A. v. Krafft's memoir on the Cephalopoda of the Lower Trias have delayed the writing of this paper for a longer period than I had anticipated. This delay, however, has enabled me to include many new facts, which were not known to Noetling, when publishing his summary of the Trias of Asia in *Lethæa mesozoica* (Vol. I, Pt. 2, Stuttgart, 1905). A direct comparison will, I trust, convince the reader that the present paper has not been rendered altogether unnecessary by Noetling's memoir.

II.—LITERATURE.

Before entering upon a description of the Triassic sediments of the Himálayas, a short historical retrospect of the development of our knowledge of those deposits may be deemed appropriate.

The credit of the discovery of Triassic deposits in the Central Himálayas is due to Captain (afterwards General Sir Richard) Strachey,[1] who in 1851 mentioned their presence in several localities in the neighbourhood of the Niti Pass. Their correlation with the beds of St. Cassian by Greenough (1855), by E. Suess[2] (1862) and by T. W. Salter[3] (1865) was based on an examination of the fossils, which had been collected by Strachey from loose blocks, not *in situ*.

Although the defective state of our knowledge of the stratigraphy of the Alpine Trias and the wide range of interpretation adopted in Triassic species of Cephalopoda prevented any attempt at an exact correlation at that time, the general statement of a remarkable analogy with the Alpine Trias has been proved to be correct.

The existence of Triassic beds was confirmed by an examination of fossils, which had been collected in Spiti and Hundes by Dr. Gerard and by the brothers von Schlagintweit.

H. F. Blanford[4] described the Gerard collection and proved one of the Triassic species of ammonites (*Ptychites Gerardi* Blfd.) to belong to a genus characteristic of the Alpine Muschelkalk.

The Cephalopoda of the Schlagintweit collections were examined by A. Oppel,[5] the brachiopods and bivalves by C. W. Guembel.[6] Oppel

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[1] R. Strachey : On the geology of part of the Himálaya Mountains and Tibet, *Quart. Journ. Geol. Soc.*, VII, 1851, pp. 292-310.

[2] E. Suess : *Verhandl. K. K. Geol. Reichsanst., Wien,* XII, p. 255 (Sitzg. 31, Juli 1862).

[3] T. W. Salter and H. F. Blandford : *Palæontology of Niti in the Northern Himalayas,* Calcutta, 1865.

[4] H. F. Blanford : On Dr. Gerard's collection of fossils from the Spiti valley in the Asiatic Society's Museum. *Journal Asiat. Soc. of Bengal,* 1863, No. 2, pp. 121-138.

[5] A. Oppel : Ueber Ostindische Fossilreste aus den sekundaeren Ablagerungen von Spiti and Gnari Khorsum in Tibet. *Palæontol. Mitteilungen aus dem Museum des Kgl. bayrischen Staates,* I, p. 267.

[6] C. W. Guembel : Ueber das Vorkommen von unteren Triasschichten in Hochasien (nach den von den Gebruedern von Schlagintweit gesammelten Fundstuecken beurteilt). *Sitzgsber. Kgl. bayr. Akad. d. Wiss. Muenchen,* 1865 (XI), pp. 348-366.

recognised the Triassic character of seventeen species of ammonites. Guembel assigned three species of bivalves to the Buntsandstein.

In the meantime E. Beyrich[1] proved the ammonites described by Oppel to be of Muschelkalk age.

Thus the presence of two different Triassic horizons had been established in the Himálayas, of the Lower Trias (Buntsandstein) in a bivalve-bearing facies, and of the Muschelkalk in a facies of dark limestone rich in Cephalopoda. But this establishment had been based on the study of fossils only discovered by travellers in different parts of the sedimentary belt of the great range. Stratigraphical observations in the field were still entirely wanting.

Stoliczka was the first author, who gave a rough outline of the stratigraphy of the Himálayas after having visited a number of sections in Spiti and Rupshu in 1864.[2] His system was one strictly based upon the simple practice of giving a geographical name to a rock group, without reference of each particular local group to a place in the stratigraphical standard scale. His views have been adopted by the authors of the "Manual of the Geology of India." Both his general classification of the Himálayan Trias and its correlation with the homotaxial rock groups in Europe have required some modifications, in order to bring them into line with our more extensive knowledge.

Stoliczka grouped the sedimentary formations between the Silurian (Muth series) and the Lias (Tagling limestone) into three divisions. He distinguished, in descending order :—

3. Para limestone, corresponding to the rhætic stage (Dachsteinkalk of Austrian geologists).
2. Lilang series, Upper Trias, corresponding to the beds of Hallstatt and St. Cassian.
1. Kuling series, Carboniferous.

Stoliczka believed the Upper Trias to rest immediately on the Carboniferous and failed to recognise the Lower and Middle Trias. Without depreciating the value of Stoliczka's stratigraphical results it is neces-

[1] E. Beyrich : Ueber einige Cephalopoden aus dem Muschelkalk der Alpen und ueber verwandte Arten, *Abhandl. Kgl. Akad. d. Wiss. Berlin*, 1866, No. 2, pp. 105-179.

[2] F. Stoliczka : Geological sections across the Himálaya Mountains from Wangtu bridge on the river Sutlej to Sungdo on the Indus, *Mem. Geol. Surv. of India*, Vol. V, Pt. 1, 1865, pp. 1-154.

sary to lay special stress on this fact, because Noetling in his historical retrospect [1] somewhat exaggerates the importance of Stoliczka's work in Spiti affirming with great confidence that the only progress in the stratigraphy of the Trias since Stoliczka's memoir is marked by the discovery of the Lower Trias within the Lilang series.

Stoliczka was particularly unfortunate in confining his attention to the Kuling section, which he presumably accepted as a typical one, whereas subsequent researches have shown the Lower Trias to be cut out there by a fault, which causes the Daonella shales to lie directly on the Productus shales. We may, however, admit that his overlooking the Lower Trias is easily explained by his short visit to the Spiti sections and that his correlation of the entire Lilang series with the Upper Trias is pardonable, fossils of the Muschelkalk having been found, but not recognised as such before Stoliczka's survey began.

There is, however, no doubt that considering the circumstances under which he worked, Stoliczka's stratigraphical results were most valuable. To him belongs the credit of having been the true pioneer of Himálayan stratigraphy.

Very considerable progress was subsequently made by C. L. Griesbach, who succeeded Stoliczka in the geological exploration of the Himálayas and in 1880 gave the first systematic account of the Triassic system.[2] All subsequent accounts of the Himálayan Trias must needs be based on his work.

He was the first to discover the Lower Trias and the Muschelkalk *in situ*. In a preliminary note on his first season's work in the Himálayas he gave a detailed description of the section of the Shalshal cliff near Rimkin Paiar, in Painkhanda, together with description and figures of the fossils characteristic of the *Otoceras* horizon, which was then considered by him as a passage bed between the Permian and Triassic systems.[3] In the Upper Trias he distinguished a number of subdivisions, which still remain unaltered, although the knowledge of their fossils has led to a correlation with Alpine Triassic stages, differing widely from that which had been established by Griesbach.

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[1] F. Noetling, Asiatische Trias, *Lethœa mesozoica*, 1. c., p. 125.

[2] C. L. Griesbach : Geological notes, *Records, Geol. Surv. of India,* XIII, 1880, pp. 83-93.

[3] C. L. Griesbach : Palæontological notes on the lower Trias of the Himálayas, *ibid.*, XIII, pp. 94-113, XIV, pp. 154, 155.

In 1883 C. L. Griesbach visited Spiti in order to remove certain discrepancies between Stoliczka's description and his own observations in the Central Himálayas of Kumaon and Garhwal. He was able to show that Stoliczka's Kuling shales were of Permian age and followed conformably by the Lower Trias and by the Muschelkalk, which Stoliczka had failed to recognise in his Triassic sections.[1]

In the meantime the survey of Kashmir and Ladakh had been brought to a close by R. Lydekker. He made an attempt to identify in Kashmir the subdivisions established by Stoliczka in Spiti. Being obliged by the difficulty of the terrane to include in one single group—his "Supra-Kuling series" all the beds from the Lilang series upwards to the Chikkim limestone, he was not able to establish any subdivisions of the Triassic rocks, which he found, however, widely distributed throughout the district, which had been surveyed by him during the years 1875 to 1882.[2]

In 1891 C. L. Griesbach published his memoir on the geology of the Central Himálayas.[3]

This is, indeed, a standard work to the student of Himálayan geology, dealing with the vast area of high ranges of Garhwal and Kumaon, including Byans and some of the adjoining parts of Hundes.

The fossil Cephalopoda collected by him in his researches were sent to Vienna and examined by E. v. Mojsisovics.[4] They indicated the existence of several Triassic localities and horizons sufficiently rich in fossils to encourage the promotion of a special expedition into the Central Himálayas. This joint expedition of the Imperial Academy of Vienna and of the Geological Survey of India (May to October 1892), in which Diener, Griesbach and Middlemiss took part, made a detailed survey of the Bambanag and Shalshal cliff sections and had the good fortune to discover the remarkable region of exotic blocks near Chitichun No. 1.

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[1] C. L. Griesbach: Geological notes, *Records, Geol. Surv. of India*, XXII, 1889, pp. 158, 167.

[2] R. Lydekker: The Geology of the Kashmir and Chamba territories, and the British district of Khagan. *Mem., Geol. Surv. of India*, Vol. XXII, 1883.

[3] C. L. Griesbach: Geology of the Central Himálayas. *Mem., Geol. Surv. of India*, Vol. XXIII, 1891.

[4] E. v. Mojsisovics: Vorläufige Bemerkungen ueber die Cephalopodenfaunen der Himálaya-Trias. *Sitzgsber-Kais. Akad. d. Wissensch.* C. I, Abt. 1. p. 272.

Large collections from all the fossiliferous Triassic beds were obtained, but Griesbach's classification of the Triassic system underwent only slight modification. The most important, perhaps, was the evidence—supported by the palæontological researches of Bittner and F. E. Suess—that beds with Koessen types were not known to occur in the Himálayas of Painkhanda and Johar, and that Griesbach's "Upper Rhætic" is in fact younger, probably Lias. The boundary between the Triassic and Jurassic systems is consequently to be drawn considerably lower in the sequence of beds than was done by Griesbach.

In addition to Diener's detailed account of the stratigraphical results of the expedition in 1892,[1] C. Diener,[2] E. v Mojsisovics[3] and A. Bittner[4] have published exhaustive descriptions of the various Triassic fossil faunæ in series XV of the *Palæontologia Indica.*

Those palæontological researches offered the possibility of a detailed comparison of the succession of the individual Triassic faunæ both in the Himálayas and in the Eastern Alps. They might even seem to justify the opinion that our knowledge of the Himálayan Trias had arrived at a point beyond which no new results of any great importance could be expected. But although this may be true to some extent with regard to the sections of Painkhanda and Western Johar, the Trias of the Himálayas as a whole was by no means known in great detail.

Even in the two classical sections of the Bambanag and Shalshal cliffs two gaps had to be filled by later examinations, the absence of the ladinic stage and of beds representing the zone of *Tropites subbullatus.* On the other hand considerable interest in Himálayan geology had been aroused by the memoirs mentioned above.

After several years' intermission the geological survey of the higher ranges of the Himálayas was resumed in 1898. H. Hayden was deputed to Spiti and made detailed studies in the Palæozoic and Triassic regions

[1] C. Diener : Ergebnisse einer geologischen Expedition in den Central Himálaya von Johar, Hundus und Painkhanda, *Denkschr. Kais. Akad. d. Wiss.*, LXII, 1895, pp. 533-608.

[2] C. Diener : Cephalopoda of the Muschelkalk, Himálayan Fossils, *Palæontologia Indica*, ser. XV, Vol. II, Pt. 2, (1895). Cephalopoda of the Lower Trias, *ibidem* Vol. II, Pt. 1, (1897).

[3] E. v. Mojsisovics : Upper Triassic Cephalopoda faunæ of the Himálayas, *ibidem* Vol. III, Pt. 1, (1899). The German original was published in 1896 in Vol. LXIII of the *Denkschr. d. Kais. Akad. d. Wissensch.*

[4] A. Bittner : Trias Brachiopoda and Lamellibranchiata of the Himálayas, *Palæontologia Indica, l. c.*, Vol. III, Pt. 2, (1899).

of the upper Pin valley and adjoining areas. The survey work was continued in Spiti during the summer of 1899 by H. Hayden and A. von Krafft. The Triassic beds were found to be of greater thickness and to contain a larger number of fossiliferous horizons than in the sections of Painkhanda studied by Griesbach and Diener. Three distinct stratigraphical horizons were observed in the Lower Trias (Scythian stage) and an equal number in the Muschelkalk. Both the ladinic stage and the zone of *Tropites subbullatus*, which Griesbach and Diener had failed to recognise in Painkhanda, proved to be especially well developed. At the base of the Dachsteinkalk a series of quartzites and shales, not known from the Bambanag and Shalshal cliffs, were found to constitute a well-marked stratigraphical horizon.[1]

In the season of 1898 T. H. D. La Touche was charged with a detailed survey of the upper Lissar valley and F. H. Smith with the survey of Byans. The work of the latter geologist was resumed in 1900 by A. v. Krafft. Large collections were made from the Lower Trias, the Muschelkalk, and the Tropites limestone. Descriptions and figures of the fauna of the latter were published by Diener in Vol. V of the "Himálayan Fossils."[2]

After his survey of Byans A. v. Krafft visited the sections of the Bambanag and Shalshal cliffs, in order to make a comparison with the Spiti sections based on personal examination.

He was able to prove the ladinic stage to be represented there, although poor in fossils and extremely reduced in thickness. He also found his classification of the Muschelkalk, as adopted for Spiti, to be correct. On the progress attained by him with respect to the subdivisions of the Muschelkalk, he has reported in a special paper.[3]

Both in the Halorites beds and in the Traumatocrinus limestone he collected a large number of fossils, which were examined subsequently by C. Diener.[4]

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[1] A. v. Krafft: Stratigraphical notes on the mesozoic rocks of Spiti, *General Report, Geol. Surv. of India*, 1899-1900, pp. 199-230.

[2] C. Diener: The fauna of the Tropites limestone of Byans. *Palæontologia Indica*, ser. XV, Vol. V, Pt. 1, (1906).

[3] A. v. Krafft: Zur Gliederung des Muschelkalkes im Himálaya. *Verhandl. K. K. Geol. Reichsanst.*, 1901, p. 52.

[4] C. Diener: Note on some fossils from the Halorites limestone of the Bambanag cliff (Kumaon), collected by the late Dr. A. v. Krafft. in the year 1900. *Records, Geol. Surv. of India*, Vol. XXXIV, 1906, pp. 1-11. The fauna of the Traumatocrinus limestone. *Palæont. Ind.*, ser. XV, Vol. VI, Pt. 2, (1909).

A. v. Krafft's greatest success was the discovery of rich Triassic and Liassic faunæ in the exotic blocks of Malla Johar, where the Mesozoic beds are developed in a facies differing completely from the normal facies of the main sedimentary belt of the Central Himálayas. The stratigraphical and tectonic results of his survey have been summarized in a very interesting paper.[1] Soon after having finished his manuscript, he died suddenly on the 22nd September 1901. By his death the Geological Survey of India suffered the loss of a most valuable Himálayan explorer.

In 1900 a new problem came up, concerning particularly the correlation of the Lower Triassic beds of the Himálayas and the Salt Range.

In the Salt Range, which had given the most perfect sections of upper Palæozoic and Lower Triassic formations, there appeared a complete series of beds distinguished by easily recognised differences in their lithological characters and in their fossils. A lower division, the Productus limestone, had been assigned to the Permian, and an upper one, the Ceratite formation to the Triassic system.

Noetling's researches in the Salt Range had led him to views regarding the Permo-Triassic boundary in the Ceratite beds which differed considerably from those of previous workers both in that area and in the Central Himálayas. In 1900 he visited the sections of the Shalshal cliff and of the vicinity of the Niti Pass, in order to study the boundary between the undoubted Permian and the Otoceras beds. His proposal to draw the actual boundary between the Permian and Triassic systems above the top of the Otoceras beds, has given rise to a careful discussion of all the points, in which he and Diener differed in their interpretation.

In this discussion Noetling was supported by A. v. Krafft, Diener by J. P. Smith.[2]

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[1] A. v. Krafft: Notes on the exotic blocks of Malla Johar in the Bhot Mahals of Kumaon. *Mem. Geol. Surv. of India*, Vol. XXXII, Pt. 3, 1902.—For descriptions and figures of fossils, *vide* C. Diener, Triassic and Liassic faunæ from the exotic blocks of Malla Johar in the Bhot Mahals of Kumaon. *Palæont. Ind.*, ser. XV, Vol. I, Pt. 1, (1908).

F. Noetling: Die Otoceras beds in India. *Centralblatt f. Mineral*, etc., 1900, p. 216, and *General Report, Geol. Surv. of India* for 1900-01, p. 28. A. v. Krafft:

After the death of A. v. Krafft the task of finishing the survey of Spiti and Rupshu devolved upon H. Hayden. The results of his work carried out during the three seasons of 1898, 1899 and 1901, were exposed in a memoir, in which the chapter dealing with the Triassic rocks, has been based chiefly on the notes left by his late companion in the field.[1]

Of the rich fossil materials collected by those distinguished officers in the Muschelkalk and in the Upper Trias only a cursory examination had been made by A. v. Krafft.[2] A full account, with the descriptions and figures of new forms discovered since 1897, was published in the *Palæontologia Indica* by Diener,[3] who also undertook the work of revising and editing a monograph of the Cephalopoda from the Lower Trias, which had been left unfinished by A. v. Krafft in 1901.[4]

A synopsis of the stratigraphy of the Trias in Asia by F. Noetling,[5] which appeared in 1905, deserves special mention. As I shall have to refer to this memoir repeatedly, a short abstract will be found useful.

As the best representative of the Indo-Chinese zoogeographical province, the Trias of the Himálayas is treated rather extensively. The boundary between the Permian and Triassic systems is drawn by Noetling above the Otoceras beds, according to his views expressed in 1900. The Trias begins with the zone of *Proptychites* (*Prionolobus*) *Markhami* Dien., and includes ten cephalopod-bearing horizons,

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Ueber das permische Alter der Otoceras-Stufe des Himálaya. *Centralblatt f. Mineral*, 1901, p. 275; C. Diener: Ueber das Alter der Otoceras beds des Himálaya, *ibidem*, p. 510; C. Diener: Zur Frage des Alters der Otoceras beds im Himálaya, *ibid.*, p. 655. F. Noetling in F. Frech, *Lethæa Palæozoica*, II, Dyas, p. 653; F. Noetling: Ueber das Alter der Otoceras Schichten von Rimkin Paiar (*Painkhanda*) im Himálaya. *Neues Jahrb. f. Mineral*, Beil. Bd. XVIII, p. 258. C. Diener: Ueber die stratigraphische Stellung der Otoceras beds des Himálaya, *Centralbl. f. Mineral*, 1905, pp. 1-9, 36-45.

[1] H. Hayden: The geology of Spiti, with parts of Bashahr and Rupshu, *Mem. Geol. Surv. of India*, Vol. XXXVI, Pt. 1, 1904.

[2] A. v. Krafft: *General Report Geol. Surv. of India*, 1898-99, pp. 11-12.

[3] C. Diener: The fauna of the Himálayan Muschelkalk, *Palæont. Indica*, ser. XV, Himálayan, Foss. Vol. V, Pt. 2, (1907); Ladinic, carni and noric faunæ of Spiti, *ibidem*, Vol. V, Pt. 3, (1908).

[4] *Palæontologia Indica*, ser. XV, Himál. Foss., Vol. VI, Pt. 1, (1909).

[5] F. Noetling: Die asiatische Trias, *Lethæa geognostica*, II, Teil, Das Mesozoicum, Bd. I, Trias, 2. Liefg., Stuttgart, Schweizerbart, 1905.

distinguished by their fauna. Those horizons are enumerated by Noetling, as follows :—

Upper Trias	10. *Sagenites* beds. 9. *Halorites* beds. 8. *Hauerites* beds. 7. *Tropites* beds. 6. *Joannites* beds.
Middle Trias	5. *Ptychites* beds. 4. *Robustites* beds.
Lower Trias	3. *Stephanites* beds. 2. *Hedenstrœmia* beds. 1. *Prionolobus* beds.

Regarding the Lower Trias, Noetling admits that the *Stephanites* beds[1] are only known from Byans and that there is no evidence of their being overlain directly by the *Robustites* beds (with *Ceratites subrobustus*).

He considers the mass of unfossiliferous limestone resting conformably on the horizon of *Rhynchonella Griesbachi* and followed by the beds containing *Spiriferina Stracheyi* as the lowest element of the Middle Trias (Muschelkalk); for this mass of limestones the name of Niti limestone is introduced.

In Spiti the boundary line between the ladinic and carnic stages is drawn by him right across the Grey beds, although their basal Cephalopod horizon with *Joannites cymbiformis* contains a fauna of decidedly carnic habit. The Daonella beds with *Halobia comata* of the Shalshal cliff are also correlated erroneously with the ladinic stage (page 147).

The great difference in the thickness of nearly all the zones of Upper Triassic age in Spiti and Painkhanda which is abundantly evident from A. v. Krafft's sections, is considered doubtful. The affinities between the Himálayan and Alpine faunæ of Middle and Upper Triassic age appear to him rather distant. " The affinities with the Alpine Trias are marked by a general relationship, by the association of various genera only (page 158).[2] The faunæ of Lower Triassic age have no affinity whatever with those of the Eastern Alps. There is, indeed,

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[1] The genus *Stephanites* is altogether unknown from the Lower Trias of the Himálayas.

[2] This statement is contradicted by a footnote, which has been added by Frech.

no strict evidence for the homotaxy with the Buntsandstein of the beds underlying the Niti limestone."

The annexed table clearly shows the progress which has been made in the classification of the Himálayan Trias since 1865.

The stratigraphy of the Trias in the Central Himálayas is fixed with sufficient certainty now to exclude the probability of any considerable alterations in the sequence of horizons. It is necessary to lay special stress on the fact that, even where differences of opinion still exist between two authors—as for instance in the case of the question of the Permo-Triassic boundary—those authors agree in their views concerning the local stratigraphy, as established in the classical sections of Spiti and Painkhanda. It is in the interpretation of the facts observed that they differ, not in the facts themselves.

Stoliczka Spiti, 1864.	Griesbach Painkhanda, 1891.		Diener Painkhanda, 1895.		Hayden and A. v. Krafft, Spiti, 1904.	
Lower Tagling limestone = Kœssen beds (Lower Lias). Para Limestone = Rhætic.	13. Grey crinoid limestone thick bedded, with intercalated shales, rich in brachiopods and bivalves.	Passage beds .	13. Thin bedded limestones, with many bivalves.	Lias ?	19. Megalodon limestone.	Lias and Dachsteinkalk.
Lilang series = upper Trias.	12. Lithodendron limestone, interbedded with sandstones, crinoid limestone and shales, with Kœssen types. 11. Thick bedded limestone with *Megalodon*. 10. Dolomite and limestone.	Hauptlithodendronkalk and Kœssen beds (Upper Rhætic). Dachsteinkalk . Hauptdolomit (Lower Rhætic)	12. Stratified limestones, with Lithodendron and crinoids, Megalodus lc., massive or thick bedded dolomites and limestones.	Dachsteinkalk	18. Quartzite series with *Spiriferina Griesbachi*. 17. Monotis shales . . 16. Coral limestone with *Spiriferina Griesbachi*. 15. Juvavites beds.	Noric stage.
Kuling series = Carboniferous.	9. Liver coloured limestone and greenish shales with *Corbis Mellingi*. 8. Greenish grey shales and shaly limestone, with *Spirifer lilangensis*. 7. Hard grey limestone, marly and shaly beds, with *Tropites Feistmanteli*. 6. Black limestones and splintery black shales (Daonella beds).	Upper Trias	11. Liver coloured limestone with *Sagenites*. 10. Dolomitic limestones with *Spiriferina Griesbachi*. 9. Halorites beds. 8. Hauerites beds.	Noric stage	14. Tropites beds. 13. Grey shales. 12. Halobia beds. 11. Daonella limestone. 10. Daonella shales.	Carnic stage. Ladinic stage.
Lydekker Kashmiri, 1883.			7. Shales and limestones with *Cladiscites cf. subtornatus*, Daonella beds. 6. Traumatocrinus lc., with *Joannites cymbiformis*.	Carnic stage	9. Limestone with *Ptychites rugifer*. 8. Zone of *Spiriferina Stracheyi* and *Ceratites subrobustus*. 7. Nodular limestone.	Muschelkalk.
Supra-Kuling series (*in parte*).	5. Hard grey limestone, with *Ptychites Gerardi*. 4. Earthy limestone, with *Rhynchonella cf. semiplecta var*.	Muschelkalk .	5. Massive and stratified limestone with *Ptychites rugifer*. 4. Earthy limestone with *Sibirites Prahlada* and *Rhynchonella Griesbachi*.	Muschelkalk	6. Shaly lc. with *Rhynchonella Griesbachi*. 5. Hedenstrœmia beds. 4. *Meekoceras* zone. 3. *Ophiceras* zone.	Lower Trias.
Kuling series = Carboniferous.	3. Black limestones and shales with *Norites planulatus*. 2. Black limestones and shales with *Otoceras Woodwardi*.	Buntsandstein .	3. Subrobustus beds . . 2. Otoceras beds . .	Lower Trias	2. *Otoceras* zone.	?
	1. Productus shales . .	Permian . .	1. Productus shales . .	Permian	1. Productus shales.	Permian.

III.—GENERAL DEVELOPMENT OF THE HIMALAYAN TRIAS.

A broad sedimentary belt extends from Kashmir through Spiti, Garhwal and Kumaon to the N.-W. boundary of Nepal.

In this sedimentary zone of fossiliferous deposits, which range from Middle Cambrian to Cretaceous, the Trias is developed in a facies of dark shales and limestones of exclusively marine origin. No igneous rocks have been noticed within the Triassic or Jurassic series. The limestones are of dark or grey colour, well bedded as a rule, and in some horizons either concretionary or dolomitic. In the majority of sections there is a remarkable contrast between the light grey dolomitic limestones of the upper and the dark coloured shales and limestones of the lower portion of the Triassic rocks, the total thickness of which amounts to more than 4,000 feet in Spiti.

This normal development of the Himálayan Trias is chiefly characterised by the regular distribution of each single horizon over a comparatively large area, and by the absence of a facies of red marble.

In the region of the exotic blocks in Malla Johar and near Chitichun No. I, the Triassic strata show a development differing considerably from that observed in the normal sections of the main region of the Himálayas. In this region the Triassic system is of only comparatively small thickness, and most of the Triassic horizons are developed in a facies of red limestone and marble exhibiting a striking resemblance to the Hallstatt limestone of the Eastern Alps. Especially in the beds of the carnic stage are there remarkable agreements with their homotaxial equivalents in the Mediterranean region, the agreement being faunistic as well as lithological.

Thus two regions of different development can be distinguished within the area of Triassic rocks in the Central Himálayas, one of them representing the normal facies of the Mesozoic belt, and the other representing the facies of exotic blocks connected intimately with igneous intrusions.

The former A. v. Krafft termed the Himálayan and the latter the Tibetan *facies* of the marine Trias.

A. Himalayan Facies.

I. The Lower Trias.

a. Spiti.

The most complete section of the marine lower Trias is found in Spiti, although in thickness it is inferior to that of Painkhanda and Byans.

Lower Triassic fossils were known from the Himálayas as far back as 1865, when C. W. Guembel [1] recognised in the collections of the brothers von Schlagintweit several species of bivalves, which he identified with *Anodontophora fassaensis* Wissm., *Lima costata* Muenst., *Nucula Goldfussi* Alb. from the Werfen beds of the Eastern Alps. The locality from which those fossils are quoted is Balamsali near Dankhar. The identity of this locality with a place near Lilang in Spiti is very doubtful, as will be shown below.

Stoliczka failed to recognise the existence of lower Triassic rocks in Spiti. The credit of their discovery *in situ* is due to C. L. Griesbach. He found the lowest beds, following immediately above the Permian Productus, or Kuling, shales to contain the fauna of the Otoceras beds, discovered by him in 1879 in the Painkhanda sections near the Niti pass.

He also recognised that a second higher division was present in the Lower Triassic section of Muth, although he did not separate the two horizons distinctly.

The Spiti sections were studied in great detail by H. Hayden and A. v. Krafft in 1899. On their researches and on the examination by Diener of their rich collections the following statements are based.

The best exposures of lower Triassic rocks have been observed in a section near Lilang. The sequence[2] is as follows, in descending order :—

1 C. W. Guembel : Ueber das Vorkommen von unteren Triasschichten in Hochasien, nach den von den Gebruedern Schlagintweit gesammelten Fossilstuecken beurteilt. *Sitzgsber. kgl. bayr. Akad.*, Muenchen, 1865, Pt. 2, p. 348.

2 Described in *General Report Geol. Surv. of India* for 1899-1900, p. 200, and in H. Hayden, *Geology of Spiti*, *l. c.*, pp. 63-67.

	Ft.	In.	
11. Nodular limestone . . .	60	0	; (Niti limestone, Noetling).
10. Calcareous shales . . .	6	0	; containing *Rhynchonella Griesbachi* Bittn.
9. Shaly limestone			; containing *Pseudomonotis himaica* Bittn.
8. Grey shaly limestones and grey shales, alternating very regularly.	24	0	; unfossiliferous.
7. Nodular limestone with very thin shaly partings.	5	7	; with *Hedenstrœmia Mojsisovicsi*, *Xenodiscus nivalis*, *Pseudosageceras mulilobatum*.
6. Grey shaly limestones . .	0	7	; } poor in fossils. No determinable ammonites.
5. Shales	0	10	; }
4. Concretionary limestones and shales.	3	0	; very rich in *Meekoceras*, especially *M. lilangense* and *M. Varaha*.
3. Grey limestones . . .	1	5	; containing *Ophiceras Sakuntala* and *Pseudomonotis Griesbachi*.
2. Sandy limestones weathering brown.	1	7	; no fossils.
1. Rusty brown, ferruginous limestone.	0	5	; *Ophiceras div. sp.*, *Otoceras sp.*

Productus, or Kuling shales.

In this, as in several other sections, the band of grey shaly limestones and shales (5 and 6), from which no determinable ammonites have been obtained, marks a lithological as well as a faunistic boundary between a lower and an upper division of the sequence of beds which are exposed between the Permian Productus shales and the nodular limestone of the Muschelkalk.

This boundary is marked even more strongly in the section S. E. of Muth, because the bands 5 and 6 there reach a thickness of four feet and are entirely unfossiliferous, whereas the ammonites restricted to bed 7 in the Lilang section occur throughout the entire series of thin-bedded grey shales and limestones (8) in the hills S. E. of Muth.

It has therefore been found convenient to divide the lower Trias of Spiti into two divisions, the lower of these comprising beds 1 to 4 and reaching an entire thickness of 6 feet 5 inches only, the upper comprising beds 6 to 10 and attaining a thickness of 35 feet 7 inches in the Lilang section.

The genus *Otoceras* Griesb. is restricted to the rusty brown ferruginous limestone at the very base of the series. Even here it is very rare, In the large collections which were made by H. Hayden and A. v. Krafft, the following species are represented :—

Otoceras Woodwardi Griesb. (Khar, 5 miles S. of Ensa, S. E. of Muth, Kuling).
,, *cf. undatum* Griesb. (5 miles S. of Ensa).
,, *Clivei* Dien. (5 miles S. of Ensa, S. E. of Muth, S. W. of
,, Gaichund).
,, *nov. sp. ind. aff. Clivei* Dien. (S. W. of Gaichund).

They occur together with *Episageceras Dalailamaœ* Dien., *Prosphingites nala* Dien. and several species of *Ophiceras*, especially *O. Sakuntala* Dien., which is also the most frequent companion of the genus *Otoceras* in the corresponding beds of Painkhanda.

From the higher beds of the lower Trias of Spiti *Otoceras* is completely absent.

The next fossiliferous horizon is bed 3. Both *Ophiceras* and *Pseudomonotis Griesbachi*—a representative of the Alpine group of *Claraia*—are very common. The genus *Ophiceras* Griesb. is represented by the following species :—

Ophiceras Sakuntala Dien.
,, *tibeticum* Griesb.
,, *cf. demissum* Opp.
,, *Chamunda* Dien.

Xenodiscus radians Waag. also occurs in this main layer of *Ophiceras*, whereas the presence of *Meekoceras*, although quoted by A. v. Krafft (General Report Geol. Surv. of India for 1899-1900, p. 200) and Hayden (Geology of Spiti, l. c., pp. 63, 65), cannot yet be considered as beyond dispute.

Whereas in bed 3 *Ophiceras* is the predominating genus, it is extremely rare in bed 4, being represented there by a single species only (*Ophiceras obtuso-angulatum* Dien.). Its place is taken by the genus *Meekoceras*. Including the two subgenera *Aspidites* and *Koninckites*, not less than fourteen species are present, namely :—

Meekoceras Varaha Dien.
,, *Markhami* Dien.
,, *lilangense* Krafft.
,, *lingtiense* Krafft.
,, *tenuistriatum* Krafft

Meekoceras rugosum Krafft.
,, *jolinkense* Krafft.
,, *disciforme* Krafft.
,, *cf. discus* Waag.
Aspidites spitiensis Krafft.
,, *ensanus* Krafft.
,, *crassus* Krafft.
Koninckites Haydeni Krafft.
,, *alterammonoides* Krafft.

To those species of ammonites must be added :—

Xenodiscus radians Waag.
,, *lilangensis* v. Krafft.
Hedenstrœmia lilangensis v. Krafft, the most primitive species of this genus, together with a new genus, nearly allied to *Hedenstrœmia*, but holding a position intermediate between it and *Pseudosageceras* in the arrangement of its sutural line.

Of *Nautiloidea* one species only—*Grypoceras lilangense* Krafft—is at present known.

Lithologically the *Ophiceras* beds and the *Meekoceras* beds are connected so intimately, that A. v. Krafft and H. Hayden did not succeed in keeping separate the fossils which they collected in some of their detailed sections. Those two faunistic subdivisions should therefore not be taken as sharply defined stratigraphical horizons of paramount importance. The two faunæ are, it is true, as a whole distinct, but it must be understood that we cannot yet say anything definite about their affinities, the original layer of a considerable number of species, which are perhaps common to both of them, remaining uncertain.[1]

[1] There are not less than thirteen species of doubtful stratigraphical position, namely :—

Meekoceras boreale Dien.
,, *cf. radiosum* Waag.
,, *dubium* Krafft.
,, *kyokticum* Krafft.
Aspidites Vidarbha Dien.
Proptychites typicus Krafft.
,, *sp. ind. aff. typico.*
Xenodiscus rigidus Dien.
,, *rotula* Waag.
,, *cf. plicosus* Waag.
Nannites hindostanus Dien.
,, *Herberti* Dien.
Flemingites Guyerdeti Dien.

All of these certainly belong to the lower division of the Lower Trias, but the particular horizon in which they have their habitat, is not known.

Thus from a faunistic point of view we can distinguish three subdivisions in the lower portion of the Lower Trias of Spiti, namely, the *Otoceras* bed (1), the *Ophiceras* bed (3), the *Meekoceras* bed (4), each of them being characterised by the abundance—but not, as a rule, the exclusive occurrence—of one genus of ammonite, which predominates in that particular horizon.

Beds 7 and 8, which are separated in all sections studied by Hayden and A. v. Krafft, by a band of unfossiliferous rock from 1½ to 4 feet in thickness from the lower division (*Meekoceras* bed), contain a fauna of uniform character, in which some species of *Xenodiscus* (especially *X. nivalis* Dien.), *Hedenstrœmia* and *Flemingites* predominate. For this horizon the name of "Hedenstrœmia beds" or "Zone of *Flemingites Rohilla*" has been proposed by A. v. Krafft. A rich fauna of this horizon was first discovered by C. L. Griesbach in 1883 S. E. of the village of Muth, and its stratigraphical independence was recognised by Diener in 1895.

The fauna of the Hedenstrœmia beds of Spiti comprises the following species of Cephalopoda :—

Pleuronautilus Dieneri Krafft.
Meekoceras pseudoplanulatum Krafft.
,, *sp. ind. aff. pilato* Hyatt et Smith.
,, *cf. joharense* Krafft.
,, *solitarium* Krafft.
Aspidites Muthianus Krafft.
,, *superbiformis* Dien.
,, *nov. sp. ind. aff. superbo* Waag.
Koninckites Yudishthira Dien.
,, *giganteus* Krafft.
Xenodiscus Kapila Dien.
,, *Purusha* Dien.
,, *nivalis* Dien.
,, *nov. sp. ind. ex. aff. nivalis.*
,, *cf. trapezoidalis* Waag.
,, *asiaticus* Krafft.
Flemingites Rohilla Dien.
,, *Muthensis* Krafft.
,, *Griesbachi* Krafft.

Flemingites Salya Dien.
,, *sp. ind. ex. aff. Salya.*
,, *nov. sp. ind.*
Ceratites pumilio Krafft.
Prionites nov. sp. ind.
Tirolites injucundus Krafft.
Nanites hindostanus Dien.
,, *medius* Dien.
Pseudosageceras multilobatum Noetl.
Hedenstrœmia Mojsisovicsi Dien.
,, *muthiana* Krafft.
Sibirites spitiensis Krafft.

There is only one single species, *Nannites hindostanus* Dien., which connects the faunæ of the Hedenstrœmia beds and of the lower division of the Lower Trias. Otherwise the two are separated much more distinctly than those of the Meekoceras and Ophiceras beds.

The presence of the first true *Ceratites*, of numerous species of *Flemingites*, of *Hedenstrœmia* with sutures far more advanced than in *H. lilangensis*, of species of *Aspidites* and *Koninckites* of large size and with complicated sutures, imparts to the fauna of the Hedenstrœmia beds its peculiar aspect.

On the top of the Hedenstrœmia beds there follow lithologically similar beds of shales and limestones having a thickness of about 6 feet. Two fossiliferous horizons were discovered in those beds by H. Hayden. The lower horizon has yielded large numbers of bivalves, chiefly *Pseudomonotis himaica* Bittn. and *Ps. decidens* Bittn. The upper horizon with *Rhynchonella Griesbachi* Bittn., and *Rh. himaica* Bittn., corresponds to a layer, which in Painkhanda has been included in the lower Muschelkalk by Griesbach and Diener.

b. Painkhanda.

Our knowledge of the development of the Lower Trias in Painkhanda has been derived chiefly from the examination of the classical section of the Shalshal cliff near Rimkin Paiar by C. L. Griesbach, C. Diener and F. Noetling.

In 1879 the *Otoceras* fauna was discovered by C. L. Griesbach on the top of the Permian Productus shales. The bed containing this fauna was considered by him as a passage bed, whereas all the beds of dark limestone and shale following above, up to the earthy limestone with *Rhynchonella Griesbachi* Bittn., amounting to 51 feet in thickness, were assigned to the Lower Trias.

In 1892 a second fossiliferous horizon was discovered by Diener in the upper division of this rock group, not far below the lower limit of the earthy limestone with *Rhynchonella Griesbachi*. In 1900 F. Noetling discovered a third fossiliferous bed in the lower division of the Lower Trias about 21 feet above the top of the Kuling (Productus) shales.

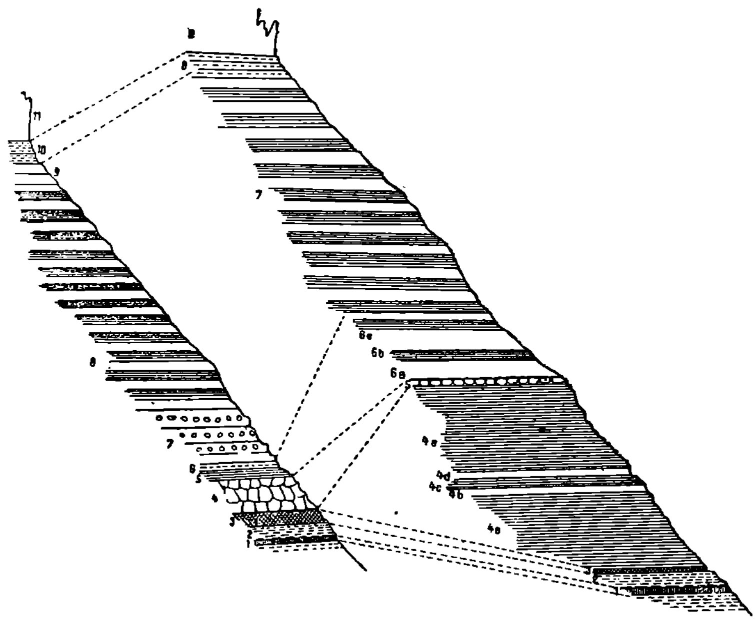

FIG. 1.—*Detailed sections through the Lower Trias near Lilang (left) and of the Shalshal cliff (right).*

Figures corresponding to the text on pp. 16 and 22.

Although the correlation of those horizons has been the subject of many discussions, the learned authors who have examined the section of the Shalshal cliff, agree entirely regarding the actual sequence of the Lower Triassic beds. According to Noetling's[1] and Diener's observations, this sequence is as follows, in descending order[2] :—

9. Hard, splintery, nodular limestone (Niti limestone) 60 feet.
8. Earthy, grey limestone, shaly near base, with *Rhynchonella Griesbachi* and *Sibirites Prahlada* : 3 ft.
7. Thin-bedded, grey limestone, with regular partings of shale, containing *Flemingites Rohilla* and *Pseudomonotis himaica* near top : 25 ft.
6. Grey limestone, divided into two bands by a shaly parting No determinable fossils : 5 ft.
5. Dark concretionary limestone, containing the main-layer of *Meekoceras Markhami* and *M. Varaha* : 8 ins.
4. Dark-blue shales, separated by a band of grey limestone. Unfossiliferous : 18 ft.
3. Dark blue limestone, with *Otoceras Woodwardi* and *Ophiceras tibeticum* : 5 ins.
2. Dark hard clay, with limestone concretions, containing very few fossils (*Episageceras Dalailamæ, Proptychites Scheibleri*) : 1½ ft.
1. Dark-blue limestone, main-layer of *Otoceras Woodwardi* and *Ophiceras Sakuntala*. Near top very rich in *Pseudomonotis Griesbachi* : 1 ft.

Productus or Kuling shales. Dark, thin-bedded shales, with partings of concretionary limestone.

Of the section of Kiunglung, *e.g.*, on the southern slope of the Niti pass, our knowledge is less complete.

[1] F. Noetling : Ueber das Alter der Otocerasschichten von Rimkin Paiar (Painkhanda) im Himálaya. *Neues Jahrb. f. Miner, etc.*, Beilagebd, XVIII, 1904, p. 541 ; *Lethœa mesozoica* Bd. I. Asiatische Trias, 1905, pp. 128, 149.

[2] Noetling's measurements, as given on pages 541 and 544 of his memoir on the age of the Otoceras beds of Rimkin Paiar, do not agree. On p. 541 the thickness of unfossiliferous beds between beds 3 and 5 is estimated at 10 feet, whereas it is estimated (more correctly) at 6 metres on page 544. The thickness of the Hedenstrœmia beds is given as 20 feet on p. 341, whereas it is estimated at 10 or 12 metres on p. 149 of the *Lethœa mesozoica* (Asiatische Trias, l. c.). The higher figures agree better with Griesbach's and my own measurements.

Bed 1 is the main layer of *Otoceras Woodwardi* Griesb., which is, however, far inferior to *O. Sakuntala* in number of individuals. From bed 2 two specimens of ammonites only are known to me. Both were collected by myself in 1892. There is no specimen from this bed either in Noetling's or in A. v. Krafft's collections. My species are :—

Episageceras Dalailamæ Dien.
Proptychites Scheibleri Dien.

Of the first species a fragment has also been discovered in bed 1, the main layer of the genus *Otoceras*.

In bed 3 *Ophiceras tibeticum*, which occurs also in bed 1, still persists together with the genus *Otoceras*, which is, however, rare and represented there by a variety of *O. Woodwardi*.

Those three beds, with their uniform fauna, can therefore be united in one single division, to which the name of "*Otoceras* beds," as proposed in 1879 by C. L. Griesbach, has been restricted by Noetling.

The fauna occurring in the Otoceras beds of Painkhanda is composed of the following species of Cephalopoda :

Grypoceras brahmanicum Griesb.
Episageceras Dalailamæ Dien.
Otoceras Woodwardi Griesb.
,, *undatum* Griesb.
,, *Clivei* Dien.
,, *Draupadi* Dien.
,, *fissisellatum* Dien.
,, *Parbati* Dien.
Hungarites sp. ind.
Ophiceras Sakuntala Dien.
,, *tibeticum* Griesb.
,, *medium* Griesb.
,, *gibbosom* Griesb.
,, *demissum* Opp.
,, *ptychodes* Dien.
,, *serpentinum* Dien.
,, *stricturatum* Frech et Noetl.
Meekoceras Hodgsoni Dien.

Proptychites Scheibleri Dien.
Prosphingites Kama Dien.
,, *nala* Dien.
Xenodiscus himalayanus Griesb.
Vishnuites Pralambha Dien.

On the top of bed 1, *Pseudomonotis* (*Claraia*) *Griesbachi* Bittn. is most common, but not restricted to this bed exclusively.

Bed 5, which is separated from the topmost fossiliferous bed of the Otoceras stage by a mass of dark blue shales with limestone partings, 18 feet in thickness, contains the *Meekoceras*-fauna, discovered by Noetling in 1900.

It is less rich in species than in the Spiti sections, the commonest types being *Meekoceras Markhami* Dien. and *M. Varaha* Dien. Besides these we have to enumerate :—

Meekoceras shalshalense Krafft.
Aspidites spitiensis Krafft.

and with great probability at least, *Meekoceras boreale* Dien., and, according to Noetling (*Lethæa mesozoica*, l. c., p. 149), *Meekoceras cf. radiosum* Waag. and *M. cf. discus* Waag.

Ophiceras tibeticum Griesb. probably also ranges from the Otoceras stage into the Meekoceras beds. One of Griesbach's specimens from the Shalshal cliff is marked bed 70 (25 feet above the layer of *Otoceras Woodwardi*). This is approximately the position of the fossiliferous layer of the Meekoceras beds. There is no valid reason for questioning the accuracy of Griesbach's statement.

The lithological boundary between the lower and upper divisions of the Lower Trias in Painkhanda passes just along the top of the concretionary limestone containing the *Meekoceras*-fauna. The lowest bands of grey limestone (bed 6) are very poor in fossils, but such occur throughout the entire thickness of the higher beds (7), which consist of light grey limestones, 4 to 6 inches in thickness, and alternating very regularly with shales of less or equal thickness. The fauna is, however, less rich in species than in the corresponding beds of Spiti, in the sections S. E. of Muth. The following Cephalopoda have been collected by Griesbach and Diener[1]:—

Pleuronautilus Dieneri Krafft.
Xenodiscus nivalis Dien.
,, *Purusha* Dien.
Flemingites Rohilla Dien.
Proavites Sisupala Dien.

Pseudomonotis himaica Bittn. and *Ps. decidens* Bittn. have also been quoted from bed 7 by Bittner, but their exact layer has not been ascertained. We do not know if they are distributed throughout the entire thickness of this subdivision or restricted to its topmost bed, as in the section at Lilang in Spiti.

For this upper division of the Lower Trias in Painkhanda the name "Subrobustus beds" was proposed by Diener in 1895, because he considered his type-specimen of *Ceratites subrobustus* (=*Keyserlingites Dieneri* Mojs.) to have been derived from its topmost layers, in which *Flemingites Rohilla* is the chief leading fossil. But this specimen was probably extracted from a detached block of the overlying Muschelkalk, since H. Hayden and A. v. Krafft have obtained numerous examples of *Keyserlingites* (*Durgaites*) *Dieneri* and its allies from the Muschelkalk, but not a single specimen from the Lower Trias. In the face of such convincing evidence we are justified in claiming the Indian group of *Ceratites subrobusti* (*Durgaites*) as a subgenus of Muschelkalk, not of Lower Triassic, age.

The name "Subrobustus beds" must consequently be discarded and replaced by the name "Hedenstrœmia beds," which was introduced for this rock-group (horizon of *Flemingites Rohilla*) by A. v. Krafft.

c. Eastern Johar.

The presence of marine sediments of Lower Triassic age in Eastern Johar has been recorded by C. L. Griesbach and by T. D. La Touche in several sections of the Dharma and Lissar valleys.

[1] To this list *Hedenstrœmia Mojsisovicsi* Dien. has been added by Noetling (*Lethœa mesozoica*, l. c., p. 149), but the specimens have not been found among the Lower Triassic materials belonging to the Geological Survey.

The Lower Trias seems to be developed in a facies of dark limestones and shales in the lower, and of light grey limestones in the upper, division. In the Lissar valley this group reaches an entire thickness of 80 to 100 feet, according to Griesbach (Central Himálayas, l. c., p. 175).

Palæontologically those two divisions are well characterised by two different associations of fossils, which can be easily distinguished among the collections of those two learned authors, which were made on the crest of a ridge separating the Lissar and Dharma valleys. The presence of the lower division, including equivalents of the Otoceras and Meekoceras beds, is clearly proved by the following species :—

Pseudomonotis (*Claraia*) *Griesbachi* Bittn.
Xenodiscus himalayanus Griesb.
,, *cf. rotula* Waag.
Ophiceras Sakuntala Dien.
Proptychites typicus Krafft.
Meekoceras boreale Dien.
,, *dubium* Krafft.
Aspidites Vidarbha Dien.

The upper division of the Lower Trias (Hedenstrœmia beds) is indicated by *Xenodiscus Purusha* Dien.

d. Byans.

The Lower Trias of Byans differs considerably from that of Johar, Painkhanda and Spiti.

According to the notes of F. H. Smith (1899) and A. v. Krafft (1900), it is represented by a mass of chocolate limestone attaining about 150 feet in thickness. This limestone passes by interstratification into the underlying Productus, or Kuling, shales. No fossils have been found in those passage-beds by Smith, but near the base of the compact, chocolate-coloured limestone both A. v. Krafft and F. H. Smith have collected numerous fossils in a sandy rock near Jolinka and Kuti. They point distinctly to the lower division of the Lower Trias.

One species, *Ophiceras cf. serpentinum* Dien., is characteristic of the Otoceras stage. The rest are chiefly elements of the *Meekoceras* fauna, namely :—

Meekoceras boreale Dien.
,, *dubium* Krafft.

Meekoceras jolinkense Krafft.
Aspidites spitiensis Krafft.
,, *Vidarbha* Dien.
Proptychites typicus Krafft.
Xenodiscus radians Waag.
,, *rotula* Waag.

The presence of the upper division of the Lower Trias in the chocolate limestone of Kalapani, Lilinthi, Jolinka and Kuti is indicated by the following species of ammonites :—

Flemingites cf. Griesbachi Krafft.
Hedenstrœmia Mojsisovicsi Dien.
,, *acuta* Kafft.

From Jolinka only the following species of *Sibirites* are known :—

Sibrites spiniger Krafft.
,, *robustus* Krafft.
,, *sp. ind. aff. robusto.*
,, *stephanitiformis* Krafft.

Together with a considerable number of new species of this genus which are too badly preserved to permit of specific determination.

In the fauna of Jolinka a peculiar element is represented by the genus *Sibirites*, which is comparatively rich in species and was regarded by the late Dr. A. v. Krafft as indicative of a special palæontological horizon.

e. *Kashmir.*

Lower Trias was not until recently known with certainty from any part of Kashmir, but A. v. Krafft insisted that it was represented there for the following reasons[1] :—

Among the Triassic fossil material sent to him for description, A. Bittner discovered several specimens of a *Myophoria*, which belongs to the group of *M. ovata* of the Alpine Werfen beds (*Myophoria sp. ind. ex aff. ovatæ* Goldfuss).[2] The specimens had been collected by Stoliczka in

A. v. Krafft: Zur unteren Trias von Spiti. *Centralblatt f. Mineral*, etc., 1901, pp. 197-199.
[2] A. Bittner: *Palæontologia Indica*, ser. XV, Vol. III, pt. 2, p. 67.

the Dras valley, and originally determined by him as *Megalodon columbella.*[1]

According to Bittner, they are imbedded in an impure calcareo-arenaceous rock, and he suggests that the specimens may belong to the same horizon—or one nearly related to it—as those bivalves which had been described in 1865 by C. W. Guembel from the collections of the brothers Schlagintweit.[2] Those bivalves proved in part identical with species from the Alpine Werfen beds, and were imbedded in a shaly, micaceous, very dense, yellow-grey, calcareous sandstone, resembling "Grauwacke," which, according to Guembel, is scarcely distinguishable from certain layers of the Alpine Werfen beds.

A. v. Krafft lays special stress on the fact that in the Himálayas, as far as they have been surveyed, the Lower Trias has always been found to consist of limestones with Cephalopoda and bivalves, intercalated with shales, but that sandstones have been observed nowhere. This is also the case at Lilang, only a few miles from Dankhar, the locality at which the Schlagintweit fossils are reported to have been found. A. v. Krafft therefore peremptorily emphasizes the fact that sandstones are entirely absent from the Lower Trias of Spiti.

When visiting Spiti in 1899, he endeavoured, but in vain, to clear up the evident discrepancy existing between the actual facts and Guembel's record.

On inquiry of several natives of Dankhar and the neighbourhood as to the existence of a village of the name Balamsali, he invariably received the answer that no village of that name was known. Nor could he find in the sections near Dankhar any support for Guembel's statement.

The Lower Trias is—with the Muschelkalk—cut out near Dankhar by a big fault running parallel to the Spiti valley. He searched in the few rivulets, in which sections are exposed, but observed in one locality only a thin wedge of black limestone with Cephalopoda, belonging to the Lower Trias and compressed between the Permian Productus shales and a limestone mass of ladinic or carnic age, which had been pushed by a fault over this wedge.

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1 F. Stoliczka : *Memoirs, Geol. Surv. of India*, V, p. 349.

2 *Sitzungsber. kgl. Akad. d. Wissensch.* Muenchen, 1865, II, p. 348.

The rocks in the neighbourhood of Dankhar are therefore of such a character, that the sandstones with Werfen types cannot have possibly come from there. Moreover no village of the name Balamsali is known.

A. v. Krafft thinks that on the labels accompanying the specimens collected by the brothers Schlagintweit, the localities have been confused. In this opinion he is supported by the fact that not infrequently the localities of specimens collected by those travellers are not known exactly, and that in one other instance localities must needs have been confused.

This is the case of a specimen of *Ceratites Voiti* Opp. (coll. Schlagintweit) described by Diener (Muschelkalk Cephalopoda, l. c., p. 9), which was said to have come from the Kunzum pass in Spiti. Both H. Hayden and A. v. Krafft have traversed the Kunzum pass (leading from Losar in the Spiti valley to the Chandra valley), and have found it built up chiefly of Haimantas. The nearest locality, where Muschelkalk occurs, is situated about ten miles to the N.E. of the Kunzum pass, on the left bank of the Spiti river. Thus there can be hardly any room for doubt that the brothers Schlagintweit collected their fossils of Werfen facies somewhere else, far away from Dankhar in Spiti. Probably those fossils may have come from a layer similar to that in which *Myophoria sp. ind. ex. aff. ovatæ* was found by Stoliczka.

I feel, however, obliged to remark that species belonging to the group of *Myophoria ovata* Goldf. are not restricted to the Alpine Werfen beds, but range also into the Muschelkalk, and that there is, consequently, no convincing proof of the Lower Triassic age of the beds discovered by Stoliczka in the valley of the Dras river.

F. Noetling [1] also claims the discovery of Lower Triassic beds in Kashmir. "Near Pastuni, three days' march from Srinagar"—he writes—"I collected a faunula of Cephalopoda in a hard dark blue limestone. They have not yet been examined, but from a preliminary comparison with other Himálayan faunæ it was soon evident that they could neither represent Muschelkalk nor Upper Trias. There exists great probability of their Lower Triassic age. We may, perhaps, consider them as an equivalent of the Hedenstrœmia beds."

[1] F. Noetling : Asiatischi Trias, *Lethæa mesozoica*, I. c., p. 172.

F. Frech[1] infers the presence of beds of Lower Triassic age in Ladakh from a new examination of *Ammonites peregrinus* Beyr. in the Museum of Berlin. The specimen had been collected by the missionary Prochnow and described by E. Beyrich in 1864 and 1867.[2] From the illustrations and descriptions I did not dare to decide whether the poorly preserved fragment belonged to an ammonite of Muschelkalk or Lower Triassic or even Permian age.[3] Frech, however, on the strength of a personal examination, includes it in the genus *Flemingites* Waag., thus proving the presence of the Hedenstrœmia stage.

The recent researches of Hayden[4] and Middlemiss[5] in the Vihi district have done much to ascertain the wide distribution of Lower Triassic sediments in Kashmir.

Hayden was fortunate enough to discover a fossiliferous horizon in the Guryul ravine, containing *Pseudomonotis*, *Bellerophon*, *Xenodiscus*, *Flemingites*. The sections in the Guryul ravine and east of it have been examined in detail by C. S. Middlemiss (l. c., p. 303). He found the beds, which seem to be included in the Lower Trias, of unusual thickness (about 150 feet). The lower division of hard, thin-bedded limestones (about 100 feet) has not yielded any fossils, but in the upper division consisting of shales with thin limestone beds intercalated, several fossiliferous horizons have been noticed. Among the species of Cephalopoda enumerated by Middlemiss, *Meekoceras cf. lilangense* Krafft points to the Meekoceras stage, whereas *Xenodiscus* of the group of *X. Purusha* and the sharp-keeled ammonites recalling *Hedenstrœmia* suggest the presence of a younger (Hedenstrœmia) stage. Equivalents of the lowest (Otoceras) stage have not as yet been found in Kashmir.

f. Interregional Correlation of fossiliferous horizons.

The development of the Lower Trias is almost identical in Painkhanda and Spiti. The two sections of the Shalshal cliff and of Lilang

[1] F. Frech: Triasammoniten aus Kashmir, *Centralbl. f. Miner*, etc., 1902, p. 134.

[2] E. Beyrich: *Monatsber Kgl. Akad. d. Wissensch. Berlin*, 18 January 1864, p. 58, and "Ueber einige Cephalopoden aus dem Muschelkalk der Alpen, etc.," *Abhand. kgl. preuss. Akad. Berlin*, 1866, No. 2, p. 123, Taf. V, fig. 4.

[3] Cephalopoda of the Lower Trias, *Palæont. Ind.*, l. c., p. 1.

[4] Records, *Geol. Surv. of India*, XXXVI, (1907), p. 23.

[5] C. S. Middlemiss: Gondwanas and related marine sedimentary systems of Kashmir. *Records, Geol. Surv. of India*, XXXVII, (1909), p. 297.

agree very closely, although their distance apart is 130 miles. The Lower Trias in both districts consists of dark limestones alternating with shales. In the lower division, following above the Permian Kuling, or Productus, shales, black limestones predominate. In the upper division the limestones are of a dark grey colour and thin-bedded. In Spiti the upper division is of considerably greater thickness than the lower one, 30 feet to 6 feet, whereas in the Shalshal cliff this proportion is only 30 feet to 21 feet. The lithological boundary, although not very sharp, is well marked both in the sections of Painkhanda and of Spiti.

The lower division contains three fossiliferous horizons in Spiti and four in Painkhanda, but in both regions the topmost horizon only has yielded a fauna which is distinguished from that of the lower horizons. The lower horizons represent the Otoceras beds *sensu stricto.*

In 1901 two different zones were distinguished in the Otoceras beds of Painkhanda by Noetling,[1] the lower containing the fauna of *Otoceras Woodwardi*, the upper being characterised by the predominance of *Ophiceras tibeticum.* In 1904 a third zone was added to them by Noetling,[2] who consequently distinguished among the Otoceras beds the following three zones :—

3. *Zone of Ophiceras tibeticum* Griesb.
2. ,, *Episageceras Dalailamæ* Dien.
1. ,, *Otoceras Woodwardi* Griesb.

Noetling's statement that those " three zones are sharply separated faunistically " is contradictory to the facts, as I have tried to show in my memoir on the stratigraphical position of the Otoceras beds.[3] A distinction of separate palæontological zones in the uniform fauna of the Otoceras stage is purely artificial. There is no element in the fauna of either horizon which might justify its palæontological independence from the others. They are minute local subdivisions of one single zone only.

Those local subdivisions can also be recognised in the section of Lilang, Spiti, although their faunæ do not correspond exactly. The

[1] F. Noetling in *Lethæa palæozoica*, Vol. II. Dyas, p. 656.

[2] F. Noetling, *Neues Jahrb. f. Min.*, Beil. Bd. XVIII, 1904, and *Lethæa mes.*, Asiatische Trias, l. c., p. 132.

[3] C. Diener : Ueber die stratigraphische Stellung der Otoceras beds des Himalaya, *Centralbl. f. Min.*, 1905, p. 2.

main layer of *Otoceras Woodwardi* in the Shalshal cliff agrees with the rusty-brown, ferruginous layer at the base of the Triassic series in the Lilang section, to which the genus *Otoceras* is restricted in Spiti. The place of the hard, dark clay with *Episageceras Dalailamæ* is taken by the unfossiliferous sandy limestone (bed 2) of Lilang. The main layer of *Ophiceras* in Spiti corresponds to the bed containing *Ophiceras tibeticum* in the Painkhanda sections.

The vertical distribution of *Otoceras* is smaller in Spiti than in Painkhanda. The absence of this genus in the second fossiliferous horizon of the sections near Lilang justifies the distinction of an *Otoceras* bed and an *Ophiceras* bed, as advocated by A. v. Krafft,[1] but it is no valid reason for dividing the fauna of the *Otoceras* stage into two separate palæontological zones, since the predominating types of *Ophiceras* persist throughout the two horizons and impart to the fauna a uniform aspect.

Thus the fauna of the *Otoceras* stage represents one single palæontological zone only, which, from its most conspicuous types, should be called zone of *Otoceras Woodwardi* and *Ophiceras Sakuntala.*

The second fauna of Lower Triassic age, which represents a special stratigraphical horizon, is the fauna of the Meekoceras beds.

In the section of Lilang it follows immediately above the Ophiceras bed and is only three feet in thickness. In Painkhanda it is separated from the bed with *Ophiceras tibeticum* by a large mass of unfossiliferous rock.

The following detailed section has been published by Noetling (Asiatische Trias, l. c., pp. 129, 130) :—

5.	Dark, concretionary limestone, with *Meekoceras Markhami* Dien.	cm. 20
4*e*.	Dark blue shales	2m. 80
4*d*.	Hard, grey limestone	17
4*c*.	Dark blue shales	25
4*b*.	Hard, grey limestone	30
4*a*.	Dark blue shales	2m. 50
3.	Hard, blue, very tough limestone, with *Ophiceras tibeticum* Griesb.	12

In the section of the Shalshal cliff the Meekoceras fauna makes its appearance only nineteen feet above the top of the Otoceras beds, but it

[1] A. v. Krafft: *Gen. Report, Geol. Surv. of India*, 1900-01, p. 4.

agrees entirely with that of Spiti and is also contained in a concretionary limestone of dark blue colour.

The direct superposition of the Meekoceras horizon above the Ophiceras bed in Spiti has often rendered an exact separation of their faunæ *in situ* very difficult or even impossible. They are certainly linked together by a number of species common to both of them. Neither is *Meekoceras* entirely absent in the lower horizon nor *Ophiceras* in the upper one. In Spiti *Meekoceras Varaha* and *M. lilangense* are the commonest species, whereas in Painkhanda *M. Markhami* predominates. In Spiti the Otoceras stage is poor in species, compared with the rich fauna of the Otoceras beds in Painkhanda, but the *Meekoceras* fauna is more richly developed in the Spiti sections.

Throughout the upper division of the Lower Trias in Painkhanda and Spiti a single and uniform fauna only has been found. This is the fauna of the Hedenstrœmia beds or the zone of *Flemingites Rohilla.* It differs considerably from that of the Meekoceras beds. The genus *Meekoceras* is chiefly represented by large species belonging to the subgenera *Aspidites* and *Koninckites*. *Xenodiscus*, *Flemingites* and *Hedenstrœmia* have reached their maximal development.

In the topmost beds of the Hedenstrœmia stage of Spiti a bivalve facies, with *Pseudomonotis himaica* Bittn. as leading fossil, makes its appearance, but the stratigraphical independence of this bivalve limestone as a distinctly marked palæontological horizon is very doubtful.

The fourth and youngest fauna of Lower Triassic age is hitherto known from one locality in Byans only.

A small faunula collected by F. H. Smith near Jolinka has been attributed by A. v. Krafft to a stratigraphically well defined bed, not far from the top of the chocolate limestone. It represents the zone of *Sibirites spiniger* and consists exclusively of species of the genus *Sibirites*, which is restricted to the upper Ceratite limestone of the Salt Range.

Sibirites spitiensis in the section of Muth is perhaps indicative of a representation of this palæontological zone in the Hedenstrœmia beds of Spiti.

g. Correlation with the Ceratite beds of the Salt Range.

A large area of Lower Triassic sediments is exhibited in the Ceratite beds of the Salt Range. Here, as in the Himálayas, the most interesting problems in correlation were those concerning the termination of the Permian system. In both areas, however, the sedimentation introducing the Triassic system was strikingly different. In the Central Himálayas arenaceous deposits are entirely wanting, and the Lower Trias is made up of limestones and shales. In the Salt Range arenaceous limestones, calcareous sandstones and marls play a very important part. Those rocks contain rich fossil faunæ, and their classification by Wynne, Waagen and Noetling constitutes one of the most interesting chapters in Indian Geology.

This difference in the development of the Lower Triassic deposits in the Himálayas and in the Salt Range renders an attempt at correlation difficult, notwithstanding the considerable number of species common to both regions. A discussion on this subject between A. v. Krafft, Noetling and Diener indicates considerable confusion, and the inference to be drawn from a study of its results is that the palæontological evidence available is not sufficient for a correlation of the strata down to the smaller divisions of the scale. A detailed account of this discussion has been given by Diener in Vol. VI, No. 1, of the "Himálayan Fossils."

The youngest Himálayan fauna from the top of the chocolate limestone of Jolinka (Byans) has been correlated with that of the upper Ceratite limestone by A. v. Krafft. This homotaxis has been accepted unanimously by all authors dealing with this subject. There is, indeed, a close agreement in the character of the two faunæ, that of Jolinka consisting exclusively of species of the genus *Sibirites*, one of them very closely allied to *Sibirites* (*Ceratites* antea) *inflatus* Waag.

The Hedenstrœmia beds are in a general way equivalent to the upper division of the Ceratite marls (in Noetling's interpretation) or to the *zone of Konnickites volutus* Noetl. and to the Ceratite sandstone (*Flemingites Flemingianus* beds).

The Meekoceras beds probably correspond to the lower division of the Ceratite marls (*zone of Prionolobus rotundatus* Noetl.) and to the lower Ceratite limestone.

The most obscure point in the controversy is the problem of the correlation of the Otoceras beds, owing to the different lithological development in the two regions and to the absence of the most characteristic elements of the Otoceras fauna from the Salt Range. Diener looks for equivalents of the Otoceras beds in the unfossiliferous shales and sandstones, which in the sections of Chideru and Virgal separate the Chideru group of the Upper Productus Limestone from the Ceratite formation. Noetling correlates them with his zone of *Euphemus indicus* of the Upper Productus Limestone, but this correlation is not based on palæontological evidence, not one single identical species having been found in the two horizons.

The special development, which the Lower Triassic faunæ have taken in those two regions, renders it evident that a correlation of the minor subdivisions cannot be made except in a most general way, and always with the mental reservation that their lower and upper boundaries do not strictly coincide.

When the examination of the fossils collected in the Ceratite beds by Noetling and Koken is finished, it may be possible to form a better scheme of classification, in which the relative positions of the Lower Triassic strata in the two regions may be determined more exactly. For the present the following tabular statement will show the conclusions reached, as indicated above, by those best qualified to determine the relations of the lower Himálayan Trias with the Ceratite formation of the Salt Range :—

Himálayas	Salt Range	
	Noetling, 1905.	Diener, 1908.
Zone of *Sibirites spiniger* (Byans).	Upper Ceratite limestone.	Upper Ceratite limestone.
Hedenstrœmia beds (zone of *Flemingites Rohilla*).	Ceratite sandstones.	Ceratite sandstones.
	Ceratite marl.	Ceratite marl.
Meekoceras beds (zone of *Meekoceras Markhami*).	Lower Ceratite limestone.	Lower Ceratite limestone.
Otoceras beds (zone of *Otoceras Woodwardi*).	Zone of *Euphemus indicus* (Upper Productus limestone).	Unfossiliferous clay and shales.
Kuling (Productus) shales.		Upper Productus Limestone.

h. Correlation with the lower Trias of Europe, North America and Siberia.

Until the examination of Hayden's and A. v. Krafft's fossil materials from Spiti the evidence for the Lower Triassic age of the Hedenstrœmia beds was merely circumstantial. Until then no affinities were known between their fauna and that of the Campil or upper Werfen beds of the Mediterranean region.

Noetling[1] in his discussion of the age of the Otoceras beds thinks that the fauna of the Hedenstrœmia beds might be attributed to the lower Muschelkalk or to the Lower Trias with equal reason, and in the introduction to his synopsis of the Himálayan Trias[2] he even emphasizes the assertion that the presence of Lower Trias in the Himálayas merely rests on palæontological subtilties, without any decisive proof.

Similar opinions have been expressed more or less definitely by other writers.

Three faunistic elements connecting the Alpine Campil beds and the Hedenstrœmia beds, which have been discovered among the *Cephalopoda* from the latter group, are sufficient to show that those two stages may be placed in general parallelism. These three species of *Cephalopoda* are:—

Tirolites injucundus Krafft.
Xenodiscus asiaticus Krafft.
Meekoceras pseudoplanulatum Krafft.

Tirolites injucundus is an ammonite of the group of *Tirolites spinosi*, and its discovery in the Himálayas has been so much the more astonishing, because the absence of *Tirolitinæ* was considered by E. v. Mojsisovics as one of the most remarkable faunistic characters of the Indian zoo-geographical region.

Xenodiscus asiaticus is distinguished from *Paraceratites prior* Kittl. from the Campil beds of Muc by some very subordinate details only. A near affinity of *Meekoceras pseudoplanulatum* to *Meekoceras caprilense* Mojs. from the Campil beds of the south-eastern Tyrol is also extremely probable.

[1] *Neues Jahrb. f. Miner.*, Beil. Bd., XVIII, p. 551.

[2] Asiatische Trias, *Lethæa mesozoica*, l. c., p. 125.

Thus a solid base for a direct correlation between the Hedenstrœmia beds of the Himálayas and the Alpine Campil beds has been established by A. v. Krafft's and Hayden's discoveries. Nevertheless the affinities of the two faunæ are rather distant, all the nearly allied species being of extremely rare occurrence, either in one of the two regions or in both of them.

But the gap, by which the two faunæ had hitherto been separated, has been bridged over —partly at least—by the interesting discovery of Campil beds in North Albania in a development of red limestones (Hallstatt facies). This is a cephalopod facies of the Campil or upper Werfen beds formerly unknown in Europe, which has yielded a considerable number of fossils near the village of Kcira, about 25 km. to the east of Skutari. The fossils, which were collected by F. v. Nopcsa in 1906 and 1907, have been described by G. v. Arthaber,[1] who correctly refers to the astonishing association of Mediterranean, Indian and Pacific types. The Indian types even predominate in number. Among them the following may be mentioned :—

Pseudosageceras multilobatum Noetl.
Xenaspis mediterranea Arth.
Nannites Herberti Dien.
Monophyllites Hara Dien.
Meekoceras marginale Arth.
Hedenstrœmia sp. ind.

This fauna, which contains several types, chiefly Mediterranean (*Tirolites seminudus* Mojs., *Celtites kcirensis* Arth.) but also some Californian (*Columbites*), connects the Lower Triassic faunæ of India and Europe much more closely than had been hitherto anticipated. In contradiction to Noetling's views there can be no further doubt that during the Lower Trias the great central sea of the Tethys extended from the Mediterranean to the Indian basin in the shape of an open canal across the present mountain ranges of Afghanistan and Northern Persia, by which an intercommunication of the faunæ of both regions became possible within certain limits.[2]

[1] G. v. Arthaber : Ueber die Entwicklung der Untertrias in Albanien und ihre faunistische Bewertung. *Mitteil. Geol. Ges. Wien*, I, 1908, pp. 245-289.

[2] New researches in 1908 by F. v. Nopcsa have added considerably to our knowledge of the Lower Triassic faunæ of Albania. The rich collections of fossils which were made in some favourable places, enable us now to appreciate the

It has been demonstrated by J. P. Smith, that the Tethys of the Lower Trias extended from India to the Western States of North America across the entire Pacific Ocean. There are some strong affinities between the Lower Triassic faunæ of the Himálayas and Eastern Siberia on one side and of California and Idaho on the other, but an attempt to correlate the stratigraphical subdivisions on either side of the Pacific Ocean meets with considerable obstacles, owing to the differences in the geological history of the two regions.

In America the oldest fauna of Lower Triassic age is concentrated in the Meekoceras beds of California and Idaho. According to J. P. Smith [1] this fauna shows an intimate relationship to that of India and Eastern Siberia (Ussuri district) and none to the fauna of the Mediterranean region. After the deposition of the Meekoceras beds an invasion of Mediterranean forms took place. The fauna of the Tirolites beds, which is characterised by this incursion of Mediterranean types—three European species of *Tirolites*, one of *Dalmatites* and one of *Dinarites*—is decidedly the same as that of the upper Werfen or Campil beds in the Alps. But this incursion was only sporadic, for in the overlying Columbites beds there is an assemblage of Mediterranean, Asiatic and autochthonous forms.

All those three horizons of the Lower Trias are exposed in Idaho in a continuous section in Paris canyon, the Columbites beds occurring 15 metres above the Tirolites horizon and 90 metres above the main layer of the Meekoceras beds.

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importance of the association of Mediterranean, Pacific and Indian elements in this fauna.

The results of G. v. Arthaber's examination of these new materials have not yet been published, but I owe to Prof. v. Arthaber the valuable and interesting communication, that both the Indian and Pacific elements far exceed the Mediterranean ones. *Columbites* and *Pseudosageceras* are represented in large numbers in the new collections. The local peculiarities are rather remarkable. A striking character is the presence of a primitive stock of generalized forms, which might be considered as radicles of different types of *Ceratitidæ* and of *Monophyllites*. A primitive ancestor of the genus *Tropites* deserves special mention. The presence of the genus *Japonites*, which hitherto has not been found in beds older than Muschelkalk, forms a sharp contrast with those generalized forms which give a rather old aspect to the Lower Triassic fauna of Albania.

[1] A. Hyatt and J. P. Smith: Triassic cephalopod genera of North America, *U. S. Geol. Survey, Profess. Pap.* No. 40, Washington, 1905—J. P. Smith: The stratigraphy of the Western American Trias. *Sonderabdr. aus Koenen Festschrift*, 1907, pp. 377-394.

Now the most important moment in the geological history of Idaho during the Lower Triassic epoch, the opening of a new connection between the American and Mediterranean regions at the beginning of the Tirolites stage, has left only faint traces in the deposits of the Himálayan Lower Trias. That this invasion of Mediterranean types did not take place through India, is evident from the fact that the admixture of such types in the Hedenstrœmia beds is extremely scanty, and that no fauna comparable with that of the Tirolites beds of Idaho has ever been met with either in the Salt Range or in the Himálayas.

The difficulty of correlating the subdivisions of the American and Indian Lower Trias is chiefly due to the fact that the faunistic influence of India on the American region was never counterbalanced by an incursion of American forms into the Indian province. The American Meekoceras-fauna is probably—and in this opinion I agree entirely with J. P. Smith—of Asiatic origin, for there is nothing known in the American Permian that could have given rise to the forms of the Meekoceras zone. In India, however, no autochthonous types of the American Lower Trias are known, which, like *Columbites*, have reached the Mediterranean region as sporadic immigrants, but not the Indian Triassic province.

Near affinities are therefore restricted to the fauna of the American Meekoceras beds, but this fauna shows, indeed, a strong kinship both with the faunæ of the lower and upper divisions of the Himálayan Lower Trias. Not less than twelve genera are common to both regions, namely, *Meekoceras*, *Aspidites*, *Koninckites*, *Flemingites*, *Xenodiscus*, *Ophiceras*, *Pseudosageceras*, *Hedenstrœmia*, *Sibirites*, *Proptychites*, *Nannites*, *Tirolites*.

There are equally close relationships with the fauna of the Meekoceras beds of the Himálayas and of the Hedenstrœmia beds. There is a small number of very characteristic species, which point to a direct correlation with the Hedenstrœmia beds. *Hedenstrœmia Mojsisovicsi* is represented in America by *H. Kossmati*, *Pseudosageceras multilobatum* by *Ps. intermontanum*, *Flemingites Salya* by *Fl. cirrus*. Among three species of *Sibirites* two are closely allied with forms from the Upper Ceratite limestone of the Salt Range. On the other hand the affinities with the Himálayan Meekoceras beds are at least equally close, and even with the fauna of the Ophiceras bed of the Otoceras zone in Spiti.

Four species of *Ophiceras*, among them *O. cf. Sakuntala* Dien. and *O. cf. gibbosum* Griesb., together with *Meekoceras cf. Hodgsoni* Dien., have been quoted from the Meekoceras beds of south-eastern Idaho by J. P. Smith.

This learned author correlates the Meekoceras beds of America with the Hedenstrœmia beds, which, according to his view have been placed too high in the column by Diener. But the Hedenstrœmia beds cannot be regarded as equivalents of the Alpine Seis beds, since their fauna is undoubtedly homotaxial with the fauna of the Campil beds, as is evident from its affinity to the fauna of Kcira in Albania. The presence of a species of *Tirolites* in the Hedenstrœmia beds and the persistence of a small number of Indian types in the Columbites beds of Idaho are rather in favour of a correlation of the Hedenstrœmia stage with the higher subdivisions of the American Lower Trias.

Although there is a great probability of a homotaxis of the Hedenstrœmia beds with the whole of the upper divisions of the Lower Trias of Idaho, we should not forget that the fauna of the American Meekoceras zone contains elements of the Hedenstrœmia beds, Meekoceras beds and even Otoceras beds. This is one of the instances demonstrating the difficulty of correlating terranes in widely separated areas, although this correlation has been attempted on the basis of a large number of fossils either generically or specifically identical. But the natural divisions are not the same in India and Idaho and therefore they cannot be correlated except in the most general way.

The development of Lower Triassic rocks near Vladivostok in the southern Ussuri district of the coast province of Eastern Siberia [1] is another illustration of the uniformity of the fauna around the Pacific Ocean during the Lower Triassic age. The association of genera is the same as exhibited in the Meekoceras beds of California and Idaho. The ammonites have their nearest representatives in the Meekoceras zone of the Himálayas—both *Meekoceras Varaha* and *M. boreale* have been found in the Proptychites beds of Vladivostok — but the presence of a species referable to *Ophiceras Sakuntala* Dien. indicates, perhaps, also a correspondence with the Ophiceras bed of the Otoceras stage.

[1] C. Diener: Triadische Cephalopodenfaunen der ostsibirischen Kuestenprovinz. *Mém. Com. Géol. St. Pétersbourg*, 1895, Vol. XIV, No. 3.

The evidence furnished by a comparison of the lamellibranchs must be considered as very important, justifying a direct correlation with the Alpine Seis beds, with which the fauna of Vladivostok has not less than twelve species in common.[1]

Ammonites of Lower Triassic age, which can, however, not be assigned to a definite stratigraphical horizon, have been quoted from Yunnan by Douvillé, and from the Semenow Range (N. E. Tibet) by Schellwien.

Less close than the relations of the Indian Meekoceras beds with the fauna of Vladivostok are those of the Hedenstrœmia stage with the Olenek beds of Northern Siberia. The richest Triassic fauna from Siberia hitherto known has been collected from a concretionary limestone imbedded in dark shales, at the mouth of the Olenek river. Not less than forty species of Cephalopoda have been described by E. v. Mojsisovics.[2] Nevertheless the age of the fauna has been a subject of controversy.

E. v. Mojsisovics considered the Olenek beds as the homotaxial equivalent of the Campil beds, although no identical or even nearly allied species were known to him from both regions and this correlation was only based on the general zoological character of the Olenek fauna. A considerably younger age was assigned to the latter by Noetling.[3] His opinion is supported by the three following arguments :—(1) *Ceratites* (*Keyserlingites*) *subrobustus* Mojs. has its habitat in the zone of *Spiriferina Stracheyi* of the Himálayan Muschelkalk ; (2) in India the genus *Ceratites*, which in the Olenek fauna is represented by several groups, does not make its appearance before the commencement of the Muschelkalk ; (3) the differences between the faunæ of the Indian Lower Trias and of the Olenek beds are sufficiently remarkable to exclude their homotaxis.

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1 A. Bittner : Versteinerungen aus den Triasablagerungen des Sued-Ussurigebietes, etc., *ibidem*, Vol. VII, No. 4, 1899. P. v. Wittenburg : Neue Beitræge zur Geol. und Palæont. d. Werfener Schichten Suedtirols mit Berueckvsichtigung der Schichten von Wladiwostok. *Centralbl. f. Min.*, 1908, p. 67. Notiz ueber Trias und Jura bei Wladiwostok. *Neues. Jahrb. f. Min.*, 1909, Bd. I, p. 1.

2 E. v. Mojsisovics : Arktische Triasfaunen, *Mém. Acad. impér. des sciences, St. Pétersbourg*, 1886, VII. Sér., Vol. XXXIII. Ueber einige arktische Triasammoniten des. noerdl. Sibirien. *ibidem*, 1888, Vol. XXXVI, No. 5.

3 F. Noetling : Asiatische Trias, *Lethæa mesozoica*, I, p. 200.

In a special paper treating with the problem of the age of the Olenek beds [1] I have tried to refute Noetling's arguments. The Indian and Siberian species of *Keyserlingites* (*Ceratites subrobusti*) are not identical and do not even belong to the same group of forms. In the Himálayas the genus *Ceratites* is not restricted to the Muschelkalk, but is represented in the Hedenstrœmia beds by typical species of the group of *circumplicati* (*Hollandites*). There are some affinities between the Olenek fauna and the Hedenstrœmia stage, but none at all with the Himálayan Muschelkalk. *Hedenstrœmia Mojsisovicsi* Dien. is either identical or very closely allied to the Siberian species, which has been described as *Meekoceras sp. ind. aff. Hedenstrœmia* by E. v. Mojsisovics. There are also strong affinities between some Indian and Siberian representatives of the genera *Meekoceras* and *Xenodiscus*, as has been suggested by Frech, especially between *Xenodiscus rotula* Waag. and *X. hyperboræus* Mojs. But the most important argument in favour of a correlation with the Hedenstrœmia beds is the occurrence of *Xenodiscus*, *Meekoceras*, *Aspidites*, *Hedenstrœmia* and *Prosphinngites* in the Olenek fauna, all genera, which in the Himálayas are restricted to the Lower Trias and do not range into the Muschelkalk.

The faunistic affinities of the Olenek beds with the Columbites beds of North America, as advocated by J. P. Smith, is in accordance with this correlation.

On the other hand Noetling is certainly right in assuming that the connection of the Indo-Chinese and Northern Siberian provinces has not been a very close one. The peculiar character of the Olenek fauna, especially the enormous preponderance of *Dinarites spiniplicati* (*Olenekites* Hyatt), is indicative of a comparative isolation of this basin of the Triassic Arctic sea.

i. The Permo-Triassic boundary.

The determination of the upper limit of the Permian rocks in the marine series of India did not trouble the students of the geological formations in the Himálayas until it had been suggested by Noetling's studies in the Salt Range.

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[1] C. Diener: Das Alter der Olenekschichten Sibiriens. *Centralblatt. f. Min., etc.*, 1908, p. 233.

By C. L. Griesbach the base of the Himálayan Trias had been assumed to lie at the top of the Permian Productus, or Kuling, shales, which in all normal sections of Spiti and Painkhanda are overlain conformably by a series of dark thin-bedded shales and limestones, which have yielded the fauna of the Otoceras beds.

Griesbach himself determined the Otoceras beds as Triassic at the time of their discovery (1879). In his memoir on the geology of the Central Himálayas (1891, p. 71) he looked upon them as a true passage bed between the Permian and Triassic systems, "as a horizon still lower than the Werfen beds of the Alps, and considerably lower than what is understood now as Bunter," but nevertheless decided to include them with the Lower Trias (l. c., pp. 121, 146, 174, 175, 177, 219).

Waagen[1] correlated the Himálayan Otoceras stage with the Otoceras beds of Julfa in Armenia and consequently included it in the Upper Permian, although he considered it to be younger than the Jabi or Cephalopod beds of the Upper Productus Limestone, "because the mesozoic types seemed to predominate over the palæozoic ones" (l. c., p. 232).

The correlation with the Permian Otoceras beds of Julfa was refuted by E. v. Mojsisovics,[2] because the species of *Otoceras* in the last mentioned deposits occupy a remarkably lower stage of development than the Indian ones. The Otoceras stage of the Himálayas was therefore regarded as the oldest cephalopod-bearing horizon of the Lower Trias in India. In a subsequent paper Waagen[3] acknowledged the Triassic character of the *Otoceras* fauna and defined the age of the beds including it as Lower Triassic.

In 1897 C. Diener,[4] after his examination of the fossil materials collected by Griesbach and by the expedition of 1892, supported the view given by E. v. Mojsisovics, by new evidence, enumerating the remarkable differences between the *Otoceras* faunæ of Julfa and of the

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[1] W. Waagen: Salt Range Fossils, *Palæont. Ind.*, ser. XIII, Vol. IV, Geological Results, p. 225.

[2] E. v. Mojsisovics: Vorlaeufige Bemerkungen ueber die Cephalopodenfaunen der Himálaya-Trias. *Sitzgsber. kais. Akad. d. Wissensch. Wien*, 1892, CI, pp. 372-378.

[3] E. v. Mojsisovics, W. Waagen, C. Diener: Entwurf einer Gliederung der pelagischen Sedimente des Triassystems, *ibidem*, CIV, 1895, p. 1286.

[4] C. Diener: Himálayan Fossils, *Palæont. Ind.*, ser. XV, Vol. II, Pt. 1.

Shalshal cliff, and emphasizing the decidedly Triassic aspect of the latter. In his summary (p. 172) he considers the Indian Otoceras beds as forming the base of the Buntsandstein, that is the lowest Triassic beds following immediately above the upper boundary of the Permian deposits, without any distinct demarcation. "The fauna of *Otoceras Woodwardi* is the oldest fauna of Triassic age containing cephalopoda, which has as yet been discovered. It is somewhat younger than the Otoceras beds of Julfa, but older than the cephalopod horizon of the Alpine Werfen beds.[1] In the Alps no cephalopod-bearing strata correspond to this Himálayan horizon, but only the bivalve fauna of the lower division of the Werfen beds (Seiser Schichten of F. v. Richthofen)."

This correlation of the Otoceras stage with the Seis beds has been fully corroborated by A. Bittner [2] who on the strength of his examination of the *Lamellibranchiata* collected by Griesbach and Diener, compared them with species from the lower division of the Werfen beds (horizon of Seis) and decided that they were also of Triassic, not of Permian, age.

A different interpretation of the age of the *Otoceras* fauna was attempted in 1900 by F. Noetling after a tour among the Ceratite beds of the Salt Range.

In his "Geological Results" W. Waagen had come to the conclusion that a stratigraphical gap existed in the sequence of the Salt Range between the Permian Productus limestone and the Ceratite beds. Noetling, who was deputed to the Salt Range, found Waagen's statement contradicted by actual facts. He held the view that the entire Ceratite formation must be included with the Permian system, the gradual passage from the Productus limestone to the Ceratite beds making a stratigraphical subdivision into two great periods an impossibility. He also reported that he had discovered *Otoceras* in the Ceratite marls, which must consequently be correlated with the Himálayan Otoceras beds.[3]

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[1] = Campil beds (F. v. Richthofen).

[2] A. Bittner: Himálayan Fossils, *Palæont. Ind.*, ser. XV., Vol. III, Pt. 2, pp. 74, 76.

[3] F. Noetling: *General Report, Geol. Surv. of India*, 1899-1900, p. 42.—Ueber die Auffindung von *Otoceras sp.* in der Salt Range, *Neues Jahrb. f. Min.*, 1900, p. 130.

This report soon turned out to be incorrect, and the correlation of the Himálayan Otoceras beds with the Ceratite marls consequently fell to the ground. But the discussion of the true limit between the Permian and Triassic systems in the Indian zoo-geographical region was nevertheless continued by C. Diener, A. v. Krafft and F. Noetling.

Noetling's view set forth in his paper in the *Neues Jahrbuch* was answered by Diener,[1] who maintained the Triassic age of the Otoceras beds and of the corresponding beds in the Salt Range. He claimed that no proof had been given of their homotaxis with any extra-Indian strata of recognised Permian age, but that their bivalve fauna was decidedly in favour of a paralellism with the Seis (lower Werfen) beds.

Noetling's next paper[2] is controversial and adds little to the settlement of the problem. But in 1901 the question of the true stratigraphical position of the Himálayan Otoceras beds was taken up by A. v. Krafft. During the summer of 1899 this author had worked out the sequence of Permian and Triassic strata in Spiti, together with H. Hayden, but the incorrect report of the discovery of *Otoceras* in the Salt Range led him to the conclusion that the Otoceras beds were equivalent to the Ceratite marls and to the lower Ceratite limestone of the Salt Range.[3] In the next season, however, he took an entirely different view of the subject. He divided the series between the Kuling shales and the Hedenstrœmia beds into three palæontological zones, the Otoceras bed *s. s.*, the Ophiceras bed and the Meekoceras bed. The Meekoceras bed is referred to the Lower Trias, the age of the Ophiceras bed is left doubtful, there being no decisive proof of its fauna being either Permian or Triassic, but the Otoceras bed *s. s.*, is correlated with the Chideru group or Upper Productus Limestone, on the strength of an identification of *Medlicottia* (*Episageceras*) *Dalailamæ* Dien. with *Medlicottia Wynnei* Waag. from the zone of *Euphemus indicus* in the Salt Range.[4]

1 C. Diener: Ueber die Grenze des Perm-und Triassystems im ostindischen Faunengebiet, *Centralbl. f. Miner., etc.*, 1900, p. 1.

2 F. Noetling: Die Otoceras beds in Indien, *Centralblatt. f. Miner., etc.*, 1900, p. 216.

3 A. v. Krafft: Stratigraphical notes on the mesozoic rocks of Spiti, *Gen. Report, Geol. Sur. of India*, 1899-1900, p. 203.

4 A. v. Krafft: Ueber das permische Alter der Otoceras-Stufe des Himalaya, *Centralbl. f. Miner., etc.*, 1901, p. 275.

This paper was again answered by Diener, who refused to admit the identity of the two species of *Medlicottia* (*Episageceras*).[1]

In the meantime an extensive memoir on the Permian and Triassic rocks of the Salt Range was published by Noetling.[2] Revising his former views on the Permian age of the Ceratite formation, he now admits their correlation with the Triassic system and draws the boundary between the two zones of *Euphemus indicus* below, and *Celtites sp.* of the lower Ceratite limestone above. The Otoceras beds o. the Himálayas are no longer considered as equivalent to the Ceratite marls, as in 1900, but to the Upper Productus limestone. Noetling places the Otoceras bed *s. s.* even lower in the series than A. v. Krafft, correlating it with the Permian zone of *Bellerophon impressus* and the overlying Ophiceras bed with the zone of *Euphemus indicus* of the Chideru group.

These views have been set forth more fully in a chapter of the *Lethœa Palœozoica*, dealing with the Permian rocks of the Himálayas,[3] and support has been given to them by F. Frech,[4] who correlated the Indian Otoceras beds with the Permian Bellerophon limestone of the Eastern Alps.

Both papers were answered in a short note by Diener, who commented on the remarkable change in Noetling's system of correlation.[5]

The attitudes of the two disputants are brought out clearly by their principal reports on the problem of the Permo-Triassic boundary in the Himálayas, which appeared in 1905. An exhaustive study of the stratigraphy and age of the Otoceras beds was published by Noetling who divided the uninterrupted complex of dark limestone and shaly clay with its uniform fauna into three palæontological

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1 C. Diener: Ueber das Alter der Otoceras beds des Himalaya. *ibidem*, p. 513.

2 F. Noetling: Beitræge zur Geologie der Salt Range, insbesondere der permischen und triadischen Ablagerungen. *Neues Jahrb. f. Min., etc.*, Beilagebd. XIV, p. 467.

3 F. Noetling: Die Dyas des Himalaya, *Lethœa palœozoica*, II, p. 653.

4 F. Frech: *ibidem*, p. 577.

5 C. Diener: Zur Frage des Alters der Otoceras beds in Himalaya, *Centralbl. f. Min.*, 1901, p. 655.

zones and draws the boundary between the Permian and Triassic systems below the Meekoceras beds.[1]

This study, which was based on a personal examination of the Shalshal cliff in 1900, was answered by Diener, who declared that neither lithological nor palæontological nor historical reasons were valid for a decision in favour of Noetling's opinion.[2] In a subsequent paper on the genus *Episageceras* [3] Noetling himself admitted the incorrectness of A. v. Krafft's identification of *Episageceras Dalailamæ* Dien. with *E. Wynnei* Waag., thus acknowledging his mistake in having accepted this identification as a proven fact.[4]

The conclusions reached in those papers by Noetling have been maintained in his synopsis of the stratigraphy of the Trias in Asia.[5]

The only result which this history of correlation emphasizes, is the fact that all attempts to assign the Otoceras stage definitely to one system or the other, have hitherto failed. The present state of the discussion may be summed up as follows :—

From a palæontological point of view the classification of the beds included between the Kuling, or Productus, shales, of undoubtedly Permian age, and the Hedenstrœmia stage, as proposed by Noetling, is too minute, and a combination of the three zones distinguished by him within the Otoceras beds will better express our present knowledge regarding their true faunistic relations. The Meekoceras beds have been referred unanimously to the Trias. There is indeed no doubt about their parallelism with the Seis or lower Werfen beds, since the homotaxis of the overlying Hedenstrœmia stage with the Campil beds of the Eastern Alps has been proved by the recent discovery of the fauna of Kcira in Albania. The Otoceras beds have been included with the Permian system by Noetling,

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1 F. Noetling: Ueber das Alter der Otoceras Schichten von Rimkin Paiar (Painkhanda) im Himalaya. *Neues Jahrb. f. Mineral, etc.*, Beilagebd., XVIII, p. 518.

2 C. Diener : Ueber die stratigraphische Stellung der Otoceras beds im Himalaya, *Centralbl. f. Miner., etc.*, 1905, pp. 1-50, 36-45.

3 F. Noetling: Ueber *Medlicottia* und *Episageceras* aus den permischen und triadischen Schichten Indiens. *Neues Jahrb. f. Mineral, etc.*, Beilagebd., XIX, p. 369.

4 *Lethœa palæozoica*, II, p. 656.

5 Asiatische Trias. *Lethœa mesozoica*, Bd. I, Trias, 2 Lieferg., 1905, p. 127.

with the Trias by Diener, but those two authors are entirely in accord in acknowledging the fact that there is a gradual transition of the deposits from the Kuling shales to the Hedenstrœmia beds, without any break or unconformity.

Since the discussion of the Permo-Triassic problem in the Himálayas had come to a preliminary close in 1905, much new evidence has been gathered from an examination of the Triassic fossils from Spiti and Painkhanda by A. v. Krafft and C. Diener, from the study of the Meekoceras fauna in California and Idaho by J. P. Smith, and from the discovery of a rich Permian fauna in the Bellerophon limestone of Carniola by Kossmat and Schellwien. A sufficient number of facts, I believe, has been accumulated now to enable us to delimit the Permian and Triassic systems on the same basis in the Eastern Alps and in the Himálayas.

Noetling has laid special stress on the absence of any defined break in the series between the Hedenstrœmia beds and the Productus shales. Nevertheless he draws his boundary *below* the Meekoceras beds, not above them, where the lithological change is certainly marked more sharply. But I shall not insist on this objection to his division of the two systems, because in my opinion lithological affinities can never give a clue to the true position of horizons in the standard stratigraphical scale. The object of correlation is and has been to bring newly discovered horizons into their proper places in systematic classifications already established. Such correlations, however, can be made with any precision on *palæontological* evidence only, the apparent lithological affinity of two strata never being a safe means for their association in one stratigraphical subdivision.

A remarkable instance may be quoted here regarding the question of the Permo-Triassic boundary in the Eastern Alps, which in many respects is similar to the same problem in India.

There is no unconformity between the Permian Bellerophonkalk and the shales of the lower Werfen (Seis) beds, but the lithological contrast between the two groups is rather sharply marked, considerably more so, as a rule, than between the Productus shales and the Otoceras stage. Nevertheless sections have been found, where the Bellerophon limestone passes gradually into the overlying shales. Now in the vicinity of Sarajevo a very interesting section has been described by E. Kittl (Geologie der Umgebung von Sarajevo. *Jahrb. K. K. Geol. Reichsanst.*, 1904, LIII. p. 17), where a bed of limestone containing fossils of the Bellerophonkalk is intercalated in shales lithologically identical with those of the Werfen beds. It is evident that in this section the highest beds of Permian age are developed in the facies of the Triassic Werfen shales and that the lithological boundary does not coincide with the true limit of the two systems. A development of Triassic limestones within the shales at the base of the Seis beds has been described recently by F. v. Kerner (Die Trias am Suedrande der Svilaja Planina, *Verhandl. K. K. Geol. Reichsanst.*, 1908, p. 263).

The Permian age of the Otoceras beds was defended on this lithological basis for a number of years against the counter-evidence of fossils. Noetling had indeed no palæontological evidence in favour of the supposed homotaxis of the Himálayan Otoceras beds with the Chideru stage of the Salt Range. His only reasons for assigning a Permian age to the Otoceras stage, as deduced from a study of its fossils, are the following :—

(1) the genus *Otoceras* is only known from Permian rocks ;
(2) *Episageceras Dalailamæ* is a Permian species, so far as we can judge from the character of its suture-line.

The fallacy in those two assumptions is so evident that it should not have deceived able geologists like Kayser (*Lehrbuch der Geologie*, II, Formationskunde, 3. Aufl. 1908, p. 301) or Steinmann (*Einfuehrung in die Palæontologie*, 2. Aufl. 1907, p. 326).

It is true that the genus *Otoceras* is known outside the Himálayas from Permian rocks only, a small number of species, represented by a few fragmentary examples, having been collected from a single locality (Julfa on the frontier of Persia and Russian Armenia). But there is not a single case of specific identity with Himálayan forms. The Armenian species of *Otoceras* are associated with a rich fauna of distinctly Palæozoic aspect. The numerous types of *Productidæ*, *Orthidæ*, *Spiriferidæ*, *Gastrioceras*, differ so widely from anything that is seen in the fauna of the Indian Otoceras beds, that the presence of the genus *Otoceras* at Julfa does not justify the assumption of its being restricted to the Permian. *Hungarites*, the nearest ally of *Otoceras*, is certainly a Triassic genus, although it makes its first appearance in the Otoceras beds of Julfa. *Xenodiscus* also ranges from the true Permian into the upper division of the Lower Trias. The *species* of *Otoceras*, which have been described from the fauna of Julfa, are leading fossils of the Upper Permian, but the *genus Otoceras* is not.

A similar remark applies to *Episageceras Dalailamæ.* The genus *Episageceras* in Noetling's interpretation is represented by three species only. *Episageceras Wynnei* Waag., from the Upper Productus limestone of the Salt Range, *E. Dalailamæ* Dien., from the Otoceras beds of the Himálayas, *E. latidorsatum* Noetling from the zone of *Prionolobus rotundatus* (lowest Ceratite marls) of the Salt Range. In its sutures *E. Dalailamæ* agrees more nearly with the Permian *E. Wynnei* than with the Triassic *E. latidorsatum.* This affinity is considered sufficient for claiming a Permian age for *E. Dalailamæ.* But this conclusion far exceeds the limit of the true relations of the elements of organic form to geological age, and the specific discrepancy between *E. Dalailamæ* and *E. Wynnei* cannot be corrected by interpreting *E. Dalailamæ* as a representative of a Permian group of forms in the face of the absence of all faunal guides pointing to a Permian age of the Otoceras beds.

By this method of correlation the Permo-Triassic problem in the Himálayas has not been solved but simply reserved.

Noetling looks upon the genus *Otoceras* and the group of *Episageceras Dalailamæ* as leading fossils of the Permian system and infers from their presence in the Indian Otoceras beds a Permian age for that stage. But in reality it is this character of the two ammonites quoted above as leading fossils of the Permian system, which ought to be proved first and this can only be done with reliable evidence of the Permian age of the Otoceras beds. Provided the Otoceras beds of India be really Permian, then, but only then, *Otoceras* is indeed a Permian genus. Otherwise it would be common to the Permian and the Trias, as are *Xenodiscus* and *Hungarites.* No diagnosis of the age of the formation can be based on the presence of *Otoceras*, but the stratigraphical value of the genus depends on the way in which the problem of the Otoceras beds is solved.

All mistakes in the correlation of the Indian Otoceras beds were an outcome of the faultiness of this method. It has therefore been necessary to go into full details, since a general reliance among European geologists upon Noetling's authority still stands in the way of the acceptance of the truth.

Positive palæontological evidence is decidedly contradictory to the assumption of a Permian age for the Indian Otoceras beds. The general character of the cephalopod fauna is what we should expect to find in a Mesozoic horizon, the overwhelming majority of the ammonites being provided with ceratitic sutures. This character is not exhibited in any Permian cephalopod fauna hitherto known.

Among the genera of ammonites *Meekoceras*[1] and *Ophiceras* are in common with the fauna of the Triassic Meekoceras beds. *Proptychites* and *Prosphingites* are Triassic genera. In the Meekoceras beds of Idaho species of the Ophiceras bed in Spiti are associated with an undoubtedly Triassic fauna. Among those species which have been quoted by J. P. Smith [2] three are probably identical with Himálayan forms, namely :—

Ophiceras cf. Sakuntala Dien.
„ *cf. gibbosum* Griesb.
Meekoceraf cf. Hodgsoni Dien.

Two other species of *Ophiceras* are very nearly allied to Indian ones, namely, *Ophiceras Spencei* Hyatt et Smith to *O. ptychodes* Dien., and *O. Dieneri* Hyatt et Smith to *O. demissum* Opp.[3]

All the numerous types of Palæozoic brachiopods, which are the predominating and most characteristic element both in the Productus Limestone of the Salt Range and in the Kuling shales of the Himálayas, are completely absent from the Otoceras beds. There is no stratigraphical break in the uninterrupted sequence of beds, which in the Himálayas connects the Permian and Triassic systems, but there is a distinct palæontological break or hiatus at the base of the Otoceras beds. In the Himálayan region there is certainly no gradual shading-off from a Palœozoic to a Mesozoic marine fauna through an intermediate group, but a sharply defined limit, which none of the characteristic species of Permian brachiopods transgresses. This absolute distinction between the brachiopods of the Kuling shales and of the Otoceras beds is so sharp that *the limit between the two faunœ offers itself as the most natural boundary of the two systems.*

I must object strongly to Noetling's criticism upon the importance of the absence of the Palæozoic brachiopod fauna from the Otoceras

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[1] Noetling's report of the absence of the genus *Meekoceras* from the Otoceras stage has turned out to be incorrect.

[2] J. P. Smith : The stratigraphy of the Western American Trias, l. c., p. 394.

[3] A. Hyatt and J. P. Smith : Triassic cephalopod genera of America, l. c., pp. 118, 119.

stage. Being obliged to acknowledge the fact, he attempts to lessen its stratigraphical value by a hypothesis, which is, perhaps, the best argument that could be produced against an adoption of his views.

As an explanation of the sudden extinction of Palæozoic brachiopods in the Salt Range he suggests an increase of the temperature of the sea, which he believes to have advanced from north to south. Thus the Palæozoic brachiopods still persisted in the Salt Range after they had already been extinguished in the Himálayas. The biological change was not synchronous in the two regions and the line of demarcation, which in the Salt Range separates the two systems, does not separate them in the Himálayas.

When we examine this argument critically, we find that the theory to account for the supposed difference in the periods of extinction of the Palæozoic brachiopods in the Himálayas and in the Salt Range has no solid foundation whatever. But even if the validity of this theory should be conceded, there was the error at the start that Noetling has mistaken synchronism for homotaxis. It is on homotaxis, however, not on synchronism, that all stratigraphical correlation must needs be based.

With this negative evidence of the absence of Palæozoic brachiopods the positive evidence of a faunula of Triassic lamellibranchs agrees. From the unquestionable affinity or even identity of some *Ammonoidea* and *Lamellibranchiata* in the Indian Otoceras fauna with species of the American Meekoceras and of the Alpine Seis beds, there is scarcely room to doubt that the Otoceras stage is, indeed, of *Triassic* age.

We are led to the same conclusion by the method of comparing the Permo-Triassic sequence of the Himálayas with that of the Eastern Alps, where, exactly as in India, the gap between the two systems is filled up by an uninterrupted series of marine deposits, ranging from the Groeden sandstones into the Werfen beds without the slightest trace of an unconformity. The Permian age of the Alpine Bellerophon Limestone having been ascertained, the question arises, whether it should be correlated with the Kuling shales and Upper Productus Limestone or with the Otoceras beds.

Such faunistic affinities as exist between the Otoceras beds and the corresponding Alpine deposits point in the direction of the Seis beds, not of the Bellerophonkalk, as has been demonstrated by Bittner.

One species of *Bellerophon* (*B. cf. Vaceki* Bittn.) is probably identical. Among three species of lamellibranchs two are allied very closely to types from the Seis beds, *Pseudomonotis* (*Claraia*) *Griesbachi* Bittn. to *Claraia ovata* Schaur., and a species of *Avicula* to the common *A. Venetiana* v. Hauer. Brachiopoda of Palæozoic habit have not been met with either in the Otoceras beds or in the Seis beds. Their only representative in the Otoceras beds, *Norella procreatrix* Bittn., belongs to a group or subgenus which is at present known only from Triassic rocks.

On the other hand the recent discoveries of Kossmat and Schellwien in Carniola clearly prove the Productus Limestone of the Salt Range to be the Indian representative of the Bellerophonkalk. The faunula from the hills to the west of Laibach exhibits striking affinities with the Permian faunæ of the Punjab. From this locality the following species have been quoted by Schellwien [1] :—

Richthofenia aff. Lawrenciana de Kon.
Productus indicus Waag.
,, *Abichi* Waag.
Marginifera ovalis Waag.
Lonsdaleia indica Waag. et Wentz.

The discovery of this fauna excludes any possibility of correlating the Bellerophonkalk with the Ceratite formation or with the Otoceras beds. The homotaxis of the Bellerophonkalk with the Ceratite formation has been advocated recently by G. Caneva.[2] This author admits the existence of faunistic affinities between the Bellerophonkalk and the Productus Limestone, but considers them to be too small to justify a homotaxis of the two groups. He prefers to correlate the Bellerophonkalk with the Ceratite formation, to which no faunistic affinities whatever exist. This is one of the most instructive illustrations of a method of correlation founded on wrong principles.

The only ammonite hitherto known from the Bellerophon limestone, *Paralecanites sextensis* Dien.[3] belongs to a genus which has also

[1] E. Schellwien : *Monatsber, d. Deutschen Geol. Ges.*, 1905, p. 35 f.

[2] G. Caneva : Ueber die Bellerophonkalk fauna. Zur Frage der Perm-Triasgrenze *Neues Jahrb. f. Mineral*, etc., 1906, II, pp. 52-60.

[3] C. Diener : Ueber ein Vorkommen von Ammoniten und Orthoceren im suedtirolischen Bellerophonkalk, *Sitzgsber. kais. Akad. d. Wissensch.*, CVI, 1897, Math Nat. Kl. p. 66.

been found in the Meekoceras beds of Idaho associated with a typical Lower Triassic fauna. But the American species, *P. Arnoldi* Hyatt et Smith,[1] is not identical with the Alpine form. The two distinguished authors are probably right in regarding it as a survival of the ancestral type, whose mature form is very much like the larval stages of *Meekoceras*.

I may be permitted to quote in this place a note from my memoir on the Permian fossils of the Central Himálayas (*Palæont. Ind.*, ser. XV., Himál. Foss., Vol. I, Pt. 5, p. 196):—

" A bed of peculiar interest is the Permian limestone, which south of Pomarang, is intercalated in the dark micaceous Kuling shales. It is rich in gasteropods and bivalves, and recalls the Bellerophon limestone of the South-eastern Alps. With the fauna of this remarkable horizon it has probably one species, *Bellerophon Vigilii* Stache, in common. The predominance of European Permian types in this limestone is an interesting fact. Three species of bivalves—*Modiolopsis Teploffi* Vern., *Solemya biarmica* Vern., *Oxytoma latecostatum* Netsch.—are identical with such from the Permian strata of Russia, whereas another one is most nearly allied to *Conocardium siculum* Gemm., from the Permian Fusulina limestone of Sosio in Sicily."

Any attempt to include the Otoceras stage in the Permian system is contradictory to palæontological evidence. It necessitates a correlation of the Otoceras beds with the Bellerophonkalk, to which their fauna has no affinity.

On the principle of establishing correlation of horizons in distant countries by identity of the fossils all the evidence goes to prove that the Bellerophonkalk is the homotaxial equivalent of the Upper Productus Limestone and of the Kuling shales, especially of the limestone of Pomarang containing *Bellerophon Vigilii*, whereas the Otoceras stage corresponds stratigraphically to the lowest division of the Werfen beds (lower Seis beds).

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1 A. Hyatt and J. P. Smith: Triassic cephalopod genera of America, l. c., p. 136.

The following table shows this correlation of Permo-Triassic beds in the Eastern Alps and in India :—

	Eastern Alps.	Salt Range.	Himálayas.
Buntsand-stein	Campil beds	Upper Ceratite limestone.	Zone of *Sibirites spiniger.*
		Ceratite sandstones	Hedenstrœmia beds.
		Ceratite marls	Meekoceras beds.
		Lower Ceratite lime-stone.	
(Scythian stage.)	Seis beds with *Claraia sp., Bellerophon Vaceki*, etc.	Unfossiliferous beds in the section of Chideru.	Otoceras beds with *Claraia sp., Avicula aff. Uenetiana, Bellerophon cf. Vaceki.*
Upper Permian.	Bellerophonkalk, with *Productus indicus, P. Abichi Bellerophon Vigilii*, etc.	Upper Productus limestone.	Kuling shales (lime-stone of Pomarang with *Bellerophon Vigilii*).

On considering these several facts, I have been confirmed in my view published in 1897, that the Otoceras beds of the Himálayas must be included with the Lower Trias and that the boundary between the Permian and Triassic systems must be drawn between the Otoceras beds and the Kuling shales in the Himálayas, between the Chideru stage of the Upper Productus Limestone and the Lower Ceratite Lime-stone in the Salt Range, between the Bellerophonkalk and the lower Werfen beds (Seis beds) in the Eastern Alps.

II. The Middle Trias.

(Muschelkalk and Ladinic stage.)

a. The Muschelkalk of Spiti and Painkhanda.

There is an almost perfect identity in the development of the Muschelkalk in Spiti and Painkhanda, although it has taken a considerable time to establish this fact with full certainty. A. v. Krafft was the first to draw attention to this uniform development, which goes so far that almost every single bed found in the one area can be recognised in the other, as will be seen from a comparison of the section near Lilang with that of the Bambanag cliff.

The section observed by A. v. Krafft and H. Hayden near Lilang in Spiti is as follows (in descending order):—

4. Dark grey limestone, often concretionary, with shaly partings. Upper Muschelkalk	22 feet.
3 *f* Grey limestone with *Ceratites Ravana*	16 ins.
3 *e* Grey concretionary limestone	6 ins.
3 *d* Shales with *Spiriferina Stracheyi*	4 ins.
3 *c* Grey limestone	3 ins.
3 *b* Hard, grey limestone with *Keyserlingites Dieneri*	4 ins.
3 *a* Thin layers of grey limestone and shale	3 feet.
2. Nodular limestone (Niti limestone Noetl.)	60 feet.
1. Shaly limestone with *Rhynchonella Griesbachi*	3 feet.

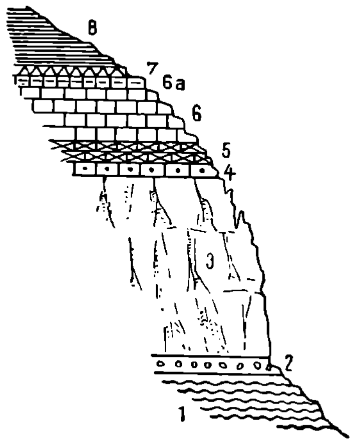

FIG. 2. *Section through the Middle Trias along the Lingti river (from A. v. Krafft's diary).*

8. Daonella shales, with *Daonella Lommeli.*
7. Passage beds.
6. Upper Muschelkalk.
6*a* Main layer of *Ptychites rugifer.*
5. Zone of *Spiriferina Stracheyi.*
4. Zone of *Keyserlingites Dieneri.*
3. Nodular limestone.
2. Limestone with *Rhynchonella Griesbachi.*
1. Hedenstrœmia beds.

At the Bambanag cliff the following section was observed by A. v. Krafft in 1900 :—

4.	Upper Muschelkalk with numerous specimens of *Ptychites, Hollandites, Beyrichites Khanikoffi* Opp., *Gymnites Vasantasena*, Dien, etc.	20 feet.
3 *i*	Shales with many concretions, containing *Spiriferina Stracheyi*	2 feet.
3 *h*	Dark grey limestone with *Spiriferina Stracheyi* and *Spirigera Stoliczkai*	1 foot.
3 *g*	Black shales	5 ins.
3 *f*	Dark grey limestone with *Keyserlingites Dieneri Monophyllites Hara, M. Kingi, Spiriferina Stracheyi, Spirigera Stoliczkai*	5 ins.
3 *e*	Black shale	2 ins.
3 *d*	Limestone as 3 *f* containing *Gymnites sp.*	7 ins.
3 *c*	Black shales	5 ins.
3 *b*	Limestone as 3 *h* with *Monophyllites sp.* and *Dalmatites Ropini* Dien.	6 ins.
3 *a*	Black shales with *Keyserlingites sp.*	5-6 ins.
2.	Nodular limestone (Niti limestone Noetl.) unfossiliferous	50 feet.
1.	Earthy limestone with *Rhynchonella Griesbachi* and *Retzia himaica*	3 feet.

In geological delimitation the Muschelkalk begins with the basal limestone No. 1. In biological definition the first marine fauna of a typical character is that included in the shales and limestones No. 3. The overlying dark grey and well-bedded limestones (No. 4) have yielded a large number of *Cephalopoda*.

The difference between the faunæ contained in the two subdivisions Nos. 3 and 4 gave occasion for drawing the boundary line between the Lower and Upper Muschelkalk at the top of No. 3. The massive nodular limestone No. 2 is practically unfossiliferous, but is very conspicuous in the scenery, towering in a steep escarpment above the slope of the Lower Triassic beds. For this horizon the name of Niti limestone was suggested by Noetling.

This fourfold division of the Muschelkalk has also been observed in the section of the Shalshal cliff by A. v. Krafft, where he distinguished the following groups (in descending order) :—

4. Upper Mulchelkalk very rich in ammonites.

3 *b* Thin beds of limestone with the brachiopod fauna of *Spiriferina Stracheyi.*

3 *a* Shaly limestone with *Keyserlingites Dieneri.*
2. Nodular limestone, unfossiliferous.
1. Earthy limestone, with *Rhynchonella Griesbachi* and *Retzia haimica.*

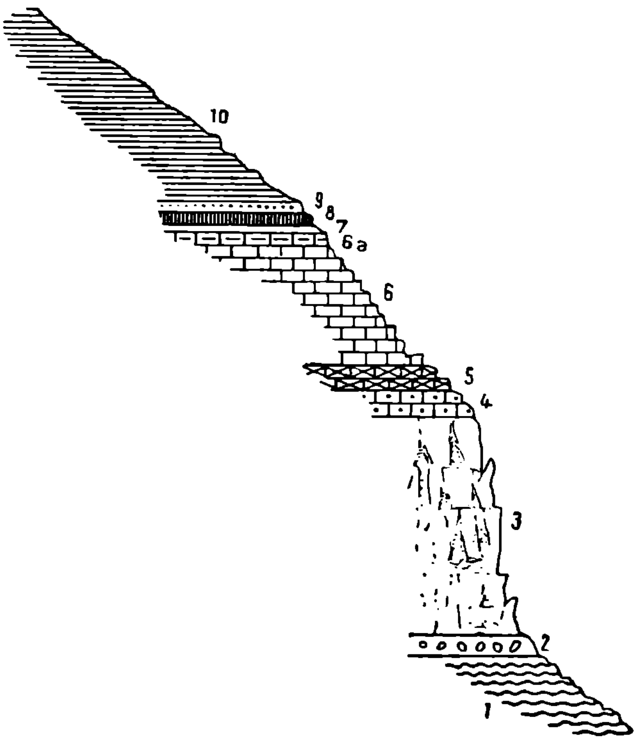

FIG. 3. *Section through the Middle Trias of the Shalshal cliff, opposite Rimkin Paiar.*

10. Shales with *Halobia comata.*
9. Shaly limestone with *Daonella indica.*
8. Traumatocrinus limestone.
7. Passage beds (ladinic stage).
6. Upper Muschelkalk.
6 *a* Main layer of *Ptychites rugifer.*
5. Thin beds of limestone with *Spiriferina Stracheyi.*
4. Shaly limestone with *Keyserlingites Dieneri.*
3. Nodular limestone (Niti limestone).
2. Limestone with *Rhynchonella Griesbachi.*
1. Hedenstrœmia beds.

The recognition of these four subdivisions in the section of the Shalshal cliff settles for us several disputed questions, for this section had furnished the basis for the classification of the Muschelkalk by Griesbach and Diener in which they had been particularly unfortunate.[1]

Those two authors distinguished a thin lower division with *Brachiopoda* (*Rhynchonella Griesbachi*), corresponding to No. 1, and a thick upper division, corresponding to beds Nos. 2, 3, 4 in A. v. Krafft's classification, but did not appreciate the stratigraphical importance of the horizon No. 3, because the fossils from it became mixed up with those of other horizons in the collections made by the expedition in 1892. Thus two different brachiopod faunæ were included in Diener's list of species from bed No. 1, the fauna of *Rhynchonella Griesbachi* which actually belongs to this horizon, and the fauna of *Spiriferina Stracheyi*, which has its habitat in the shaly beds (No. 3) above the Niti limestone.[2]

This mistake was combined with a second one from which considerable confusion arose. It was the supposed discovery of a specimen of *Keyserlingites* (group of *Ceratites subrobusti* Mojs.) in the Hedenstrœmia beds, for which, consequently the name "Subrobustus beds" was then proposed by Diener. Since the actual layer of this ammonite was fixed in the beds with *Spiriferina Stracheyi* by A. v. Krafft, not in the upper division of the Lower Trias, as suggested by Diener, the name "Subrobustus beds" had to be dropped afterwards.

The two brachiopod faunæ of the zones of *Rhynchonella Griesbachi* and *Spiriferina Stracheyi* (beds Nos. 1 and 3) were first distinguished by A. Bittner,[3] but his view only depended upon palæontological evidence. Their existence was, however, soon afterwards confirmed by geological researches, thus proving the fact that the testimony of fossils can always be relied on to the extent and precision which a palæontologist's ability to interpret them will permit.

In 1899 A. v. Krafft [4] ascertained the presence of the brachiopod-bearing horizon with *Spiriferina Stracheyi* Salt. in Spiti between the underlying mass of the Nodular limestone (Niti limestone) and the

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[1] *Jahrb k. k. Geol. Reichsanst.*, 1899, p. 692.

[2] In the classification adopted by the Geological Survey of India, this is known as the "Nodular limestone" (*see* Burrard and Hayden, *Geography and Geology of the Himalaya and Tibet,* p. 239).—EDITOR.

[3] C. Diener: Ergebnisse einer geologischen Expedition in den Central-Himálaya, *Denkschr. kais. Akad.*, LXII, 1895, pp. 571, 572.

[4] *General Report, Geol. Surv. of India* for 1899-1900, p. 202.

Upper Muschelkalk, and discovered the bed No. 3, containing *Keyserlingites Dieneri* Mojs. (*Ceratites subrobustus* antea). In 1900 he fixed the horizons distinguished by the two brachiopod faunas in the Bambanag and Shalshal cliffs, showing that the upper one (bed 3) was characterised by *Spiriferina Stracheyi*, and the lower one (bed 1) by *Rhynchonella Griesbachi.*

In Spiti this question was finally settled by H. Hayden's discovery of the layer with *Rhynchonella Griesbachi* at the base of the Nodular limestone, in the exact position in which it had been found in the Bambanag and Shalshal cliffs by Griesbach, Diener and A. v. Krafft.[2]

The evidence now available enables us to point out exactly where to draw the stratigraphical lines to indicate the four subdivisions which can be distinguished in the Muschelkalk in Painkhanda and Spiti, but the position of the two lower subdivisions in the general standard of the Triassic system is not quite clear.

The age of the bed with *Rhynchonella Griesbachi* (No. 1) and of the Nodular limestone (No. 2) is looked upon as doubtful by Hayden and A. v. Krafft. Noetling[3] includes bed No. 1 with the Hedenstrœmia stage of the Lower Trias and bed No. 2 (his Niti limestone) with the Muschelkalk.

From the horizon of *Rhynchonella Griesbachi* three species of *brachiopoda* are known, namely :—

Rhynchonella Griesbachi Bittn.
Norella Kingi Bittn.
Retzia himaica Bittn.

Although *Rhynchonella Griesbachi* belongs to the Alpine group of *Rh. trinodosi* Bittn. which is one of the chief leading fossils of the Muschelkalk, its presence cannot be regarded as a sufficient proof in favour of a Muschelkalk age of this horizon.

Diener records one ammonite from the layer with *Rhynchonella Griesbachi, Sibirites Prahlada,* which he claims to have chiselled out from

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[1] *General Report, Geol. Surv. of India* for 1900-01, p. 26. Zur Glieberung des Muschelkelkes im Himalaya, *Verhandl, k. k. Geol. Reichsanst,* 1901, p. 52.

[2] H. Hayden : The Geology of Spiti, l. c., p. 69.

[3] Asiatische Trias, *Lethœa mesozoica,* l. c., pp. 138, 139.

the rocks *in situ* in a section of the Shalshal cliff, not locally identical with the section where the large species of brachiopods from the zone of *Spiriferina Stracheyi* have been found.[1] In Spiti, however, several examples of this species have been collected in bed 3*b* of the section near Lilang by A. v. Krafft.[2] Now the question arises, whether *Sibirites Prahlada* is restricted to bed 3 or ranges from the layer with *Rhynchonella Griesbachi* into a horizon of undoubted Muschelkalk age. No second specimen has been found in Painkhanda, neither in bed 1, nor in bed 3 of the Bambanag and Shalshal cliffs.

Provided the species could be proved to have its habitat in bed No. 1 of the Shalshal cliff, this might be accepted as a strong reason for including the horizon of *Rhynchonella Griesbachi* with the Muschelkalk.

On the other hand two ammonites, which have been discovered in the Niti [3] limestone of Spiti by H. Hayden, were identified with species from the Hedenstrœmia beds of Muth by A. v. Krafft.[4] He therefore proposes to draw the boundary line between the Lower and Middle Trias at or above the middle of the Niti limestone. But Diener, on the strength of a re-examination of the specimens collected by Hayden, refuses to admit their identity with Lower Triassic species declaring them to be altogether indeterminable owing to their unfavourable state of preservation.[5]

In the absence of more convincing evidence, the age of the bed containing *Rhynchonella Griesbachi* and of the overlying Niti limestone must still remain an open question. For the present I prefer to leave them with the Muschelkalk, both from respect for historical priority—Griesbach having included them in the Upper Trias—and because from a geological point of view the Niti limestone certainly belongs to this group, not to the Lower Trias.

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[1] C. Diener: The fauna of the Himálayan Muschelkalk, *Palæont. Ind.*, Ser. XV, Vol. V, Pt. 2, p. 130.

[2] The name 'zone of *Sibirites Prahlada*,' in the sense in which it was used by Diener must be discarded, since this species has in Spiti its main layer above, not below the Niti limestone.

[3] *See* footnote to p. 59.—ED.

[4] H. Hayden, Geology of Spiti, l. c., p. 67.

[5] In *General Report, Geol. Surv. of India*, 1899-1900, p. 192, H. Hayden mentions one species of *Nautilidæ, Grypoceras sp. ind. ex. aff. Palladii* Mojs. from the Niti limestone of Spiti.

Leaving aside the horizon of *Rhynchonella Griesbachi* and the Niti limestone, which in thickness is the predominating element of the Middle Trias of Painkhanda, the rest of the Muschelkalk falls naturally into two subdivisions, a lower one about six feet in thickness, consisting of thin-bedded, grey limestones, partly alternating with shales (bed No. 3), and a higher one (No. 4) reaching a thickness of 20 feet, consisting of dark grey, regularly bedded limestones. In the scenery the group No. 3 is often indicated by a softer slope, interrupting the outlines of the steep escarpments above and below.

The Lower Muschelkalk (group No. 3) constitutes one single stratigraphical horizon. There is no definite boundary between the lower beds containing ammonites and the higher ones containing brachiopods. As we pass upwards in the sections—especially in that of the Bambanag cliff,—the ammonites are gradually replaced by brachiopods, according to A. v. Krafft's observations. The whole series between the Niti limestone and the Upper Muschelkalk must therefore be united in one group, but it must be understood that the cephalopoda prevail in the lower part of the group, and the brachiopoda in the upper.

The brachiopod fauna of the zone of *Spiriferina Stracheyi* is very uniform in Painkhanda and Spiti. From both regions the following three species are known:—

Spiriferina Stracheyi Salt.
Spirigera Stoliczkai Bittn.
Rhynchonella Dieneri Bittn.

A fourth species, *Rhynchonella mutabilis* Stol., is hitherto known from Spiti only. Three other species of brachiopods, which have been described by Stoliczka in volume V of the *Memoirs of the Geological Survey of India*, are of doubtful position, since it is uncertain whether they belong to the Lower or to the Upper Muschelkalk.

Regarding the cephalopod-fauna of the Lower Muschelkalk, the Spiti sections—especially those of Lilang and along the Gyundi river—have yielded a considerably larger number of fossils than the sections of Painkhanda.

The following four species, all of which were collected by A. v. Krafft and Hayden, are common to both districts:—

Keyserlingites Dieneri Mojs.
Dalmatites Ropini Dien.

Monophyllites Hara Dien.
,, *Kingi* Dien.

Twelve species are peculiar to Spiti, namely :—

Ceratites (*Hollandites*) *Vyasa* Dien.
,, (*Danubites*) *cf. Kansa* Dien.
Keyserlingites Pahari Dien.
,, *pagoda* Dien.
,, *sp. ind. aff. Bungei* Mojs.
Japonites cf. Ugra Dien.
Stacheites Webbianus Dien.
Sibirites Prahlada Dien.
Gymnites depauperatus Dien.
,, *sp. ind. aff. Sankara* Dien.
Monophyllites (*Mojsvarites*) *Confucii* Dien.
,, ,, *Pradyumna* Dien.

Only two species of *Nautiloidea* which appear in A. v. Krafft's collections from the Shalshal cliff have not as yet been noticed in the Lower Muschelkalk of Spiti. Those species are :—

Orthoceras cf. multilabiatum Hauer.
,, *cf. campanile* Mojs.[1]

The most characteristic element in this fauna is the group of *Keyserlingites Dieneri* (*Ceratites subrobusti*).

The Himálayan representatives of this group are not identical with those from the Olenek beds of Siberia. It might even be questioned whether they should actually be included in the genus (or subgenus) *Keyserlingites*. They serve indeed to illustrate one of the most interesting cases of convergence. Full grown individuals of *Keyserlingites Dieneri* agree so closely with the Siberian *Keyserlingites subrobustus* Mojs. in all their external characters, that their examination did not lead to the discovery of any features which might justify a specific separation. It was only the examination of inner nuclei—not known before 1905—which showed the larval and adolescent stages to differ remarkably from the corresponding stages in *Keys. subrobustus*. Whereas inner nuclei of the latter species resemble mature stages of *Dinarites* (*Olenekites*)

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[1] All the species quoted in this list have been described and illustrated in Diener, Fauna of the Himálayan Muschelkalk, *Pal. Ind.*, ser. XV, Vol. V, Pt. 2.

spiniplicatus, its Indian representative passes through stages resembling *Tirolites* and afterwards *Sibirites*.

There is consequently no real affinity between the Indian and Siberian types corresponding to their astonishing resemblance in external shape, sculpture and sutures. A new subgeneric denomination, *Durgaites*, might be proposed for the Himálayan forms.

The Upper Muschelkalk (No. 4) is a cephalopod-facies, in which very few remains of *Brachiopoda*, *Gastropoda* and *Lamellibranchiata* are associated with a large number of ammonites. The following species of *Brachiopoda* certainly belong to the Upper Muschelkalk of Spiti :—

Coenothyris vulgaris Schloth.
Mentzelia Mentzelii Dunk.
,, *kœveskalliensis* Suess.

The following species of *Gastropoda* and *Lamellibranchiata* must be added to this list :—

Pleurotomaria indica Blaschke.
Worthenia Dieneri Blaschke.
Tectospira gracilis Blaschke.
Omphaloptycha sp. ind.
Pseudomelania sp. ind.
Cardiomorpha (?) *Haydeni* Dien.
Lima sp. ind. aff. lineata Desh.
Posidonomya sp. ind. aff. pannonica Mojs.

The differences between the cephalopod faunæ of Spiti and of Painkhanda are of small importance. In both areas the fauna of the Upper Muschelkalk is richer in species than that of any other Triassic horizon. Not less than 23 species of *Cephalopoda* are common to the two districts, among them all the important leading fossils of this horizon. These species are :—

Ceratites Thuilleri Opp.
,, *Kamadeva* Dien.
,, (*Hollandites*) *Voiti* Opp.
,, ,, *Ravana* Dien.
,, ,, *Airavata* Dien.
,, ,, *Visvakarma* Dien.
,, ,, *Dungara* Dien.

Ceratites (*Hollandites*) *Moorei* Dien.
,, ,, *Vyasa* Dien.
,, ,, *Cecilii* Dien.
Beyrichites Khanikoffi Opp.
,, *Kesava* Dien.
Acrochordiceras Balarama Dien.
Sturia Sansovinii Mojs.
Buddhaites Rama Dien.
Gymnites Jollyanus Opp.
,, *Sankara* Dien.
Ptychites rugifer Opp.
,, *cochleatus* Opp.
,, *Everesti* Opp.
,, *Gerardi* Blfd.
,, *Sumitra* Dien.
,, *Mahendra* Dien.

The following 44 species of *Cephalopoda* are confined to Spiti :—

Orthoceras spitiense Dien.
Mojsvaroceras kagæ Dien.
Germanonautilus cf. salinarius Mojs.
Syringonautilus spitiensis Stol.
Grypoceras Griesbachi Dien.
Paranautilus Bullockii Dien.
Ceratites trinodosus Mojs.
,, *himalayanus* Blfd.
,, *sp. ind. ex. aff. Abichi* Mojs.
,, *superbiformis* Dien.
,, *truncus* Opp.
,, *Devasena* Dien.
,, *Padma* Dien.
,, (*Hollandites*) *Hidimba* Dien.
,, (*Salterites*) *Oberhummeri* Dien.
,, (*Haydenites*) *Hatschekii* Dien.
Beyrichites proximus Opp.
Cuccoceras yoga Dien.
Japonites cf. Dieneri Mart.
Isculites Hauerinus Stol.
Acrochordiceras cf. Carolinæ Mojs.

Acrochordiceras sp. ind. aff. pusterico Mojs.
Monophyllites sphærophyllus Hauer.
Pinacoceras Rajah Dien.
Gymnites incultus Beyr.
,, *cf. Humboldti* Mojs.
,, *Mandiva* Dien.
,, *Kirata* Dien.
,, *religiosus* Dien.
,, *sp. ind. aff. subclausus* Hauer.
Anagymnites Lamarcki Opp.
,, *cf. acutus* Hau.
,, *Torrensii* Dien.
Ptychites cognatus Opp.
,, *Sukra* Dien.
,, *Asura* Dien.
,, *Durandii* Dien.
,, *Vidura* Dien.
,, *Malletianus* Stol.
,, *impletus* Opp.
,, *Mangala* Dien.
Joannites cf. proavus Dien.
Proarcestes Balfouri Opp. (=*Escheri* Mojs.)
,, *sp. ind. aff. Bramantei* Mojs.

The following thirteen species are restricted to Painkhanda according to the present state of our knowledge :—

Ceratites Royleanus Dien.
,, *Arjuna* Dien.
,, (*Gymnotoceras*) *aff. geminato* Mojs.
,, (*Hollandites*) *Nalikanta* Dien.
,, ,, *Srikanta* Dien.
,, ,, *Narada* Dien.
Ananorites monticola Dien.
Japonites Sugriva Dien.
,, *Chandra* Dien.
Beyrichites Gangadhara Dien.
,, *affinis* Mojs.
,, *Rudra* Dien.

A faunula of the Upper Muschelkalk of a rather peculiar character was collected by Diener on the southern slope of the Uttardhura leading from Milam (Johar) to the Girthi valley (Painkhanda). The three following species are peculiar to this locality and have not been found in the sections of Painkhanda and Spiti :—

Orthoceras cf. campanile Mojs.
Acrochordiceras joharense Dien.
Pseudodanubites Dritarashtra Dien.

An exposure of Muschelkalk, probably rich in beautifully preserved fossils, but not yet examined thoroughly, was discovered by Griesbach on the eastern slope of the Tsang Tsok La (Hop Gádh) in Hundes. It has yielded the following species :—

Ceratites (Hollandites) Hidimba Dien.
Beyrichites Khanikoffi Opp.
Ptychites Govinda Dien.
Proarcestes Balfouri Opp.

In general the fauna of the Upper Muschelkalk is very uniform in Painkhanda and Spiti. The number of species peculiar to either of the two districts will no doubt be reduced still more considerably by future researches.

b. The Muschelkalk of Kashmir.

The presence of Muschelkalk in Kashmir is proved by a small number of ammonites and brachiopods, collected by Prochnow, the brothers von Schlagintweit, Stoliczka and Lydekker.

Spiriferina Stracheyi Salt. from the Tsarap valley (Zanskar basin) points to the lower division of the Muschelkalk (group No. 3).

The fauna of the Upper Muschelkalk is indicated by *Ceratites Thuilleri* (Sonamarg), *Gymnites Salteri* Beyr. (Ladakh, exact locality not known), *Proarcestes Balfouri* Opp. (=*Escheri* Mojs.,) from Dras (50 to 60 miles E. N. E. of Srinagar), *Ptychites Durandii* Dien. from Padam (Zanskar valley).[1]

In the sections of the Guryul ravine the Muschelkalk is represented by sandy shales with subordinate limestones, which follow conformably above the Lower Trias. In the middle division of this group

[1] *Palæont. Indica,* ser. XV, Vol. V, Pt. 2, p. 139.

Rhynchonella cf. trinodosi Bittn., *Rh. cf. mutabilis* Stol. and *Spiriferina Stracheyi* Salt. have been collected by C. S. Middlemiss.

c. The Muschelkalk of Eastern Johar.

The development of the Muschelkalk in Eastern Johar agrees, as far as known, with that observed in Spiti and Painkhanda. The fossils, which have been collected from the ridge between the Dharma and Lissar valleys, are imbedded in a dark shaly limestone. Among the *Cephalopoda* the overwhelming majority are identical with species from the Shalshal cliff. The following species belong to the Upper Muschelkalk :—

Grypoceras sp. ind. ex. aff. Palladii Mojs.
Ceratites Thuilleri Opp.
,, (*Hollandites*) *Ravana* Dien.
,, ,, *Airavata* Dien.
,, ,, *Dungara* Dien.
Beyrichites cf. Rudra Dien.
Pseudodanubites cf. Dritarashtra Dien.
Acrochordiceras Balarama Dien.
,, *cf. Carolinæ* Mojs.
,, *sp. ind. aff. pusterico* Mojs.
Gymnites Sankara Dien.
,, *Jollyanus* Opp.

The presence of the zone of *Spiriferina Stracheyi* is indicated by this species and by *Dielasma himalayanum* Bittn.

d. The Muschelkalk of Byans.

A. v. Krafft has drawn the attention of Indian geologists to the remarkable uniformity of the Muschelkalk in Spiti, Garhwal and Kumaon, a uniformity which goes so far that almost every single bed found in the one area can be recognised in the other. It seems, however, that a change takes place towards the east, for in Byans, in the north-eastern corner of Kumaon, near the boundary of Nepal, the Muschelkalk is developed in the facies of light grey limestone, without any trace of

Records, Geol. Surv. of India, XXXVII, (1909), p. 304.

shaly partings. This is evident from the notes left by Smith and A. v. Krafft, which have been published in my memoir on the fauna of the Himálayan Muschelkalk.

This eastern facies of the Himálayan Muschelkalk consists of pure limestones of a light grey colour, which overlie the chocolate limestone of Lower Triassic age. The dark, concretionary limestone with shaly partings, which is characteristic of the Muschelkalk in the north-western districts of the Central Himálayas, is entirely absent. In this development of light grey, pure limestones even the zone of *Rhynchonella Griesbachi* is included, as is proved by a large number of examples of this species in Smith's collections from Kalapani.

Noetling proposed to group the bed with *Rhynchonella Griesbachi* with the Hedenstrœmia stage, because in the section of the Shalshal cliff he found it to agree lithologically with this stage. Any geologist starting from an examination of the sections in Byans will be inclined to draw the boundary between the Lower and Middle Trias at the base, not at the top of the bed with *Rhynchonella Griesbachi*, which is united with the Muschelkalk into one uniform mass of light grey limestone.

The presence of the zone of *Spiriferina Stracheyi* is indicated by several species of brachiopods, characteristic of that zone, in Smith's collections from Jolinka and Kalapani, namely :—

Spiriferina Stracheyi Salt.
Spirigera Stoliczkai Salt.
Dielasma himalayanum Bittn.

It cannot be decided whether the two specimens of *Rhynchonella trinodosi* Bittn., one of the most characteristic species of the Alpine Muschelkalk, which I discovered among Smith's collections from Kalapani, have their habitat in this zone (group No. 3) or in the Upper Muschelkalk. The Indian group of *Ceratites subrobusti* (*Keyserlingites* Hyatt, *Durgaites* Dien.) is not yet known to us from Byans.

The layer of brachiopods, representing the zone of *Spiriferina Stracheyi* in the uniform mass of the Muschelkalk in Byans, occurs about 50 feet above the top of the chocolate limestone, according to A. v. Krafft. Thus the lower part of the Muschelkalk might be considered as an equivalent of the Niti[1] limestone in Painkhanda and Spiti. A bed of

[1] See footnote to p. 59.—Ed.

limestone, following above this brachiopod-layer, is rich in *Cephalopoda* of the Upper Muschelkalk. Fossils, which are as a rule strongly deformed and elliptical in outlines, have been found in considerable numbers near Kalapani (Griesbach) and Jolinka (Smith, A. v. Krafft).

The following species have been determined by Diener :—

Atractites Smithii Dien.
Orthoceras cf. campanile Mojs.
Grypoceras Griesbachi Dien.
Mojsvaroceras sp. ind. aff. Morloti Mojs.
,, *nivicola* Dien.
Ceratites Thuilleri Opp.
,, *Kuvera* Dien.
,, (*Philippites*) *jolinkanus* Dien.
,, (*Hollandites*) *Vyasa* Dien.
,, ,, *Roxburghii* Dien.
,, (*Peripleurecyclus*) *Smithianus* Dien.
Smithoceras Drummondii Dien.
Sageceras sp. ind.
Buddhaites Rama Dien.
Bukowskiites Colvini Dien.
Pinacoceras Loomisii Dien.
Gymnites Jollyanus Opp.
,, *Kirata* Dien.
,, *Sankara* Dien.
Ptychites Sahadeva Dien.

This fauna, although showing unmistakably the character of the Upper Muschelkalk, is remarkable for the large number of types peculiar to this area. Not only the lithological, but also the faunistic development of the Muschelkalk in Byans is different from that of the north-western facies. Among twenty species of *Cephalopoda* not less than ten have not yet been found in any Himálayan district outside Byans. Some very remarkable types, as *Smithoceras*, *Philippites*, *Peripleurocyclus*, *Bukowskiites*, *Pinacoceras Loomisii* are represented among them. *Smithoceras Drummondii* deserves special interest, as the most primitive ancestor of the highly specialised types of *Haloritinæ* and *Juvavitinæ* in the Upper Trias.

Detailed researches will be necessary before anything more definite can be said about the Muschelkalk of Byans.

e. The Ladinic stage of Spiti.

One of the most important stratigraphical results of A. v. Krafft's and Hayden's researches in Spiti was the discovery of a very rich development of the Ladinic stage. The presence of this stage, which Diener and Griesbach had failed to recognise in the sections of the Bambanag and Shalshal cliffs, had been predicted by Bittner,[1] on the ground of his discovery of a specimen of *Daonella Lommeli* Wissm. among Griesbach's collections from Muth.

From H. Hayden's and A. v. Krafft's descriptions it is evident that no stratigraphical break occurs in Spiti above the Upper Muschelkalk, but that the passage into the ladinic stage is so gradual, that no boundary line can be fixed between the two. In the sections of Kágá, of Muth and in the Thanam valley, the topmost bed of the Muschelkalk group, which stratigraphically cannot be separated from the beds containing *Ptychites rugifer* Opp., has yielded a fauna of a decidedly ladinic aspect.

Above this passage bed follows a series of thin-bedded black, shaly limestones and earthy shales, with some hard, black limestone beds (weathering brown), of 160 feet in thickness. This is the group of 'Daonella shales,' the prototype of the ladinic stage in Spiti.

The fauna of the passage beds in Spiti consists of the following species :—

Spirigera hunica Bittn.
Ceratites (?) *Wetsoni* Opp.[2]
Arpadites cf. lissarensis Mojs.
,, *rimkinensis* Mojs.
Hungarites Pradoi d'Arch.
,, *sp. ind. aff. Mojisisovicsi* Bœckh.
Protrachyceras longobardicum Mojs.
,, *spitiense* Dien.
,, *Cautleyi* Dien.

[1] A. Bittner, *Palæont. Indica*, ser. XV, Himálayan Foss., Vol. III, Pt. 2, p. 38.
[2] The appurtenance of this species to the genus *Ceratites* is extremely doubtful.

Thanamites bicuspidatus Dien.
,, *bannaensis* Dien.
Rimkinites nitiensis Mojs.
,, *Edmondii* Dien.
Sturia sp. ind.
Ptychites Gerardi Blanf.
Megaphyllites Jarbas Muenst.
Joannites Kossmati Dien.
, *cf. proavus* Dien.
Proarcestes cf. Balfouri Opp.

This fauna has ten species in common with the Daonella shales and three only with the Upper Muschelkalk. All of them—*Ptychites Gerardi, Joannites cf. proavus, Proarcestes Balfouri*—range from the Upper Muschelkalk into the Daonella shales. The topmost bed of the Muschelkalk group must, consequently, be included in the ladinic stage.

All the sections in Spiti examined by H. Hayden and A. v. Krafft, prove that there is a gradual passage both lithologically and faunistically from the Upper Muschelkalk into the ladinic stage. The typical fauna of the latter stage is concentrated in the Daonella shales near the base of which the following species have been found :—

Daonella Lommeli Wissm.
,, *sp. ind. aff. Lommeli* Wissm.
,, *indica* Bittn.
Spirigera hunica Bittn.
Rhynchonella cf. Theobaldiana Stol.
Ceratites Narsingha Dien.
Arpadites rimkinensis Mojs.
Hungarites Pradoi d'Arch.
Thanamites bicuspidatus Dien.
Rimkinites nitiensis Mojs.
,, *Edmondii* Mojs.
Anolcites Laczkoi Dien.
Protrachyceras Archelaus Lbe.
,, *spitiense* Dien.
,, *ladinum* Mojs.
,, *cf. longobardicum* Mojs.
,, *sp. ind. cf. regoledanum* Mojs.

Sturia sp. ind.
Gymnites calosoma Dien.
Pinacoceras sp. ind. aff. Damesi Mojs.
Ptychites Gerardi Blfd.
Joannites cf. proavus Dien.
  ,, *sp. ind. cf. tridentinus* Mojs.
  ,, *Kossmati* Dien.
Proarcestes bicinctus Mojs.
  ,, *cf. Balfouri* Opp.
  ,, *sp. ind. aff. esinensi* Mojs.

This fauna clearly bears the stamp of ladinic age, as shown by the relationship of a large number of species to European ones. *Daonella Lommeli*, the leading fossil of the ladinic stage in the Tyrol (Wengen beds) occurs throughout the entire thickness of the Daonella shales.

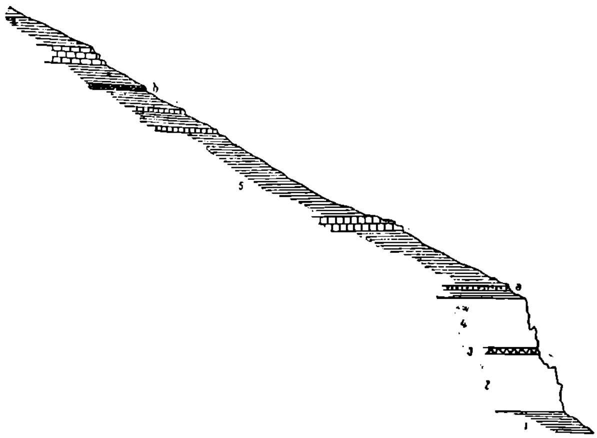

FIG. 4. *Detailed section through the upper ladinic and lower carnic beds near Lilang from A. v. Krafft's diary* :—

5. Grey beds (shales alternating with limestones).
4. Halobia limestone.
3. Horizon of *Joannites thanamensis.*
2. Daonella limestone.
1. Daonella shales, with *Daonella Lommeli.*

The Daonella shales are overlain by a homogeneous mass of dark, plintery limestone, about 280 feet in thickness. This mass is divided by a band of black limestone intercalated with shales. The lower division contains *Daonella indica* Bittn., and, in its lower part, als *Daonella Lommeli*, whereas in the upper region *Halobia cf. comata* Bittn., a species of the carnic group of *rugosæ*, has been found.

A. v. Krafft, who designated the lower division as "*Daonella limestone*" and the upper as "*Halobia limestone,*" gives the following sequence of beds between the Upper Muschelkalk, and the grey shales with *Joanites cymbiformis*[1]:—

4. Hard, black, splintery limestone, somewhat bituminous, with calcite veins, weathering greyish brown, intercalated with shaly limestones in layers of one to three feet containing *Halobia cf. comata* Bittn., and *H. fascigera* Bittn. . . . . 111 ft.
3. Black limestones, intercalated with shales containing *Joannites thanamensis* Dien. . . . . . . 25 ft.
2. Hard black limestones, as 4 with *Daonella indica* Bittn. *Daonella Lommeli* occurs in the lower division, but not higher up than to the upper third of this group . . 145 ft.
1. Series of thin-bedded black shales and limestones (Daonella shales) with *Daonella Indica* Bittn. and *D. Lommelli* Wissm. . . . . 160 ft.

Series No. 2 corresponds to A. v. Krafft's "Daonella limestone." It contains a fauna consisting of the following species:—

Traumatocrinus sp. ind.
Daonella Lommeli Wissm.
  ,, *indica* Bittn.
  ,, *sp. ind. aff. Cassianæ* Mojs.
Rhynchonella cf. rimkinensis Bittn.
Phloioceras deliciosum Dien.
Styrites lilangensis Dien.
Celtites trigonalis Dien.
  ,, *perauritus* Dien.
Rimkinites nitiensis Mojs.
Monophyllites cf. wengensis Klipst.
Joannites cf. Klipsteini Mojs.
  ,, *Kossmati* Dien.

In this fauna Wengen and St. Cassian types are associated so closely that both equivalents of the highest ladinic and of the lowest carnic beds of the Mediterranean regions seem to be represented in the Daonella limestone of Spiti.

[1] *General Report, Geol. Surv. of India,* 1899-1900, p. 208.

The entire thickness of the ladinic stage in Spiti undoubtedly exceeds that of the Muschelkalk considerably. If we include the lower half of the Daonella limestone (group 2 in the sequence as given above), in which *Daonella Lommeli* has been found [1], it amounts to 240 feet. At any rate group No. 1, of 160 feet in thickness, is a typical representative of the ladinic stage in the Himálayas.

f. The Ladinic stage of Painkhanda, Johar and Byans.

In his description of the classical section of the Shalshal cliff Diener [2] stated that the *Ptychites* beds of the Upper Muschelkalk were overlain by a series of well-bedded limestones of inconsiderable thickness, agreeing lithologically with the underlying Muschelkalk, and only distinguished from it by its abundance of crinoid stems (*Traumatocrinus* Dittm).

The faunula of this Traumatocrinus limestone was declared by E. v. Mojsisovics to belong to the carnic stage (zone of *Trachyceras Aonoides*). From this Diener concluded that the ladinic stage and the zone of *Trachyceras Aon* (St. Cassian beds) were either missing from the Trias of the Himálayas or, if really present, were of such insignificant development and thickness, that they could not be separated from the Muschelkalk, much in the same way as they occur in the North-eastern Kalkalpen of Austria.

A. v. Krafft refused to admit the homotaxis of the Traumatocrinus limestone with the zone of *Trachyceras Aonoides*, but the recent examination of the rich fauna collected by him in the Bambanag and Shalshal cliffs has proved E. v. Mojsisovics' determination of its stratigraphical position to be entirely correct.

If there are, indeed, equivalents of the ladinic stage present in Painkhanda, they are very small in thickness and extremely poor in characteristic fossils. A. v. Krafft, when revising the sections in Painkhanda in 1900, found in the Shalshal cliff, between the highest beds of the Upper Muschelkalk containing *Ptychites rugifer* and the

[1] It has been demonstrated by Bittner (Himálayan Foss., l. c., Vol. III, Pt. 2, p. 34), that the true *Daonella Lommeli* is restricted to the ladinic stage of the Alpine Trias and does not ascend into higher stages (noric Hallstatt limestone) as has been suggested by Rothpletz.

[2] C. Diener, Ergebnisse einer geologischen Expedition in den Central Himálaya, etc., l. c., pp. 546, 547.

Traumatocrinus limestone, a series of thin-bedded concretionary limestone, with shaly partings, about 25 feet in thickness, which although agreeing lithologically with the Upper Muschelkalk, yielded a different faunula consisting of the following species :—

Daonella indica Dittn.
,, *cf. obliqua* Mojs.
Spirigera hunica Bittn.
Celtites cf. trigonalis Dien.
Joannites cf. proavus Dien.

There is only the presence of *Joannites cf. proavus* which can be urged in favour of a correlation with the ladinic stage. Otherwise the fauna is closely allied with that of the Traumatocrinus limestone. *Daonella Lommeli* the most important leading fossil of the Daonella shales of Spiti, is not yet known from any Triassic section in Painkhanda.

In the Bambanag cliff the Traumatocrinus limestone is also present, but beds to which a ladinic age might be assigned with any probability were not found there by A. v. Krafft.

There is, perhaps, an indication of the ladinic stage in the faunula of a dark grey limestone, which was discovered by C. L. Griesbach opposite the Ralphu glacier in the Lissar valley and designated by him "horizon of *Ammonites Aon*." This faunula contains the following species :—

Daonella indica Bittn.
Arpadites lissarensis Mojs.
Protrachyceras ralphuanum Mojs.
Joannites sp. ind.
Ptychites Gerardi Blfd.
,, *posthumus* Mojs.

Although this fauna has an older aspect than that of the Traumatocrinus limestone, there is no direct proof of its ladinic age. It is too scanty and meagre to permit any definite statement, as it might be attributed to the ladinic or lower carnic stage with nearly equal reason.

In Byans there is no evidence whatever of a representation of the ladinic stage. It might be looked for in the uniform mass of light grey limestones, which have yielded a fauna of Muschelkalk age in their lower, and the *Tropites* fauna in their upper, portions.

Thus we come to the following conclusions :—E. v. Mojsisovics and Diener were right in attributing the Traumatocrinus limestone to the carnic stage. Yet this limestone does not follow immediately above the *Ptychites* beds of the Muschelkalk, at least not in all sections of Painkhanda, but there is a small thickness of limestones, from which *Ptychites rugifer* is absent, intercalated between the Muschelkalk and the carnic stage. It is probably of ladinic age. There is no hiatus in the stratigraphy of the Himálayan Trias in the Shalshal cliff, but the ladinic beds, provided they are represented at all, are extremely reduced in thickness, lithologically identical with the Upper Muschelkalk, and at the same time very poor in characteristic fossils.

The ladinic stage is therefore of much less importance in the sections of Painkhanda than it is in Spiti. The black shales and limestones with *Daonella Lommeli*, which are 160 to 240 feet thick in Spiti and very rich in fossils, dwindle down towards the east until they are restricted to a few feet in the section of the Shalshal cliff. This is a very interesting fact. For while, as we have seen, the Muschelkalk is constant in thickness in the two areas, a remarkable change sets in during the ladinic stage. We shall see later on that this tendency of the Triassic deposits of the Himálayas to thin out towards the east, becomes still more marked in the Upper Trias.

g. Correlation of the Middle Triassic deposits of the Himalayas with those of Europe and America.

The similarity of the stratigraphical development of the Muschelkalk both in the Himálayas and the Eastern Alps is most striking, as has been stated by A. v. Krafft.

In both regions a thick mass of unfossiliferous limestones forms the basal division of the group. In the South-eastern Alps, more especially in the district of Recoaro, where the development of the Muschelkalk is more complete than anywhere else in the Mediterranean region, this mighty mass, which is very poor in fossils, corresponds to the limestone with *Dadocrinus gracilis*. It has yielded a few bivalves which are closely allied to Lower Triassic species from the Campil beds, but never any *Cephalopoda*. It is followed by a zone of marls and limestones rich in brachiopods. The topmost bed contains ammonites of the zone of *Ceratites binodosus*. This is the fossiliferous horizon which in Alpine geological literature has often been designated as "Lower Muschelkalk," but lies proportionately high in the mass of the Alpine Muschelkalk. It is overlain conformably by the limestones of the Upper Muschelkalk containing the Cephalopod fauna of the zone of *Ceratites trinodosus*.

Each of those three divisions of the Alpine Muschelkalk might be compared to a corresponding division of the Muschelkalk group in the Central Himálayas, the Niti[1] limestone, including the horizon of *Rhynchonella Griesbachi* at its base, to the limestone with *Dadocrinus gracilis*, the brachiopod-bearing beds with *Spiriferina Stracheyi* Salt. and the underlying horizon of *Keyserlingites* (*Durgaites*) *Dieneri* to the brachiopod-bearing zone of *Rhynchonella decurtata* and to the *binodosus* bed, the upper division with *Ceratites Thuillieri* and *Ptychites rugifer* to the cephalopod-bearing horizon of *Ceratites trinodosus*.

But as far as palæontological evidence goes, the correctness of this correlation, which is based on stratigraphical grounds, can only be proved for the upper division. In this division both the association of genera and the affinity or even identity of species indicate very close faunistic relations with the zone of *Ceratites trinodosus*.

Four species of *Brachiopoda* are identical, all of them representing very common and widespread types of the Alpine Muschelkalk, namely:—

Mentzelia Mentzelii Dunk.
Spiriferina Koeveskalliensis Suess.
Coenothyris vulgaris Schloth.
Rhynchonella trinodosi Bittn.

It must, however, be remarked that the exact layer of the last-mentioned species, which was collected from Kalapani in Byans by F. H. Smith, is not known exactly.

Among the class of *Cephalopoda* the following species are either directly or most probably identical with Alpine forms:—

Orthoceras campanile Mojs.
Germanonautilus cf. salinarius Mojs.
Ceratites trinodosus Mojs.

[1] See footnote to p. 59.—Ed.

Japonites cf. Dieneri Mart.
Acrochordiceras cf. Carolinæ Mojs.
Sturia Sansovinii Mojs.
Gymnites incultus Beyr.
,, *cf. Humboldti* Mojs.
Anagymnites cf. acutus Hauer.
Ptychites Everesti Opp.[1]
Proarcestes Balfouri Opp. (—*Escheri* Mojs).
Joannites cf. proavus Dien.
Monophyllites sphærophyllus Hau.

The close affinity of a considerable number of other species is scarcely less remarkable. The genus *Ptychites*, which plays a very important part both in the Upper Muschelkalk of the Alps and of the Himálayas, especially in number of individuals, is represented in both regions by many ' vicarious ' types. The Himálayan species of *Pleuronautilus* are all nearly allied to others from the Reiflingerkalk of the North-eastern Alps. Among the Ceratites three species, *Ceratites Thuillieri* Opp., *C. himalayanus* Blfd., *C. sp. ind. aff. Abichi* Mojs. exhibit close relations to congeneric forms of the *nodosi* group. The subgenera *Halilucites*, especially characteristic of the Bosnian Muschelkalk, and *Cuccoceras* are also represented in India, each by a single form nearly allied to European ones.

On the other hand there remains a sufficient number of peculiar faunistic elements, which impart to the Indian Triassic province the character of a zoo-geographical region of its own.

The most important of those elements peculiar to the Muschelkalk fauna of the Indian Trias are several subgenera of *Ceratites*, which predominate in the Upper Muschelkalk of the Himálayas. The section of *Ceratites circumplicati* (*Hollandites*), which is very poorly developed in the Mediterranean region, is the most remarkable group of Indian ceratites, being represented there by fifteen species. Those species of *Hollandites* show but very remote affinities with the Alpine representatives of this subgenus. Three species of *Ceratites* differ from all European types

[1] In the fauna of the Schiechlinghœhe near Hallstatt this species is represented by a form very closely allied or perhaps even identical with it, although its fragmentary state of preservation did not allow any definite judgment. *Vide* C. Diener, Die Cephalopodenfauna der Schiechlinghœhe, *Beitræge zur Palæont. und Geo., Oesterr. Ungarns.* etc., XIII, p. 32.

so widely, that they have to be considered as prototypes of isolated subgenera. They are: *Peripleurocyclus Smithianus* Dien., *Salterites Oberhummeri* Dien., *Haydenites Hatschekii* Dien. Two more new subgenera with ceratitic sutures, peculiar to the Indian Trias, are *Pseudodanubites* Hyatt. and *Bukowskiites* Dien.

In the genus *Beyrichites* we meet two isolated forms—*B. Gangadhara* Dien. and *B. Rudra* Dien. The same remark applies to the group of *Ptychites Malletianus* Stol. and *Ptychites Gerardi* Blfd., both representing types, which differ completely from the *Ptychites* of the Mediterranean region. Nor does *Buddhaites Rama* Dien. bear any closer relation to any of the Alpine species of *Gymnites*, *Pinacoceras* or *Carnites* although it unites characters of those three genera.

The most aberrant type in this fauna is perhaps *Smithoceras Durandii* Dien., the primitive ancestor of Upper Triassic *Juvavitinæ*.

The *Lamellibranchiata* of the Himálayan Upper Muschelkalk are known to us very superficially only, but some species, as *Posidonomya cf. bosniaca* Bittn., are probably nearly allied to Alpine forms. A similar remark applies to the *Gastropoda*, which have been studied by Blaschke. Species of *Pleurotomaria* and *Worthenia* largely predominate, whereas species of *Naticopsidæ*, *Neritidæ* and all types with Palæozoic affinities, such as *Bellerophon*, *Capulus*, *Euomphalus*, are entirely absent.

In the zone of *Spiriferina Stracheyi* the affinities of the Indian and Alpine faunæ are much more remote. The species of *Brachiopoda* are all isolated types, which differ considerably from all Alpine congeneric forms, as has been stated by Bittner. Among the cephalopods *Stacheites* and *Dalmatites* are in Europe hitherto known only from the Campil beds of the Lower Trias. Four species of *Monophyllites*, which belong to the sections of *M. sphærophyllus* and *M. Suessii* (*Mojsvarites*), are distinguished from the congeneric forms of the Alpine Upper Muschelkalk by their simpler sutures, but one of them, *Monophyllites* (*Mojsvarites*) *Confucii* Dien., is so closely allied to *M. Suessii*, that Frech proposes to unite it with that species as a variety.[1] A second species, *Monophyllites Hara* Dien., has been discovered among Nopcsa's collections from

[1] F. Frech, Neue Cephalopoden aus dem suedlichen Bakony, *Palæontologischer Anhang zu Resultate der Wissenschaftl. Erforschg. des Balatonsees*, Bd. I, Erster Teil., p. 17.

the Lower Trias of Kcira in Albania by G. v. Arthaber.[1] Two species of *Orthoceras*—*O. cf. campanile* Mojs. and *O. cf. multilabiatum* Hauer—are probably identical with Alpine forms. A very interesting type is *Gymnites depauperatus* Dien., the most primitive species of that genus, any trace of ramification being absent in its sutural line, which is provided with saddles entirely dolichophyllic.

The most characteristic group of ammonites in the zone of *Spiriferina Stracheyi* is the Indian section of *Keyserlingites* (*Durgaites*) which, notwithstanding a remarkable convergence in external features, is not identical with the Siberian types of *Keyserlingites* (*Ceratites subrobusti*), their mode of development showing considerable differences. Since the Indian types of Keyserlingites cannot be allied phylogenetically to the Siberian ones, they must be considered as a faunistic element peculiar to the Himálayan Muschelkalk.

In America the fauna of the Muschelkalk in the West Humboldt range of Nevada, as studied by J. P. Smith,[2] shows such a distinctly Mediterranean character, " that a palæontologist from Austria might be set down in the Humboldt desert and he could hardly tell from the character of the fauna, whether he was collecting in Bosnia or in Nevada."

Although the predominance of Alpine elements shows that the relationship is much closer with the Mediterranean than with the Himálayan Muschelkalk fauna, there is sufficient evidence for a direct connection of the American Triassic province with the Indian regions during this epoch.

The subgenus *Hollandites*, which is of Indian origin, is represented in Nevada by two species nearly allied with Himálayan ones, *H. aff. Voiti* Opp. and *H. aff. Hidimba* Dien. The subgenus *Gymnotoceras* Hyatt (group of *Ceratites geminati*), which occurs abundantly in Nevada, is also represented in the Olenek beds of Siberia and in the Indian Muschelkalk, but not in the Alpine region. It seems therefore probable that at the Muschelkalk epoch the American Triassic province was connected on one side with the Mediterranean and on the other side

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1 Ueber die Entdeckung der Untertrias in Albanien, etc. *Mitteil. Geol. Ges. Wien.*, I, p. 286, Taf. XII, fig. 4.

2 J. P. Smith, The stratigraphy of the Western American Trias. *Ad. v. Kœnen Festschrift*, Schweizerbart, Stuttgart, 1907, p. 401.

with the Indian region, that the Central Mediterranean sea or "Tethys" formed an uninterrupted belt around the globe to the North of the Tropic of Cancer.

The faunistic affinities both with the boreal region of Siberia and with the Japanese province are more remote. The relationship of the American and Japanese faunæ has been exaggerated by E. v. Mojsisovics.[1] As has been demonstrated by J. P. Smith, there is almost no kinship whatever between the rich fauna of the Muschelkalk of Nevada and the poor faunæ from the Middle Trias of Japan. But the Indian fauna of this epoch is almost equally unlike that of Japan. *Ceratites (Danubites) Kansa* Dien. is perhaps the only species which has a remarkable resemblance with a Japanese form, *viz.*, *Ceratites (Danubites) Naumanni* Mojs. The Indian species of *Japonites* are less closely allied to *J. planiplicatus* Mojs. from Okatsuhama than to the European types of this genus recently discovered in the Trias of Montenegro. It is therefore not likely that the connection between the American and Indian Triassic provinces was established by way of Japan during the Muschelkalk epoch. Their faunæ are related to each other more closely than either of them is to the fauna of Japan.

In the Siberian region deposits of Muschelkalk age are known to us from two localities only, from the Magyl rocks on the lower Yana, and from the Russian Island near Vladivostok (Ussuri district).

In the small fauna of the Magyl rocks discovered by Baron E. v. Toll, there is one species, *Beyrichites affinis* Mojs., which occurs also in the upper Muschelkalk of the Shalshal cliff. An affinity with the faunula from the Russian Island is indicated by the presence of a species of *Ptychites rugiferi*. There is also a close relationship between the Indian representatives of this group and the congeneric forms from Spitzbergen, but it is not closer than with the Mediterranean types.

Otherwise a comparison between the faunæ of the Himálayan Muschelkalk and of the Olenek beds of North-eastern Siberia offers but little support on behalf of a near kinship between the Indian and boreal regions. In this respect only the presence of *Gymnotoceras* (group of *Ceratites geminati*) in both regions might be mentioned, and the strange group of *Ceratites (Philippites) Jolinkanus* Dien. in Byans,

[1] E. v. Mojsisovics: Ueber einige Japanische Triasfossilien. *Beitræge zur Palæont. Oesterr. Ungarns*, etc., VII, 1888, p. 163.

which in its external sculpture recalls the Arctic section of *Dinarites spiniplicati* (*Olenekites*), whereas in its sutures it agrees with *Keyserlingites Middendorffi* Keys. The affinity of the Arctic group of *Ceratites polaris* to the Indian subgenus *Hollandites* is extremely doubtful.

During the *ladinic* stage a close kinship still persists between the marine faunæ of the Himâlayan and Mediterranean provinces. The Daonella shales of Spiti, which must be taken as prototype of this stage in India, have a considerable number of species in common with the Wengen beds of Tyrol. Those species are :—

Protrachyceras Archelaus Lbe.
,, *longobardicum* Mojs.
,, *ladinum* Mojs.
,, *cf. regoledanum* Mojs.
Anolcites cf. Laczkoi Dien.
Hungarites Pradoi D'Arch.
Joannites cf. Tridentinus Mojs.
Daonella Lommeli Wissm.

Out of thirty species of the fauna of the Daonella shales only four belong to faunistic elements which are peculiar to the Indian zoo-geographical region. One of them is *Ptychites Gerardi* Blfd., which together with *Joannites cf. proavus* Dien. ranges from the Upper Muschelkalk into the ladinic stage. The second, *Thanamites bicuspidatus* Dien., belongs to a genus which recalls some Palæozoic ammonites in its very simple sutures, among which the narrow and bifid lateral lobe is especially conspicuous. It is a dwarf genus, which probably originated from some more specialised type by regressive evolution. Two more species are representatives of the genus *Rimkinites*, which is not known hitherto to occur in any extra-Indian territory.

This proportion of Mediterranean and exclusively Indian elements in the ladinic fauna of Spiti is not altered, if the fauna of the passage beds connecting the *Ptychites* limestone of the Upper Muschelkalk and the Daonella shales is included. Leaving aside such species as do not exhibit any affinity with Mediterranean forms, the relationship to Wengen species prevails so remarkably, that the fauna of the passage beds must also be considered as an equivalent of the zone of *Protrachyceras Archelaus* (longobardic substage).

Neither in the fauna of the Himálayan Muschelkalk nor of the Daonella shales and the passage beds connecting both divisions have any representatives of the Buchenstein beds of the Eastern Alps been noticed.

In the Mediterranean region the zones of *Protrachyceras Curionii* and *Dinarites avisianus* (Marmolatakalk) are intercalated between the zones of *Ceratites trinodosus* (Upper Muschelkalk) and of *Protrachyceras Archelaus* (Wengen beds), but no types of those two zones have been discovered in the Himálayan Trias. Two species only—*Hungarites sp. ind. aff. Mojsisovicsi* Boeckh and *Protrachyceras Cautleyi* Dien.,—from the passage beds in Spiti, show a distant affinity to the Buchenstein fauna. As there is certainly no stratigraphical break nor hiatus in the succession of Triassic beds in Spiti, equivalents of the Buchenstein beds of Tyrol must be included either in the Upper Muschelkalk or in the passage beds connecting it with the Daonella shales. The absence of any distinct Buchenstein types we may reasonably explain by the suggestion, that no independent fauna corresponding to that of the zone of *Protrachyceras Curionii* lived in the Indian Triassic province at the commencement of the ladinic epoch, which in the Himálayas was characterised by a survival of species from the zone of *Ceratites Thuillieri* and *Ptychites rugifer* into this stage.

This explanation has been adopted by J. P. Smith for the mingling of anisic and ladinic faunæ in the horizon of *Daonella dubia* in the West Humboldt range of Nevada, where otherwise typical equivalents of the ladinic stage are missing altogether.

As has been stated in the preceding chapter, the Daonella limestone, following conformably above the Daonella shales, must—partly at least—be included in the ladinic stage.

Monophyllites cf. Wengensis Klipst. and *Daonella Lommeli* Wissm. point to the Wengen beds, whereas *Joannites cf. Klipsteini* Mojs. and *Daonella aff. cassianæ* Mojs. are more nearly allied to species from the beds of St. Cassian (lower carnic stage). The genera *Traumatocrinus, Phloioceras, Styrites* have not as yet been found in Triassic beds older than the carnic stage. As fossils occur throughout the entire thickness of the Daonella limestone, this assemblage might be explained by their having been mixed in collecting from different horizons. In favour of such an explanation the fact might be urged, that according to A. v, Krafft's notes, *Daonella Lommeli*, the most characteristic type of the ladinic stage in Europe, does not occur in the upper third of the Daonella limestone.

Thus there appears to be a gradual passage from the ladinic into the carnic stage in the Daonella limestone of Spiti.

III. The Upper Trias.

(Carnic, Noric and Rhætic stages.)

a. General notes on the classification of the Upper Trias in Spiti and Painkhanda.

The division of the Upper Trias in the Austrian Alps has been based on faunistic, not on lithological characters. Nevertheless the two main stages are marked by lithological differences in the majority of sections, the carnic stage being comparatively poor in limestones, as compared with the ladinic and noric stages. This is, at least, the case throughout the entire range of the Noerdliche Kalkalpen.

In the Himálayas there is no doubt about the possibility of distinguishing two different rock groups in the Upper Trias, a lower one, poor in limestones, and an upper one consisting of pure limestones and dolomites. In the Himálayas, a natural classification, based on lithological characters, suggests itself at once to the geologist who is surprised by the sharp contrast between the dark-coloured slopes, consisting of alternating shales, marls, limestones and quartzites, which form the pedestal of the high ranges, and the light grey dolomites and limestones of the cliffs and jagged peaks towering above them.

To the lower group, which is comparatively poor in limestones, belong the beds between the Daonella limestone and the white quartzite series in Spiti and the zone of *Halobia comata* in Painkhanda. Of the upper division the Himálayan Dachsteinkalk is the prototype in both districts.

It might, perhaps, be more correct to say that the lower division is not exactly poor in limestones, but that calcareous sediments are always intermixed with marly, clayey and arenaceous ones to such an extent that the latter rocks predominate considerably. Pure limestones—nearly always of a dark colour—are noticed only as intercalations between shales, sandstones and quartzites. Such limestone horizons are in Spiti : the limestone banks within the grey beds, the black, splintery limestone intercalated between the shaly limestones and shales of the covering series, the very thick mass (about 300 feet and even more) of the limestone with *Spiriferina Griesbachi*, the so-called "Coral limestone" and the limestone between the two quartzite series. In Painkhanda we may mention the limestones containing the faunæ of *Proclydonautilus Griesbachi* and *Halorites procyon*, the brachiopod-bearing beds with *Spiriferina Griesbachi*, and the liver-coloured limestones with *Sagerites sp. ind.*, which are intercalated between arenaceous shales, sandstones and quartzites.

It is consequently evident that in the Upper Trias of the Central Himálayas of Painkhanda and Spiti two natural rock groups can be distinguished lithologically, a lower one composed of clayey, arenaceous and calcareous sediments and an upper one of pure limestones and dolomites. But those two natural rock groups do not correspond to stratigraphical stages. The boundary between the carnic and noric stages is not at all marked lithologically, but runs through a uniform series of sediments equally developed, which are comparatively poor in pure limestones. The same physical conditions prevailed during the carnic and lower noric epochs. Nor does the remarkable change in sedimentation, which corresponds to the limits between the Upper Triassic quartzites and the dolomites of the Dachsteinkalk coincide with the boundary of the two stratigraphical stages.

The lower group of the Himálayan Upper Trias comprises both the carnic and noric stages of the Alpine Trias, whereas the uniform mass of grey limestones and dolomites following above, includes not only equivalents of the noric and rhætic Dachsteinkalk of the Eastern Alps, but even of the Lias and Oolite.

b. The Carnic stage in Spiti and Painkhanda.

It has been explained that in Spiti, according to A. v. Krafft's descriptions, the ladinic Daonella shales are overlaid by a homogeneous mass of dark splintery limestone, measuring about 280 feet in thickness. In its lower division—A. v. Krafft's "*Daonella limestone*"—it contains a fauna with ladinic nd carnic affinities. As far as *Daonella Lommeli* Wissm. occurs in this rock-group, its ladinic age has been ascertained.

The topmost portion of the Daonella limestone is probably of carnic age.

On the top of the Daonella limestone—145 feet above the upper limit of the Daonella shales in the section of Lilang — a black limestone alternating with shales, 25 feet in thickness, has been observed by A. v. Krafft dividing the otherwise homogeneous mass of limestone. This is the bed of *Joannites thanamensis* Dien. The upper division of the mass of dark splintery limestone, following above the bed of *Joannites thanamensis*, has yielded *Halobia cf. comata* Bittn., a species typical of the julic substage in the Himálayas.[1]

Above the " Halobia limestone " grey, earthy shales follow, in which grey, shaly limestones of various thickness are intercalated. About 260 feet above the base of this series of " grey beds " a thin-bedded, shaly limestone of 20 feet in thickness has been noticed.

Fossils have been discovered in two horizons. Almost immediately above the Halobia limestone the shales contain a band of black concretions, which enclose numerous ammonites. The following species have been determined by Diener [2]: —

Trachyceras sp. ind. aff. Ariae Mojs.
,, *sp. ind.* (group of *acanthica*).
Carnites floridus Wulf.
,, *cf. nodiger* Dien.
Joannites cymbiformis Wulf.
Monophyllites sp. ind. aff. Simonyi Hauer.

The second fossiliferous horizon occurs about 300 feet above the base and about 40 feet above the thin-bedded limestone referred to above, Fossils are known from two localities, N. N. W. of Lilang and N. W. of Muth. There is only one single species of ammonite among them, and this is so poorly preserved that an exact determination is impossible. It has been referred to the genus *Paratropites* Mojs. provisionally by Diener (*l. c.*, p. 149). But the fauna of both localities is rich in brachiopods and bivalves, which belong to the following species :—

Rhynchonella laucana Bittn.
,, *laucana var. lilangensis* Bittn.

[1] H. Hayden, Geology of Spiti, l. c., p. 76.

[2] C. Diener, Ladinic, carnic and noric faunæ of Spiti, Himál. Foss., *Pal. Ind.*, ser. XV, Vol. V, Pt. 3, p. 148.

Rhynchonella cf. semiplecta Muenst.
,, *Freshfieldi* Dien.
,, *himaica* Dien.
,, *cf. bajuvarica* Bittn.
,, *(Austriella) sp. ind. aff. nux* Suess.
Spiriferina gregaria Suess.
,, *aff. shalshalensis* Bittn.
,, *orophila* Dien.
,, *deodarae* Dien.
Mentzelia Mentzelii Dunk.
Aspidothyris Kraffti Dien.
Dielasma Julicum Dittn.
,, *Haydeni* Dien.
Cruratula (?) *indica* Dien.
Lilangina nobilis Dien.
Pomarangina Haydeni Dien.
Lima sp. ind. aff. alternans Bittn.

The series of shaly limestones, grey earthy shales and calcareous shales, with bands of dark, splintery limestones intercalated occasionally, continues above this second fossiliferous horizon, until a bed of nodular limestone, 15 feet in thickness, is reached, 600 feet above the brachiopod bed or 900 feet above the basal horizon of *Joannites cymbiformis*.

This third fossiliferous horizon of carnic age is the "Tropites limestone" of Lilang and Tikha. It is rich in *Cephalopoda*, most of which, however, are badly preserved. The following forms permit of a specific determination :—

Clydonautilus acutilobatus Dien.
Germanonautilus cf. Breunneri Hauer.
Styrionautilus cf. Sauperi Hauer.
Pleuronautilus sp. ind. aff. Wulfeni Mojs.
Tropites cf. subbullatus Hau.
,, *discobullatus* Mojs.
,, *cf. torquillus* Mojs.
,, *sp. ind. aff. Paracelsi* Mojs.
Paratropites tikhensis Dien.
Trachysagenites cf. Herbichi Mojs.

Trachysagenites galeatus Dien.
Discotropites sp. ind. aff. Plinii Mojs.
Anatomites cf. Bacchus Mojs.
Jovites spectabilis Dien.
,, *cf. siculus* Gemm.
Sandlingites nov. sp. aff. Reyeri Mojs.
,, *nov. sp. aff. Castellii* Mojs.
Clionites heraclitiformis Dien.
Proarcestes cf. Gaytani Klipst.[1]

Grey shaly limestones and calcareous shales continue with the same lithological characters for the next 200 feet. Seventy feet above the nodular limestone a specimen of *Jovites spectabilis* Dien. was discovered by A. v. Krafft, who consequently includes the entire series following above the concretionary limestone with *Cephalopoda* in his " Tropites beds. "

The next overlying bed is a dolomitic limestone, whose thickness amounts to 300 feet. It has yielded few and badly preserved fossils, with carnic affinities, among them :—

Dielasma julicum Bittn.
Terebratula sp. ind. aff. piriformis Suess.
Spiriferina sp. ind. aff. shalshalensis Bittn.
Lima cf. austriaca Bittn.
Halobia aff. superba Mojs.
Daonella aff. styriaca Mojs.

With this complex of dolomitic limestones the carnic stage comes to a close. Its entire thickness in the section of Lilang amounts to at least 1,600 feet.

In Painkhanda the development of the carnic stage is more uniform.

In the Bambanag and Shalshal cliffs the lowest cephalopod horizon of this stage was discovered by Diener in the grey "Traumatocrinus limestone," which, according to A. v. Krafft, is separated from the *Ptychites* beds of the Upper Muschelkalk by an insignificant

[1] To this list *Griesbachites Medleyanus* Stol. must probably be added. Stoliczka's type-specimen, which was found loose in the Pin valley near Kuling, is referred to the Tropites beds by A. v. Krafft. A similar remark applies to *Paracladiscites indicus* Mojs. from the same locality.

development of the ladinic stage. It has, however, been demonstrated in the preceding chapter that the ladinic age of those passage beds has not yet been established with full certainty.

The scanty materials collected by the expedition in 1892 were described by E. v. Mojsisovics and A. Bittner. The rich fauna, which was brought together by A. v. Krafft in 1900, has been examined by Diener.[1] It consists of the following species, which show at once and indubitably the julic age of the Traumatocrinus limestone :—

Proclydonautilus cf. buddhaicus Dien.
Grypoceras rimkinense Dien.
,, *sp. ind. aff. rimkinensi* Dien.
,, *Stirlingii* Dien
Joannites cymbiformis Wulf.
,, *Klipsteini* Mojs.
,, *Kossmati* Dien.
,, *Mojsvari* Dien.
Proarcestcs cf. ausseanus Hau.
,, *sp. ind.*
Lobites (Coroceras) cf. delphinocephalus Hau.
,, ,, *valdecucullatus* Dien.
Monophyllites cf. Simonyi Hau.
,, *(Mojsvarites) Agenor* Muenst.
Juvavites (Anatomites) sp. ind.
Isculites cf. Heimi Mojs.
Celtites contractifrons Dien.
Carnites cf. floridus Wulf.
Placites cf. polydactylus var. Oldhami Mojs.
Rimkinites nitiensis Mojs.
,, *Edmondii* Dien.
Arpadites rimkinensis Mojs.
,, *(Dittmarites) cf. circumscissus* Mojs.
,, ,, *sp. ind. aff. Ladon* Dittm.
Clionites nov. sp. ind. aff. Doræ Mojs.
Trachyceras austriacum Mojs.
,, *austriacum var. tibetica* Mojs.
Protrachyceras sp. ind. aff. Arion Mojs.

[1] C. Diener, The fauna of the Traumatocrinus limestone, etc., Himál. Foss., *Pal. Ind.*, ser. XV, Vol. VI, Pt. 2.

Protrachyceras sp. ind. (group of *furcosa*).
Sirenites Cookei Dien.
Girthiceras pernodosum Dien.
Daonella indica Bittn.
,, *sp. ind. aff. obliqua* Mojs.
Avicula sp. ind. aff. seisiana Broili.
Pecten nov. sp. ind. aff. subalternans Bittn.
Heminajas sp. ind. (*cf. Woehrmanni* Waag).
Spirigera hunica Bittn.
Retzia sp. ind. aff. ladina Bittn.
Aulacothyris nilangensis Bittn.
Rhynchonella rimkinensis Bittn.
,, (*Austriella*) *sp. ind. aff. Middlemissii.*
,, (*Norella*) *Kingi var. tibetica* Bittn.
Traumatocrinus sp. ind.

Above the Traumatocrinus limestone, whose thickness barely exceeds ten feet, follows a thin limestone bed, which has yielded the following brachiopods and bivalves :—

Norella Kingi Bittn.
,, *tibetica* Bittn.
Spirigera hunica Bittn.
Aulacothyris nilangensis Bittn.
Daonella indica Bittn.

This is the highest stratigraphical horizon into which *Daonella indica* Bittn. reaches.

Before continuing this account of the carnic deposits of Painkhanda, it is worth mentioning that a fauna corresponding to that from the bed following immediately above the Traumatocrinus limestone was discovered by C. L. Griesbach on the summit of a pass leading from Hop gádh to Dogkwa aur, N.E. of Tsang chok La in Hundes. From this locality the following fossils were determined by Bittner[1]:—

Aulacothyris nilangensis Bittn.
Spirigera hunica Bittn.
Norella tibetica Bittn.
Discina sp. ind.
Daonella indica Bittn.

[1] A. Bittner, Himál. Foss., Vol. III, Pt. 2, pp. 30, 31, 32, 33, 39.

These fossils point to a carnic age of the beds from which they were derived. The actual section in the Trias of the Hop gádh differs, according to Griesbach (*Memoirs, Geol. Surv. India,* Vol. XXIII, p. 205), in no way from those of the Niti area.

Above the limestone bed with *Daonella indica* there follows in the sections of the Shalshal and Bambanag cliffs a mighty series of dark, calcareous shales and shaly limestones, amounting to between 650 and 800 feet in thickness. Cephalopods and bivalves occur throughout this series, but especially in the lower beds. Most of the fossils were collected near Lauka encamping ground on the way from the Uttar-dhura to the Girthi valley by Diener. The complex was originally designated "Daonella beds" by Griesbach, but the name "Beds with Halobia comata" appears to be more appropriate, since *Daonella* is replaced in those beds by *Halobiæ* of the *rugosa*-group.

The following species of *Brachiopoda* and *Lamellibranchiata* were described by A. Bittner (l. c., p. 72) :—

Spiriferina shalshalensis Bittn.
Retzia Schwageri var. asiatica Bittn.
Rhynchonella laucana Bittn.
Halobia comata Bittn.
" *fascigera* Bittn.
Avicula girthiana Bittn.
Cassianella pl. sp. ind.

The following species of *Cephalopoda* were quoted by E. v. Mojsisovics (l. c., p. 129) :—

Pleuronautilus tibeticus Mojs.
Jovites sp. ind. ex. aff. daci Mojs.
Discotropites sp. ind. aff. Plinii Mojs.
Juvavites cf. tonkinensis Dien.[1]
Anatomites bambanagensis Mojs.
" *Eugenii* Mojs.
" *Caroli* Mojs.
Griesbachites Hanni Mojs.
Hypocladiscites subaratus Mojs.
Placites sp. ind. ex. aff. peraucto Mojs.
" *polydactylus var. Oldhami* Mojs.

[1] C. Diener, Note sur deux espèces d' Ammonites Triasiques du Tonkin, *Bull. Soc. Geol. de France,* 3, ser. XXIV, p. 882.

Mojsvarites eugyrus Mojs.
Discophyllites Ebneri Mojs.

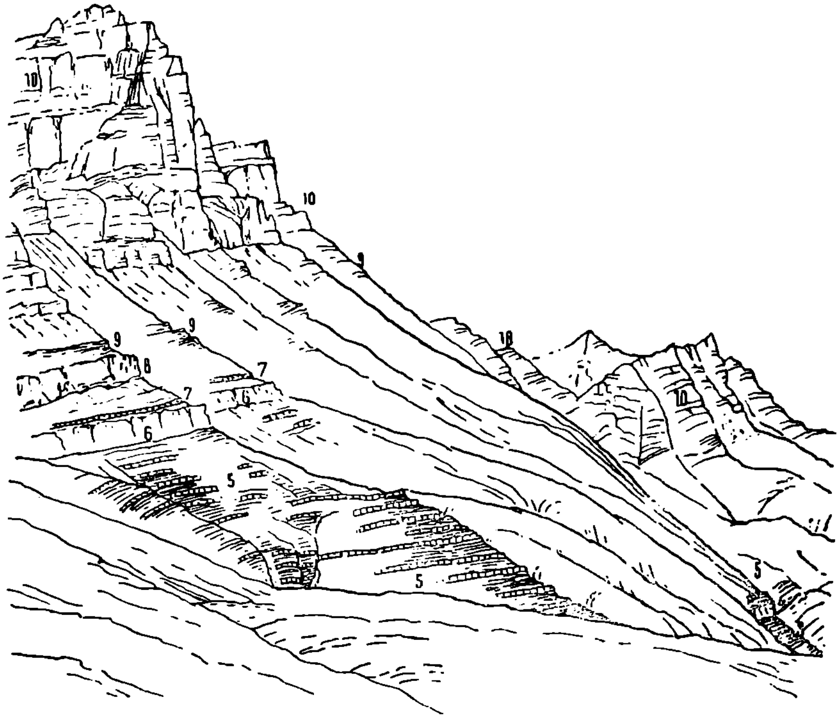

FIG. 5. *Slopes of the Shalshal cliff above Rimkin Paiar E. G.*

10. Megalodon limestone.
9. Quartzite series.
8. Dolomitic limestone with *Spiriferina Griesbachi.*
7. Halorites limestone.
6. Limestone with *Proclydonautilus Griesbachi.*
5. Shaly limestones and shales with *Halobia comata.*
4. Muschelkalk.
3. Lower Trias and Productus shales.
2. White Quartzite.
1. Silurian.

To these species must be added a considerable number of forms, belonging to the genera *Juvavites, Sagenites, Styrites, Tibetites,* *Paracladiscites, Megaphyllites, Proarcestes, Clydonautilus,* which could not be determined specifically.

The beds with *Halobia comata* are overlaid by the nodular limestone with *Proclydonautilus Griesbachi* Mojs., which contains a fauna of indubitably noric age.

The entire thickness of the carnic stage in Painkhanda barely exceeds 800 feet, that is to say only half of the thickness of this stage in Spiti. Nor can an equal number of stratigraphical horizons be distinguished in the carnic series of the two districts.

c. The Noric and Rhætic stages in Spiti and Painkhanda.

In the section of Lilang a series of brown-weathering limestones alternating with shales and sandstones, follows conformably above the dolomitic limestone with *Lima cf. austriaca* Bittn. and *Dielasma julicum* Bittn. Its thickness amounts to 500 feet.

In the upper division of this series *Cephalopoda* are common, especially ammonites of the genus *Juvavites* Mojs. The name "Juvavites beds" proposed by A. v. Krafft is indeed very appropriate for this rock group.

Juvavites angulatus Dien. is the chief leading fossil. It is a representative of the section of *continui,* but does not show a close affinity to any European or American species of this genus. The fauna of the Juvavites beds consists of the following forms :—

Atractites sp. ind. cf. alveolaris Quenst.
Paranautilus arcestiformis Dien.
Pleuronautilus sp. ind. aff. Kossmati Dien.
,, *cf. ibeticus* Mojs.
Indonautilus cf. Kraffti Mojs.
Dittmarites lilliiformis Dien.
,, *cf. trailliformis* Dien.
Clionites sp. ind. cf. Hughesii Mojs.
Metacarnites Footei Dien.
,, *Hendersoni* Dien.
Pinacoceras sp. ind. ex. aff. parma Mojs.
Tibetites cf. Ryalli Mojs.
Anatibetites Kelviniformis Dien.

Paratibetites Tornquisti Mojs.
,, *sp. ind. aff. Wheeleri* Dien.
Juvavites angulatus Dien.
,, *sp. ind. aff. Ehrlichii* Hau.
Anatomites sp. ind. aff. Melchioris Mojs.
,, *sp. ind. aff. Caroli* Mojs.
,, *sp. ind. aff. Alphonsi* Mojs.
Dielasma aff. julico Bittn.
Halobia sp. ind. aff. fascigeræ Bittn.
Pecton (Amusium) margarito costatus Dien.
Pecten sp. ind. aff. monilifero Muenst.
Lima cf. serraticosta Bittn.
Homomya sp. ind. aff. larianæ Stopp.
Mytilus sp. ind. aff. rugoso Roem.
Mysidioptera sp. ind.

The Juvavites shales become calcareous in the upper portions and pass into concretionary limestones, which resemble gradually the concretionary limestone of the Muschelkalk in their lithological characters. Near the top of the series some beds of calcareous sandstones with plant remains have been noticed by A. v. Krafft.

The calcareous sandstones with plant remains form the base of the next rock-group, A. v. Krafft's "Coral limestone." It is a mass of grey limestone, about 100 feet in thickness. In the section of Lilang it is a true organogenic limestone in which remains of crinoids and corals abound. But in the section of Kágá corals occur rather rarely, and none at all have been found W. of Chabrang. Otherwise the coral limestone is very poor in well-preserved fossils. Only two species of brachiopods are known from it, namely :—

Spiriferina Griesbachi Bittn.
Rhynchonella bambanagensis Bittn.

The coral limestone is overlain by flaggy sandstones alternating with black, splintery shaly limestones and sandy shales. The thickness of this series, which lithologically recalls the Juvavites beds, is about 30 feet.

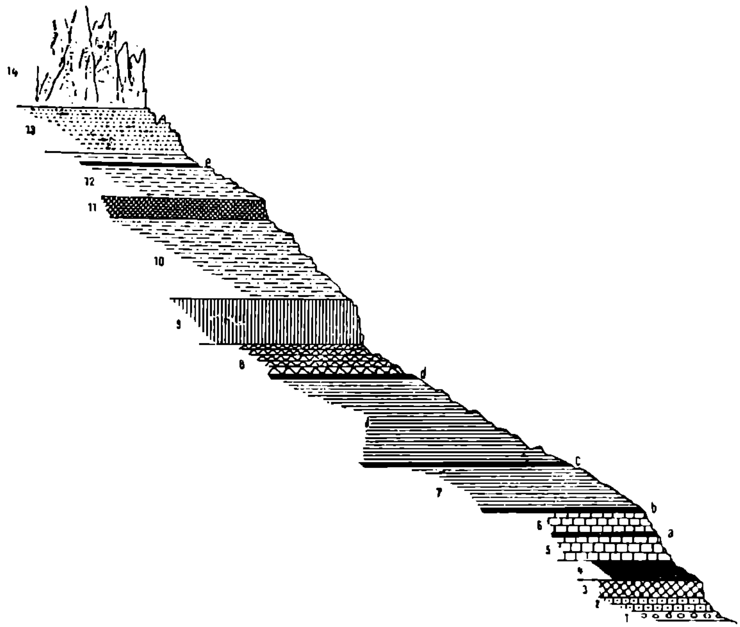

FIG. 6.—*Generalized section near Lilang (from A. v. Krafft's diary).*

14. Megalodon limestone.
13. Quartzite series.
12. Monotis beds.
11. Coral limestone.
10. Juvavites shales.
9. Dolomitic limestone with *Lima cf. austriaca.*
8. Tropites shales.
7. Grey beds.
6. Halobia limestone.
5. Daonella limestone.
4. Daonella shales.
3. Muschelkalk.
2. Lower Trias.
1. Productus shales.

a. Horizon of *Joannites thanamensis.*
b. ,, ,, *Joannites cymbiformis.*
c. Brachiopod layer of the Grey Beds.
d. Main layer of *Tropites subbullatus.*
e. ,, ,, ,, *Monotis salinaria.*

A. v. Krafft describes a sequence, which he observed near Lilang, as follows :—

6. Yellow-weathering, shaly limestones and shales with *Spiriferina Griesbachi* Bittn.
5. Brown sandstones, alternating with grey sandy shales, rich in *Lamellibranchiata* (chiefly *Monotis salinaria* Schloth).
4. Black, splintery limestone.
3. Brown, flaggy sandstones, with partings of sandy shales.
2. Grey, hard limestone, with calcite veins.
1. Brown, flaggy sandstones.

It is chiefly the group No. 5, which has yielded a considerable number of fossils, among them *Monotis salinaria* Schloth.

Together with this characteristic bivalve, the following species of *Brachiopoda*, *Lamellibranchiata*, and *Cephalopoda* were collected in the "Monotis beds" by A. v. Krafft :—

Spiriferina Griesbachi Bittn.
Spirigera Dieneri Bittn.
Aulacothyris joharensis Bittn.
Rhynchonella bambanagensis Bittn.
Anodontophora Griesbachi Bittn.
Pecten margariticostatus Dien.
,, *sp. ind. aff. Massolongi* Stopp.
,, *sp. ind. aff. monilifero* Muenst.
Lima cf. serraticosta Bittn.
Pleuromya himaica Dien.
Trachypleuraspidites nov. sp. ind. aff. Griffithi Dien.

Immediately above the Monotis beds a series of white and brown quartzites occurs, which has a thickness of about 300 feet. This characteristic "Quartzite series" forms a most conspicuous horizon throughout Spiti and in the scenery is often distinguishable at great distances by the whiteness of the quartzite bands.

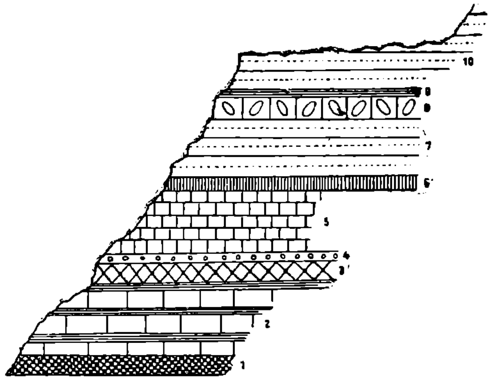

Fig. 7.—*Section between Mani and Pin valley (from A. v. Krafft's diary).*

10. White quartzite.
9. Shales.
8. Limestone with big markings.
7. Quartzite.
6. Dolomitic band with bivalves.
5. Sandy dolomites with *Rhynchonella maniensis.*
4. Brown quartzite.
3. Megalodon limestone.
2. Limestones with shaly partings, containing *Spiriferina Griesbachi.*
1. Monotis shales.

As a rule three different layers of quartzite can be distinguished, separated from each other in the lower part of the series by limestones, but towards the top by black, shaly beds. The system varies somewhat, but it will suffice to mention the sequence, as observed near Lilang by A. v. Krafft, which is as follows (in descending order) :—

6. Great thickness of black and grey dolomitic limestones.
5. Thick brown quartzite.
4. Black, sandy shales, with *Aulacothyris joharensis* Bittn., alternating with thin, brown quartzite layers : 100 feet.
3. Thin band of white quartzite.
2. Dark grey hard limestone with *Spiriferina Griesbachi* Bittn. and *Lima serraticosta* Bittn. : about 200 feet.
1. Brown quartzite : about 20 feet.

Faunistically the quartzite series is distinguished by the presence of *Spirigera maniensis* Krafft, which is restricted to this stratigraphical horizon. Most of the species are common to this series and to the lower Monotis beds.

The fauna of the quartzite series consists of the following forms :—

Spiriferina Griesbachi Bittn.
Spirigera maniensis Krafft.
,, (?) *maniensiformis* Dien.
Aulacothyris joharensis Bittn.
Rhynchonella bambanagensis Bittn.
Pecten sp. ind. aff. monilifero Muenst.
Lima cf. serraticosta Bittn.
,, *sp. ind. aff. cumaunicæ* Bittn.

The lower series of the Upper Trias, which is comparatively poor in pure limestones, is overlaid in all sections conformably and regularly by a great thickness of grey limestones and dolomites, which in their lithological characters recall most strongly the Alpine Dachsteinkalk. Part of this enormous limestone mass, which underlies the Jurassic Spiti shales, represents indeed the European Dachsteinkalk while another part belongs to geologically younger beds (Lias and Oolite).

This Upper Triassic group of well-bedded limestones and dolomites, which C. L. Griesbach included almost entirely in his "rhætic system," is well defined towards its base by the quartzite series, but its upper boundary is quite uncertain. The entire thickness of the limestone mass is about 2,300 feet, of which at least 800 feet belong to the Upper Trias.

Lithologically this mass of limestones and dolomites is too uniform and faunistically it is too poor in fossils to be subdivided in any greater detail.

Near Hansi a band of limestone, about 20 feet thick, which occur. 50 feet above the quartzite series, contains immense numbers of *Megalodon ladakhensis* Bittn. and *Dicerocardium himalayanese* Stol.[1] This is the horizon of Stoliczka's "Para limestone,"[2] blocks of which are very common throughout the upper Para valley, according to Hayden.

1 H. Hayden, Geology of Spiti, l.c., p. 84.

2 F. Stoliczka, *Mem., Geol. Surv. of India*, Vol. V, p. 124.

Between 200 and 300 feet above the base of the system the following species were found by A. v. Krafft :—

Spirigera Noetlingi Bittn.
Spiriferina cf. Haueri Suess.
Lima cumaunica Bittn.
Pecten chabrangensis Dien.
,, *sp. ind. aff. Landrano* Bittn.
Entolium cf. subdemissum Muenst.
Megalodon ladakhensis Bittn.

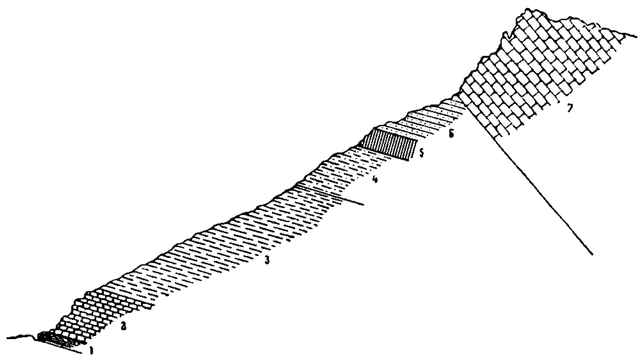

FIG. 8.—*Section between Kibber and Ki (from A. v. Krafft's diary).*

7. Megalodon limestone.
6. Juvavites shales.
5. Dolomites with *Lima cf. austriaca.*
4. Tropites shales.
3. Grey Beds.
2. Daonella and Halobia limestone.
1. Daonella shales.

It is evident from this faunula that, notwithstanding the scarcity of fossils, the beds including it are still equivalent to the Upper Trias.

About 400 feet above the base of the system a white, dolomitic band, 30 feet in thickness, was observed in several sections by A. v. Krafft, but has not yielded any fossils. Beds with rhætic types are entirely absent.

That the upper portion of the limestone mass is of Middle Jurassic age, may be inferred from the occurrence of *Stephanoceras cf. coronatum* Brug. in a limestone band, situated about 370 feet below the base of the Spiti shales near Giumal.

About 1,000 feet below the layer in which *Stephanoceras cf. coronatum* was found by A. v. Krafft, specimens of *Spiriferina cf. obtusa* Opp. have been collected between Giumal and Chabrang. This species may probably indicate a liassic age for the bed in which it occurs. We may therefore assume that approximately 500 feet of the limestone mass capped by the Spiti shales belongs to the Jurassic and 800 feet to the Triassic system. The middle portion of the limestone series must be of liassic age. To define the various horizons accurately within this homogeneous mass, is entirely impossible, owing to the scarcity of determinable fossils.

What has been said about the Upper Triassic limestone or Dachsteinkalk of Spiti, applies equally to Painkhanda and Johar, the boundary between the Triassic and Jurassic systems being not known exactly.

In the sections examined by Diener[1] the homogeneous mass of grey limestones and dolomites is capped by beds which are certainly younger than Triassic.

Two sections have been described by Diener. One of them, which follows the ravine cutting through the rim of the Shalshal cliff near Shalshal encamping ground, runs as follows :—

7. Lower Spiti shales, with *Belemnites Gerardi* Opp.
6. Sulcacutus beds, Kelloway : 6 feet.
5. Yellow-grey, earthy limestones and marls, with *Rhynchonella sp. ind.*: 4 feet.
4. Thin-bedded yellow-grey limestones with *Belemnites sp.*, *Ostraea sp.*, *Pecten sp.* : 20 feet.
3. *Lithodendron* limestone, with crinoid stems : 100 feet.
2. Thin-bedded limestones, with many bivalves of liassic affinities.
1. Well-bedded limestones, lithologically identical with the Upper Triassic limestones, following above the quartzite series.

1 C. Diener, Ergebnisse, etc., l. c., pp. 583, 584.

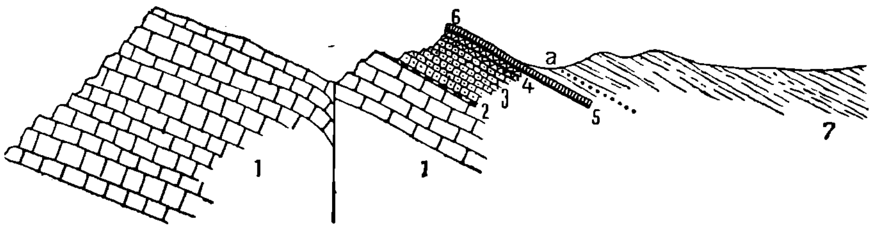

FIG. 9.—*Section between the edge of the Shalshal cliff and the watershed along the route from Shalshal E. G. to Chota Hoti.*

7. Spiti shales.
7*a*. Main layer of *Belnemnites Gerardi.*
6. Sulcacutus beds.
5. Yellow-grey, earthy limestones and marls with *Rhynchonella sp.*
4. Yellow-grey, thin-bedded limestone with bivalves.
3. Lithodendron limestone.
2. Thin-bedded bivalve limestone.
1. Well-bedded limestone lithologically identical with the Upper Triassic Megalodon limestone.

The second section between Chidamu E. G. and Kiangur E. G. is distinguished from the preceding one only by the absence of the *Lithodendron* limestone No. 3. The fossils collected from the bivalve limestone No. 2 are of a rather indifferent habit, but rhætic types are certainly absent, as has been stated by Bittner, our late authority on Alpine Triassic lamellibranchs.

Thus the beds capping the limestone No. 1 are certainly younger than Triassic, but whether they should be included in the Lias or Oolite, could not be decided.

Below the bivalve limestone No. 2 there still remains a limestone mass of approximately 1,800 to 2,000 feet in thickness, the lower portion of which certainly belongs to the Upper Trias. But from what we know of Spiti, it is hardly possible that the entire mass is of Triassic age. In Griesbach's section of the Shalshal cliff,[1] *Belemnites sp.* is mentioned from bed 28, that is 189 feet below the base of the Spiti shales. This discovery cannot be overlooked, although the specimen has been apparently lost.

[1] C. L. Griesbach, *Mem., Geol. Surv. of India,* l. c., p. 139 (Geology of the Central Himálayas).

It is true that sections of *Megalodon* have been noticed occasionally even in the topmost beds of the limestone No. 1, but the mere occurrence of a specifically indeterminable *Megalodon* is, of course, no proof of a Triassic age, for in Southern Tyrol this genus ranges up from Triassic into liassic strata.

The development of the noric stage below the homogeneous mass of Upper Triassic limestones is nearly identical in Spiti and Painkhanda.

At the base of the Dachsteinkalk, if we are permitted to make use of this term, a series of white and brown quartzites, alternating with concretionary limestones and shales, can be observed in the sections of the Bambanag and Shalshal cliffs. Its thickness amounts to 250 feet.

Diener, it is true, has already mentioned beds of quartzitic sandstone as occurring at the base of the Dachsteinkalk, but A. v. Krafft was the first to recognise the stratigraphical importance of this horizon. The development of this quartzite series is very similar to that in Spiti. Moreover, the characteristic leading fossil, *Spirigera maniensis*, was also found by him in the Bambanag section, besides a few other forms, known from lower and higher beds, namely :—

Aulacothyris joharensis Bittn.
Spirigera cf. Noetlingi Bittn.
,, *Dieneri* Bittn.
Pecten interruptus Bittn.

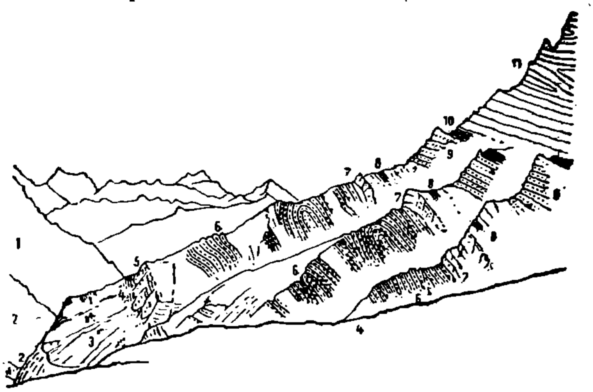

FIG. 10.—*Section through the slopes of the Bambanag cliff.*

11. Megalodon limestone.
10. Quartzite series.
9. Limestone with *Spiriferina Griesbachi*.

8. Halorites beds.
7. Limestone with *Proclydonautilus Griesbachi*.
6. Shales with *Halobia comata*.
5. Muschelkalk.
4. Lower Trias.
3. Productus shales.
2. White Quartzite.
1. Silurian.

The quartzite series is underlain by liver-coloured limestones recalling the beds of the Torer Sattel in the section of Raibl (Carinthia) in their lithological character. They have yielded only one fragmentary specimen of an ammonite, *Sagenites sp. ind.*, from which the group was named "Sagenites beds." Seeing that this fragment of *Sagenites* is not determinable specifically, it is perhaps advisable to discard that name. As *Anodontophora Griesbachi* Bittn. (Griesbach's *Corbis cf. mellingi*) is particularly common in this horizon, it might be termed from this leading fossil "Beds with *Anodontophora Griesbachi*."

The thickness of this group has been estimated at 130 feet by Diener, and 160 feet by A. v. Krafft in the Bambanag section.

Below the liver-coloured limestone with *Anodontophora Griesbachi* there follows a mass of compact limestones, which are often dolomitic or micaceous and about 320 feet in thickness.

They are rich in brachiopods and bivalves, which were described by A. Bittner (l.c., p. 72). From their leading fossil they have been termed "Beds with *Spiriferina Griesbachi*." Their fauna consists of the following forms :—

Spiriferina Griesbachi Bittn.
Retzia Schwageri Bittn.
Spirigera Dieneri Bittn.
Amphiclina sp. ind.
Rhynchonella bambanagensis Bittn.
,, *martoliana* Bittn.
Aulacothyris joharensis Bittn.
Lima cumaunica Bittn.
Pecten biformatus Bittn.
,, *interruptus* Bittn.
Anodontophora Griesbachi Bittn.
Cassianella pulchella Bittn.

The brachiopod-bearing limestones with *Spiriferina Griesbachi* gradually pass at their base into black calcareous shales, with dark limestone bands intercalated between them. One of those limestone bands, situated about 180 feet below the lower limit of the beds with *Spiriferina Griesbachi*, contains the richest fauna of noric age, which has as yet been discovered in the Himálayas. This is Diener's "Halorites limestone" of the Bambanag section.

The fossiliferous horizon of the Halorites beds was traced by Diener, Griesbach and Middlemiss from Lauka encamping ground and the Jandi pass in Johar to the Shalshal cliff in Painkhanda, but nowhere was there found a section which, for abundance of *Cephalopoda* could be compared with that of the Bambanag cliff. The rich fauna collected by the expedition in 1892 was described by E. v. Mojsisovics.[1] Very extensive collections obtained by A. v. Krafft in 1900 were examined by C. Diener.[2]

The following *Cephalopoda* have been determined specifically by those two authors :—

Halorites Sapphonis Mojs.
,, *procyon* Mojs.
,, *Charaxi* Mojs.
,, *Phaonis* Mojs.
,, *Alcaci* Mojs.
,, *Trotteri* Dien.
,, *alternans* Dien.
Anatomites sp. ind. ex. aff. scissi Mojs.
Parajuvavites Blanfordi Mojs.
,, *laukanus* Mojs.
,, *Sternbergi* Mojs.
,, *Feistmanteli* Griesb.
,, *Jacquini* Mojs.
,, *Tyndalli* Mojs.
,, *Renardi* Mojs.
,, *Ludolfi* Mojs.

1 E. v. Mojsisovics, Himálayan Foss., *Palæont. Ind.*, ser. XV, Vol. III, Pt. 1, p. 132.

2 C. Diener, Note on some fossils from the Halorites limestone of the Bambanag cliff, *Records, Geol. Surv. of India*, Vol. XXXIV, 1906, p. 1.

Parajuvavites minor Mojs.
,, *Brintoni* Mojs.
,, *buddhaicus* Mojs.
,, *Stoliczkai* Mojs.
Thetidites Guidonis Mojs.
,, *Huxleyi* Mojs.
Griesbachites jandianus Mojs.
Martolites Kraffti Dien.
Tibetites Ryalli Mojs.
,, *Murchisoni* Mojs.
,, *Perrin-Smithii* Mojs.
Anatibetites Kelvini Mojs.
Paratibetites Bertrandi Mojs.
,, *Geikiei* Mojs.
,, *Adolfi* Mojs.
,, *angustisellatus* Mojs.
,, *Tornquisti* Mojs.
Helictites Atalanta Mojs.
Dittmarites Hindei Mojs.
Dionites cf. Asbolus Mojs.
Steinmannites Desiderii Mojs.
,, *clionitoides* Mojs.
,, *Noetlingi* Mojs.
,, *undulatostriatus* Mojs.
Lubbockii Mojs.
Clionites Woodwardi Mojs.
,, *Salteri* Mojs.
,, *aberrans* Mojs.
,, *spinosus* Mojs.
,, *Hughesii* Mojs.
Sirenites Richteri Mojs.
,, *elegans* Mojs.
,, *elegantiformis* Dien.
Sandlingites Nicolai Mojs.
,, *Archibaldi* Mojs.
Arcestes Leonardii Mojs.
Pinacoceras Metternichii Hauer.

Pinacoceras parma Mojs.
,, *postparma* Mojs.
Bambanagites Dieneri Mojs.
,, *Schlagintweiti* Mojs.
Placites Sakuntala Mojs.
Paranautilus bambanagensis Mojs.
Indonautilus Kraffti Mojs.[1]
Clydonautilus biangularis Mojs.

The Halorites limestone is eminently a cephalopod horizon, in which ammonites predominate very considerably among the invertebrate fauna. The number of species of *Brachiopoda* and *Lamellibranchiata* which have been described by Bittner (l.c., p. 72), is very small. He mentions the following forms :—

Rhynchonella bambanagensis Bittn.
Halobia aff. comata Bittn.
Lima serraticosta Bittn.
Anodontophora Griesbachi Bittn.

The lowest noric horizon in Painkhanda is a complex of nodular and slaty limestones, from 70 to 100 feet in thickness, which succeeds the beds with *Halobia comata* in the Bambanag section and is overlain immediately by the fossiliferous layer of the Halorites beds. The small fauna consists of badly preserved cephalopoda, of which only a single species has been found worthy of a specific name. The rest are indeterminable fragments.

The following forms have been enumerated by E. v. Mojsisovics :—

Proclydonautilus Griesbachi Mojs.
Pinacoceras sp. ind. aff. imperator Mojs.
Hauerites sp. ind. (=*Metacarnites* Dien).
Arcestes sp. ind.
Sagenites sp. ind.
Juvavites sp. ind.
Parajuvavites sp. ind. aff. Jacquini Mojs.
,, *sp. ind.*

[1] E. v. Mojsisovics, Die Cephalopoden der Hallstætter Kalke, *Abhandl. K. K. Geol. Reichsanst.*, VI-1, Supplem., p. 205.

Of brachiopods *Rhynchonella bambanagensis* has been mentioned by Bittner.

This group of nodular limestones, which lithologically recalls the Muschelkalk, was first designated "Hauerites beds" by E. v. Mojsisovics, a name which later on was replaced by "Zone of *Proclydonautilus Griesbachi*." The name "Hauerites beds" has become untenable, since Diener[1] has proved the fragments assigned to *Hauerites* by E. v. Mojsisovics to belong to a new subgenus, allied very nearly to the Alpine *Carnites floridus* Wulf.

d. *Interregional correlation and homotaxis of the Upper Triassic deposits of Spiti and Painkhanda with those of Europe and America.*

In Spiti the carnic stage opens with the Halobia limestone, but in its meagre fauna *Halobia cf. comata* Bittn. is the only fossil directly indicative of a carnic age. Whether it ought to be correlated with the cordevolic or julic substage of the Alpine Trias, cannot be decided. There is, indeed, no evidence of the cordevolic substage being represented faunistically in the Himálayas.

In the "Grey beds," following above the Halobia limestone, the lower fossiliferous horizon with *Joannites cymbiformis* Wulf. is certainly a homotaxial equivalent of the zone of *Trachyceras aonoides* of the julic substage in the Alps. Among six species of ammonites three are identical with European forms from this zone, and the rest, which could not be determined specifically, equally point in the same direction.

The brachiopod-bearing horizon of the grey beds, situated 300 feet above the basal fossiliferous layer, has yielded several elements peculiar to the Indian region, among them the genera *Lilangina*, *Pomarangina*, *Aspidothyris*. Among the species of *Brachiopoda* with European affinities, there are some remarkable types, which point more nearly to a Muschelkalk than to an Upper Triassic age. But all of them—especially *Mentzelia Mentzelii* Dunk.—range as stragglers into the julic substage of the Eastern Alps. There is no palæontological evidence in favour of a correlation of this horizon with the upper carnic or tuvalic substage.

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[1] C. Diener, Himál. Foss., Vol. V, Pt. 3, p. 108.

The homotaxial equivalent of the tuvalic substage or zone of *Tropites subbullatus* is found in the Tropites beds of Spiti. In this cephalopod horizon Indian faunistic elements are in a minority. European affinities predominate to a large extent. There is not a single genus in the fauna of the Tropites beds, which was not known from the carnic stage of the Alpine Trias. All elements, which are conspicuous for their fecundity and give to this fauna its peculiar aspect, are characteristic of the zone of *Tropites subbullatus* of the Hallstatt limestone. Eight species among 22 are identical or nearly identical with congeneric forms from the carnic stage of the Salzkammergut.

From this fauna noric elements are as completely absent as from its homotaxial equivalent, the tuvalic substage of Hallstatt and Aussee.

In the tuvalic substage the dolomitic limestone with *Halobia aff. superba* Mojs. must be included, the association of *Dielasma julicum* Bittn., *Halobia aff. superba* Mojs., *Daonella cf. styriaca* Mojs., *Lima cf. austriaca* Bittn. being characteristic of a carnic age.

In Painkhanda two carnic horizons, both rich in *Cephalopoda*, are known to us, both of them pointing to the julic substage.

The lower horizon is the Traumatocrinus limestone of the Shalshal and Bambanag cliffs. Its fauna was assigned to the julic substage in 1896 by E. v. Mojsisovics. This correlation was questioned by A. v. Krafft, but proved to be correct by Diener's examination of the rich fossil materials collected by A. v. Krafft in 1900.

The European affinities are marked very clearly in this fauna, eleven species being common to the Indian and Alpine regions, among them the most important and the most frequently occurring. There are only two genera, *Girthiceras* and *Rimkinites* of exclusively Indian habit.

The Traumatocrinus limestone is overlaid conformably and immediately by a limestone bed containing *Daonella indica* Bittn. This bed must, consequently, be of julic age. From this fact it is evident that there is no distinct stratigraphical horizon in the Himálayas characterised by the presence of *Daonella indica*, as had been suggested by Bittner. This species has, on the contrary, a very wide stratigraphical distribution, ranging through the entire ladinic and the lower division of the carnic stage.

The beds with *Halobia comata* of Painkhanda and Johar—with the exception, however, of their uppermost layers—must also be included in the julic substage. The cephalopods described by E. v. Mojsisovics exhibit a striking similarity to the fauna of the beds with *Lobites ellipticus* near Aussee. The genera *Anatomites, Griesbachites, Hypocladiscites* and *Styrites* are represented by species nearly allied in both areas. Among the *Lamellibranchiata, Halobiæ* of the group of *H. rugosa* are an important element characteristic of the julic substage.

Both the Traumatocrinus limestone and the main mass of the beds with *Halobia comata* in the Bambanag and Shalshal cliffs must therefore be correlated with the Grey beds of Spiti.

The fauna of the Tropites beds has not yet been found in the sections of Painkhanda examined by Griesbach, Diener and A. v. Krafft, but we have strong evidence in favour of this horizon being represented there by the uppermost layers of the calcareous shales with *Halobia comata.* Nearly all the ammonites described by E. v. Mojsisovics were collected from the lower and middle divisions of this rock-group, whereas only one species with European affinities, *Mojsvarites eugyrus* Mojs., is known from the topmost beds, but this species has been found in Europe not only in beds of julic age. but also in the zone of *Tropites subbullatus.*

It is not probable that no sediment at all was deposited in this region of the Himálayas during the tuvalic period. I prefer to agree with E. v. Mojsisovics in suggesting that the uppermost layers of the beds with *Halobia comata* underlying the nodular limestone with *Proclydonautilus Griesbachi,* correspond with the Tropites beds and that their fauna will be discovered there some day, for cephalopods are not rare in this thick mass of shaly beds, but it is very difficult to secure them owing to their fragility.[1]

Both the Halobia limestone and the dolomitic limestone with *Lima cf. austriaca* and *Halobia aff. superba* of Spiti are wanting in the more eastern sections. The tuvalic substage, with a thickness of about 900 feet in Spiti, is reduced to an insignificant band of calcareous shales in Painkhanda.

Of the two divisions, into which the noric stage of the Himálayas falls naturally in Spiti and Painkhanda, the upper one is developed

[1] The ammonites collected in the beds with *Halobia comata* in 1900 by A. v. Krafft belong chiefly to the genera *Juvavites, Anatomites* and *Arcestes,* but do not admit of specific determination. The specimen of *Griesbachites Medleyanus* quoted in "Himálayan Fossils," Vol. V, Pt. 3, p. 152, has not been found in A. v. Krafft's collections.

very equally in both districts. The correlation of the noric beds underlying the Dachsteinkalk has been based on stratigraphical evidence by A. v. Krafft. The fauna is too indifferent, especially in Painkhanda, either to contradict or to support this evidence.

A. v. Krafft correlated the quartzite series, with *Spirigera maniensis* of Spiti with the corresponding series in Painkhanda, the Monotis beds of Mani and Lilang with the main layer of *Anodontophora Griesbachi* in the Bambanag cliff, where *Monotis salinaria* is, however, absent, the coral limestone of Spiti with the dolomitic limestone containing *Spiriferina Griesbachi* in Painkhanda. Those three rock-groups are rather poor in fossils and have a considerable number of faunistic elements in common. *Cephalopoda* are extremely rare. Two species of *Trachypleuraspidites* from the Monotis beds of Mani and a fragment of *Sagenites* from the main layer of *Anodontophora Griesbachi* of the Bambanag cliff afford no clue to the geological age of those beds. The only species of stratigraphical importance is *Monotis salinaria* Schloth., which is also known to us from the Pamir and from the Pishin district, Baluchistan.

The cephalopod-bearing beds, which form the lower division of the noric stage, exhibit a different development in Painkhanda and Spiti. In Painkhanda two cephalopod horizons occur, the nodular limestone with *Proclydonautilus Griesbachi* and the Halorites limestone. In Spiti one single horizon only, the Juvavites beds, corresponds to them.

The nodular limestone with *Proclydonautilus Griesbachi* is very poor in fossils, but among those fossils two species of *Parajuvavites*, and one species of *Pinacoceras*, nearly allied to *P. imperator*, have been described by E. v. Mojsisovics, all of them types with decidedly noric affinities. A correlation of this nodular limestone with the dolomitic limestone, following above the Tropites beds of Spiti, is consequently impossible. The nodular limestone with *Proclydonautilus Griesbachi* has been considered by E. v. Mojsisovics as a horizon independent from the Halorites limestone both stratigraphically and faunistically, but the arguments put forward by this learned author are not convincing.

Regarding the great deficiency of fossil materials from the nodular limestone with *Proclydonautilus Griesbachi*, it cannot be decided whether the faunas of this horizon and of the overlying Halorites beds represent one single or two distinct palæontological zones, although there is some evidence in favour of the latter alternative.

The richest Upper Triassic fauna in Painkhanda is included in the Halorites limestone. It contains 67 species of *Cephalopoda*, 61 of them determinable specifically. *Parajuvavites* and acatenate species of *Halorites* are the leading types. *Bambanagites* and *Guembelites*—both of them rare elements in this fauna—are of exclusively Indian habit. The Alpine genera *Metasibirites* and *Cyrtopleurites* are replaced by their Indian representatives *Thetidites* and *Tibetites.*

Four species are probably identical with forms from the noric Hallstatt limestone, namely :—

Pinacoceras Metternichii Hau.
,, *parma* Mojs.
,, *postparma* Mojs.
Dionites cf. Asbolus Mojs.

As has been demonstrated by E. v. Mojsisovics, the fauna of the Halorites limestone has relations with the faunæ both of the lower (lacic) and middle noric (alaunic) substages. But the preponderance of lacic elements, together with the absence of all types confined to the alaunic substage exclusively, is so obvious, that the lower noric or lacic age of the Halorites limestone can be established with certainty.

The fauna of the Juvavites beds of Spiti also bears the stamp of a lacic age, but does not show any close affinity to the fauna of the Halorites limestone. Three species only are identical, and two more very nearly allied, but those specific similarities are confined to forms which do not play any important part in the lower noric faunæ of Painkhanda or Spiti. *Halorites* and *Parajuvavites*, the two most prominent elements in the fauna of the Halorites limestone, have not been met with in Spiti, where they are replaced by species of *Juvavites*, which do not show any close affinity to the congeneric forms of the Alpine region. Although the lower noric cephalopod beds of Spiti and Painkhanda must be correlated, both for stratigraphical and palæontological reasons, their faunæ exhibit very distinct local peculiarities in both districts. This difference between the faunæ of the Juvavites beds in Spiti and the Halorites beds in the Bambanag section indicates a considerable change in the conditions of life since the end of the Muschelkalk epoch, the fauna of which is distinguished by a very uniform character throughout the Mesozoic belt of the central Himálayas.

In Asia beds of Upper Triassic age are not distributed widely outside the Indian region. In Asia Minor the rhætic stage has been discovered by G. v. Bukowski.[1] The fauna, consisting chiefly of brachiopods and lamellibranchs, bears the stamp of an upper noric or rhætic Mediterranean fauna, but shows no affinity to the noric faunæ of the Himálayas.[2]

On the Island of Kotelny (New Siberia) Upper Triassic shales and marly limestones have been discovered by Baron E. Toll. A preliminary examination of the rich fauna has convinced me of its carnic age. The most important elements are *Halobiæ* of the group of *H. fascigera* Bittn. This is a decidedly Indian type in this Arctic fauna, which is not known from any other Arctic region, where Triassic sediments are developed in a bivalve facies (Eureka sound, Bears Island, Spitzbergen). *Cephalopoda* are very rare and represented in Baron Toll's collection by only a few specimens of *Cladiscites*, *Pinacoceras* (group of *P. rex* Mojs.) and *Arcestes*.[3]

In Western America the carnic stage is represented by the *Tropites* beds of the Hosselkus limestone in Shasta county, California. According to J. P. Smith [4] the affinity of their rich fauna is much greater to the Mediterranean than to the Indian faunæ, although several species are probably common to both areas. The following species are directly or nearly identical :—

Tropites subbullatus Hau.
,, *torquillus* Mojs.
Trachysagenites Herbichi Mojs.

A considerable number of American carnic species are represented in India by forms, which are very closely related.

The association of *Tropites* and *Trachyceras* in California points to an early appearance of the *Tropitidæ* in America, where they

[1] G. v. Bukowski, Die geologischen Verhæltnisse der Umgebung von Balia Maaden, etc., *Sitzgsber. Kais. Akad. Wiss. Wien*, CI. 1892, p. 214.

[2] A. Bittner, Triaspetrefakte von Balia Maaden in Kleinasien, *Jahrb. K. K. Geol. Reichsanst.*, XLI, (1891), p. 97, XLII, (1892), p. 77, XLV, (1895), p. 249.

[3] *Lethœa mesozoica*, Vol. I, Trias, p. 542.

[4] J. P. Smith, The stratigraphy of the Western American Trias, l.c., p. 402.

probably originated. From this region they migrated into the Indian and Mediterranean Triassic provinces, where they make a sudden appearance without any local ancestors. But the path of this migration probably led into the Tethys by the way of the Atlantic rather than of the Pacific Ocean, since the affinities of the Californian carnic fauna are Alpine rather than Himálayan.

In the noric stage the affinities between the American and Indian faunæ are very remote. The fauna of *Pseudomonotis ochotica* Keyserl., which is probably identical with *Ps. subcircularis* Gabb, is widely distributed in Northern Asia and along the coasts on either side of the Pacific Ocean, but reached neither India nor the Alpine region. The exchange of faunistic elements between America and the Himálayas appears to have been suspended entirely during the noric period. It was probably resumed during the liassic epoch, as we may judge from the universal distribution of the genus *Arietites*, which is known from Europe, Western Asia, India, Timor, California, Nevada, Mexico, South America.

e. The Upper Trias of Kashmir and the Pamir.

a.—KASHMIR.

The researches on which our knowledge of the Upper Triassic deposits of Kashmir are based were carried out before the publication of C. L. Griesbach's memoir on the central Himálayas. Since Stoliczka's early reconnaissances and R. Lydekker's memoir on Kashmir (1883), no recent surveys have been made in that State although certain parts of Rupshu have been visited by Hayden and found to be stratigraphically almost identical with Spiti.

Naturally the data available for a description of the Upper Triassic deposits of Kashmir are therefore very scanty and very often antiquated. We are so far entirely in want of detailed stratigraphical data, while the fossils, which we know to have been derived from the Triassic beds of this area, are extremely small in number. This is all the more to be regretted, since Triassic beds are widely distributed in several isolated districts of Kashmir, chiefly in the Kashmir, Zanskar, Changchenmo, Karakoram and Baltistan basins (Lydekker: *Mem., Geol. Surv. Ind.*, XXII, pp. 133, 147, 154, 168, 169, 171, 182).

Detailed stratigraphical researches would no doubt yield most interesting results.

As to the stratigraphy of the Upper Trias of Kashmir, we only know that the thick limestone masses (" Para " limestone), which elsewhere form the base of the Spiti shales, are represented there also. It further appears from Lydekker's accounts (l.c., p. 168) that this limestone mass is underlain by sandy and shaly deposits, as is also the case in Spiti and Painkhanda. The lower division is said to contain *Monotis salinaria* Schloth., the upper one chiefly *Megalodon* and *Dicerocardium.*

Only three fossils belonging to the noric stage have so far been described :—

1. *Spirigera Noetlingi* Bittn.[1] collected by Stoliczka from Nio Sumdo in Karnag, Zanskar basin, probably also from Pankpo Pass (Zanskar basin). The fossil was regarded as liassic by Stoliczka (*Memoirs, Geol. Surv. Ind.*, V, pp. 342, 345, 346).

This species is also known from the noric stage of Spiti and of the Bambanag section.

2. *Megalodon cultridens* Bittn. (l.c., p. 62), collected by Stoliczka in the vicinity of Lingti Sumdo, probably a locality in the Lingti valley, Zanskar basin. This species has not yet been obtained from the Dachsteinkalk of Spiti.

3. *Megalodon ladakhensis* Bittn. (l.c., p. 65), from Shargol at the north-western termination of the Zanskar basin. It has been described and illustrated as *Megalodon cf. gryphoides* by Lydekker (l.c., p. 164, Pl. IV, figs. 1-4). This species also occurs in the Dachsteinkalk of Spiti.

To those three forms a few more may be added, the stratigraphical position of which is, however, somewhat doubtful.

One of them is *Dicerocardium himalayense* Stol., which Stoliczka (l.c., p. 342) records from the " Para " limestone in the section between Lahaul and Karag. It is according to his observations very common in the " Para " limestone of Ladakh and indicative of either Upper Triassic or liassic age. The type-specimen of *Dicerocardium himalayense* was collected east of Kioto in north-western Spiti. The forms, which are abundant in the " Para " limestone of Spiti, Ladakh and Rupshu, are

[1] A. Bittner, Himál. Foss., Vol. III, Pt. 2, p. 68.

perhaps specifically different, as has been remarked by A. Bittner (l.c., p. 66).

Another species, which is probably derived from the noric beds of Kashmir, is *Monotis salinaria* Schloth., recorded from Khar (Zanskar basin) by Stoliczka (l.c., p. 345). That the species recorded by Stoliczka, is identical with the Alpine leading fossil of the noric Hallstatt limestone, is very probable, for it is known to occur both to the south-east and north-west of Kashmir. Among Stoliczka's collections from Shargol (north-western corner of the Zanskar basin) a few flags of grey limestone have been noticed by Suess, which seem to have been derived from the Monotis beds. The fossils are, however, badly preserved.

From the Upper Triassic limestones of the Karakoram Pass *Heterastridium* and *Stoliczkaria* have been collected by A. le Coq.[1]

β.—Pamir.

Stoliczka, when about to return to India from Chinese Turkestan, whither he had accompanied the second Yarkand Mission, traversed the eastern Pamir and obtained some very interesting geological results. A record of the Triassic fossils collected by him, is contained in a paper by Prof. E. Suess "Zur Stratigraphie Centralasiens."[2]

Near Aktash Stoliczka observed the following sequence of beds, in descending order :—

4. Black, crumbling shales, with intercalated limestones, containing *Halorella*.
3. Grey shales.
2. Brownish sandstone, somewhat silicious.
1. Limestone.

The limestone beds intercalated between the black shales (No. 4) have yielded the ollowing species :—

Halorella rectifrons Bittn.
,, *Stoliczkai* Suess.

[1] P. Oppenheim, Ueber von Herrn A. le Coq gesammelte Heterastridien vom Karakoram Pass *Centralbl. f. Min., etc.*, 1907, p. 722.

[2] *Denkschriften Kais. Akad. d. Wissench.*, 1894, Bd. LXI, pp. 432-466.

Halorella pedata Bronn.
Monotis salinaria Schloth.
Thamnastraea rectilamellosa Winkl.

Of those five species only *Monotis salinaria* is known to occur in the Central Himálayas of Spiti. It was first discovered by H. Hayden near Mani on the Spiti river in 1899, where it abounds in a grey, shaly limestone. It was also observed in the section of Lilang by A. v. Krafft, where it is, however, much rarer.

The rock in which it occurs in Spiti is very similar to that of the Pamir. According to A. v. Krafft's notes hand-specimens from the one locality can scarcely be distinguished from those from the other.

Species of *Halorella* are as yet unknown from the Himálayas proper, but have been found in the south-eastern area of the Indian province, namely, in the Upper Trias of the Malayan archipelago.

f. The Upper Trias of Byans.

The Upper Trias of Byans differs considerably from that of Johar, Painkhanda and Spiti. Very little, however, is known at present about its fossiliferous horizons. The country has not yet been surveyed in detail, owing to the difficulty of a correct interpretation of the different sections, which appear to be so intensely crushed and disturbed that an exact determination of the single horizons, which lithologically resemble each other most closely, becomes almost an impossibility.

Only the general sequence of the beds has been ascertained by F. H. Smith in 1899 and by A. v. Krafft in 1900 during their short visits to the district.

The blue-grey limestone, 250 feet in thickness, which follows above the chocolate limestone of Lower Triassic age, has yielded the fauna of *Spiriferina Stracheyi* 70 feet above its base and, in the beds immediately above this brachiopod-bearing horizon, numerous cephalopods characteristic of the Upper Muschelkalk.

The next fossiliferous layer is situated in the topmost bed of this blue-grey limestone. This is the famous "Tropites limestone" of Kalapani with its strange association of carnic and noric types In the upper portion of the blue-grey limestone the entire ladinic and carnic stage must, consequently, be included. A very marked decrease in the thickness of Middle and Upper Triassic sediments certainly takes place from Johar towards Byans. Supposing even that the ladinic stage is completely absent, as we may infer from its reduced thickness in the Niti area, and that accordingly the thickness of the carnic stage amounts to 170 feet in the section of Kalapani, this is considerably inferior to that of the equivalent beds in Painkhanda and Johar. The proportions are expressed in feet :—

Spiti (maximum thickness)	1,290 feet.
Painkhanda and Johar (maximum thickness) .	820 „
Byans.	170 „

FIG. 11.—*Section N. W. of Kalapani (Byans) (from A. v. Krafft's diary)*

9. Megalodon limestone.
8. Shales with indeterminable ammonites.
7. Grey limestone.
6. Black shales with *Arcestes*.
5. Tropites limestone.
4. Light grey limestone (Muschelkalk, ladinic and carnic stage)
3. Chocolate limestone (Lower Trias).
2. Productus shales (Permian).
1. White Quartzite.

This decrease of the carnic stage from N. W. to S. E. is intimately connected with a change of facies. The shaly deposits of the horizon of *Halobia comata* in the Bambanag section are replaced in Byans by pure grey limestones, in which no trace of shaly layers has been found. It would be an interesting task to search for the connecting links between the different facies of the two areas, which must pass into one another somewhere between Johar and Byans.

The rich fauna of the Tropites limestone showing an assemblage of carnic and noric elements, all the higher beds following above, must be assigned to the noric stage.

In the district to the north of the Kali and Kuti Yangti rivers A. v. Krafft distinguishes the following sequence of beds above the Tropites limestone :—

4. Series of limestones (not examined in detail).
3. Shales with undeterminable ammonites.
2. Grey limestone of great thickness.
1. Black shales with *Arcestes sp.* : about 1,000 feet.

F. H. Smith in his generalized section of the Triassic rocks observed in Byans, distinguishes a larger number of rock-groups, according to the colours of the blue-grey limestone exhibited on weathered surfaces. But, broadly speaking, two main divisions can be recognised, a lower consisting of dark shales, and an upper, about 1,500 feet in thickness, in which limestones predominate. The shaly band No. 3 has been observed in the section of Kalapani only, where it is strongly crushed.

The occurrence of shaly deposits, 1,000 feet thick, in the lower division of the noric stage, once more emphasizes the dissimilarity of the Upper Triassic beds developed in Byans to those of Johar and Spiti. On the other hand the upper division of the noric (rhætic ?) beds of Byans seems to agree with that of the districts described above, consisting, as it does, of a thick limestone series extending from the Upper Trias into the Jurassic system and overlain by the Upper Jurassic Spiti shales. As is evident fron F. H. Smith's notes, the ferruginous oolites of the Sulcacutus beds form a constant and well marked horizon on the top of the limestone series No. 4 both here as well as in the more north-westerly districts.

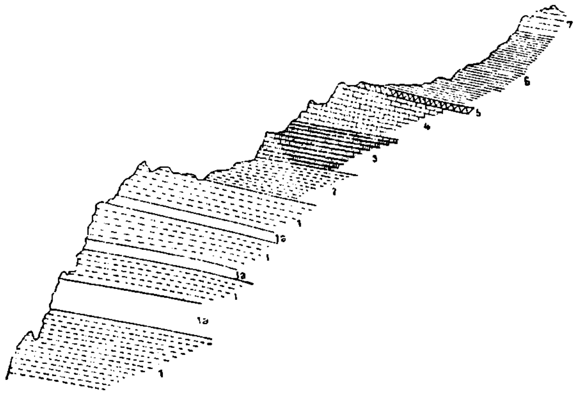


FIG. 12.—*Section along the route from Kalapani to Nabi (from A. v. Krafft's diary).*

7. Grey limestone } Noric stage.
6. Shales }
5. Tropites limestone.
4. Light grey limestone (Muschelkalk, ladinic (?) and carnic stage).
3. Chocolate limestone (Lower Trias).
2. Productus (Kuling) shales (Permian).
1. Brown quartzite.
1*a*. White quartzite.

A. v. Krafft discovered several fragments of ammonites in the topmost beds of the grey limestone (No. 2) and in the overlying shales (No. 3). Their similarity with forms from the zone of *Proclydonautilus Griesbachi* and from the Halorites limestone of the Bambanag section induced him to venture on a correlation of the shales No. 3 with the Halorites beds of Painkhanda. But the specimens in A. v. Krafft's collections are all indeterminable fragments, which do not even permit of generic identification. Moreover, the correlation with the Halorites limestone is contradicted by the zoological character of the Tropites limestone. For the present moment we are not able to say anything definite about the probable correlation of the Upper Triassic beds of Byans following above the Tropites limestone.

The only fossiliferous horizon of Upper Triassic age in Byans which is distinguished by a rich and characteristic fauna is the *Tropites* limestone. Among the fossils discovered by C. L. Griesbach near Kalapani, but assigned erroneously to the lias, representatives of the carnic genus *Tropites* were recognised by E. v. Mojsisovics.[1] Very extensive materials were collected by F. H. Smith and A. v. Krafft from Kalapani, Tera Gadh, Lilinthi, Nihal and Kuti. The following species have been described by C. Diener: [2]—

Rhynchonella angulifrons Bittn.
Halobia cf. fascigera Bittn.
,, *cf. comata* Bittn.
Avicula sp. ind. aff. caudata Stopp.
,, ,, *Tofanæ* Bittn.
Atractites cf. ellipticus Mojs.
,, *cf. convergens* Hau.
Orthoceras cf. triadicum Mojs.
,, *cf. dubium* Hau.
Grypoceras sp. ind. aff. mesodico Hau.
Proclydonautilus Griesbachiformis Dien.
Pinacoceras parma Mojs.
,, *Metternichii* Hau.
,, *cf. rex.* Mojs.
,, *Beecheri* Dien.
Placites polydactylus var. Oldhami Mojs.
,, *sp. ind. aff. peraucti* Mojs.
Bambanagites Kraffti Dien.
Carnites cf. floridus Wulf.
Monophyllites Jarbas Muenst.
Discophyllites Ebneri Mojs.
Arcestes dicerus Mojs.
,, *bicornis* Hau.
,, *subbicornis* Mojs.
Proarcestes cf. Gaytani Klipst.
,, *sp. ind. ex. aff. Zitteli* Mojs.
,, *cf. Sturi* Mojs.
,, *sp. ind. aff. sublabiati* Mojs.

[1] E. v. Mojsisovics, Vorlaeufige Bemerkungen ueber die Cephalopodenfaunen der Himalaya Trias, *Sitzgsber. Kais. Akad. d. Wiss.*, CI. Mai 1892.

[2] C. Diener, The fauna of the Tropites limestone of Byans, *Himál. Foss.*, Vol V, Pt. 1.

Stenarcestes sp. ind. aff. polysphincto Mojs.
,, ,, *subumbilicato* Mojs.
Cladiscites cf. neortus Mojs.
,, *sp. ind. aff. moroso* Mojs.
Lobites cf. ellipticus Hau.
Helictites cf. geniculatus Hau.
,, *cf. subgeniculatus* Mojs.
,, *sp. ind. aff. Beneckei* Mojs.
,, *Canningi* Dien.
Phormedites fasciatus Dien.
,, *sp. ind. aff. juvavico* Mojs.
Buchites cf. hilaris Mojs.
,, *Emersoni* Dien.
Thisbites Meleagri Mojs.
,, *Ronaldshayi* Dien.
,, *Campbelli* Dien.
Parathisbites cf. scaphitiformis Hau.
,, *cf. Hyrtli* Mojs.
,, *Wyndhami* Dien.
,, *nodiger* Dien.
Jellinekites Barnardi Dien.
,, *Saundersi* Dien.
,, *Hoveyi* Dien.
Arpadites Tassilo Mojs.
Dittmarites Rawlinsoni Dien.
,, *sp. ind. aff. Lilli* Guemb.
,, *Trailli* Dien.
,, *trailliformis* Dien.
,, *teragadhensis* Dien.
Trachypleuraspidites Griffithi Dien.
,, *Mansoni* Dien.
Steinmannites cf. Lubbocki Mojs.
Daphnites sp. ind. aff. Ungeri Mojs.
Dionites sp. ind. aff. Cæsar Mojs.
Drepanites Schucherti Dien.
,, *Eastmani* Dien.
,, *sp. ind. aff. Marsyas* Mojs.

Cyrtopleurites Freshfieldi Dien.
,, *sp. ind. aff. Agrippinæ* Mojs.
Tibetites cf. Ryalli Mojs.
Anatibetites Kelvini Mojs.
,, *Hobsoni* Dien.
Paratibetites Adolphi Mojs.
,, *cf. Bertrandi* Mojs
,, *cf. Geikiei* Mojs.
,, *sp. ind. aff. Tornquisti* Mojs.
,, *Wheeleri* Dien.
Acanthinites Hogarti Dien.
Himavatites Watsoni Dien.
Polycyclus Henseli Opp.
Clionites gracilis Dien.
,, *sp. ind. aff. Hughesii* Mojs.
,, ,, ,, *aberrans* Mojs.
,, ,, ,, *Dolloanus* Mojs.
,, *Stauntoni* Dien.
Protrachyceras Ansoni Dien.
Sandlingites cf. Oribasus v. Dittm.
,, *Pearsoni* Dien.
,, *Tuckeri* Dien.
,, *sp. ind. aff. Archibaldi* Mojs.
Sirenites trachyceratoides Dien.
,, *sp. ind. aff. Kohanyi* Mojs.
,, *Pamphagus* v. Dittm.
,, *Agriodus* v. Dittm.
,, *cf. Argonautæ* Mojs.
,, *sp. ind. aff. Argonautæ* Mojs.
,, *argonautæformis* Dien.
,, *cf. Dianæ* Mojs.
,, *Evæ* Mojs.
,, *Alixis* Dien.
,, *Vredenburgi* Dien.
,, *sp. ind. aff. Vredenburgi* Dien.
Anasirenites cf. Menelaus Mojs.
,, *Greeni* Dien.

Distichites Sollasii Dien.
„ *Falconeri* Dien.
„ *sp. ind. aff. megacantho* Mojs.
„ „ „ *celtico* Mojs.
„ „ „ *Atropus* Dittm.
„ „ „ *Minos* Mojs.
„ *cf. Harpalos* Dittm.
„ *Younghusbandi* Dien.
„ *sp. ind. aff. Younghusbandi* Dien.
„ *Reynoldsi* Dien.
„ *ectolcitiformis* Dien.
Ectolcites Hollandi Dien.
„ *arictiformis* Dien.
„ *Duncani* Dien.
„ *sp. ind. aff. Hochstetteri* Mojs.
Isculites Smithii Dien.
„ *Heimi* Mojs.
„ *sp. ind. aff. obolino* Dittm.
Halorites sp. ind. aff. procyon Mojs.
Jovites daciformis Dien.
„ *spectabilis* Dien.
Gonionotites Gemmellaroi Dien.
Parajuvavites Jacquini Mojs.
Anatomites speciosus Dien.
„ *cf. crasseplicatus* Mojs.
„ *cf. Fischeri* Mojs.
„ *cf. Theodori* Mojs.
„ *cf. Edgari* Mojs.
„ *Beresfordi* Dien.
Didymites tectus Mojs.
„ *Kitchini* Dien.
„ *sp. ind. aff. Quenstedti* Mojs.
„ „ „ *subglobus* Mojs.
Metasibirites Philippii Dien.
Discotropites Kraffti ien.
„ *Mojsisovicsi* Dien.
„ *cf. sandlingensis* Hau.

Margarites cf. auctus Dittm.
,, *nov. sp. ind. aff. aucto* Dittm.
,, *Georgii* Mojs.
,, *sp. ind. aff. Georgii* Mojs.
,, *cf. circumspinatus* Mojs.
,, *Sushena* Dien.
,, *Devasena* Dien.
Tropites subbullatus Mojs.
,, *cf. fusobullatus* Mojs.
,, *cf. discobullatus* Mojs.
,, *cf. Estellæ* Mojs.
,, *sp. ind. aff. acutangulo* Mojs.
,, *Wodani* Mojs.
,, *cf. Paracelsi* Mojs.
,, *Jalandhara* Dien.
,, *Manasa* Dien.
,, *kalapanicus* Mojs.
Anatropites nihalensis Dien.
,, *margaritiformis* Dien.
Paratropites lilinthicus Dien.
Tropiceltites arietitoides Dien.

To this list several forms must be added, belonging to the genera *Loxonema*, *Orthoceras*, *Lobites*, *Thisbites*, *Dittmarites*, *Trachyceras*, *Protrachyceras*, which did not permit of specific determination.

There are on the whole 168 species known up to the present time from the Tropites limestone. Not less than 155 species are ammonites. Among them 102 are peculiar to this horizon, whereas 53 are identical with species either from the Alpine Hallstatt limestone or from the Halorites beds of the Bambanag section. But a very large percentage of the species peculiar to the Tropites limestone are nearly allied with Alpine types. Thus the relations with Upper Triassic faunæ of the Mediterranean region are very strongly marked.

As faunistic elements peculiar to the Indian Triassic region the following must be mentioned :—*Jellinekites*, *Trachypleuraspidites* *Himavatites*, the groups of *Sirenites Vredenburgi*, *Drepanites Schucherti*, *Clionites gracilis*, *Distichites ectolicitiformis*, *Tropiceltites arietitoides*, *Anatropites margaritiformis*. Their number is, however, less considerable than the large percentage of species, which are nearly allied to European forms.

Many important types point to the carnic stage and are indicative of a homotaxis with the Alpine zone of *Tropites subbullatus*. But a second faunistic element pointing to the noric stage is almost equally distributed in the Tropites limestone. Not less than 49 species of ammonites are either identical or very closely allied with species from the noric Hallstatt limestone or (13) from the Halorites beds. A. v. Krafft was the first author to notice this strange assemblage of carnic and noric types in one single bed of limestone only three feet thick

It might be suggested that this fauna marks a transitional stage bridging over the faunistic hiatus, which exists between the carnic and noric stages of the Eastern Alps. But Diener remarks that such faunistic elements as might be regarded as transitional forms connecting the two faunæ are missing, and that the species present in variably show distinctly carnic or noric affinities. He consequently denies the possibility of considering the Tropites limestone as a true passage bed from the carnic to the noric stage.

He further insists on the remarkable similarity of the strong admixture of carnic and noric types in the Tropites limestone of Byans with the remarkable association of Kelloway and Oxford ammonites in the Jurassic oolites of Balin (Galciia), which has been explained by Neumayr by a want of sediment during that period. The association of carnic and noric faunæ in the Tropites limestone of Byans might also be explained by the want of sediment during the tuvalic and lacic periods. In this case the bed of the Tropites limestone although only three feet in thickness, might represent equivalents of the topmost division of the beds with *Halobia comata*, of the limestone with *Proclydonautilus Griesbachi* and of the Halorites beds of the Bambanag section. The want of sediment would be the real cause of the enormous fecundity of this thin layer in ammonites with carnic and noric affinities.

The correctness of this explanation has yet to be proved by the results of a detailed survey of the Upper Triassic rocks of Byans.

IV.—Summary.

The two best known areas in the Triassic belt of the Himálayas are Spiti and Painkhanda. The sections of Byans are known to us in general outlines, whereas from Kashmir and Ladakh only isolated data are as yet available.

1. Lower Trias and Muschelkalk are developed almost equally well in Spiti on the one hand and in Painkhanda on the other. The lower Trias contains at least three separate faunæ, namely, the *Otoceras-Ophiceras* fauna, the *Meekoceras* fauna, and the *Flemingites-Hedenstrœmia* fauna. To this must be added the *Sibirites* fauna, which is hitherto known with certainty from Byans only. Subdivisions of the Lower Trias must therefore be based on those clearly marked palæontological horizons. The former subdivision into Otoceras beds and Subrobustus beds must be abandoned, since the genus *Otoceras* is confined to a thin layer at the base of the lower Trias, while *Ceratites subrobustus* (= *Keyserlingites Dieneri* Mojs.) belongs exclusively to the Lower Muschelkalk.

The Muschelkalk naturally falls into three subdivisions. The lower division consists of a nodular limestone poor in fossils, which is underlaid by a brachiopod-bearing layer with *Rhynchonella Griesbachi*. The middle division (zone of *Spiriferina Stracheyi*) contains the fauna of *Keyserlingites Dieneri* (*Ceratites subrobustus* antea). The Upper Muschelkalk is very rich in cephalopods and represents, indeed, the richest and most widely spread fossil horizon of the Himálayas.

In Byans Lower Trias and Muschelkalk show a development different to that found in the other districts. The Muschelkalk consists of a much purer limestone facies than is the case to the north-west of that district. Faunistically, however, Lower Trias and Muschelkalk of Byans do not differ considerably from the equivalent beds of Spiti and Painkhanda. The topmost beds of Lower Triassic age contain the fauna of *Sibirites spiniger* which is probably homotaxial with that of the Upper Ceratite limestone in the Salt Range.

2. A strongly marked difference in thickness and lithological character sets in in the ladinic stage. While this stage is rich in fossils and of considerable thickness in Spiti, it is thin and poor in fossils in Painkhanda. Further to the east the ladinic stage has not yet been traced.

3. The marked difference just referred to is equally prominent in the carnic deposits. These are rich in shaly beds and very thick in Spiti, but dwindle considerably towards the east till in Byans their thickness is almost insignificant. At the same time the shales disappear and their place is taken by pure limestones.

In the carnic stage two ammonite faunæ can be distinguished, an upper with *Tropites subbullatus*, and a lower one with *Joannites cymbiformis*. The Tropites fauna has not yet been found in Painkhanda and Johar.

4. The noric deposits are, in their lower and middle divisions, richer in limestones and contain more natural rock groups in Spiti than in Painkhanda and Johar. They are divided into three groups of beds :—

Quartzite series.
Brachiopod beds.
Cephalopod beds.

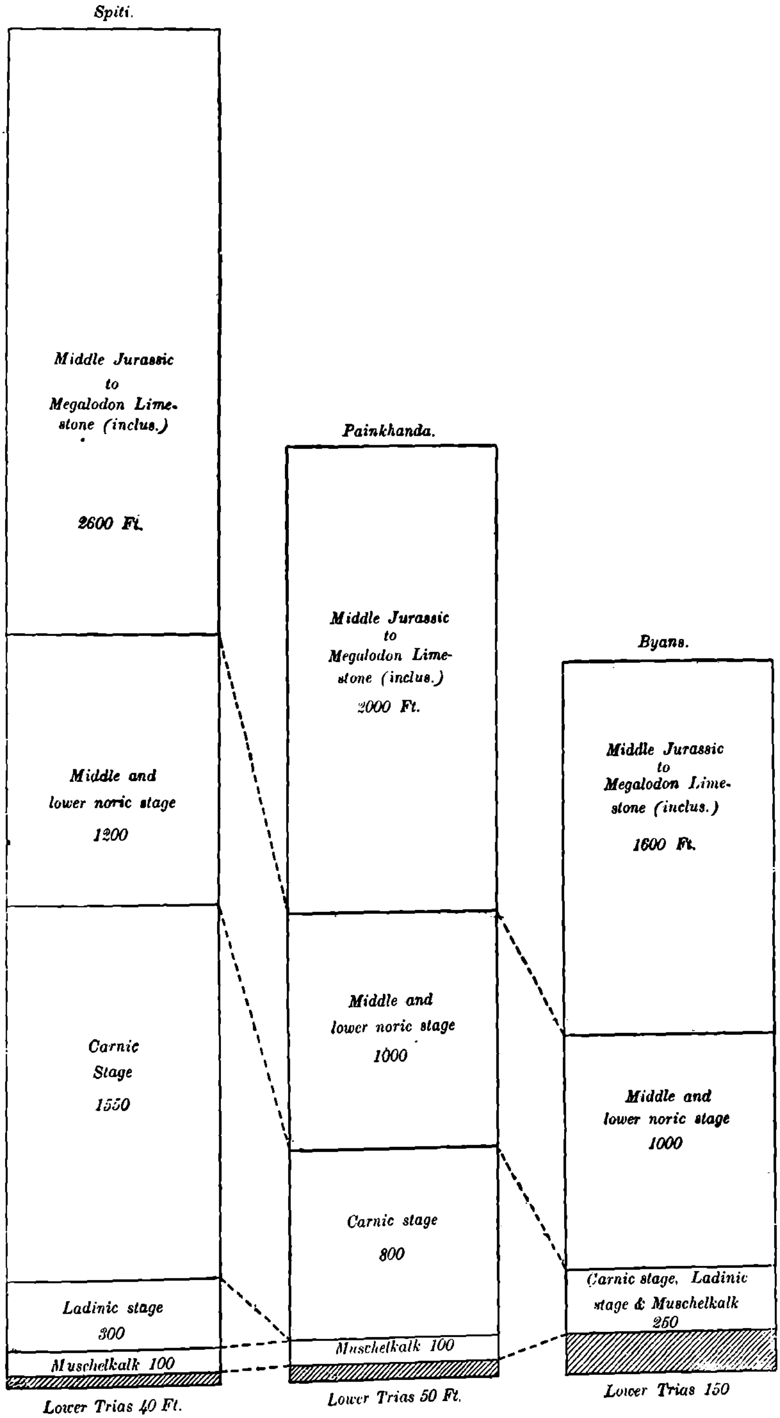
Locally the cephalopod beds are very rich in fossils in Johar (Bambanag cliff). But these beds (Halorites limestone) form no such constant stratigraphical horizon as the Muschelkalk.

The lower noric beds of Byans show peculiar features, being made up of black shales of great thickness, which are wanting in the other districts known.

Everywhere in the Himálayas the upper noric beds as far as we know consist of thick limestones and pass through beds of doubtful age into limestones of middle Jurassic age, which are overlain by the Upper Jurassic Spiti shales. From Spiti to Byans throughout the Mesozoic belt of the Himálayas a ferruginous oolitic layer (Sulcacutus beds) occurs at the base of the Spiti shales and constitutes a very constant horizon (Kelloway) in the Mesozoic deposits of the Himálayas.

The following table shows the relative thickness of the beds between the Productus shales and Spiti shales. It illustrates the remarkable decrease in thickness from north-west to south-east.

The second table gives a classification of the Triassic series of Spiti, Painkhanda, Johar and Byans. This table shows clearly that more detailed researches will have to be carried out before we can correlate the Trias of Byans in any detail with that of the other two districts. The Trias of Kashmir is so little known, that not even a rough outline of the stratigraphical sequence can be given.


Spiti.
Middle Jurassic to Megalodon Lime-stone (inclus.)
2600 Ft.
Middle and lower noric stage
1200
Carnic Stage
1550
Ladinic stage
300
Muschelkalk 100
Lower Trias 40 Ft.
Painkhanda.
Middle Jurassic to Megalodon Lime-stone (inclus.)
2000 Ft.
Middle and lower noric stage
1000
Carnic stage
800
Muschelkalk 100
Lower Trias 50 Ft.
Byans.
Middle Jurassic to Megalodon Lime-stone (inclus.)
1600 Ft.
Middle and lower noric stage
1000
Carnic stage, Ladinic stage & Muschelkalk
250
Lower Trias 150

Eastern Alps.			Spiti.	Thickness (feet.)	Palnkhanda.	Thickness (feet).	Byans.	Thickness (feet).
Upper Trias.	Noric stage.	Upper .	Megalodon limestone . .		Megalodon limestone .		Megalodon limestone.	
		Middle .	Quartzite series (*Spirigera maniensis*) . Monotis beds (*Monotis salinaria*) . . Coral limestone . . (*Spiriferina Griesbachi*)	300 300 100	Quartzite series (*Spirigera maniensis*) . *Anodontophora Griesbachi* beds (Sagenites beds) . Limestone with *Spiriferina Griesbachi*.	250 160 320	Greenish, black shales with sandy bands.	1,000
		Lower	Juvavites beds . .	500	Halorites beds . . Nodular limestone with *Proclydonautilus Griesbachi*.	200 100		
	Carnic stage.	Tuvalic .	Dolomitic limestone (*Lima cf. austriaca*) . Tropites shales (*Tropites cf. subbullatus*) .	300 600	Beds with *Halobia comata* .	800	Tropites limestone.	
		Julic .	Grey beds Higher beds with brachiopods and bivalves (near base *Joannites cymbiformis*). Halobia limestone (*Halobia omata*) . .	 500 150	Traumatocrinus limestone .	25	Grey, massive limestone.	250
		Cordevolic .	Daonella limestone					

Middle Trias.	Ladinic stage .	Higher beds with *Daonella indica*, near base *D. Lommeli*. Daonella shales (*Daonella Lommeli*) .	150 160	Passage beds of the Shalshal cliff.	10—20		
	Muschelkalk .	Upper Muschelkalk (*Ptychites rugifer*) . . Beds with *Spiriferina Stracheyi* and *Keyserlingites Dieneri*.	100	Upper Muschelkalk (*Ptychites rugifer*) Beds with *Spiriferina Stracheyi* and *Keyserlingites Dieneri*.	100	*Ceratites Thuillieri.*	
		Nodular limestone . .		Niti limestone .		*Spiriferina Stracheyi.*	
		Shaly bed with *Rhynchonella Griesbachi.*		Shaly bed with *Rhynchonella Griesbachi.*		Limestone with *Rhynchonella Griesbachi.*	
Lower Trias.	Campil beds .	Hedenstrœmia beds (*Flemingites Rohilla*) . .		Hedenstrœmia beds (*Flemingites Rohilla*) .		*Sibirites spiniger* near top.	
	Seis beds . .	Meekoceras beds . . . (*Meekoceras Varaha*)	40	Meekoceras beds . (*Meekoceras Markhami*)		Chocolate limestone .	150
		Ophiceras bed (*Ophiceras Sakuntala*)					
		Otoceras bed . . . (*Otoceras Woodwardi*)		Otoceras beds (*Otoceras Woodwardi, Ophiceras Sakuntala*).			
Permian . . .		Kuling or Productus shales .		Kuling or Productus shales		Kuling or Productus shales.	

B. Tibetan Facies.

The discovery of exotic blocks in Malla Johar by C. L. Griesbach, C. Diener and C. S. Middlemiss in 1892 acquainted us with a region situated to the north of the main Mesozoic belt of the Himálayas, in which a rapid change of facies takes place. The Permian and Triassic strata as exhibited in those exotic blocks show a development differing from that of the corresponding beds in the normal sections of Spiti, Painkhanda and Byans.

The facts stated by this expedition[1] were corroborated by A. v. Krafft's exploration of the exotic blocks in the neighbourhood of the Balchdhura in 1900. A. v. Krafft found a fairly complete sequence of Permian, Triassic and even liassic beds in the exotic blocks of Malla Johar, but he noticed that every single horizon was represented by beds of comparatively small thickness and belonging to a facies quite different from that of the beds of corresponding age in the Bambanag and Shalshal cliffs, notwithstanding their short distance apart of scarcely ten miles. The former A. v. Krafft termed the *Tibetan* and the latter the *Himálayan* facies.[2]

Evidence has been obtained of the representation of the following Triassic horizons :—

a. Lower Trias.

A large block of a dark red, earthy limestone, thin bedded, with a few grey layers, near the Kiogarh-Chitichun Pass (17,900 feet), marked E. B. No. 20 on the map accompanying A. v. Krafft's memoir, has yielded the following species of ammonites :—

Meekoceras joharense Krafft.
,, *infrequens* Krafft.
,, *jolinkense* Krafft.
Xenodiscus cf. nivalis Dien.
Hedenstrœmia cf. byansica Krafft.

[1] C. Diener, Ergebnisse, l.c., pp. 588-607, and *Mem., Geol. Surv. of India,* Vol. XXVIII, pp. 1-27. C. L. Griesbach, Notes on the Central Himálayas, *Records, Geol. Surv. of India,* Vol. XXVI, Pt. I, 1893, pp. 19-25, and "On the exotic blocks of the Himálayas," *Compte rendu de la IX session du Congrés Geol. internat. Vienne,* 1900, pp. 547-552.

[2] A. v. Krafft, Notes on the exotic blocks of Malla Johar in the Bhot Mahals of Kumaon, *Mem., Geol. Surv. of India,* Vol. XXXII, Pt. 3, pp. 127-183.

In number of individuals *Meekoceras joharense* predominates. A fragmentary specimen of *Meekoceras* from the Hedenstrœmia beds of Banna, *e.g.* in Spiti, has been identified with this species by A. v. Krafft, although its state of preservation is too bad to warrant a safe identification. *Xenodiscus nivalis* and *Hedenstrœmia cf. byansica* suggest a correlation with the Hedenstrœmia stage of the Himálayan series. *Meekoceras jolinkense*, which is also known from the chocolate limestone of Byans and from the horizon of *Meekoceras lilangense* in Spiti, points to the lower division of the Lower Trias.

The fauna of the exotic block No. 20 is certainly of Lower Triassic age, although its correlation with the Hedenstrœmia beds as advocated by A. v. Krafft cannot be considered to be established with full certainty.

From the Chitichun area exotic blocks of Lower Triassic age have not been recorded.

The fossils included in the exotic block No. 20 do not exhibit any affinities with the Alpine Lower Trias, but agree entirely with those from the Himálayan region. Local faunistic peculiarities, which have been mentioned by A. v. Krafft (l.c., p. 141, note) are of very slight importance only. But there is a very sharp lithological contrast, the Lower Trias of the Tibetan series consisting of dark red limestone recalling the Hallstatt limestone in the Mediterranean region.

b. Muschelkalk.

The Middlemiss crag near Chitichun No. I (17,740 feet), consisting of a small number of blocks of a red or red and white limestone, contains a rich fauna of ammonites, which were described by C. Diener in 1895.[1]

In the following list such species only have been included as admitted of a specific determination :—

Ceratites (*Danubites*) *Kansa* Dien.
,, ,, *Ambika* Dien.
Sibirites Pandya Dien.[2]

[1] *Pal. Ind.*, ser. XV, Himal. Foss., Vol. II, Pt. 3, The Cephalopoda of the Triassic limestone crag of Chitichun.

[2] The reference of this species to the genus *Sibirites* is accepted by E. v. Mojsisovics with some reserve (Himálayan Foss., Vol. III, Pt. 1, p. 51).

Monophyllites Confucii Dien.
,, *Pradyumna* Dien.
,, *Pitamaha* Dien.
,, *Hara* Dien.
,, *Kingi* Dien.
Procladiscites Yasoda Dien.
Xenaspis Middlemissii Dien.
Japonites Ugra Dien.[1]
Sturia mongolica Dien.

To the same Triassic horizon as the Middlemiss crag two more exotic blocks in the Chitichun region must be assigned. One of them is situated near the low pass west of the peak Chitichun No. I, on the route from the Kiogarh Chaldu Pass to Chitichun E. G., and the second north of Lochambelkichak E. G., near the pass which leads into the valley of the Chaldu river. Both of them have yielded *lumachellæ* of *Xenaspis* and *Monophyllites*.

The presence of this horizon in the Balchdhura district is doubtful. Some badly preserved ammonites (*Procladiscites cf. Yasoda* Dien.?) in a loose block point to the fauna of the Middlemiss crag, according to A. v. Krafft.

Judging from its zoological character, the fauna of the Middlemiss crag was correlated with the Muschelkalk by Diener in 1895. He considered this limestone to form a lower division of the Indian Muschelkalk than the beds with *Ptychites rugifer* and *Ceratites Thuillieri* in the sections of the Bambanag and Shalshal cliffs, the predominating types showing all a somewhat lower character of development than in the geologically oldest congeneric forms from the Upper Himálayan or Alpine Muschelkalk.

When this fauna was examined by Diener in 1895, the Lower Muschelkalk age of the isolated Middlemiss crag had to be decided by its fossil contents only. This correlation was afterwards fully confirmed by A. v. Krafft's discovery of the fauna of the Middlemiss crag in the zone of *Spiriferina Stracheyi* and *Keyserlingites Dieneri* in the normal

[1] Referred to *Gymnites* originally. It has been demonstrated by E. v. Mojsisovics (Cephal. der Hallstaetter Kalke, *Abhandl. K. K. Geol. Reichsanst.*, VI 2, Supplem., p. 323), that it combines the shape and sculpture of *Xenaspis* with the sutures of *Japonites* and should be included in the latter genus.

sections of Spiti and Painkhanda.[1] This zone has the following species of ammonites in common with the fauna of the Middlemiss crag :—

Ceratites (*Danubites*) *Kansa* Dien.
Japonites Ugra Dien.
Monophyllites Kingi Dien.
,, *Hara* Dien.
,, *Confucii* Dien.
,, *Pradyumna* Dien.

The presence of those species in the Lower (or middle) Muschelkalk of the main belt of the Himálayas satisfactorily proves the correctness of a correlation, which had been based on palæontological evidence only.

The fauna of the Middlemiss crag exhibits only small affinities with the Alpine Muschelkalk and with the beds corresponding in age from Ismid[2] in Asia Minor, but resembles much more nearly that of the zone of *Spiriferina Stracheyi* in the Himálayan region, although the local faunistic peculiarities are marked more distinctly than in the Lower Trias. The preponderance of *Ammonea leiostroca* (*Cladiscites, Monophyllites*) with the simultaneous diminution of *Ceratitoidea* is of special importance.

There is still the same lithological contrast prevailing between the Tibetan and Himálayan facies in both areas.

c. Lower Carnic stage.

A dark red, very ferruginous limestone of the exotic block No. I in A. v. Krafft's map (S. E. of Balchdhura No. II) has yielded *Daonella indica* Bittn. and *Halobia sp. ind.* No definite age can be assigned to this scanty auna. *Daonella indica* ranges from ladinic into carnic beds, but the presence of a true *Halobia* is rather in favour of a carnic age.

d. Carnic stage.

The credit of the first discovery of an exotic block of this age is due to C. L. Griesbach, C. Diener and C. S. Middlemiss, who in 1892 collected some specimens of Upper Triassic ammonites in a red marble near

[1] *General Report, Geol. Surv. of India,* for 1899-1900, p. 205.

[2] F. Toula, Eine Muschelkalk fauna am Golf von Ismid in Kleinasien, *Beitræge zur Geol. u. Palæontol. Oesterreich-Ungarns,* etc., **X**, p. 189.

Sangcha Talla encamping ground. The ammonites were shown by E. v. Mojsisovics (l.c., p. 18) to belong to a species of *Jovites* closely allied to *J. bosnensis* Mojs.

In the district of Malla Johar the presence of two exotic blocks of middle or upper carnic age was ascertained by A. v. Krafft. One of those blocks (No. 5) near Malla Kiogarh encamping ground was of very small size. It consisted of a massive, much altered, red limestone and yielded fragments of *Carnites sp. ind.* and of *Proarcestes sp. ind. ex aff. ausseano* Hauer. Those remains, although very scanty, are sufficient evidence of a carnic age.

The second exotic block (No. 2) was discovered by A. v. Krafft one mile to the north-west of the Balchdhura Pass. From a bright red marble agreeing very closely with the carnic Hallstatt limestone of the Roethelstein near Aussee, the richest Mesozoic fauna of the Tibetan facies has been obtained. It consists of the following species, which have been described by C. Diener [1] :—

Dictyoconites nov. sp. ind. aff. Haueri Mojs.
Proclydonautilus triadicus Mojs.
,, *Buddhaicus* Dien.
Grypoceras suessiiforme Dien.
Mojsvaroceras sp. ind. aff. Turneri Hyatt et Smith.
Cladiscites crassestriatus Mojs.
,, *cf. Gorgiæ* Gemm.
,, *sp. ind. cf. coracis* Gemm.
,, *cf. pusillus* Mojs.
Hypocladiscites subcarinatus Gemm.
,, *subaratus* Mojs.
Arcestes cf. periolcus Mojs.
,, *cf. Richthofeni* Mojs.
,, *sp. ind. aff. decipiens* Mojs.
,, *cf. placenta* Mojs.
Proarcestes Gaytani Klipst.
,, *cf. ausseanus* Hau.
,, *sp. ind. aff. Barrandei* Lbe.
Discophyllites Floweri Dien.

[1] C. Diener, Upper Triassic and liassic faunæ of the exotic blocks of Malla Johar, *Palæont. Ind.*, ser. XV, Himál Foss., Vol. I, Pt. 1.

Pinacoceras sp. ind. aff. rex. Mojs.
Placites cf. perauctus Mojs.
Discotropites cf. sandlingensis Hau.
Tropites cf. subbullatus Hau.
,, *sp. ind. aff. acutangulo* Mojs.
,, *sp. ind. aff. Wodani* Mojs.
Anatropites cf. spinosus Mojs.
,, *Pilgrimii* Dien.
Margarites irregularicostatus Dien.
Jovites cf. spectabilis Dien.
,, *daciformis* Dien.
Juvavites Kraffti Dien.
,, *dogranus* Dien.
,, *nov. sp. ind. aff. subinterrupto* Mojs.
Griesbachites pseudomedleyanus Dien.
,, *cf. Kastneri* Mojs.
Anatomites sp. ind. aff. Camilli Mojs.
,, ,, ,, ,, *Henrici* Mojs.
,, ,, ,, ,, *crasseplicato* Mojs.
Gonionotites cf. italicus Gemm.
Tibetites bhotensis Dien.
Loxonema (Polygirina) cf. elegans Hoern.
Sagana cf. geometrica Kok.
Capulus (Phryx) joharensis Dien.
Naticopsis sp. ind. aff. obvallatæ Kok.

This fauna has intimate relations both with the julic (middle carnic) and tuvalic (upper carnic) faunæ of the Alpine Hallstatt limestone. There is an assemblage of species indicating nearly equal affinities with the zones of *Trachyceras aonoides* and of *Tropites subbullatus.* The red marble of the exotic block No. 2 must therefore be considered as a homotaxial equivalent of both the middle and upper carnic substages.

The carnic stage, as represented in the exotic blocks Nos. 2 and 5, exhibits very important lithological differences from the dark shales and limestones of the beds with *Halobia comata* or the Grey beds and Tropites shales of the main region of the Himálayas. On the other hand, its lithological resemblance to the carnic Hallstatt limestone of the Roethelstein near Aussee is so great that it is no easy matter to distinguish rock specimens or fossils from those two localities without a close inspection. The agreement with the Alpine Hallstatt limestone is lithological as well as faunistic. The faunistic difference between the carnic beds of the Himálayan and Tibetan facies, which are not more than a few miles apart, is much more conspicuous than between the latter and the Hallstatt limestone of the Roethelstein.

Fifteen species are identical, or probably identical, with Alpine forms and nineteen altogether with forms which have their habitat in the Mediterranean province, including four species, which are known to us from Sicily but not from the Eastern Alps. This is an unusually large percentage of Mediterranean types in an Indian fauna, and is only exceeded by the Mediterranean affinities of the Lower Liassic fauna of the exotic blocks Nos. 16 and 17 south of the Kiogarh high plateau.

Particularly striking is the preponderance of the genera *Arcestes* and *Cladiscites* in number of individuals in the Tibetan facies, whereas those two genera are of rare occurrence in the carnic stage of the main Triassic region of the Himálayas. In this character the carnic fauna of the Tibetan facies agrees exactly with that of the Alpine Hallstatt limestone.

e. *Dachsteinkalk.*

To the east of Chitichun No. 1 an exotic block was noticed by Diener (*Ergebnisse*, etc., i.c., p. 602), which is remarkable on account of its regular conical shape. It is built up of a yellowish-grey limestone, recalling the higher beds of the Upper Triassic Dachsteinkalk of the Shalshal cliff section.

In the region of exotic blocks of Malla Johar the divide between Kiogarh No. I and No. V has been described by A. v. Krafft as consisting of a great mass of grey, dolomitic limestone, without any fossils, but resembling the upper noric or rhætic Dachsteinkalk of the main region. "Nevertheless there is no complete lithological identity between the two, the Tibetan grey limestone being massive throughout, while the Himálayan Dachsteinkalk is well bedded."[1]

f. *Summary.*

All Triassic beds represented in the exotic blocks of the Chitichun region and of Malla Johar belong to a facies different from that of the

[1] A. v. Krafft, Exotic blocks of Malla Johar, l. c., p. 147.

corresponding deposits in the Himálayan region. Those which are equivalent to the Dachsteinkalk of the Himálayan series are developed in a facies of white, dolomitic limestone. Their thickness and horizontal distribution is considerable, but the complete absence of fossils lessens their interest.

All the remaining exotic blocks agree in their mode of development with the red limestones and marbles of the Hallstatt facies in the Alpine region. Those of Lower Triassic and Muschelkalk age exhibit close faunistic affinities with the corresponding beds of the Himálayan facies from which they differ only lithologically. But in the carnic stage there is both a faunistic and lithological contrast with the Himálayan series, and a very close affinity with the middle and upper carnic faunæ of the Mediterranean zoo-geographical province.

Among the liassic fossils of the Tibetan facies the Mediterranean affinities are marked still more strongly than in the Trias, the difference between the liassic faunæ of England or Wurtemberg and those of the Alps being even more conspicuous than between the latter and the lower liassic ammonites of the Tibetan facies found in the exotic blocks.

If no other Mesozoic faunæ in the Himálayas were known than those of the carnic stage from the exotic block No. 2, and of the Lower Lias from the blocks Nos. 16 and 17, their knowledge would not justify the establishment of an Indian zoo-geographical province.

Whereas an independent development of the Mesozoic faunæ is noticed in the Eastern basin of the Tethys, which corresponds to the main belt of the Himálayas compared with the development in the Mediterranean region, the contrast between them is almost obliterated in the area of the Tibetan facies. To the north of the main belt of the Himálayas sediments were deposited of a nearly uniform lithological character, agreeing with the Hallstatt facies of the Mediterranean province, and the sea was inhabited by a fauna with insignificant local peculiarities during carnic and liassic times.

This striking lithological and faunistic agreement, which exists between a considerable part of the Mesozoic sediments of the Tibetan facies and the homotaxial beds of the Mediterranean region, is one of the most interesting facts in Himálayan stratigraphy. It cannot be explained satisfactorily by the hypothesis that the exotic blocks in Malla Johar are not found *in situ* but have been carried there from a territory lying much further to the north. This hypothesis which has been offered by Suess and in a somewhat altered form by A. v. Krafft, but which is not supported by convincing reasons, is only able to explain the rapid change of facies between the Tibetan and Himálayan series, but leaves the agreement of the Tibetan and Alpine series during the carnic and liassic periods unexplained.

IV.—THE CEPHALOPOD HORIZONS OF THE HIMALAYAN TRIAS.

The Trias of the Himálayas has been termed a cephalopod-bearing facies by several authors. But this statement can be made only with great reserve. It is true that some horizons are, indeed, conspicuous by an abundance of *Cephalopoda*, which is not surpassed by any in the Alps. But those horizons are, as a rule, of small thickness and separated by mighty masses of rocks very poor in fossils.

The cephalopod-bearing beds come to a close rather abruptly in the lower noric stage. In the higher divisions of this stage ammonites are of the rarest occurrence, and in the Indian equivalents of the Alpine Dachsteinkalk they are wanting altogether. From their fossils the enormous mass of shales, sandstones, quartzites, dolomites and limestones, which follow above the Juvavites beds of Spiti or above the Halorites limestone in Painkhanda, might be determined as a brachiopod or a bivalve facies, but certainly not as a cephalopod facies. Even in the Tibetan region of exotic blocks, where the faunæ of the Lower and Middle Triassic, carnic and liassic beds are represented almost exclusively by cephalopods, the grey limestones of the noric or rhætic stages are practically unfossiliferous. They have not yet yielded any ammonites.

It is necessary to state this, in order to prevent the student of the Himálayan Trias from forming exaggerated ideas on the abundance of cephalopod-bearing horizons. Those horizons are undoubtedly of the highest stratigraphical and faunistic importance, but are of small thickness in comparison with the unfossiliferous rocks, especially so in the Upper Trias.

In the Himálayan Trias ten cephalopod-bearing horizons have been distinguished by Noetling (Asiatische Trias, l.c., p. 177), who correlated the Otoceras beds with the Permian system.

The following table shows the distribution of cephalopod horizons in Spiti (sections near Lilang), Painkhanda (Bambanag and Shalshal cliffs), Byans and Malla Johar. It is from a combination of our experiences in those four areas, that we shall arrive at establishing a general standard of cephalopod-bearing horizons in the Central Himálayas.

It must, however, be remarked, that among those fifteen Triassic cephalopod horizons the existence of three is rather doubtful. No. 5 perhaps does not correspond to an independent palæontological zone, as defined by a peculiar fauna of ammonites, although *Rhynchonella Griesbachi* is restricted to this horizon. From No. 9 only a single ammonite, *Joannites thanamensis* Dien., is known. No. 15 has been based on two fragmentary specimens of ammonites, collected from the Monotis beds in Spiti and from the main layer of *Anodontophora Griesbachi* in Painkhanda. In neither case have I been able to determine the species.

	Spiti.	Painkhanda.	Byans.	Exotic blocks of Chitichun and Malla Johar.
Noric stage .	15. Horizon of *Trachypleuraspidites aff. Griffithi.*	15. Horizon of *Sagenites sp. ind.*		
	14. Horizon of *Juvavites angulatus.*	14. Horizon of *Halorites procyon.*	14. 13. 12. Horizon of *Tropites subbullatus* and *Halorites sp. aff. procyon.*	
		13. Horizon of *Proclydonautilus Griesbachi.*		
Carnic stage .	12. Horizon of *Tropites subbullatus.*	12. Horizon of *Mojsvarites eugyrus.*		12. 11. Horizon of *Cladiscites crassestriatus.*
		11. Horizon of *Juvavites tonkinensis* and *Hypocladiscites subaratus.*		
	10. Horizon of *Joannites cymbiformis.*	10. Horizon of *Joannites cymbiformis.*		
	9. Horizon of *Joannites thanamensis.*			

	Spiti.	Painkhanda.	Byans.	Exotic blocks of Chitichun and Malla Johar.
Ladinic stage	8. Horizon of *Protrachyceras Archelaus.*			
Muschelkalk	7. Horizon of *Ceratites Thuillieri* and *Ptychites rugifer.* 6. Horizon of *Keyserlingites Dieneri.*	7. Horizon of *Ceratites Thuillieri* and *Ptychites rugifer.* 6. Horizon of *Keyserlingites Dieneri.* 5. Horizon of *Sibirites Prahlada.*	7. Horizon of *Ceratites Thuillieri.*	6. Horizon of *Monophyllites Confucii.*
Lower Trias .	3. Horizon of *Hedenstrœmia Mojsisovicsi* and *Flemingites Rohilla.* 2. Horizon of *Meekoceras Varaha.* 1. Horizon of *Otoceras Woodwardi.*	3. Horizon of *Hedenstrœmia Mojsisovicsi* and *Flem. Rohilla.* 2. Horizon of *Meekoceras Markhami.* 1. Horizon of *Otoceras Woodwardi.*	4. Horizon of *Sibirites spiniger.* 3. Horizon of *Hedenstrœmia Mojsisovicsi.*	3. Horizon of *Meekoceras joharense.*
Permian .	Horizon of *Cyclolobus insignis.*			

Four cephalopod horizons are known to us from the Lower Trias, two or perhaps even three from the Muschelkalk, one from the ladinic, three (or four ?) from the carnic, two (or three ?) from the noric stage. In comparing the number of cephalopod horizons with the thickness of the corresponding rock-groups, it is evident at once that the Himálayan Lower Trias and Muschelkalk deserve indeed the name of cephalopod facies, whereas this is not the case in the Upper Trias. In the carnic and noric beds of Spiti we may pass through many hundred feet of shales and limestones, without meeting with a single cephalopod-bearing layer.

A correlation of the Triassic cephalopod horizons of the Himálayas and of the Eastern Alps is illustrated in the following table :—

	Eastern Alps.	Himálayas.
Rhætic .	Horizon of *Choristoceras Marshi.*	
Noric stage .	Horizon of *Sirenites Argonautæ.* „ „ *Pinacoceras Metternichii.* „ „ *Cyrtopleurites bicrenatus.* „ „ *Cladiscites ruber.* „ „ *Sagenites Giebeli.*	Horizon of *Halorites procyon.* „ „ *Proclydonautilus Griesbachi.*
Carnic stage .	Horizon of *Tropites subbullatus.* „ „ *T. Aonoides.* „ „ *T. Aon.*	Horizon of *Tropites subbullatus.* „ „ *Hypocladiscites subaratus.* „ „ *Joannites cymbiformis.* „ „ *Joannites thanamensis* (?).
Ladinic stage	Horizon of *Protrachyceras Archelaus.* „ „ *Dinarites avisianus.* „ „ *Protrachyceras Curionii.*	Horizon of *Protrachyceras Archelaus.*
Muschelkalk .	Horizon of *Ceratites trinodosus.* „ „ *Ceratites binodosus* .	Horizon of *Ceratites Thuillieri.* „ „ *Keyserlingites Dieneri.* „ „ *Sibirites Prahlada.*
Lower Trias .	Horizon of *Tirolites cassianus*	Horizon of *Sibirites spiniger.* „ „ *Hedenstræmia Mojsisovicsi* „ „ *Meekoceras Markhami.* „ „ *Otoceras Woodwardi.*
Permian .	Horizon of *Paralecanites sextensis.*	Horizon of *Cyclolobus insignis.*

It becomes clear from this table that the number of cephalopod-bearing horizons in the Himálayas is considerably larger in the Lower Trias than in the Alps, but smaller in the ladinic and noric stages. The absence of cephalopod horizons in the alaunic and sevatic (middle and upper noric) substages of the Himálayas is easily explained by the different development of facies in the Indian and Alpine regions. In the Alps it is only in the Hallstatt facies of the Salzkammergut that cephalopod facies are known, not in the *Lithothamnium* and bivalve facies of the Dachsteinkalk. But in rocks of the Hallstatt facies, as they are known to us from the Tibetan facies in the Himálayas, only the carnic stage is represented. The expectation may, however, be indulged in that in the Tibetan region further investigations may lead to the discovery of exotic blocks with middle and upper noric faunæ.

The presence of a single cephalopod fauna in the ladinic stage of the Himálayas is more remarkable. In the Alps three faunæ have been distinguished in this stage by E. v. Mojsisovics, two of them (Buchenstein and Wengen) being quite distinct and restricted to two stratigraphical horizons of wide distribution. In the Himálayas one fauna only corresponds to those three Mediterranean ones and this is the fauna of the Wengen beds with *Protrachyceras Archelaus* and *Daonella Lommeli*. But there is certainly no break in the succession of beds, either in Spiti where the ladinic stage is at least 300 feet in thickness, or in Painkhanda where it is reduced to a thickness of 10 or 20 feet. In all the sections that have been examined by A. v. Krafft, true passage beds have been noticed connecting the upper Muschelkalk with the ladinic stage. From this we must infer that the topmost beds of the upper Muschelkalk, containing *Ptychites Gerardi* Blfd. and *Joannites cf. proavus* Dien., represent also stratigraphical equivalents of the Alpine Buchenstein beds the existence of which cannot be proved on palæontological grounds.

The following table shows a correlation of the Triassic cephalopod horizons of the Himálayas and of the Boreal and Pacific regions. Our limited knowledge of the Trias in the Arctic regions and in the southern part of the Pacific is a serious obstacle to any attempt of this kind :—

	Himálayas.	Boreal region.	Western Pacific Province.	California and Idaho.
Noric .	Hor. of *Halorites procyon.* ,, ,, *Proclydonautilus Griesbachi.*		Hor. of *Asteroconites saviticus* (Savu.) Cephalopod horizon of New Caledonia.	Hor. of *Halorites americanus* and *Rhabdoceras Russelii.*
Carnic .	Hor. of *Tropites subbullatus.* ,, ,, *Hypocladiscites subaratus.* ,, ,, *Joannites cymbiformis.* ,, ,, *Joannites thanamensis.*	Hor. of *Clionites Barrentsi* (Bears Island). Cephalopod horizon of New Siberia. Hor. of *Protrachyceras Sverdrupi* (*Eureka Sound*).		Hor. of *Tropites subbullatus* (Hosselkus limestone). Hor. of *Protrachyceras cf. Homfrayi.*
Ladinic .	Hor. of *Protrachyceras Archelaus.*		Hor. of *Japonites Japonicus* (Rikuzen).	
Muschelkalk	Hor. of *Ptychites rugifer* and *Ceratites Thuillieri.* ,, ,, *Keyserlingites Dieneri.* ,, ,, *Sibirites Prahlada.*	Hor. of *Ptychites trochleæformis* (Spitzbergen) ,, ,, *Ceratites Vega* (Spitzbergen).	,, ,, *Monophyllites sichoticus* (Ussuri).	Hor. of *Ceratites trinodosus.* Hor. of *Parapopanoceras Haugi.*
Lower Trias .	Hor. of *Sibirites spiriger.* ,, ,, *Hedenstræmia Mojsisovicsi.* ,, ,, *Meekoceras Markhami.* ,, ,, *Otoceras Woodwardi* and *Ophiceras Sakuntala.*	Hor. of *Keyserlingites subrobustus* (Olenek).	Hor. of *Dinarites Hirschii* (Timor). Hor. of *Proptychites hiemalis* (Ussuri).	Hor. of *Columbites parisianus.* Hor. of *Tirolites cf. Haueri.* Hor. of *Meekoceras gracilitatis.*

It is evident from this table that the Triassic Cephalopod horizons of the Himálayas are more complete than in any part of the Pacific or Boreal regions. It is especially in the ladinic and noric stages that cephalopod-bearing beds are rare, being represented by bivalve faunæ and only very few ammonites in those two zoo-geographical provinces.

V.—THE INDIAN TRIASSIC PROVINCE.

It is generally accepted that in the region occupied by the Himálayas, the Salt Range of the Punjab ; the Pamir, the frontier ranges of Yunnan, Burmah and Tonking there existed in the Mesozoic era a part of the ancient ocean, known as Tethys, the Triassic faunæ of which bear quite a distinct local character, which distinguishes them from the homotaxial faunæ of the Mediterranean and Pacific regions.

E. v. Mojsisovics[1] in 1896 pointed out the succession of the Indian Triassic cephalopod faunæ and the relation that the Indian province bears to the Mediterranean and Pacific provinces. As has been demonstrated in the preceding chapter, we are able now to construct a more complete and detailed account of the succession of cephalopod horizons, although the younger divisions of the noric stage are still wanting.

Now we can also move a considerable step further in the direction of defining more clearly the relation of the Indian to the Pacific region during the Triassic period. The points formerly obscure in our knowledge of the Trias of North America have been settled by the careful investigations of Hyatt and J. P. Smith, and very important new data respecting the Triassic deposits of New Caledonia have been published quite recently by Piroutet. The large gap between the Trias of the Himálayas and of the western Pacific region has been filled partly by the investigations of Leclere, Lantenois and Mansuy in Yunnan and Tonking and of Boehm, Hirschi, Voltz in the Sunda Islands.

The boundary between the Triassic deposits of the Indian and Mediterranean regions is very sharp. What is known of Triassic rocks in Asia Minor, in the Caucasus and in Darwaz, bears the stamp of the normal Mediterranean development. In Asia Minor the Triassic series

[1] E. v. Mojsisovics: Beitræge zur Kenntnis der obertraidischen Cephalopodenfaunen des Himálaya, *Denkschr. kais. Akad. d. Wiss. Wien*, LXIII, p. 686.—Himaláyan Fossils, l.c., Vol. II, pt. 2, p. 66.

is more complete than in any other district of Western Asia. Lower Trias is known from Gebse (gulf of Ismid) in the facies of Werfen beds. The fauna, which has been described by A. Bittner,[1] agrees exactly with that of the Alpine Buntsandstein. It is overlain by grey crinoid limestones and by grey and red limestones containing a rich fauna of the Muschelkalk. This fauna in which cephalopods predominate, has been assigned to the upper Muschelkalk (zone of *Ceratites trinodosus*) by Toula,[2] to the lower Muschelkalk by G. v. Arthaber [3] and Noetling.[4] The presence of the ladinic stage is indicated by *Protrachyceras anotolicum* Toula.

Upper Triassic deposits are known to us from Baalia Maaden (Mysia) by the investigations of G. v. Bukowski,[6] who stated them to overlie unconformably beds of an Upper Carboniferous age. Their fauna was studied by Bittner.[7] It contains both noric and rhætic [8] elements, but exclusively *Brachiopoda*, *Lamellibranchiata* and *Gastropoda*. *Spirigera Manzavinii* Bittn., *Mysidia* Bittn., *Pergamidia* Bittn., are the most remarkable types. There is no affinity whatever with the Upper Trias of the Himálayas.

In the Caucasus, sediments of the marine Trias were discovered at three different localities by W. J. Worobieff in 1906. The most complete section was observed on the slope of Mount Tchatch near the source of the river Sokhraia, a tributary of the Bielaia. According to the preliminary descriptions given by Th. Tschernyschew,[9] who examined

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1 A. Bittner : *Neues Jahrb. f. Min.*, 1899, I. p. 66.

2 F. Toula : Eine Muschelkalkfauna am Golf von Ismid in Kleinasien, *Beitræge zur Geol. u. Palœont. Oesterr-Ungarns etc.*, 1896, X, pp. 153-191.

3 G. v. Arthaber, *ibidem*, XII, p. 226.

4 F. Noetling, Asiatische Trias, l. c., p. 115.

5 F. Toula : Ueber *Protrachyceras anatolicum*, ein neues Triasfossil vom Golfe von Ismid, *Neues Jahrb. f. Min.* etc., 1898, I. p. 26.

6 G. v. Bukowski : Die geologischen Verhaeltnisse der Umgebung von Baalia Maaden im nordwestl. Kleinasien. *Sitzgsber, Kais. Akad. d. Wiss. Wien.*, CI, 1892, p. 214.

7 A. Bittner : Triaspetrefakten von Baalia in Kleinasien, *Jahrb. K. K. Geol. Reichsanst.*, 1891, XLI, p. 97.—Neue Arten aus der Trias von Baalia, etc., *ibid.*, 1892, XLII, p. 77.

8 Bittner determined the age of this fauna as " rhætic," taking the rhætic stage in the wide circumscription of F. v. Hauer, who united in this stage all Triassic beds younger than carnic.

9 Th. Tschernyschew : Ueber die Entdeckung von oberer Trias im nœrdl. Kaukasus. *Bull. Acad. Imper. des sciences, St. Petersbourg*, 1907, p. 277.

the rich materials of *Brachiopoda* and *Lamellibranchiata* collected by Worobieff, the Triassic series begins with shales containing *Koninckina Telleri* Bittn. and *Nucula strigillata* Goldf., which must be correlated with the carnic stage. They are overlaid by grey and red limestones, which have yielded a rich fauna of noric and rhætic age. The following are the most characteristic species :—

Pseudomonotis ochotica Keyserl.
Amphiclinodonta Katzeri Bittn.
,, *Suessii* Hofm.
Terebratula pyriformis Suess.
,, *turcica* Bittn.
Waldheimia reflexa Bittn.
Spiriferina Suessi Winkl.
,, *cf. kœssenensis* Zugm.
Spirigera Manzabinii Bittn.
,, *oxykolpos* Emmr.
Retzia superbesescens Bittn.
Rhynchonella fissicostata Suess.
,, *levantina* Bittn.
,, *Fuggeri* Bittn.

This fauna shows a decidedly Mediterranean character, with the sole exception of *Pseudomonotis ochotica,* which points to a connection of the Mediterranean with the Siberian region.[1] Most of the fossils are identical or closely allied with species from Baalia Maaden. There is no affinity with the Upper Triassic faunæ of the Himálayas.

Fossils of Lower Triassic age—*Pseudomonotis* (*Claraia*) *Clarai* and *Tirolites sp.*—were noticed from Djulfa (Armenia) by E. v. Mojsisovics.[2] They occur in a quartzite series, which follows above grey marls and limestones containing *Lima Footei* Waag. Their stratigraphical position is considerably higher than that of the Permian Otoceras beds of Djulfa, but F. Frech and G. v. Arthaber[3] have not succeeded in fixing it exactly in Abich's section across the Araxes

1 *Pseudomonotis ochotica* is also known from the Upper Triassic shales and sandstones of Simferopol in the Crimea (G. v. Arthaber, Alpine Trias, *Lethœa mesoz.*, Bd. I, p. 440).

2 E. v. Mojsisovics : Zur Altersbestimmung der Sedimentærformationen in der Araxesenge bei Djulfa in Armenien, *Verhandl. K. K. Geol. Reichsanst.*, 1879, p. 171.

3 F. Frech and G. v. Arthaber : Ueber das Palaeozoikum in Hocharmenien und Persen, *Beitræge zur Geol. u. Pal. Œsterr. Ungarns etc.*, XII, 1900, p. 176.

valley. The presence of *Tirolites* is indicative of the Mediterranean facies of the Lower Trias in Armenia.

Typical Werfen beds were discovered in Darwaz near Raman not far from the Afghan frontier by A. v. Krafft.[1] They consist of red sandstone, grey limestone, red and grey clay of enormous thickness (800 to 1,000 m.). Both the sandstone and limestone are rich in gastropods and bivalves. Ten species were determined by Bittner,[2] all of them characteristic elements of the Alpine Werfen beds. Thus the faunistic and lithological agreement is equally close.

The difference between the Lower Trias of the Himálayas and of the Salt Range on the one hand, and of Darwaz on the other is very sharp, but not sharper than that between the Himálayan and Tibetan facies of the Indian Trias.

The presence of Triassic sediments in Oman near Elphinstone inlet, is still rather doubtful, although *Myophoria omanica* Dien., which is nearly allied to the Alpine *M. inaequicostata* Klipst., indicates a Triassic age for some of the rocks.[3]

During the Middle and Upper Triassic periods Afghanistan was the western branch of the Indian zoo-geographical region.

The fauna of the shales and sandstones of the Kara Koh in the province of Herat, which were discovered by C. L. Griesbach in 1886,[4] is unfortunately known too little to fix its age with any certainty. The presence of coal measures, of *Daonella Lommeli* and of *Monotis salinaria*, two bivalves standing widely apart in the stratigraphical scale of the Alpine Trias, has been recorded by Griesbach, but the cursory field-determinations of these fossils have not been confirmed by any subsequent examination.[5]

The association of marine strata rich in *Daonella*, with terrestrial plant-bearing beds reminds us strongly of the development of the Upper Trias in Sumatra, as has been stated by Noetling.

1 A. v. Krafft: Geologische Ergebnisse einer Reise durch das Chanat Bokhara, *Denkschr. Kais. Akad. d. Wissensch.*, Wein, LXX, 1901, pp. 49-72.

2 A. Bittner: *Jahrb. K. K. Geol. Reichsanst*, 1898, 48 Bd., pp. 689-718.

3 C. Diener, Note on some fossils from the sedimentary rocks of Oman (Arabia).—*Records, Geol. Surv. of India*, Vol. XXXVI, 1908, p. 156.

4 C. L. Griesbach: Field notes, etc. *Records, Geol. Surv. of India*, 1886, Vol. XIX, pp. 235-267.

5 Recent work in Afghanistan has thrown considerable doubt on the accuracy of these determinations (*Mem., Geol. Surv. India*, Vol. XXXIX, p. 31).—Ed.

A large development of Upper Triassic rocks was disclosed in the highlands of the Pishin district (Baluchistan) by E. Vredenburg in 1901.[1] *Monotis salinaria* Schloth. and *Halorites sp. ind. aff. subcatenato* Mojs. point to a noric age. The shales including those species are probably homotaxial with the Monotis beds of Spiti and certainly not older than the middle noric (alaunic) substage.

From the Himálayas of Nepal our knowledge of Triassic fossils is limited to a valve of *Halobia* comparable to *H. Charleyana* Mojs. and to the cast of a *Ptychites* belonging to the section *rugiferi*, both of them represented in Wallich's collections from Muktinath, on the upper part of the river Kali or Buria Gandak, and south of Lob Mantang. A description of those scanty materials has been given recently by F. R. Cowper Reed.[2]

In Tonking the presence of the carnic stage has been established by Diener, who discovered *Juvavites tonkinensis* Dien., one of the species of the julic beds with *Halobia comata* in the Bambanag section, among the materials brought from the source of the Red river by French officers.[3] A wide distribution of Triassic rocks has been recorded recently by Zeil, Lantenois, Camillon, Mansuy,[4] in the environs of Lang-son and Binn-Lieuh. The fossils, which have been described by H. Mansuy,[5] indicate the presence of Lower, Middle and Upper Triassic horizons.

The Trias of Tonking consists of shales, sandstones and limestones, which have been folded very strongly. *Xenodiscus cf. lissarensis* Dien. and *Pseudomonotis Griesbachi* Bittn. are referable to the Lower Trias, perhaps to its lowest stage, the Otoceras beds. The occurrence of *Inyoites cf. Oweni* Hyatt et Smith and of an ammonite, which has

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[1] E. Vredenburg: On the occurrence of a species of *Halorites* in the Trias of Baluchistan. *Records, Geol. Surv. of India*, 1904, Vol. XXXI, p. 162.—C. Diener: Notes on an Upper Triassic fauna from the Pishin district, Baluchistan, *ibidem*, 1906, XXXIV, p. 12.

[2] F. R. Cowper Reed: Fossils from Nepal, *Geol. Magazine*, Dec. V, New ser., Vol. V, 1908, p. 261.

[3] C. Diener: Note sur deux espèces d' Ammonites triassiques du Tonkin, *Bull. Soc. Geol. de France*, 3 ser., T. XXIV, p. 882.

[4] G. Zeill, H. Lantenois, R. de Lamothe: Contribution à l'étude géologique de l'Indochine, *Mém. Soc. Geol.*, IV ser., T. I., 1907, Mem. No. 4, p. 24.

[5] H. Mansuy: *Contribution géologique à la carte de l'Indochine, Paléontologie*, Hanoi 1908, pp. 62-73.

been compared to *Columbites* by Mansuy, points to a close faunistic affinity with the Lower Trias of Idaho and California. The determination of *Norites*, which was quoted by Douvillé [1] in 1896, is rather doubtful.

The presence of Muschelkalk is very uncertain. It might be inferred from a badly preserved specimen of *Ceratites*, recalling *C. Airavata* Dien.

The fauna of the carnic stage is represented by the following species :—

Lima cf. subpunctata D'Orb.
Pecten cf. tubulifer Muenst.
Hoferia cf. auplicata Muenst.
Hœrnesia cf. Joannis Austriæ Klipst.
Palæoneilo cf. Faba Wism.
Myophoria cf. inaequicostata Klipst.
,, *Goldfussi* Alb.

The noric stage is indicated by *Clionites cf. Salteri* Mojs., by some fragments of ammonites, which have been compared to *Paratibetites* Mojs. by Mansuy, by a species of *Spiriferina*, which is perhaps nearly allied to *Sp. Griesbachi* Bittn., and by a cast of a bivalve resembling *Anodontophora Griesbachi* Bittn.

The development of the carnic stage in the vicinity of Lang-son differs considerably from that in the Himálayas. It exhibits a closer affinity with the homotaxial Triassic beds in south-eastern China, as represented by the faunæ of Chungtien (Loczy)[2], Kwechou (Koken)[3] and A-mi-chu (Mansuy).

The Triassic fauna discovered by L. von Loczy north of the great Buddhist temple of Chungtien in the valley of the Kingcha-Kiang, is imbedded in argillaceous shales, marls and sandstones. Its affinity with the German Muschelkalk has been overestimated. *Myophoria elegans* Dunk. is the only identical species. All the remaining forms point to a ladinic or carnic age, especially to the fauna of St. Cassian. This is also the age of the fauna of Kwei-chou, according to Koken.

[1] H. Douvillé, *Bull. Soc. Géol. de France*, 3 sér. I, XXIV, p. 454.

[2] Die wissenschaftlichen Ergebnisse der Reise des Grafen Béla Széchényi in Ostasien 1877-1880, Wien 1893, I, p. 738 III, p. 208.

[3] E. Koken : Uber triadsiche Bersteinerungen aus China, *Neues Jahrb. f. Min.* etc., 1900, I, pp. 186-215.

[4] Résultats de la mission géologique et minière du Yunnan Méridional Sept. 1903-Janvier 1904, *Annales des Mines*, 1907, pp. 71, 172.

The two faunæ are composed almost exclusively of *Brachiopoda*, *Gastropoda* and *Lamellibranchiata*, but have not yielded one single ammonite. A Himálayan fauna of this facies was discovered in the Grey beds of Spiti by H. Hayden and A. v. Krafft, but is certainly of younger age. The scientific mission to southern China in 1898 under command of M. Leclère discovered the beds with *Myophoria Szechenyi* Loczy near Sui-Longtien. By the expedition to Yunnan in 1903 the presence of two Upper Triassic horizons has been recorded near A-mi-chu and Yen-fen-chwang. The lower horizon corresponds to the bed with *Myophoria Szechenyi*, which in this section is associated with *Daonolla indica* Bittn. This association is a strong argument in favour of a ladinic or lower carnic age of the fauna of Chungtien. The second horizon is the equivalent of the Raibl beds or zone of *Trachyceras aonoides*. It has yielded the following species of ammonites:—

Protrachyceras Thous Dittm.
Trachyceras Suessii Mojs.
Trachyceras austriacum var. tibetica Mojs.

In the district of A-mi-chu the Triassic fossils are imbedded in limestones, shales and variegated sandstones, which have been compressed into several sharp folds.

The northern borderland of the Indian Triassic province corresponds to the southern shore of the Angara continent (Suess). It must have been shifted considerably to the south since the close of the anthracolithic epoch. No rocks of Triassic age have as yet been found beyond the Semenow range near the boundary of North-eastern Tibet and the Chinese territory of Kansu.

The extension of the Indian marine Trias into the Malay Archipelago has been proved by the discovery of Triassic fossils in Wichmann's collections from the island of Rotti by Rothpletz.[1] But the researches of Voltz in Sumatra, Vogel in Borneo, Hirschi in Timor, G. Boehm in the islands of Serang, Savu and Misol, have carried the distribution of the distinctive faunæ of the carnic and noric stages still further to the east and west.

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1 A. Rothpletz: Die Perm Trias-und Juraformation auf Timor und Rotti im Malayischen Archipel. *Palæontographica*, Vol. XXXIX, p. 89.

Rotti is the classical locality in the Malay Archipelago, from which the first Triassic fossils were described in 1892 by Rothpletz. He distinguished a lower limestone and marl of carnic and a younger reddish-yellow limestone of noric age. This classification has been proved to be entirely correct, although a revision of the fossils by Renz[1] and Wanner[2] has led to some alterations in the determination of the species.

The leading fossils of the lower or carnic horizon are *Daonella Wichmanni* Rothpl. and *D. styriaca* Mojs. In the upper or noric horizon *Pseudomonotis ochotica var. densistriata* Tell. predominates. *Halobia cf. Hoernesi* Mojs., *H. cf. norica* Mojs., *H. cf. lineata* Muenst. point also to a probably noric age, but have not been found associated with the casts of *Pseudomonotis ochotica*, according to Rothpletz.

In Sumatra W. Voltz[3] has acquainted us with a rich development of the carnic stage near the source of the Kwalu river. The Triassic beds consist of a yellow clay, about 600 feet in thickness, which is overlaid conformably by a series of sandstones, the average thickness of which amounts to 1,600 feet. In the sandstones thin bands of grey clay are intercalated irregularly. They contain casts of bivalves and numerous plant remains. This development has been compared with the coal-bearing Trias in the Afghan province of Herat by F. Noetling.

The yellow shaly clay at the base of the Kwalu sandstone has yielded *Daonella styriaca* Mojs. and *D. cassiana* Mojs. From the grey clay intercalated with the sandstone one species of *Daonella* and four of *Halobia* have been quoted by Voltz. All of them are new species, with the exception of a *Halobia*, which is probably identical with the Alpine *H. Charlyana* Mojs. From this fauna the carnic age of the entire series is evident.

From Kendai, in south-eastern Borneo, crumbling shales, rich in casts of *Monotis salinaria* Schloth., have been quoted by F. Vogel.[4]

[1] C. Renz: Timor und Rotti in Noetling, *Asiatische Trias*, l. c., p. 211, — Ueber *Halobia* und *Daonella* aus Griechenland nebst asiatischen Vergleichstuecken, *Neues Jahrb. f. Min.* etc., 1906, I, p. 37.

[2] T. Wanner: Triaspetrefakten der Molukken und des Timorarchipels, in G. Boehm, Geologische Mitteilungen aus dem Indo-austral. Archipel, *Neues Jahrb. f. Min. etc.*, Beilagebd. XXIV, 1907.

[4] W. Voltz: Beitræge zur geol. Kenntniss von Nord Sumatra, *Zeitschr. Deutsch, Geol. Ges.*, LI, pp. 1-61.

F. Vogel: Beitræge zur Kenntnis der mesozoischen Formationen in Borneo, *Sammlgn, d. Geol. Reichsmuseums in Leiden*, ser. I, Bd. VII, 1902, p. 217.

It is impossible to decide whether or not this determination was correct since both *Pseudomonotis ochotica* and *Monotis salinaria* have been proved to occur in the Upper Triassic rocks of the Malay Archipelago.

Our knowledge of the Trias of Misol and Savu is very limited. Among the collections gathered from those islands by G. Boehm, *Daonella lilintana* from the shales of Lilinta (Misol) is identical with a species from the carnic beds of Sumatra. In the island of Savu the presence of Upper Triassic beds has been proved by the discovery of *Asteroconites savuticus* Boehm. According to the present state of our knowledge the genus *Asteroconites* is restricted to the noric stage of the Alpine Trias.

In eastern Serang a rich development of marine shales, sandstones and limestones of noric age was discovered by J. Wanner in 1904. It has yielded the following species :—

Montlivaltia moluccana Wann.
Thecosmilia nov. sp. ex. aff. clathratae Emmr.
Pachypora intabulata Wann.
Halorella amphitoma Bronn.
,, *plicatifrons* Bittn.
,, *rectifrons* Bittn.
Monotis salinaria Schloth.
Amonotis Rothpletzi Wann.
Vanikoro serangensis Wann.

The facies of the noric beds in Serang recalls strongly the carnic Kwalu sandstone of Sumatra. In the sandstones of Serang which occasionally pass into pure quartzites, plant remains and coal seams are met with rather frequently.

The fossils collected in the Triassic areas of Timor by Verbeek and Hirschi [1] and described by Wanner, belong to at least three different Triassic horizons. *Dinarites* (*Liccaites*) *Hirschii* Wann., represents a type of this genus which in the Mediterranean Triassic province is characteristic of the upper Werfen beds. It would therefore point to a Lower Triassic age. *Koninckina alfurica* Wann., which is associated with indeterminable *Halobiæ* of the *rugosa* group, from Bahabubu (Portuguese Timor), *Daonella indica* Bittn. and *D. cf. styriaca*, which have

[1] H. Hirschi: Zur Geographie und Geologie von Portugiesisch Timor, *Neues Jahrb. f. Min. etc.*, Beilagebd, XXIV, 1907, p. 460.

not been found *in situ*, must be assigned to the carnic stage. The same conclusion is arrived at with respect to *Halobia moluccana*, a species allied very nearly to *H. Charlyana* Mojs., from Meta Mano Ledo. A reddish-yellow limestone, agreeing lithologically with the *Pseudomonotis* bed of Rotti, has yielded a cast of *Pseudomonotis ochotica var. densistriata*. This limestone must consequently be considered to be of noric age.

The Upper Triassic faunæ of the Malay Archipelago are distinguished by their close relationship to Indian and Mediterranean forms. The Halorella limestone of Serang agrees entirely with the Halorella lim e stone of the Eastern Pamir. The true *Monotis salinaria*, so often incorrectly cited, occurs in the two rock groups. It is a type characteristic of the Tethys, both in the Mediterranean and Indian regions. It is replaced by the group of *Pseudomonotis ochotica* in the Siberian and Pacific regions. It is only in the noric stage of Rotti that we find this Pacific type, which otherwise seems to be excluded from the Indian Upper Trias.

Thus the Malay region appears to have formed a connecting link between the Indian and Pacific Provinces during the Upper Triassic period. A similar connecting link between the Alpine and Siberian development of the Upper Trias is indicated by the noric beds of the Crimea and of the Caucasus, where *Pseudomonotis ochotica* is associated with a large number of brachiopods of truly Mediterranean type.

In the south of the Himalayan Mesozoic belt the Triassic Tethys was bordered by the old continent of Gondwanaland, the counterpart of the Angara continent to the north. But south-east of the Malay Archipelago an uninterrupted open connection must have existed between the Indian and Pacific oceans of the Upper Trias. This is evident from the astonishing influence of Indian and even Mediterranean elements on the Triassic faunæ of New Caledonia.

According to the valuable data which have been obtained recently by Piroutet,[1] there can now be no doubt as to the fact that in the marine Trias of New Caledonia several horizons exist comprising equivalents of the noric, carnic and even ladinic stages.

Two facies may be distinguished among the Triassic beds of this

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[1] M. Piroutet, Note sommaire sur le Trias de la Nouvelle Calédonie, *Bull., Soc. Geol. de France*, 4 ser. t, VIII, 1908, pp. 324-329.

island. The eastern facies is represented by graphitic argillaceous shales with *Pseudomonotis Richmondiana* Zittel, which must be considered as deposits of considerable depth. The deposits of the western facier have been formed near the ancient shore. They are much thicker and partly rich in fossils. Their entire thickness is about 3,000 metres. Three main divisions are distinguishable among them.

The lowest division, attaining a thickness of nearly 1,000 metres, consists of basal conglomerates, argillaceous sandstones and shales, in which a mighty series of trachytic tufa and breccia is intercalated. One single fragment of *Orthoceras* only has been found near the base. The stratigraphical position of this division, which some geologists have correlated with Upper Palæozoic beds, is consequently uncertain.

The middle division has been divided into seven horizons by Piroutet. It consists of shales, clay, grauwacke, andesitic tufa and breccia. The owest horizon is a bed with *Halobia Zitteli* Lindstr. and *Halobia Kwaluana* Volz. The first species is one of the leading bivalves of the shales and Myophoria sandstones of Bears Island [1] and of the calcareous shales of the Eureka sound.[2] The second species has been quoted from the grey Daonella clay of Sumatra by Volz. Thus this horizon is probably of carnic, not of ladinic age, as has been suggested by Piroutet.

This lowest horizon is overlaid by a bed with *Mytilus problematicus* Zittel and with large species of *Spirigera* and *Spiriferina.*

Then follows a bed very rich in fossils, which represent rather conflicting characters. With several species of *Halobia* of typical carnic habit numerous brachiopods are associated, all of them Mediterranean forms, but characteristic of different stratigraphical horizons of the Alpine Trias. *Spiriferina fragilis* Schloth., *Rhynchonella decurtata var. dalmatina* Bittn., *var. devota* Bittn are indicative of the Muschelkalk, *Spiriferina Lipoldi* Bittn., *Spiriferina gregaria* Suess, *Retzia ladina* Bittn., *Retzia quadricosta* Muenst., *Spirigera contraplecta* Muenst., *Spirigera indistincta* Beyr., *Terebratula Oppeli* Lbe. of the St. Cassian and Raibl beds, *Halorella* sp., *Rhynchonella angulifrons* Bittn., *Rhynchonella salinaria* Bittn. even of the noric Hallstatt limestone and Dachsteinkalk.

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[1] J. Boehm: Ueber die obertriadische Fauna der Bæreninsel, *Konigl, Svenska Vetensk. Akad. Handl.*, Vol. XXXVII, No. 3, 1903, p. 30.

[2] E. Kittl: Die Triasfossilien vom Eurekasund, *Report second Norwegian Arctic Expedition "Fram,"* No. 7, 1907, p. 14.

In the three following horizons very large species of *Spiriferina* and *Spirigera*, belonging chiefly to the group of *Sp. Wreyi* Zitt., predominate. From the uppermost of those three horizons all the ammonites hitherto known have been collected. Besides *Rhacophyllites cf. neojurensis* Quenst. and *Stenarcestes nov. sp. ind.* described by E. v. Mojsisovics (Ammonites triasiques de la Nouvelle Caledonie, *Compte Rendu Acad. des Sciences*, Paris, 18, Novembre 1895), several indeterminable species of *Arcestes* have been found by Piroutet, among them representatives of the groups of *intuslabiati*, *bicarinati*, *coloni*, *sublabiati*.

This cephalopod-bearing horizon is overlaid by a bed containing numerous bivalves, among them *Halobia austriaca* Mojs., *H. cf. Suessii* Mojs., *H. cf. celtica* Mojs., *H. cf. comata* Bittn. Those species point to the carnic stage as decidedly as the ammonites of the preceding horizon to the noric stage. In the topmost beds of this division an amalgamation of carnic and noric elements seems to exist, which recalls the two different faunæ—one with carnic and the other with noric affinities —in the Tropites limestone of Byans.

The highest division of the Trias in New Caledonia agrees with the middle one lithologically, if we except the occasional intercalation of calcareous sandstones, but is of very considerable thickness (about 1,800 metres). It has yielded *Halobia rarestriata* near its base and *Pseudomonotis Richmondiana* in the upper part of the series, together with plant remains. It is only in this horizon of undoubtedly noric age, that the Alpine fauna is replaced entirely by an element characteristic of the Arctic-Pacific province.

The affinities of the Triassic faunæ of New Caledonia with the Indian and Mediterranean faunæ are so close, that the Trias of this island can scarcely put in a claim for being separated from the Indian Triassic province as a special faunistic district.

No more recent data are available respecting the Triassic deposits of New Zealand, which belong to the noric stage. In South America the presence of the marine Trias has been denied altogether by Steinmann,[1] who examined the section of Utcubamba in Peru, where the fossils reported hitherto as Triassic had been collected. Those fossils, which had been assigned to the Upper Trias by E. v. Mojsisovics (*Pseudomonotis ochotica*, *Metasibirites*, *Helictites*) have their habitat in a bed

[1] G. Steinmann, Keine marine Trias in Suedamerika, *Centralblatt, f. Min, etc.*, 1909, p. 1.

stratigraphically younger than the lower lias with *Agassizeras globosum*. The results of the detailed palæontological investigation of the faunæ from the valley of Utcubamba must be awaited before our uncertainty about the exact position of the South American beds with *Pseudomonotis ochotica* can be removed.

We have become acquainted with a wide extent of the Indian Triassic fauna from the province of Herat to New Caledonia. Over this large area the successive faunæ were distributed uniformly and had the same vertical range. But although the sediments were once continuous, a tolerably complete and connected account of their succession can only be constructed for the Himálayan region. In this district we have an uninterrupted development of *Cephalopoda*, which enables us to decide the enigmatical question as to the habitat of some cryptogene types.

It has been shown that *Xenodiscus* ranges from Permian into Lower Triassic strata, undergoing several modifications, among which the most typical genera of Lower Triassic ammonites might be found. The most important phylum of Triassic ammonites has its root in the Indian genus *Xenodiscus* Waag., but *Xenodiscus, Xenaspis, Ophiceras, Meekoceras* are all so closely allied at the commencement of the Mesozoic era, that it is barely possible to point out a distinct ancestor to every Triassic genus within this stock of radicals.

Meekoceras itself is probably a descendant of *Ophiceras*, more particularly of the type with a narrow umbilicus, which is represented by *O. Sakuntala*. Another branch of the genus *Ophiceras* is *Flemingites*, an intermediate shape between the two genera, *Fl. prœnuntius*, having been described by Frech. But with equal reason some other species of *Flemingites* might be referred to *Xenodiscus*, as is demonstrated by the remarkable agreement of *Flemingites radiatus* Waag. with *Xenodiscus plicatus* Waag.

An important branch of discoidal ammonites with adventitious lobes certainly originated from *Meekoceras*. *Hedenstrœmia* is also connected with this genus most intimately by *Clypites* Waag. (group of *Hedenstrœmia lilangensis* Kr.). Types specialized more strongly are *Aspenites* Hyatt and *Pseudosageceras* Dien., which is connected with *Hedentrœmia* by a fragmentary species from the Meekoceras beds of Spiti.

Proavites, *Proptychites*, *Beyrichites* are all probably descendants from *Meekoceras* which have retained the originally smooth shells. But there is some probability of *Meekoceras* being also the root from which a large phylum of *Ammonea trachyostraca* originated. Forms of *Meekoceras* with a faintly developed ornamentation, which crosses the external part (*M. Hodgsoni* Dien.) belong to a genetic series leading to *Sibirites* in the upper division of the Lower Trias and to *Acrochrodiceras* in the Muschelkalk.

But the most important Indian family of Triassic *Trachyostraca*, the *Ceratitidæ*, probably originated from *Xenodiscus*. This is pretty certain at least for the group of *Ceratites circumplicati* (*Hollandites*). *Ceratites pumilio*, the oldest representative of the genus, agrees with typical species of *Hollandites* in the shape of its cross section and in the pattern of its sculpture, with *Xenodiscus* in the development of its sutures and in its comparatively wide umbilicus.

The restriction of *Tirolitidæ* to the Mediterranean province during the Scythian period, emphasized by E. v. Mojsisovics in 1896, has not been confirmed by later researches, but their sporadic appearance clearly proves them to have been immigrants from the Mediterranean region, not autochthonous elements, such as the *Meekoceratidæ* and *Xenodiscidæ*. *Dinarites* also became independently developed within the Mediterranean and Boreal provinces, but cannot be regarded as an ancestor of the Indian *Ceratitidæ*.

The Indian Lower Trias is entirely deficient in *Arcestoidea*, which make a sudden simultaneous appearance both in the Himálayan and Alpine Muschelkalk. The considerable temporary intermittence between *Joannites* and the Permian *Cyclolobus* makes a genetic connection between those two genera questionable.

A second stock of cryptogene types, the *Haloritidæ*, which were not known to E. v. Mojsisovics before the carnic stage have been discovered recently in the Muschelkalk, where *Smithoceras* is a peculiar representative of this family. This fact proves the *Haloritidæ* to be an endemic element of the Indian province. But the problem of the habitat of *Haloritidæ* during the ladinic and lower carnic periods still remains undecided.

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CONTENTS.

PART I.

THE GEOLOGY OF SPITI, WITH PARTS OF BASHAHR AND RUPSHU. *By* H. H. HAYDEN, B.A., B.E., F.G.S., *Deputy Superintendent, Geo'ogical Survey of India.* (With 18 plates.)

PART II.

THE GEOLOGY OF THE PROVINCES OF TSAN AND Ü. IN CENTRAL TIBET. *By* H. H. HAYDEN, B.A., B.E., F.G.S., *Superintendent, Geological Survey of India.* (With 15 plates.)

PART II—*contd.*

PART III.

THE TRIAS OF THE HIMALAYAS. *By* C. DIENER, PH.D., *Professor of Palæontology at the University of Vienna.*

VI.—GEOGRAPHICAL INDEX.

VII.—SUBJECT INDEX.

CALCUTTA: PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8 HASTINGS STREET.

VOL. XVIII, 1885.

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

Part 2.—Fossiliferous series in Lower Himalaya, Garhwal. Age of Mandhali series in Lower Himalaya. Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). Geology of Chamba. Probability of obtaining water by means of artesian wells in plains of Upper India. Artesian sources in plains of Upper India. Geology of Aka Hills. Alleged tendency of Arakan mud volcanoes to burst into eruption most frequently during rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3.—Geology of Andaman Islands. Third species of Merycopotamus. Percolation as affected by current. Pirthalla and Chandpur meteorites. Oil-wells and coal in Thayetmyo district, British Burma. Antimony deposits in Maulmain district. Kashmir earthquake of 30th May 1885. Bengal earthquake of 14th July 1885.

Part 4.—Geological work in Chhattisgarh division of Central Provinces. Bengal earthquake of 14th July 1885. Kashmir earthquake of 30th May 1885. Excavations in Billa Surgam caves. Nepaulite. Sabetmahet meteorite.

VOL. XIX, 1886.

Part 1.—Annual report for 1885. International Geological Congress of Berlin. Palæozoic Fossils in Olive group of Salt-range. Correlation of Indian and Australian coal-bearing beds. Afghan and Persian Field-notes. Section from Simla to Wangtu, and petrological character of Amphibolites and Quartz Diorites of Sutlej valley.

Part 2 (out of print).—Geology of parts of Bellary and Anantapur districts. Geology of Upper Dehing basin in Singpho Hills. Microscopic characters of eruptive rocks from Central Himalayas. Mammalia of Karnul Caves. Prospects of finding coal in Western Rajputana. Olive group of Salt-range. Boulder-beds of Salt-range. Gondwana Homotaxis.

Part 3 (out of print).—Geological sketch of Vizagapatam district, Madras. Geology of Northern Jesalmer. Microscopic structure of Malani rocks of Arvali region. Malanjkhandi copper-ore in Balaghat district, C. P.

Part 4 (out of print).—Petroleum in India. Petroleum exploration at Khátan. Boring in Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3, Turkistan, Fiery eruption from one of mud volcanoes of Cheduba Island, Arakan. Nammianthal aerolite. Analysis of gold dust from Meza valley, Upper Burma.

VOL. XX, 1887.

Part 1.—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traversed through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image-stones. Soundings recently taken off Barren Island and Narcondam. Talchir boulder-beds. Analysis of Phosphatic Nodules from Salt-range, Punjab.

Part 2.—Fossil vertebrata of India. Echinoidea of cretaceous series of Lower Narbada Valley. Field-notes: No. 5—to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east with speckled sandstone in west of Salt-range in Punjab.

Part 3 (out of print).—Retirement of Mr. Medlicott. J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section I. Geology of Simla and Jutogh. 'Lalitpur' meteorite.

Part 4.—Points in Himalayan geology. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaon, Section II. Iron industry of western portion of Raipur. Notes on Upper Burma. Boring exploration in Chattisgarh coal-fields. (Second notice). Pressure Metamorphism, with reference to foliation of Himalayan Gneissose Granite. Papers on Himalayan Geology and Microscopic Petrology.

VOL. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section III. Birds'-nest of Elephant Island, Mergui Archipelago. Exploration of Jessalmer, with a view to discovery of coal. Facetted pebble from boulder bed ('speckled sandstone') of Mount Chel in Salt-range, Punjab. Nodular stones obtained off Colombo.

Part 2.—Award of Wollaston Gold Medal, Geological Society of London, 1888. Dharwar System in South India. Igneous rocks of Raipur and Balaghat, Central Provinces. Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3 (out of print).—Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' Pre-tertiary sedimentary formations of Simla region of Lower Himalayas.

Part 4.—Indian fossil vertebrates. Geology of North-West Himalayas. Blown-sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1 (out of print).—Annual report for 1888. Dharwar System in South India. Wajra Karur diamonds, and M. Chaper's alleged discovery of diamonds in pegmatite. Generic position of so-called Plesiosaurus Indicus. Flexible sandstone or Itacolumite, its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate. "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period." Oil-fields of Twingoung and Beme, Burma. Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

Part 3 (out of print).—Coal outcrops in Sharigh Valley, Baluchistan. Trilobites in Neobolus beds of Salt-range. Geological notes. Cherra Poonjee coal-field, in Khasia Hills. Cobaltiferous Matt from Nepál. President of Geological Society of London on International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4 (out of print).—Land-tortoises of Siwaliks. Pelvis of a ruminant from Siwaliks. Assays from Sambhar Salt-Lake in Rajputana. Manganiferous iron and Manganese Ores of Jabalpur. Palagonite-bearing traps of Rájmahál hills and Deccan. Tin-smelting in Malay Peninsula. Provisional Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones and Quarry Stones in Indian Empire. Part 1.

Vol. XXIII, 1890.

Part 1.—Annual report for 1889. Lakadong coal-fields, Jaintia Hills. Pectoral and pelvic girdles and skull of Indian Dicynodonts. Vertebrate remains from Nagpur district (with description of fish-skull). Crystalline and metamorphic rocks of Lower Himalayas, Garhwál and Kumaun, Section IV. Bivalves of Olive-group, Salt-range. Mud-banks of Travancore coasts.

Part 2 (out of print).—Petroleum explorations in Harnai district, Baluchistan. Sapphire Mines of Kashmir. Supposed Matrix of Diamond at Wajra Karur, Madras. Sonapet Gold-field. Field notes from Shan Hills (Upper Burma). New species of Syringosphæridæ.

Part 3 (out of print).—Geology and Economic Resources of Country adjoining Sind-Pishin Railway between Sharigh and Spintangi, and of country between it and Khattan. Journey through India in 1888-89, by Dr. Johannes Walther. Coal-fields of Lairungao, Maosandram, and Mao-be-lar-kar, in the Khasi Hills. Indian Steatite. Provisional Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in Indian Empire.

Part 4 (out of print).—Geological sketch of Naini Tal; with remarks on natural conditions governing mountain slopes. Fossil Indian Bird Bones. Darjiling Coal between Lisu and Ramthi rivers. Basic Eruptive Rocks of Kadapah Area. Deep Boring at Lucknow. Coal Seam of Dore Ravine, Hazara.

Vol. XXIV, 1891.

Part 1.—Annual report for 1890. Geology of Salt-range of Punjab, with re-considered theory of Origin and Age of Salt-Marl. Graphite in decomposed Gneiss (Laterite) in Ceylon. Glaciers of Kabru, Pandim, etc. Salts of Sambhar Lake in Rajputana, and 'Reh' from Aligarh in North-Western Prvinces. Analysis of Dolomite from Salt-range, Punjab.

Part 2.—Oil near Moghal Kot, in Sheráni country, Suleiman Hills. Mineral Oil from Suleiman Hills. Geology of Lushai Hills. Coal-fields in Northern Shan States. Reported Namsèka Ruby-mine in Mainglôn State. Tourmaline (Schorl) Mines in Mainglôn State.—Salt-spring near Bawgyo, Thibaw State.

Part 3 (out of print).—Boring in Daltongunj Coal-field, Palamow. Death of Dr. P. Martin Duncan. Pyroxenic varieties of Gneiss and Scapolite-bearing Rocks.

Part 4.—Mammalian Bones from Mongolia. Darjiling Coal Exploration. Geology and Mineral Resources of Sikkim. Rocks from the Salt-range, Punjab.

Vol. XXV, 1892.

Part 1.—Annual report for 1891. Geology of Thal Chotiáli and part of Mari country. Petrological Notes on Boulder-bed of Salt-range, Punjab. Sub-recent and Recent Deposits of valley plains of Quetta, Pishin, and Dasht-i-Bedaolat; with appendices on Chamans of Quetta; and Artesian water-supply of Quetta and Pishin.

Part 2 (out of print).—Geology of Saféd Kóh. Jherria Coal-field.

Part 3.—Locality of Indian Tscheffkinite. Geological Sketch of country north of Bhamo. Economic resources of Amber and Jade mines area in Upper Burma. Iron-ores and Iron Industries of Salem District. Riebeckite in India. Coal on Great Tenasserim River, Lower Burma.

Part 4.—Oil Springs at Moghal Kot in Shirani Hills. Mineral Oil from Suleiman Hills. New Amber-like Resin in Burma. Triassic Deposits of Salt-range.

VOL. XXVI, 1893.

Part 1.—Annual report for 1892. Central Himalayas. Jadeite in Upper Burma. Burmite, new Fossil Resin from Upper Burma. Prospecting Operations, Mergui District, 1891-92.

Part 2.—Earthquake in Baluchistan of 20th December 1892. Burmite, new amber-like fossil resin from Upper Burma. Alluvial deposits and Subterranean water-supply of Rangoon.

Part 3.—Geology of Sherani Hills. Carboniferous Fossils from Tenasserim. Boring at Chandernagore. Granite in Tavoy and Mergui.

Part 4.—Geology of country between Chappar Rift and Harnai in Baluchistán. Geology of part of Tenasserim Valley with special reference to Tendau-Kamapying Coal-field. Magnetite containing Manganese and Alumina. Hislopite.

VOL. XXVII, 1894.

Part 1.—Annual report for 1893. Bhaganwala Coal-field, Salt-range, Punjab.

Part 2 (out of print).—Petroleum from Burma. Singareni Coal-field, Hyderabad (Deccan). Gohna Landslip, Garhwal.

Part 3 (out of print).—Cambrian Formation of Eastern Salt-range. Giridih (Karharbari) Coal-fields. Chipped (?) Flints in Upper Miocene of Burma. Velates Schmideliana, Chemn., and Provelates grandis, Sow. sp., in Tertiary Formation of India and Burma.

Part 4.—Geology of Wuntho in Upper Burma. Echinoids from Upper Cretaceous System of Baluchistán. Highly Phosphatic Mica Peridotites intrusive in Lower Gondwana Rocks of Bengal. Mica-Hypersthene-Hornblende-Peridotite in Bengal.

VOL. XXVIII, 1895.

Part 1.—Annual report for 1894. Cretaceous Formation of Pondicherry. Early allusion to Barren Island. Biblicgraphy of Barren Island and Narcondam from 1884 to 1894.

Part 2.—Cretaceous Rocks of Southern India and geographical conditions during later cretaceous times. Experimental Boring for Petroleum at Sukkur from October 1893 to March 1895. Tertiary system in Burma.

Part 3.—Jadeite and other rocks, from Tammaw in Upper Burma. Geology of Tochi Valley. Lower Gondwanas in Argentina.

Part 4.—Igneous Rocks of Giridih (Kurhurbaree) Coal-field and their Contact Effects. Vindhyan system south of Sone and their relation to so-called Lower Vindhyans. Lower Vindhyan area of Sone Valley. Tertiary system in Burma.

VOL. XXIX, 1896.

Part 1.—Annual report for 1895. Acicular inclusions in Indian Garnets. Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks.

Part 2.—Ultra-basic rocks and derived minerals of Chalk (Magnesite) hills, and other localities near Salem, Madras. Corundum localities in Salem and Coimbatore districts, Madras. Corundum and Kyanite in Manbhum district, Bengal. Ancient Geography of "Gondwanaland." Notes.

Part 3.—Igneous Rocks from the Tochi Valley. Notes.

Part 4.—Steatite mines, Minbu district, Burma. Lower Vindhyan (Sub-Kaimur) area of Sone Valley, Rewah. Notes.

VOL. XXX, 1897.

Part 1.—Annual report for 1896. Norite and associated Basic Dykes and Lava-flows in Southern India. Genus Vertebraria. On Glossopteris and Vertebraria.

Part 2.—Cretaceous Deposits of Pondicherri. Notes.

Part 3.—Flow structure in igneous dyke. Olivine-norite dykes at Coonoor. Excavations for corundum near Palakod, Salem District. Occurrence of coal at Palana in Bikanir. Geological specimens collected by Afghan-Baluch Boundary Commission of 1896.

Part 4.—Nemalite from Afghanistan. Quartz-barytes rock in Salem district, Madras Presidency. Worn femur of Hippopotamus irravadicus, Caut. and Falc., from Lower Pliocene of Burma. Supposed coal at Jaintia, Baxa Duars. Percussion Figures on micas. Notes.

VOL. XXXI, 1904.

Part 1 (out of print).—Prefatory Notice. Copper-ore near Komai, Darjeeling district. Zewan beds in Vihi district, Kashmir. Coal deposits of Isa Khel, Mianwali district, Punjab. Um-Rileng coal-beds, Assam. Sapphirine-bearing rock from Vizagapatam district. Miscellaneous Notes. Assays.

Part 2 (out of print).—Lt.-Genl. C. A. McMahon. Cyclobus Haydeni Diener. Auriferous Occurrences of Chota Nagpur, Bengal. On the feasibility of introducing modern methods of Coke-making at East Indian Railway Collieries, with supplementary note by Director, Geological Survey of India. Miscellaneous Notes.

Part 3 (*out of print*).—Upper Palæozoic formations of Eurasia. Glaciation and History of Sind Valley. Halorites in Trias of Baluchistan. Geology and Mineral Resources of Mayurbhanj. Miscellaneous Notes.

Part 4 (*out of print*).—Geology of Upper Assam. Auriferous Occurrences of Assam. Curious occurrence of Scapolite from Madras Presidency. Miscellaneous Notes. Index.

VOL. XXXII, 1905.

Part 1 (*out of print*).—Review of Mineral Production of India during 1898—1903.

Part 2 (*out of print*).—General report, April 1903 to December 1904. Geology of Provinces of Tsang and Ü in Tibet. Bauxite in India. Miscellaneous Notes.

Part 3 (*out of print*).—Anthracolithic Fauna from Subansiri Gorge, Assam. Elephas Antiquus (Namadicus) in Godavari Alluvium. Triassic Fauna of Tropites-Limestone of Byans. Amblygonite in Kashmir. Miscellaneous Notes.

Part 4.—Obituary notices of H. B. Medlicott and W. T. Blanford. Kangra Earthquake of 4th April 1905. Index to Volume XXXII.

VOL. XXXIII, 1906.

Part 1 (*out of print*).—Mineral Production of India during 1904. Pleistocene Movement in Indian Peninsula. Recent Changes in Course of Nam-tu River, Northern Shan States. Natural Bridge in Gokteik Gorge. Geology and Mineral Resources of Narnaul District (Patiala State). Miscellaneous Notes.

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Part 4 (*out of print*).—Composition and Quality of Indian Coals. Classification of the Vindhyan System. Geology of State of Panna with reference to the Diamond-bearing Deposits. Index to Volume XXXIII.

VOL. XXXIV, 1906.

Part 1.—Fossils from Halorites Limestone of Bambanag Cliff, Kumaon. Upper-Triassic Fauna from Pishin District, Baluchistan. Geology of portion of Bhutan. Coal Occurrences in Foot-hills of Bhutan. Dandli Coal-field : Coal outcrops in Kotli Tehsil of Jammu State. Miscellaneous Notes.

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VOL. XXXV, 1907.

Part 1 (*out of print*).—General report for 1906. Orthophragmina and Lepidocyclina in Nummulitic Series. Meteoric Shower of 22nd October 1903 at Dokáchi and neighbourhood, Dacca district.

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Part 4.—Preliminary survey of certain Glaciers in North-West Himalaya. B.—Notes on certain Glaciers in Lahaul. C.—Notes on certain Glaciers in Kumaon. Index to Volume XXXV.

VOL. XXXVI. 1907-08.

Part 1.—Petrological Study of Rocks from hill tracts, Vizagapatam district, Madras Presidency. Nepheline Syenites from hill tracts, Vizagapatam district, Madras Presidency. Stratigraphical Position of Gangamopteris Beds of Kashmir. Volcanic out-burst of Late Tertiary Age in South Hsenwi, N. Shan States. New suidæ from Bugti Hills, Baluchistan. Permo-Carboniferous Plants from Kashmir.

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VOL. XXXVII, 1908-09.

Part 1 (*out of print*).—General report for 1907. Mineral Production of India during 1907. Occurrence of striated boulders in Blaini formation of Simla. Miscellaneous Notes.

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VOL. XXXIX, 1910.

Quinquennial Review of Mineral Production for 1904 to 1908. Index to Volume XXXIX.

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VOL. XI, 1878.

Part 1.—Annual report for 1887. Geology of Upper Godavari basin, between river Wardha and Godavari, near Sironcha. Geology of Kashmir, Kishtwar, and Pangi. Siwalik mammals. Palæontological relations of Gondwana system. 'Erratics in Punjab.'

Part 2.—Geology of Sind (second notice). Origin of Kumaun lakes. Trip over Milam Pass, Kumaun. Mud volcanoes of Ramri and Cheduba. Mineral resources of Ramri, Cheduba and adjacent islands.

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Part 4.—Geological 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). Siwalik mammalia. Siwalik birds. Tour through Hangrang and Spiti. Mud eruption in Ramri Island (Arakan). Braunite, with Rhodonite, from Nagpur, Central Provinces. Palæontological notes from Satpura coal-basin. Coal importations into India.

Part 2.—Mohpani coal-field. Pyrolusite with Psilomelane at Gosalpur, Jabalpur district. Geological reconnaissance from Indus at Kushalgarh to Kurram at Thal on Afghan frontier. Geology of Upper Punjab.

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Part 4.—'Attock Slates' and their probable geological position. Marginal bone of undescribed tortoise, from Upper Siwaliks, near Nila, in Potwar, Punjab. Geology of North Arcot district. Road section from Murree to Abbottabad.

VOL. XIII, 1880.

Part 1.—Annual report for 1879. Geology of Upper Godavari basin in neighbourhood of Sironcha. Geology of Ladak and neighbouring districts. Teeth of fossil fishes from Ramri Island and Punjab. Fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Fossil plants from Kattywar, Shekh Budin, and Sirgujah. Volcanic foci of eruption in Konkan.

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VOL. XIV, 1881.

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Part 4.—Unification of geological nomenclature and cartography. Geology of Arvali region, central and eastern. Native antimony obtained at Pulo Obin, near Singapore. Turgite from Juggiapett, Kistnah district, and zinc carbonate from Karnul, Madras. Section from Dalhousie to Pangi, *viâ* Sach Pass. South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1 (out of print).—Annual report for 1881. Geology of North-West Kashmir and Khagan. Gondwana labyrinthodonts. Siwalik and Jamna mammals. Geology of Dalhousie, North-West Himalaya. Palm leaves from (tertiary) Murree and Kasauli beds in India. Iridosmine from Noa-Dihing river, Upper Assam, and Platinum from Chutia Nagpur. On (1) copper mine near Yongri hill, Darjiling district; (2) arsenical pyrites in same neighbourhood; (3) koalin at Darjiling. Analyses of coal and fire-clay from Makum coal-field, Upper Assam. Experiments on coal of Pind Dadun Khan, Salt-range, with reference to production of gas, made April 29th, 1881. Proceedings of International Congress of Bologna.

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Vol. XVI, 1883.

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Part 2 (out of print).—Synopsis of fossil vertebrata of India. Bijori Labyrinthodont. Skull of Hippotherium antilopinum. Iron ores, and subsidiary materials for manufacture of iron, in north-eastern part of Jabalpur district. Laterite and other manganese-ore occurring at Gosulpore, Jabalpur district. Umaria coal-field.

Part 3.—Microscopic structure of some Dalhousie rocks. Lavas of Aden. Probable occurrence of Siwalik strata in China and Japan. Mastodon angustidens in India. Traverse between Almora and Mussooree. Cretaceous coal-measures at Borsora, in Khasia Hills, near Laour, in Sylhet.

Part 4.—Palæontological notes from Daltonganj and Hutar coal-fields in Chota Nagpur. Altered basalts of Dalhousie region in North-Western Himalayas. Microscopic structure of some Sub-Himalayan rocks of tertiary age. Geology of Jaunsar and Lower Himalayas. Traverse through Eastern Khasia, Jaintia, and North Cachar Hills. Native lead from Maulmain and chromite from the Andaman Islands. Fiery eruption from one of mud volcanoes of Cheduba Island, Arakan. Irrigation from wells in North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1.—Annual report for 1883. Smooth-water anchorages or mud-banks of Narrakal and Alleppy on Travancore coast. Billa Surgam and other caves in Kurnool district. Geology of Chauari and Sihunta parganas of Chamba. Lyttonia, Waagen, in Kuling series of Kashmir.

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