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On the Cambrian Formation *of the* Eastern Salt Range.

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(With a Plate.)

It is one of the strange features in the Geology of the Salt Range, that the strata belonging to the older palæozoic age have for a long time been misapprehended, although they form petrographically as well as palæontologically a conspicuous series in the eastern part of the range. While visiting the country during the season 1893-94, I had the good luck when studying a section near Baghanwalla to discover after a long search the first authenticated fossils in the Magnesian sandstone. Besides Baghanwalla, I was able to study the development of the Cambrian formation at several other localities between that place and Khewra, which has put me in the position to give a further contribution towards its interpretation, which to a certain degree must modify the views hitherto held. I regret that I am unable to give a description of the interesting fauna which I collected, but in accordance with the views of the Director of the Survey it has been decided to send the fossils to Dr. Waagen at Vienna, who is still engaged on the description of the Salt Range Fossils found hitherto, in order to enable him to give a more detailed and concise description of this fauna. The way some Cambrian fossils were originally included by him, among those of carboniferous and permo-carboniferous age, and the manner in which the question of the Cambrian fauna has eventually got mixed up in the discussion of the geological results of the study of the younger palæozoic fauna, tend by no means to render the whole matter intelligible to the student of Salt Range Geology. I therefore feel obliged, before communicating my own observations, to review the whole state of this question.

I.—Historical Summary.

Mr. Wynne[1] mentions for the first time the existence of pre-carboniferous rocks in the Salt Range, which according to the fossils they contained, were considered of Silurian age. Mr. Wynne specially states "on the strength of Dr. Waagen's determination, who was able to free the internal aspect of a few of the valves, so as to enable them to be determined as belonging to two species of *Obolus* and *Siphonotreta*," that the "Obolus shales" as they were thenceforth called, were considered to be of Silurian age. The late Dr. Stoliczka was apparently of the same opinion as regards the generic position of these fossils (*ibid*, page 68).

[1] Geology of the Salt Range in the Punjab. Mem. Geol. Surv. of India, vol. xiv, page 86.

Professor Waagen, however, in his subsequent book on the Productus Limestone[1] has abandoned the view previously held by him; and in the preface even strongly combats the view of the Silurian age of the "Obolus," or, as he now calls them, the "Neobolus" shales. Professor Waagen after having particularly laid stress upon the intimate connection of the "Pseudomorphic Salt-crystal Zone," the "Magnesian sandstone," and the "Neobolus bed," a view which is perfectly correct as we shall presently see, continues: "We can fairly say this group follows immediately below upper carboniferous beds, and must thus be of lower carboniferous age. I cannot see anything unreasonable in these deductions; and among all possibilities these seem to me again and again the most probable ones. The palæontological facts are decidedly in opposition to the view of these beds being Silurian, not a single species or even genus being identical, and the geological facts, without straining them in any way, can be interpreted so as to let these beds appear as of carboniferous age."

I fully agree with Dr. Waagen as to the appearance of the fossils, the chief forms of which belong to genera decidedly different from *Obolus;* and that, failing the presence of further fossils of a decisive character, the Silurian age of the Obolus shales was no longer above every suspicion. On the other hand, I cannot help noticing the close relationship of the new genus *Davidsonella* with the genus *Obolella*, Bill. I must confess that I think the genus *Davidsonella* is so closely related to *Obolella*, if not identical altogether, that I would have preferred to have it included in that genus; and weighing the evidence thus at hand, I would have preferred to consider the Obolus shales of Silurian, rather than of Carboniferous age, for which view there was more support, palæontologically as well as stratigraphically, than for the latter one. Palæontologically, on account of a genus from the family of the Trimerellidæ, closely related to, if not identical with, *Obolella*; stratigraphically, because the close connection between the Magnesian Sandstone group, the Pseudomorphic Salt-crystal group, and the overlying rocks of undoubted carboniferous age is nowhere so well developed as Professor Waagen assumes it to be, and as subsequent observations have proved.

It is greatly to be regretted that the subsequent discoveries were not made in time, so as to allow Professor Waagen to amend his views regarding the age of the Neobolus shales before the publication of Vol. IV of the SALT-RANGE FOSSILS containing the "Geological Results"; otherwise he would not have been obliged to modify on page 51 ff. his views expressed on page 45, where he says: "The name introduced by Mr. Wynne for this group was simply "Silurian": I cannot accept this name on several grounds. Firstly, the fossils occurring in the group, though exhibiting a rather old-looking habitus, cannot, either generically or specifically, be identified with Silurian forms: then even if the beds should yet be proved to be of lower palæozoic age, they could never be taken as equivalent to the Silurian in general, but could no doubt only represent a small part of it; they are most intimately connected with the next following Magnesian sandstone, the Silurian age of which is also rather doubtful.

"The fossils found up to the present in the group give no decisive evidence, but there is some hope that a new search in these beds will furnish more extensive materials. Pending such new and better information, I abstain here from

[1] Palæontologia Indica, Series xiii, Salt-Range Fossils, vol. i. Productus Limestone Fossils.

reuttering my formerly expressed opinion that these beds were lower carboniferous.

"In the meantime it will be most advisable to give these beds a neutral name as "Dark shaly zone" or "Neobolus beds."

Dr. Waagen's modification on page 54 is as follows:—

"With regard to the lower series, there has been detected in the meantime not only the great discordance, which cuts just through the middle of the division, but just while I write these lines I have a letter from Dr. Warth announcing the discovery of Trilobites in the Neobolus beds—specimens which seem to be nearly related to *Conocephalites*. Thus it is no longer possible that the beds below the great unconformity which are of Permian and topmost Carboniferous age, should form one series with the more recent strata above that unconformity, and, therefore, the Lower Series (Productus Limestone) of former times will have to be cut up into two."[1]

The discovery of the Trilobites in the Neobolus shales made a fresh discussion of the age of that group necessary and on page 91 ff. Professor Waagen gives his final views as to the division and age of the pre-carboniferous rocks. He divides the Lower Palæozoic series into two groups in descending order, *viz.*:

2. Magnesian Sandstone group
   - 3 Red shaly zone (Salt-crystal Pseudomorph Zone of Wynne).
   - 2 Magnesian sandstone.
   - 1 Dark shaly zone (Neobolus beds).

1. Purple Sandstone group
   - 4 Upper Purple Sandstone.
   - 3 Rock salt and red gypsum group.
   - 2 Grey gypsum group.
   - 1 Lower Purple Sandstone.

Professor Waagen further remarks, that the most important of these sub-divisions, from a palæontological point of view, is the Neobolus bed, but that "the demarcation of the sub-group is not very easily drawn, though its lower limit against the Purple sandstones of the preceding group is somewhat better defined than the upper one towards the Magnesian sandstone."

A list of fossils, chiefly Brachiopoda, is then given, numbering nine species altogether; to which is added the description of the species collected by Dr. Warth numbering 2 species of Trilobites, 2 Gastropods and 1 Brachiopod, thus bringing the number of the fossils found in the Cambrian of the Salt-Range to 14 species altogether.

In connection with this fauna the age of the strata is discussed, and Professor Waagen eventually (after having remarked that the head of a Trilobite, which had been found by Mr. Middlemiss at Khussak in beds *above* the Brachiopoda strata of the Neobolus beds, undoubtedly represented an *Olenellus*) adopts the following sequence of the faunas as represented in the Cambrian formation of the Salt Range:

4. Olenus fauna.
3. Paradoxides fauna.
2. Olenellus fauna.
1. Neobolus fauna.

[1] By a misprint this passage says exactly the opposite of what the author wanted to express; the beds *below* the great unconformity are not of Permian, but of older age. If we, however, substitute the word "above" for the word "below" and further on read: "with the strata below that unconformity" instead of "with the more recent strata above that unconformity"; the author's views become quite clear.

I regret to say that I cannot agree with Professor Waagen in this view of the sequence of the faunas, which, quite apart from the palæontological, is certainly not borne out by the facts from a stratigraphical point of view, as I shall point out later on.

As it appeared that the exact locality where Dr. Warth had first found the trilobites could not be traced again; a party, consisting of Mr. Middlemiss and Mr. Datta, went up to the Salt Range to verify Dr. Warth's find. Mr. Middlemiss was lucky enough to find at Khussak fort hill, besides other fossils, some exceedingly well-preserved Brachiopoda and numerous fragments of Trilobites. Mr. Middlemiss[1] has given an exceedingly clear and correct section through the Neobolus shales at Khussak, locating the beds containing fossils in such a distinct way that they can be easily recognized again.

II.—The Geological Division of the Cambrian Formation.

My time being rather limited, I devoted my attention chiefly to the study of the fossiliferous Neobolus shales, with no further object originally, than my own information; but when in the course of these studies I found that the Neobolus shales were intimately connected with the Purple sandstone below, and the Magnesian sandstone above, I extended my investigations to these two groups also. As I had not, however, sufficient time to spare, I could not go into such details regarding the last two groups as I have done with the Neobolus beds; and the sections presently described deal chiefly with the structure of this series, and to some extent with that of the Magnesian sandstone, while no details are given regarding the Purple sandstone. However, one of the principal facts I elicited was, that there exists no sharp well-defined boundary between the Purple sandstone and the Neobolus beds (see section in Khewra gorge), the dark red or Purple sandstone passing gradually by light coloured passage beds into the Neobolus beds. This proves that there is no justification for dividing the lower Palæozoic Series of the Salt Range into two distinct or equally important groups. Of course the Purple sandstone will always have to be separated from the Neobolus beds; but I do not think that the two-fold division can be upheld. I, therefore, propose the following sub-division of the Salt Range Cambrian, in descending order:—

4. Bhaganwalla group, or Salt-crystal pseudomorph zone.
3. Jutana group, or Magnesian sandstone.
2. Khussak group, or Neobolus beds.
1. Khewra group, or Purple sandstone.

The whole formation might be called the Punjab Province of the Cambrian formation.

1. The Khewra group or Purple Sandstone.

There still remain some most interesting problems in the Geology of the Salt Range connected with this group; but not having studied its features in detail, I do not venture to express a decided opinion. All I can say is that from what I have seen, I fully agree with the hypothesis promulgated by Mr. Middlemiss,

[1] Records, Geol. Surv. of India, vol. xxiv, page 24.

regarding the quasi-intrusive nature of the salt-marl; and that I thus no longer consider it as an inseparable member of the series of sedimentary rocks forming the Cambrian strata of the Salt Range. I do not want to dwell here on the origin of the salt-marl, this hypothesis having been so ably discussed by my colleague, Mr. Middlemiss; all I desire to say is, that having accepted the above hypothesis as a most probable one, the salt-marl must be excluded from the series forming the lower part of the Cambrian formation in the Salt Range.

Professor Waagen distinguishes four sub-divisions in his Purple sandstone group, one of which has already been eliminated, namely, the Salt-marl. As regards the other three, I agree with Mr. Middlemiss, who is of the opinion that Professor Waagen's so-called lower Purple sandstone might much more easily be explained as an inversion of the overlying Purple sandstone. There remain, therefore, only the two upper members of Professor Waagen's sub-divisions; as to the lower of which I am not in the position to give a definite decision regarding its existence, because, as already pointed out, I have not so carefully studied the Purple sandstone group as those higher up. Until further evidence is to prove the contrary, we may therefore assume that the Khewra group consists of two divisions, the upper of which is formed by the "Purple Sandstone Group" of Wynne.

For details regarding this group I must refer the reader to Mr. Wynne's able memoir on the Geology of the Salt Range. All I can say here is that I frequently found ripple marks, and that it seems to me that the Purple Sandstone gradually thins out towards west. It is certainly not so well developed in the western as in the eastern part of the Salt Range. So far no fossils have been discovered.

Mr. Wynne states that the thickness of the Purple Sandstone varies from 200 to 400 feet.

2. Khussak group or Neobolus beds.

The series immediately following the Khewra group has, from the earliest times, attracted the attention of the geologists working in the Salt Range, not only on account of the marked way in which the dark shales of this group contrast with the dark red of the Purple sandstone below, and the light cream or ochre colour of the Magnesian sandstone above, but also because they are, whatever their real age may be, certainly the oldest formation in the Salt Range containing fossils.

The Khussak group consists of a series of more or less light cream-coloured Dolomites or Dolomitic sandstones in thin layers, alternating with thick beds of dark purple to black shales. The latter being generally preponderating, the appearance of this group is that of a dark-coloured band running along the slope of the hills, and distinctly visible at a great distance. It is intimately connected with the Khewra as well as with the Jutana group, although its boundaries are always well and sharply defined. Mr. Wynne states that the thickness of this group varies from 20 to 150 feet. There is no doubt that the Khussak group reaches its chief development in the eastern part of the Salt Range, where it attains its greatest thickness, and then gradually thins out towards west. I was unfortunately unable to visit those localities west of Khewra, where the Khussak group begins to die out; and the study of the conditions in this part must be left to the future. It will be highly interesting to follow the gradual changes of the Khussak group

from east towards west, but for the purposes of that we must first study its typical development in the eastern part of the Salt Range. The detailed sections which I give further on have proved that the Khussak group may be divided into five sub-divisions, which, although their local development varies greatly, are easily recognisable as such from the position which they invariably hold in the sequence of the beds, and from their fossils. These five sub-divisions are in descending order :—

V. ZONE OF OLENELLUS SP.—Dark compact shales thinly bedded, and subcocretionary, micaceous, but not glauconitic, containing numerous specimens of *Brachiopods* probably belonging to the family of *Trimerellidæ*, and fragments of *Trilobites*, probably belonging to the genus *Olenellus* at some localities; at others dark purple soft sandy shales without any fossils. Thickness 15 to 18 feet.

IV. ZONE OF NEOBOLUS WARTHI.—Thin bedded purple sandy and micaceous shales, full of *Neobolus warthi* Waagen. Thickness appoximately 15 feet. This zone is separated from the preceding one by a band of hard glauconitic sandstone of about 2 feet in thickness, which, notwithstanding its small thickness, is very constant.

III. UPPER ANNELID SANDSTONE.—A series of hard cream-coloured sandstones, flaggy and glauconitic, alternating with soft dark and shaly layers. Thickness about 40 feet. According to Mr. Middlemiss, the top layer of this sub-division contains many "broken shells" at Khussak fort hill, which I, however, could not discover again.

II. ZONE OF HYOLITHES WYNNEI.—Dark purple shales with green patches, lumpy and very brittle. Thickness about 10 feet. Contains numerous specimens of *Hyolithes wynnei* Waagen, besides *Neobolus* (?) sp. and fragments of small *Trilobites*.

I. LOWER ANNELID SANDSTONE.—A series of hard cream-coloured glauconitic sandstones, alternating with darker shaly partings or soft sandy beds. Except one isolated specimen of *Hyolithes* and some bi-valves, the name of which is not known to me, no other fossils have so far been discovered. The sandstone, however, is full of those worm-like traces, which are considered as the tracks of annelids. Approximate thickness about 50 feet.

Zone V varies very much in its petrographical aspect, and at such places where it is typically developed as on the west side of the Bhaganwalla ravine, the southern slope of Khussak Fort Hill, or the western branch of Khewra glen, it forms two beds of dark shale separated by a light cream-coloured micaceous shale. The dark shale is hard, sub-concretionary, thinly bedded and contains numerous fossils, which to my knowledge are the same in both layers.

When not typically developed as in the eastern branch of Khewra glen, or the north slope of Khussak Fort Hill, or Bhaganwalla Fort Hill or numerous other places, it consists of soft dark purple sandy shales containing no fossils. The most striking instance of this facial development may be seen at Bhaganwalla, where on the right side of the ravine, this zone shows its typical development, while just opposite on the other side it shows its abnormal facies. We must therefore suppose that at the time of its deposit, at some particular parts a dark clay was deposited which formed the habitat of a fauna though small in species, numerous in individuals, while at other places a sandy soft clay of dark purple colour was deposited which presented unfavourable conditions for the existence of this fauna.

The different facial development of this zone is a good deal responsible for the erroneous view of the sequence of the faunas as given by Professor Waagen. Professor Waagen was not in the favourable position of having his palæontological conclusions supported by a carefully-worked-out section, he having only such vague terms as "glauconitic sandstone" or "dark shales" to guide him; and it is only too natural, that without knowing their relative position a mistake would occur. It is to be regretted that the first observer, Dr. Warth, was unable to specify the position of the strata in which he found the Trilobites, otherwise this misunderstanding would never have occurred.

I have now to deal with the distribution of the fossils, as determined by Professor Waagen, throughout the subdivisions into which I have divided the Khussah group. I confess that this is rather risky, and I am quite prepared that one or another mistake will take place, but considering that Professor Waagen constructed the sequence of the faunas in the Khussak group on the fossils as determined by him, I must take the risk.

However we have the following facts to guide us:—

1. *Neobolus warthi*, Waagen and the closely related form *Neobolus wynnei*, Waagen do not from what we know at present ascend higher than zone IV, They may probably occur in the lowest subdivision, but to my knowledge *Neobolus warthi* characterises zone IV.
2. *Olenellus* sp. is restricted to zone V at the top of the Khussak group.

On page 92 of his memoir, Professor Waagen gives a list of fossils, stating that they come from the dark shales at the base of the group. They are the following species:—

1. *Discinolepis granulata.* Waagen.
2. *Schizopholis rugosa.* Waagen.
3. *Neobolus warthi.* Waagen.
4. „ *wynnei.* Waagen.
5. *Lakhmina linguloides.* Waagen sp.
6. „ *squama.* Waagen sp.
7. *Lingula kiurensis.* Waagen.
8. „ *warthi.* Waagen.
9. *Fenestella* sp. indet. Waagen.

Altogether nine species. I refrain from expressing my views as to their specific independence, but I think that even Professor Waagen will agree with me that the *Dictyonema*-like fossil can no longer be considerd a *Fenestella*. From personal examination of these fossils I can however fix their position so far that I am convinced that they do not come from zone V, the character of the rock still adhering to them proves that they must come from one of the lower zones, most probably from zone IV.

As regards the fossils mentioned on page 104, the following are from the glauconitic sandstone:—

Olenus (?) *indicus.* Waagen.
Trilobites gen. et. sp. indet.
Hyolithes khussakensis. Waagen.

All I can say is that, to judge from the character of the rock, these fossils may come from any horizon in the zones I to III, even IV; most probably from zone III; they certainly do not come from zone V.

As regards the fossils from the dark concretionary shales, *viz.*:—

Conocephalites warthi. Waagen.
Trilobites gen. et sp. indet.
Hyolithes wynnei. Waagen.
Orthis warthi. Waagen.

we may at once say that the term "dark concretionary shales" is as ill-chosen as possible, and would lead to serious misunderstandings. *Hyolithes wynnei* is imbedded in a rock of purple colour, differing in no way from that in which the first-named fauna of brachiopods was discovered. The other three forms come, certainly from a light coloured rock, and Dr. King's doubts as to the exact horizon of *Conocephalites warthi* Waagen are fully justified. If my views are correct *Hyolithes wynnei* is chiefly found in zone II, although it may ascend higher up, while *Conocephalites warthi* and the two other forms may come from any of the bands of cream-coloured glauconitic sandstone that occur in zones I to III.

Now the result of this criticism is, that the faunas do not exist in the sequence as depicted by Professor Waagen; if we still adhere to the combination as given by him, the sequence of the faunas in descending over would be—

Neobolus fauna,
Olenus fauna,
Conocephalites fauna,

if we take the Trilobites as the representatives of the respective faunas. We would therefore have quite the inverted order in nature from that given by Professor Waagen on page 106, where he gives the sequence of the faunas as—

4. Olenus fauna.
3. Paradoxides fauna.[1]
2. Olenellus fauna.
1. Neobolus fauna.

Now we further know that whatever their respective sequence may be, all the three faunas; Neobolus, Olenus, and Conocephalites are *below* the Olenellus fauna, and the real sequence of the faunas would be in descending order.

4. Olenellus fauna.
3. Neobolus fauna.
2. Olenus fauna.
1. Conocephalites fauna.

Such a succession of faunas in the lower Cambrian would however be against all experience if we suppose that the Conocephalites fauna represent the Paradoxides fauna, and if *Olenus* (?) *indicus* is really an *Olenus*. As we however know for certain that

(*a*) the fauna in zone V, as represented by the Oelnellus fauna, forms the top of the Khussak group;
(*b*) the Neobolus fauna (zone IV) is older than the Olenellus fauna;
(*c*) That the two *Trilobites* determined as *Olenus* (?) *indicus* and *Conocephalites warthi* must come from beds that are either older than the Neobolus fauna (zone IV), or at the outside contemporaneous with it

[1] Professor Waagen considers the Conocephalites fauna as the equivalent of the Paradoxides fauna of Europe.

we must come to the conclusion that the two Trilobites, determined as *Olenus* (?) *indicus* and *Conocephalites warthi*, do not belong to the genera they are supposed to do, and that the two faunas, if they really exist as such, represent a perfectly different horizon from what they were supposed to do by Professor Waagen. Here we will have to wait for future discoveries to throw some light on this rather vexed question.

All that we can say with certainty for the present is, that at the top of the Khussak formation a fauna occurs, which is most likely the equivalent of the Olenellus fauna of other countries, while for those faunas below it, no representative can be found in the Cambrian strata of other countries.

Professor Waagen's view that the strangeness of the fauna of the Neobolus shales may be explained by the fact that it is older than any other Cambrian fauna, is therefore fully confirmed by the above arguments, only not quite exactly in the way he was led to conjecture. Until proved otherwise, the following species as representatives of the Neobolus fauna must therefore be considered as some of the earliest forms of animal life, *viz.*:—

Neobolus warthi, Waagen.
Neobolus wynnei, Waagen.
Hyolithes wynnei, Waagen.

Besides which there existed undoubtedly a rich fauna of various species of annelids which left their traces in the shape of various tracks on the surface of the sandstones.

3. The Jutana or magnesian sandstone group.

No more unfortunate name could have been selected for this group than "Magnesian sandstone." According to the analysis of its author, Dr. Fleming,[1] it is a dolomite with an admixture of quartz sand. A specimen of Magnesian sandstone will resemble any other rock but "sandstone." The term Magnesian sandstone having however been adopted in all the papers dealing with the geology of the Salt Range, it would be inopportune to change it now.

The Jutana group is naturally divided into five subdivisions, which, although of nearly the same petrographical habitus, are easily distinguished from a long distance even. The subdivision is produced by the occurrence of shaly, thinly laminated beds which easily weather and crumble to pieces, thus forming gently inclined sloping terraces between the bold cliffs below and above. The sketch of Jutana glen (see Plate 1) gives a very fair idea of the natural appearance of this group.

Hitherto the Jutana group has been considered unfossiliferous, except the highly doubtful specimen of *Sigmodus dubius*, Waagen, which, in all probability does not come from the Magnesian sandstone at all: I was, however, lucky in discovering the *first fossils* which certainly prove the faunistic connection of the Jutana group with the older Khussak group.

When going up the Bhaganwalla ravine, I noticed that the surface of a thin band of hard limestone was covered with some fossils; unfortunately I could, only secure without blasting, a fairly-sized piece; this, however, was sufficient to prove that they represented a species of the genus *Stenotheca*. On my return, comparing

[1] See Wynne's memoir, page 88.

it with other species, I could not help noticing the great likeness with *Stenotheca rugosa, var. aspera, Billings.*[1] If my view is correct, this species would form a proof for the lower Cambrian age of the Magnesian sandstone.

Besides this form, I found in a thin bed of rather hard clay, resembling very much the dark shales of the Olenellus-zone, but being of light brown colour, about 50 feet above the base of the Magnesian sandstone, some brachiopods, in one of which I think I recognize a *Lingulella*. Another one resembles very much *Schizopholis rugosa, Waagen*, but I leave it to Professor Waagen to confirm these views or not. Anyhow it seems to me that the lower part of the Magnesian sandstone group at least must also be considered of lower Cambrian age.

As already pointed out, the changes in the composition of the rocks produce a natural division in this series; in descending order we may distinguish the following subdivisions, as coming in numerically over the five zones given in page 76 :—

X. UPPER MAGNESIAN SANDSTONE.—The same as the middle Magnesian sandstone, and forming like that a bold cliff: thickness 30 to 40 feet.

IX. UPPER PASSAGE BEDS.— Petrographically apparently the same as the lower passage beds, and like those forming a gentle slope: thickness about 15 to 20 feet.

VIII. MIDDLE MAGNESIAN SANDSTONE.—A series of thickly bedded grey dolomite forming bold inaccessible cliffs: thickness about 60 feet.

VII. LOWER PASSAGE BEDS.—A series of thinly bedded laminated sandy dolomite alternating with beds of greenish clay; the planes of the sandstone are sometimes micaceous and covered with tracks of annelids. Approximate thickness 20 to 25 feet. The outcrop generally forms a gentle slope.

VI. LOWER MAGNESIAN SANDSTONE.—This subdivision may again be divided into two parts; the lower one consisting of thinly bedded layers of dolomite or sandy dolomite, separated by thin layers of clay, and terminating in a bed of brown hard clay, which contains brachiopods, although not very frequently. In the lower parts pisolitic beds are frequently met with, and on the plane of one bed at least, *Stenotheca* sp. is pretty common. The upper portion consists chiefly of thickly bedded dolomite of grey colour. The lower part sometimes forms a sort of a slope, while the upper part stands out in a bold cliff. Approximate thickness 100 feet.

The above division can be recognized everywhere in the eastern part of the Salt Range, but it seems that already at Khewra the subdivision X, the upper Magnesian sandstone, has disappeared. Anyhow I could not trace it in section I, described in detail below. Now whether it really did not exist in that part, or whether it has been denuded afterwards is a question that must remain open for the present. As we know that the Magnesian sandstone gradually disappears towards the west, it is not quite improbable that the Upper Magnesian sandstone, as noticed near Bhaganwalla or Jutana, has already disappeared at Khewra. It would be highly interesting to follow the continuation of the Magnesian Sandstone west of Khewra, and to record in detail the changes that take place in its structure. I am fully convinced that this would result in some remarkable discoveries.

4. THE BHAGANWALLA GROUP OR SALT-CRYSTAL PSEUDOMORPH GROUP.

With reference to this group, I must refer the reader to Mr. Wynne's and Professor Waagen's papers, as I have not devoted much time to its study, but

[1] Charles D. Walcott. The fauna of the lower Cambrian or Olenellus zone. United States Geological Survey, Tenth Annual Report, 1888-89, page 617, fig. 3.

several things seem to me beyond doubt. It is certainly most intimately connected with the Magnesian sandstone below, the flaggy layers can hardly be distinguished from the dolomite below. It is further certain that it dies out rapidly to the west and although still well developed at Khussak, it has nearly disappeared near Khewra. No fossils have yet been found in this group.

I may here mention that at Khussak the top beds of this group have been worked up in such a way by the boulder clay that boulders are kneaded into it, while flakes of the Bhaganwalla group have been taken up and imbedded in the boulder clay. No further instance is required for the striking unconformity above the Bhaganwalla group, which was first noticed by Mr. Oldham.[1]

III.—Detailed Sections.

Section I. In Khewra glen, just above the masonry wall damming up the valley, western branch, in descending order.

17. *Magnesian sandstone*, thickly bedded, standing out in a bold cliff, approximately 60 feet.
16. „ very shaly and thinly bedded, forms a sloping escarpment 20 feet
15. „ thickly bedded and shaly towards the base, about 100 feet, forms aconspicuous cliff.
14. *Dark blue hard shales*, micaceous, but not glauconitic; thinly bedded, to some extent concretionary; thickness about 15 feet. *Obolella* (?) sp. rare.
13. *Cream-coloured sandstone*, hard and flaggy in thin beds, 2 feet in thickness.
12. *Dark purple shales*, occasionally with green patches; brittle and lumpy, very sandy glauconitic only to a small degree; 15 feet in thickness. *Neobolus warthi* Waagen, very common.
11. *Light cream-coloured sandstone*, very glauconitic; formed by a series of harder beds alternating with softer layers, terminating in a well-defined bed of about 2½ feet in thickness of very hard cream-coloured Magnesian sandstone. Total thickness about 20 feet.
10. *Dark purple shales*, lumpy and very brittle; very glauconitic; numerous tracks of *annelids*; 10 feet in thickness.
9. *Dark purple sandstone*, with lighter patches, micaceous and very glauconitic, 4 feet.
8. *Cream-coloured sandstone*, with purple patches, very glauconitic, 15 feet.
7. *Dark greyish-green sand*, with purple patches, 20 feet; the clayey beds getting thicker towards the top, where they alternate with irregular layers of cream-coloured sandstone, which become honeycombed or cellular where exposed.
6. *Greyish green sandy shales*, 15 feet, the same as No. 4, but dark purple patches occur frequently.
5. *Dirty green, coarse sand*, 2 feet 10 inches.
4. *Greyish-green sandy shales*, 12 feet 3 inches in thickness. The shale is thinly bedded, and consists chiefly of thin layers of brittle sandstone alternating with equally thin beds of clay. Numerous impressions of *Annelid*-marks on the sandstone.
3. *Light coloured conglomerate*, 2 feet in thickness.
2. *Greyish-green shale*, 2 inches in thickness, which is followed by,—
1. *Purple sandstone* in thick beds, approximately not less than 200 feet in thickness; the top layers gradually get lighter and eventually change into a cream-coloured coarse layer which terminates the purple sandstone.

[1] Records, Geological Survey of India, Vol. xix.

Owing to the inaccessibility of the cliffs, the upper part of the section could not be measured, and the thickness of the different strata is only given approximately.

The various beds, of which the above section consists, which form a bold cliff in the upper part of the Khewra glen, can be divided into three larger groups, representing in descending order—

C. Magnesian sandstone approximately 180 feet in thickness.
B. Neobolus shales „ 140 „ „
A. Purple sandstone „ 200 „ „

The above three members of the Cambrian formation of the Salt Range are so clearly visible from a long distance even, that they cannot possibly be mistaken, and although if examined closely, they gradually pass into each other, there is not the slightest doubt as to the actual boundaries.

It now remains to be seen whether we are able to trace well defined subdivisions in the above section. As regards the purple sandstone or Khewra group, I did not try to sub-classify it, but as regards the Khussak and Jutana group (Neobolus shales and Magnesian sandstone), some exceedingly well defined subdivisions can be marked out.

In the Jutana group we can distinguish three subdivisions, *viz.*, in descending order :—

VIII. Middle Magnesian sandstone hard and thickly bedded; thickness about 60 feet.

VII. Shaly intermediate layer, with numerous annelid-tracks, about 20 feet.

VI. Lower Magnesian sandstone, shaly and thinly bedded in the lower, thickly bedded in the upper part; forms a bold cliff. Thickness about 100 feet.

In the Khussak group we can distinguish five sub-divisions, which are well defined and which can be seen from a long distance, by either forming bold cliffs or gently sloping escarpments. In descending order, the subdivisions are as follows :—

V. Dark black shales ; zone of *Olenellus* sp. Thinly bedded and sub-concretionary; micaceous but not glauconitic. Forms a gently sloping terrace. Thickness about 15 feet.

IV. Dark purple shales, lumpy and brittle, zone of *Neobolus warthi, Waagen* ; thickness 15 feet, separated from No. 5 by a bed of cream-coloured sandstone (Nos. 12 and 13 of the above section).

III. Glauconitic sandstone. A series of more or less flaggy, hard cream-coloured, glauconitic sandstones, alternating with clayey layers. Thickness about 20 feet. No fossils except annelid marks.

II. Dark purple shales, lumpy and brittle, micaceous ; 10 feet; no fossil remains except annelid-tracks; generally forms a gently sloping terrace. No. 10 of the above section.

I. Glauconitic sandstone, a series of cream-coloured sandstones which are slightly darker towards the base, alternating with softer sandy layers of generally darker colour. Thickness about 50 feet, excepting annelid-tracks, no organic remains. Includes in the above section the beds from No. 2 to 9 inclusive.

Section 2. In Khewra glen, just above the masonary wall damming the valley, eastern branch.

In the eastern branch of the Upper Khewra glen, the Jutana group can be studied a little more in detail, as owing to the northerly dip the strata composing this group were brought within reach. As the beds forming the Khussak group (Neobolus shales) are exactly the same as in the western branch of the glen, except

that bed V (dark shales upper layer) is more like bed IV in its petrographical habitus, it is unnecessary to reiterate them again. The Jutana group consists of the following beds in descending order:—

5. *Cream-coloured hard dolomite*, in thick beds; forms always bold cliffs.
4. *Thinly bedded, flaggy, cream-coloured dolomite*, with numerous tracks of annelids on the parting planes, separated by thin layers of greenish clay: generally forms a gently sloping terrace.
3. *Cream-coloured hard dolomite* in thick layers, separated by thin beds of greenish clay. No fossils. Thickness about 70 feet.
2. *Dark shale*, pretty hard, thinly bedded and sub-concretionary; contains *Linguella* sp.[1] in small numbers. Thickness 1 foot 6 inches. This bed forms such a distinct parting in the lower magnesian sandstone, that, notwithstanding its very small thickness, it can be seen from a long distance.
1. *Cream-coloured hard dolomite*, in thin flaggy layers separated by thin layers of greenish clay. Thickness 25 feet.

Section 3. At Khussak Fort Hill, Southern Slope.

The lower part of this section could not be studied in detail, owing to the steepness of the slope which rendered it inaccessible. Mr. Middlemiss' section V forms the top of this section; in descending order:—

12. *Magnesian sandstone*, in thin beds.
11. *Dark, hard shale*, thinly bedded and sub-concretionary, with numerous specimens of *Obolella* (?) sp. and fragments of *Trilobites*. Thickness 3 feet 8 inch.
10. *a*. Dark grey, streaky, soft sandstone thinly bedded, thickness 1 foot 4 inch.
b. Light grey, thinly laminated, micaceous sandstone, in which darker streaks alternate with lighter ones, 3 inches.
c. Dark brown coloured, thinly laminated, micaceous sandstone, which gradually passes into the next bed; thickness 3 inches.
9. *Dark shale*, thinly bedded, but hard and fissile; micaceous, contains fragments of *Olenellus* sp. and *Obloella* (?) sp. Thickness 2 feet 9 inch.
8. *Glauconitic shale*, ·6 inch.
7. *Glauconitic sandstone*, thinly laminated, ·4 inch.
6. *Glauconitic, soft sandstone*, alternating with layers of hard, cream-coloured sandstone. Thickness 4 feet.
5. *Glauconitic sandstone*, very hard, 0·4 inch.
4. *Dark purple shales* alternating with flaggy layers of cream-coloured sandstone. *Annelid*-marks very frequent. Thickness 5 feet.
3. *Dark purple shale*, with green patches, very micaceous, soft. Thickness 8 feet, *Neobolus warthi*, Waagen common.
2. *Cream-coloured sandstone*, alternating with irregular layers of purple clay, terminating in a bed of hard sandstone.
1. *Purple sandstone.*

In the above section, beds Nos. 3 and 4 represent No. IV in the subdivisional grouping of the Khussak group which here has about 13 feet thickness; the sandstone parting between Nos. IV and V has 5 feet 2 inch in thickness, and then follows group No. V, the dark fossiliferous shales which have an aggregate thickness of 8 feet 3 inch, represented by the beds from No. 9 to No. 11.

Section 4. At Khussak Fort Hill, Northern Slope.

Although this section has been described in detail by Mr. Middlemiss, it will

[1] The determination of this form is doubtful. I refrain, however, from anticipating Dr. Waagen's views.

be useful to give it here in detail, so as to make comparison with other sections more easy. In descending order :—

11. Magnesian sandstone.

10. Dark purple shale, soft, lumpy and thinly bedded ; capped by a bed of cream-coloured sandstone. Thickness 10 feet.

9. Cream-coloured sandstone, firm in the middle, but shaly towards the basis, and alternating with clayey layers. Thickness 7 feet.

8. Dark purple shale, with green patches ; very glauconitic and micaceous ; contains numerous specimens of *Neobolus warthi* Waagen. Thickness 24 feet.

7. a. Hard cream-coloured sandstone, alternating with thin soft layers ; thickness 8 feet 6 inch.

b. Dark sandy shale ; ill seen ; thickness 3 feet.

c. A series of cream-coloured sandstone, alternating with thin clayey beds, terminating with a bed of hard cream-coloured glauconitic sandstone. Thickness 8 feet.

d. Dark purple shale ; thickness 3 feet.

e. Hard cream-coloured sandstone 4 feet.

6. Dark purple and green shales ; contains *Hyolithes wynnei* Waagen, and fragments of Trilobites.

5. a. Cream-coloured, flaggy sandstone ; thickness 3 feet.

b. Dark purple and green shales ; thickness 2 feet.

c. Thinly bedded cream-coloured sandstone ; thickness 3 feet.

d. Lumpy, dark purple and green shale, 0·6 inch.

e. Hard flaggy, cream-coloured sandstone ; thickness 7 feet.

f. Dark soft shale, 1 foot.

g. Cream-coloured glauconitic sandstone ; thickness 3 feet.

4. Dark purple shaly sandstone, alternating with harder beds ; thickness 30 feet.

3. Cream-coloured, glauconitic sandstone, alternating with thin beds of greenish clay ; thickness 10 feet.

2. The same as before ; ill seen ; not measured.

1. Purple sandstone.

Comparing the details of Mr. Middlemiss' section, with that given above, it will be noticed that we differ sometimes, but I do not think this of great importance, because as soon as several of the beds are taken as a whole it will be seen that we fully agree as to the sequence of the strata.

In the above section ; Nos. 2 to 4 represent Mr. Middlemiss' series of "pale cream-coloured, thin-bedded sandy layers with shaly partings and irregular mottlings of hardened purple clay, glauconitic and micaceous." No. 5*a-f*, all the strata above this, but below his Lower Gallery B ; No. 6 represents the Lower Gallery B ; No. 7*a-e*, all the beds above that, but below the "thin bedded purple sandy and micaceous shales"; No. 8 represents the "thin bedded purple sandy and micaceous shales" ; No. 9, the beds between this and the following stratum ; No. 10, the thin bedded purple shales, inclusive of passage beds.

With the greatest ease we recognise in this section the five subdivisions of the Khewra Section ; subdivision I, includes beds Nos. 2 and 3 ; subdivision II, bed No 4, subdivision III, beds 5 to 7, subdivision II, beds 8 and 9, subdivision V, bed No. 10. I need not go into details regarding Mr. Middlemiss' section, the five subdivisions will be easily recognised in his section, but still more so if his sketch of Khussak Fort Hill is looked at, where they will be distinguished at the first glance.

If we now compare the two sections of Khussak Fort Hill, it will be noticed that they materially differ in the development of subdivision V. We can easily identify

subdivision IV and the band of cream-coloured sandstone which separates it from subdivision V, but the latter shows a totally different development. Mr. Middlemiss has not expressed himself quite clearly in which way his section V correlates with section IV, but if I interpret his section on plates 1 and 2 correctly, he thinks that the dark shales containing the rich fauna of Brachiopods and Trilobites are superimposed on the "thin bedded purple shales" above B_3, or in other words that they are not represented in his section IV. The examination of the Khussak group, as developed at Bhaganwalla and Khewra, has however proved that this view cannot be maintained, but that Mr. Middlemiss' beds C and C_1, the dark fissile shales, are only a facial development of the "thin bedded purple shales" with which they are correlative.

Section 4. At Bhaganwalla Ravine, Western Branch.

The wild gorge just above the village of Bhaganwalla, shows some beautiful sections through the strata from the Purple sandstone upwards; and hardly a better place could be selected for the study of the structure of the Salt Range, as some model flexures can be studied here in all their details. As however the sides of the ravine are either exceedingly steep or covered with debris from the Magnesian sandstone, it has not always been possible to give the exact thickness of each single bed, and in this regard the following section lacks in accuracy; however I think that this is not of very great importance, as in this paper I chiefly want to demonstrate the sequence of the strata composing the Cambrian formation of the Salt Range, in order to give a reliable stratigraphical basis for the description of the fossils. In descending order:—

13. *Dolomite* in thick beds.
12. *Dolomite*, flaggy, in thin layers which are very brittle.
11. *Dolomite*, thickly bedded. Thickness 150 feet.
10. *Greenish-grey soft shale*, well defined; containing Brachiopods (*Lingulella ?* sp.) in small numbers. Thickness from 6 inch to 1 foot.
9. *Dolomitic sandstone*, in thin flaggy layers, some of which are pisolitic, in the beds near the base is a bed full of *Stenotheca* sp. Thickness 50 feet.
8. *Dark blue shale*, hard and sub-concretionary; contains the same fossils as No. 6, but in smaller numbers.
7. *Grey micaceous sandstone*, alternating with dark clayey streaks, 3 feet.
6. *Dark black shale*, hard and sub-concretionary; contains a large number of *Obolella* (?) sp. and *Olenellus* sp. Thickness 4 feet.
5. *Flaggy cream-coloured glauconitic sandstone*, alternating with thin beds of dark shale.
4. *a. Dark purple shales*, with green patches, soft and lumpy; contains numerous specimens of *Neobolus warthi* Waagen.
   b. Bed of hard cream-coloured sandstone.
   c. Dark purple shales, thinly bedded.
   d. Band of hard cream-coloured sandstone.
3. *Dark purple shales*, thinly bedded.
2. *A series of thin bedded hard flaggy cream-coloured sandstones*, alternating with beds of softer sandstone or clay.
1. *Purple sandstone.*

In the above sections the five subdivisions of the Khussak group are not so readily seen, owing probably to the incompleteness of the section directly above the purple sandstone; subdivisions Nos. V and IV can be recognized by the fossils; we know that bed No. 4 containing *Neobolus warthi* must represent subdivision

IV; then follows the separating bed of sandstone, while beds 6 to 8 represent group No. V; beds 3 *a-d*, must represent subdivisions II and III, while bed 2 represents the lower glauconitic sandstone. The chief interest remains in the fact that subdivision V is developed exactly in the same way as at Khussak Fort, on the right bank of the ravine, while just opposite on the left bank it shows exactly the same development as on the northern slope of Khussak Hill.

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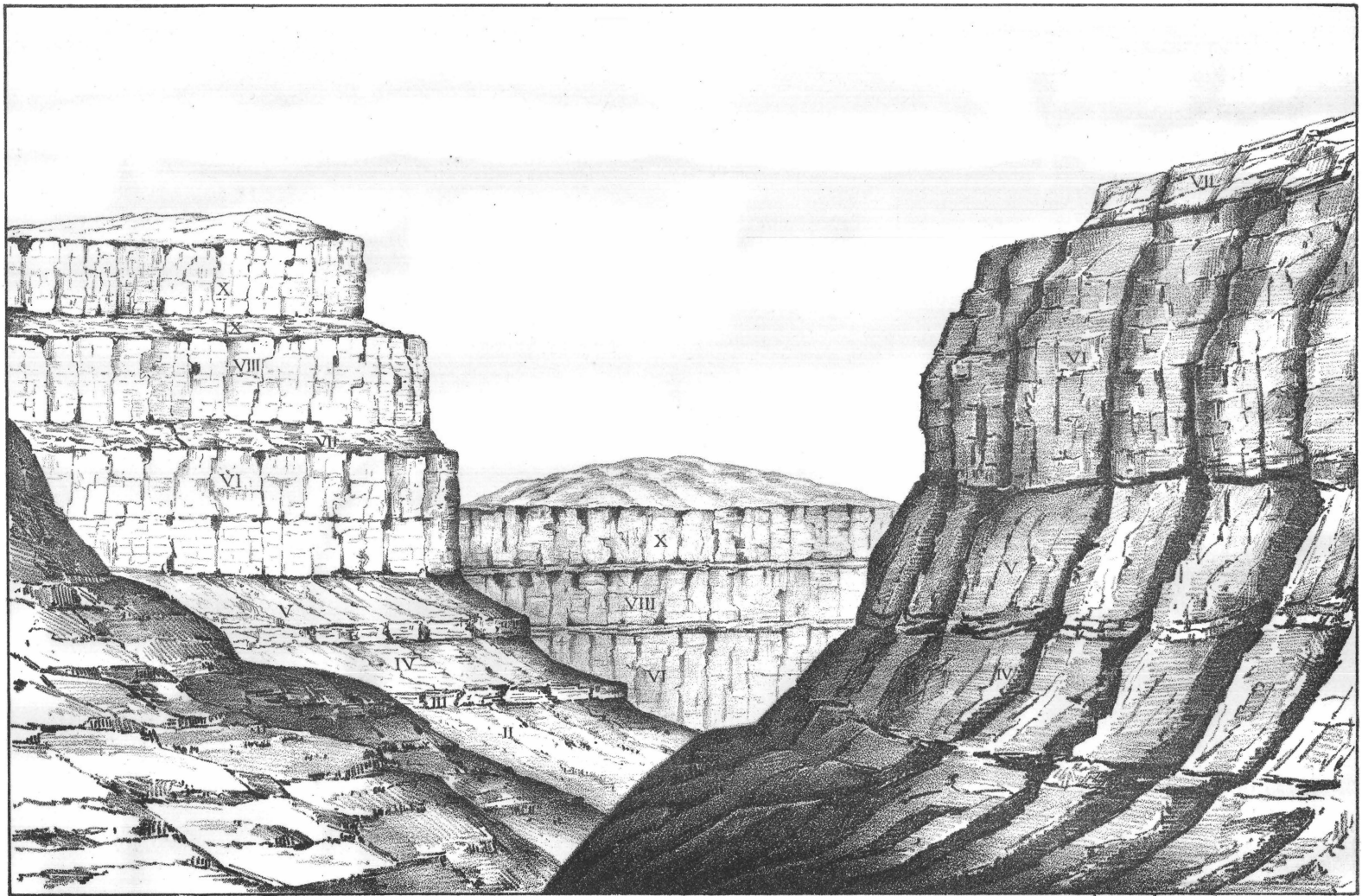

F. Noetling, del.

Litho^{a} & Print^{g} at Geo^{l} Surv Office.

VIEW OF THE MOUTH OF JUTANA GORGE SHOWING THE KHUSSAK, JUTANA, & BHAGANWALLA GROUPS.