I am indebted to Mr. Rupert Jones for the identification of the species, which he describes as

Cardium edule.	Bithinia tentaculata.
Ostræa edulis.	Paludina marginata.
Unio —— ?	Valvata cristata.
Bulimus lackamensis.	—— piscinalis.
Limnæus glaber.	

Besides these I found a small *Helix* and a *Planorbis*, which have been unfortunately broken.

From the numerous species of the land and freshwater shells enumerated by Mr. Morris* from a deposit about twelve miles north of this, I have no doubt that the future researches of the Marchioness of Huntly will add several species to the above list.

The marine shells (*Cardium*) from this pit were given me by the men, from a heap of fragments of bones and bouldered oolitic shells, and were evidently freshly detached from their matrix. Their position in the lower part of the gravel rests on their authority.

At the other pit I extracted the marine shells myself, at the depth, as I have stated, of 7 feet from the surface.

The prevalent fragments in the gravel are derived from various oolitic rocks; they are considerably water-worn, and are mixed with chalk-flints. There are also fragments of flinty slate, quartzose sandstone, and other rocks of more distant origin.

This gravel appears to have been formed from the materials of the denuded boulder-clay, with an increased proportion of oolitic materials brought down by the ancient Nene. Chalk, which abounds in the boulder-clay, has nearly, if not entirely, disappeared from the gravel. The only specimens of it which I could find were small rolled pebbles of the very hardest varieties, in the sand interstratified with the clay in the bed *d* of the preceding section.

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2. *On the* Geological Structure *of part of the* Bavarian Alps; *with Remarks on the* Erratic Phænomena. By Dr. Adolphe Schlagintweit.

[Communicated by Sir R. I. Murchison, F.R.S., F.G.S.]

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* Quart. Journ. Geol. Soc. vol. ix. p. 321.

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   B. Structure of the mountains between the Loisach and the Amper.
4. Remarks upon the Diluvial and Erratic Phænomena.
   On Polished Rock-surfaces.

Introduction.—The observations a brief account of which I have now the honour to lay before the Society refer chiefly to that portion of the Bavarian Alps which includes the affluents of the Loisach and Ammer, and partly of the Tsar, to the south of Munich*.

The group of the Zugspitze and the Wetterstein, between the Loisach and the Tsar, forms the greatest elevation in the outer zone of the Alps from the Lake of Constance to the Salzach. It presents a peculiar attraction to the geologist from its very complicated and irregular structure.

The following observations were made in the autumn of 1852 and in the course of the summer of 1853, more particularly during the latter period. In my investigations I was especially guided by the works of Escher von der Linth and Studer, of Schafhaütl, Emmrich, Von Hauer, and by the excellent memoir of Sir Roderick Murchison, which gives such a clear outline of the succession of the sedimentary strata of the Alps, and of the enormous dislocations and disturbances to which they have been subjected.

In the latter part of my paper I have offered some general remarks upon the diluvial and erratic deposits, and upon the polished and striated rocks connected with this subject.

§ General view of the Formations.

I. *Lower Alpine Limestone* (Unterer Alpenkalk)=*Muschelkalk.*

This is the *lowest* of the formations which are found in the upper affluent valleys of the River Loisach. It consists chiefly of grey dolomites, between which, but rarely, occur strata of dark-coloured grey and brown limestones. Fossils were nowhere found in these dolomites, neither in these parts of the Bavarian Alps nor in the eastern portions explored by Prof. Emmrich.

The dolomites of the inferior Alpenkalk, forming the base of the subsequent fossiliferous strata of the lower Lias, may well be considered as an equivalent of a portion of the Trias.

II. *Lower Lias.*

This formation, which covers a great area in this part of the Bavarian Alps, consists generally of dark-coloured marls and marly limestones. In many places very dark slates, not effervescing with acids, are met with. Occasionally there appear masses of lighter

* The author and his brother, Dr. Hermann Schlagintweit, have in preparation a larger Memoir on the subject of this communication, to be illustrated by a geological map and plates. The map and some of the plates were exhibited to the Meeting, and are referred to in this paper.

coloured and harder limestones, which nevertheless are generally characterized by a certain amount of aluminous contents.

In different places there are found in this formation very remarkable and extensive strata of a finely-grained grey sandstone, becoming brown by decomposition; it contains little pieces of mica, and either effervesces but slightly, or not at all, with acids. These sandstones contain few fossils; I found only some indistinct vegetable impressions and fragments of *Avicula* and *Nucula*.

By investigating the superposition and the mutual relations of the strata, I came to the conclusion that these sandstones were to be considered as a part of the Lower Lias formation.

These sandstones seemed to me to be very analogous with those which in the Vorarlberg and in Austria accompany the "alpine coal," according to Escher and Von Hauer. M. Hauer replied to my suggestions, upon making these comparisons, that he also was inclined to admit, after the inspection of the specimens I had sent him, such an analogy, and that in Austria the sandstones accompanying what was termed alpine coal (Alpenkohle) were now also considered as a part of the Lower Lias formation, though with a different *facies*, and in many respects a different fauna.

All the strata here spoken of, I have laid down on the map under the name of "Lower Lias," which was first used by M. Hauer of Vienna, who admits that these strata must be separated from the Cassian beds, which form the uppermost part of the alpine Trias and contain a very different fauna. Other geologists, Emmrich, Escher, and Merian, are inclined to consider these as an equivalent of the Cassian strata. They endeavour to infer this from the mode of superposition in the southern Alps, and from analogy in some palæontological characters.

According to the recent investigations in the Austrian and in the Bavarian Alps, it seems that we must consider as Upper Muschelkalk the strata of Hallstadt, forming an equivalent of the Cassian beds of Münster and Klipstein with *Ammonites Aon*, &c.

The Lower Lias is considered to comprise as *contemporaneous* deposits:

a. The strata of Kössen = Gervillia-strata of Prof. Emmrich = upper Cassian beds of the Swiss geologists.

b. The Dachstein-limestones with *Cardium triquetrum* (=*Megalodus scutatus*, Schafhaütl).

The fossiliferous portions of the alpine Trias not being exposed in that part of the mountains to which I more closely directed my investigations, I could not obtain any proofs of the relation of the Gervillia-beds and their fauna to that of the lower formations.

The strata of the inferior Lias are in many places very rich in organic remains; the following is a list of the most characteristic and generally distributed of these fossils. They have been collected and determined by myself. Fortunately I was enabled to send specimens of all of them to M. Hauer, who has compared them with the beautiful collection of alpine fossils now accumulating at Vienna.

Ammonites Roberti, *Hauer*; very distinctly found in this forma-

tion in the Lahnewiesgraben; in Austria it had been met with until now only in the next higher formation,—the Upper Lias.

Avicula inæquiradiata, *Schafhaütl.* Many specimens; this species is found, though rarely, in the strata of Kössen in the Austrian Alps.

Avicula intermedia, *Emmrich*; differing from the very similar forms, *Avicula inæquivalvis* and *A. Munsteri*, by the number of the ribs.

Cardium austriacum, *Hauer*. In some places found in considerable abundance. This is the species designated very often as *Cardita crenata*. Two lateral teeth in the hinge, which M. Hauer could clearly observe in some of the specimens, place this species in the genus *Cardium*. The true *Cardita crenata* of St. Cassian seems to have a very different hinge, although, until now, it has not been quite clearly made out.

Cardium rhæticum, *Merian*.

Gervillia inflata, *Schafhaütl.* In some localities very common, and very characteristic of this formation.

Lima gigantea, *Sow.*

Modiola Schafhautli, *Stur.*=Modiola texta, *Schafh.*

Nucula complanata, *Phill.* In some localities very common.

Ostrea Haidingeriana, *Emmrich.*

Pecten Lugdunensis, *Mich.*, according to a determination by M. Merian; and some other as yet undescribed species of *Pecten*.

Pholadomya lagenalis, *Schafhaütl.*

Pinna Hartmanni, *Zieten.*

Trigonia; similar, according to Von Hauer, to *Trigonia harpa*, Münster, or *Trig. Whateleyæ*, Buch; but differing from it, and probably a new species.

Rhynchonella fissicostata, *Suess.*

Terebratula cornigera, *Schafhaütl.*

Terebratula gregaria, *Suess.*

Terebratula subrimosa, *Schafhaütl.*

Spirifer Emmrichi, *Suess.*

Spirigera oxycolpos, *Emmrich.*

Corals are met with in some parts of this formation, especially in the lower strata, sometimes in great abundance; the species of these corals, principally *Lithodendron* and *Astræa*, have not yet been described.

Only in one locality, on the Katzenstein, some fossils have been found which might seem to indicate a triassic formation; these were *Terebratula trigonella*, Schlotheim, and parts of *Crinoidea* very similar to those of *Dadocrinus gracilis*, H. von Meyer; but with these fossils was associated *Natica alpina*, Merian, belonging very evidently to the Kössen beds; nor does the position of these strata give the least evidence of their being different from the Lower Lias in general.

III. and IV. *Upper Lias and Jura.*

A. *Upper Lias of Ammergau.*—Very well developed and fossiliferous strata of the Upper Lias occur near Ammergau, immediately in

the north of my geological map. The blue and grey marly limestones contain numerous and well-preserved specimens of

Ammonites amaltheus, *Schlth.*
Ammonites Nodotianus, *D'Orb.* (also found at Adneth).
Ammonites radians, *Schlth.*
Ammonites Reussi, *Hauer.* Similar to *Am. Humphreysianus*, Sow., but with very different lobes.
Ammonites Partschi, *Stur.*
Ammonites tatricus, *Pusch.*
Inoceramus ventricosus, *Sow.*

These Lias strata dip with very steep angles, being nearly vertical to the south, and are evidently in a very irregular position. They lie conformably on enormous masses of sandy and marly Flysch rocks, which extend to the north, and contain immediately under the Lias strata (which in their mineralogical characters are often scarcely to be distinguished from them) nothing but many specimens of the *Fucus intricatus.*

Above the Lias strata is found a small zone of dolomite, dipping everywhere at 70° and 75° to the south, or south 70° west. Ascending the slopes of the Sonnenberg, we find a thickly-wooded declivity, above which begin the sandstones of the chalk with *Orbitulites*, but dipping with quite an opposite direction to the north.

B. *Lias and Jura on the Hirschbühel and the Wetterstein.* Under the designation of "*Upper Lias and Jura*," I have laid down on the map two separate zones of strata; the one in the Lahnewiesgraben, the other on the southern foot of the Wetterstein. In both localities are found strata of marl and limestone, in general of a red or of greyish and greenish colour. Amongst the many fragments of fossils I had collected, there could be determined with accuracy only

Ammonites radians, *Schlth.* In small specimens.
Ammonites tatricus, *Pusch.*

Aptychus, similar to *A. lamellosus*, but recently distinguished from it by M. Schafhaütl under the name of *A. subalpinus.* They occur very often in the contorted red marly limestones of the Lahnewiesgraben, but not in the Wetterstein.

According to the order of superposition of the strata, this formation is evidently situated, as seen in the Gaisthal, between the inferior Lias and the upper Alpenkalk.

The above-quoted fossils might indicate them to belong either to the Lias or to a higher Jurassic group. I have comprised these strata on the map under the collective name of "Lias and Jura," since I expect that further investigation may possibly lead to a separation of these strata into two distinct groups.

If we follow out the distribution of these strata on the geological map, we find that in the Lahnewiesgraben their eastern prolongation is stopped by a very remarkable transgressive position of the dolomites of the Kramerberg, of which we shall speak hereafter. On the Wetterstein it is very difficult to trace accurately the limits of the western and eastern prolongation of the band of the Lias and Jura strata. Large masses of debris and the difficulty of traversing the

steep declivities made it impossible for me to lay down the eastern and western termination of these strata as distinctly as I could have wished to do.

C. *Red Marble of Graswang and Ettal.*—Very well developed strata of this marble, generally of red, sometimes of white or yellowish colours, are found in the valley of Graswang and at Ettal, a little north from the mountains. Though the structure of the mountains and the position of the strata are here very irregular, as I have endeavoured more fully to describe in my large memoir, it is quite evident, by comparative observations in different localities, that these marbles are generally covered by the white upper Alpine limestone, which dips generally to the north, and contains the same small coral-remains which are so very characteristic of it on the Zugspitze and in other localities. The marbles are clearly underlied by grey and blue marls and limestones, containing in different places *Cardium austriacum, Gervillia inflata, Nucula complanata,* and other fossils characteristic of what we have termed "inferior Lias or Gervillia-strata."

The marbles lying thus between the upper Alpenkalk and the inferior Lias contain very often numerous specimens of *Terebratulæ*. M. Suess at Vienna, who has recently very thoroughly examined the Brachiopoda of the Trias and Lias formations of the Eastern Alps, recognised among the specimens I had collected *Rynchonella Hornesi*, Suess, and *Rhynchonella variabilis*, Schlth.

The Hierlatz-strata of the Austrian Alps, which are characterized by the same fossils, probably form, according to the recent investigations of MM. Hauer and Suess, a part of the Upper Lias (=Adneth strata), though with a very peculiar *facies*.

V. *Upper Alpine Limestone.*

This formation consists, in the mountain ranges under consideration, of a light-coloured, white, or yellowish limestone, which appears in great masses on the Zugspitze, on the Alpspitze, and on the Wetterstein, and forms high and steep escarpments.

These strata here evidently cover all the jurassic deposits; but as yet the investigation of the fossils which they contain is not far enough advanced for determining with perfect accuracy the geological age of this Upper Alpenkalk. In different places, for instance on the summit of the Zugspitze, in the Höllenthalkahr, on the Wetterstein, there occur in this limestone numerous coral-remains. Prof. Schafhaütl has described and figured some of these corals under the name of *Nullipora annulata**.

I have also been able to collect in the Höllenthal, as well as in the upper Bainthal, not far from the end of the Plattacher Glacier, several specimens of *Nerinæa*. According to Von Hauer's comparison of these specimens, they seem to be quite identical with the *Nerinæa* found on the Plassen near Hallstadt.

"The limestone of the Plassen," he writes, "is almost certainly identical with the fossiliferous strata of Stramberg in Moravia, and

* Leonh. and Bronn's Jahrbuch 1853, p. 303, tab. 6. fig. 1.

these latter probably belong, according to the recent investigations of M. Hohenegger, to the Neocomian formation."

In the same stratigraphical relations, and with fossil corals identical with those found in the group of the Zugspitze and the Wetterstein, we find the upper Alpine limestone also in the Kahrwendel range, which extends immediately to the east of the Valley of the Tsar, as well as to the north of my geological map, where it appears again in the environs of Ammergau on the Laberberg, and on the Kofel and Sonnenberg.

VI. *Cretaceous Formations. Orbitulite-sandstones.*

The cretaceous strata, characterized by numerous *Orbitulites*, do not appear within my map, but occur immediately to the north of it, in the environs of Ammergau. They consist of grey sandstones with a calcareous and marly cement. The latter is sometimes very predominant; and the mineralogical composition of the rocks varies very much.

In some strata the quartz and hornstone grains are very predominant, and sometimes attain a considerable size. The rock is then very hard, and the surface becomes very rough and uneven by the effects of weathering.

Among the fossils the most characteristic are numerous *Orbitulites*, of which there are at least two distinct species. There has been also found a well-preserved fragment of an *Ammonite* south of the Rappenkopf, which, according to Von Hauer, agrees with no known species, and is probably undescribed. Different specimens of *Ostræa*, *Nerinæa*, and *Turbo* occurred south of the Rappenkopf and in the Soile-Alpe.

These deposits seem perfectly to agree, as regards their lithological and palæontological characters, with very similar strata observed by Prof. Emmrich in the Urschelau in the Traun Valley. The latter contain more numerous and better-preserved fossils, and belong evidently to the Upper Cretaceous formation.

The cretaceous strata are well developed in the basin of the Soile- and Nebele-Alpe between the Laberköpfen and the Ettales Mändl; they occur also on the southern slope of this mountain range in the Spitzschlaggraben. We find them again on the opposite side of the Amper, on the Rappenkopf, south of the Kofel, and they are prolonged in a westerly direction to the Brunnberg, and probably still farther. The very complicated structure of the Laberberg and the Brunnberg makes it difficult to follow out exactly the distribution of the cretaceous strata. It is evident, by observations on different spots, that they rest immediately upon the Upper Alpine Limestone. Generally speaking they seem to have been deposited not quite conformably upon the older formations, which had in part been previously disturbed.

By a great general upheaval which took place afterwards, and by many powerful contortions and faults, the cretaceous strata have been brought in many places, as in the Rappenkopf and the Soile-

Alpe, into very irregular and puzzling stratigraphical relations to the older formations.

Tertiary Formations.

Proceeding farther to the north in the Valley of the Amper, we find of later formations the Eocene Flysch with *Fucoidea* in great development, and the tertiary strata of Kohlgrub Rottenbuch and the Peissenberg; but these do not belong to the subject of this paper.

The diluvial deposits, which cover to a great thickness the large valleys in the interior of these mountains as well as the elevated plains of Bavaria, will be spoken of in the last part of this paper.

§ The Elevatory Relations of the Rock-masses (*Hebungsverhaltnisse.*)

In the mountain group under consideration, there is a very important and extensive system of joints, which are quite independent of the stratification.

These joints are especially well developed in the hard upper Alpenkalk; but they extend into the liassic marls, as well as into the dolomites. It is evident, 1st, that these joints, which can often be followed to great distances, retain very often in the same district a very regular mean direction; and 2ndly, that in the same district different systems of joints occur, crossing each other at various angles.

I will mention some more special examples of these phænomena in the Höllenthal, where they are particularly well developed. I had here also the opportunity, by the mining operations conducted at different spots, to follow these joints in the interior of the mountain masses. The mean strike of the one predominant system of joints runs from N.E. to S.W. (N. 25°–50° E. to S. 25°–50° W.). They stand almost vertical, and their sides are, generally speaking, smooth and somewhat polished. They can be traced to great distances along the steep escarpments of the mountains, and along the course of different small rivulets, which especially follow the direction of these joints, where they have produced remarkably deep erosions.

Besides this system of joints, I could observe in the Höllenthal another subordinate system, running from W.N.W to E.S.E. They are by far less extensive and regular. In some places where both systems are well developed and exposed, as in the Höllenthalkahr and the surrounding bare ridges, they are seen mutually intersecting at very high, sometimes nearly right angles. By these intersections many derangements of the rocks are produced.

Attentively following these long joints, we are soon aware of a certain connexion which evidently exists between their mean direction and the direction of many valleys and steep mountain escarpments; and we are naturally led to the conclusion that the formation of many valleys, or many ridges and steep escarpments, which can in no way be explained by the strike or the inclination of the strata, are due to the same causes which have produced these long joints and faults.

A. *Structure of the Mountain Group of the Zugspitze and the Wetterstein.*—The light-coloured upper Alpine limestone forms a high continuous escarpment, which is visible from a great distance, and runs from the Wetterstein over the Dreithorspitzen to the western slope of the Zugspitze towards the Eibsee. In the west and in the south the upper Alpine limestone reposes in a regular succession upon the older formations, which dip under it; but on the northern side of this mountain the arrangement of the strata is much more irregular. They have been distorted and broken up by many extensive faults; and isolated portions, comparable to enormous ice-floes in a river or in an arctic sea, have been pressed together by later upheavals and by lateral compressions, in the most extraordinary manner. Very often the upper Alpine limestone dips apparently regularly under the dark marls and limestones of the lower Lias; and these latter are then again covered by the upper Alpine limestone, or even by the dolomites of the lower Alpine limestone.

These abnormal positions of the strata are very well seen, for instance, on the little saddle between the Langenfeld and the Osterfeld. The dolomite which follows farther on in the Bodenlahne, also dipping to the north-east, must be considered as belonging to the lower Alpine limestone, although it seems here to repose upon the Lias; but in its eastern and north-eastern prolongation, at Krün and north of the Barmsee, it is intimately connected with the dolomites of the lower Alpine limestones, which there form quite regularly the base of the lower Lias.

In following a section in a northern direction across the Wetterstein, the complicated structure of these mountains is seen in a very interesting manner.

In the Paiten Valley are laid open the marls of the lower Lias, with an anticlinal dip, covered on both sides by the upper Alpine limestone. On the highest ridge of the Wetterstein these strata dip with an angle of 40° and 50° to the north, 15° west. Along the northern foot of the Wetterstein runs a great fault, and the strata of the lower Lias are then pressed upon and partly over the upper Alpine limestones in a most irregular manner. A very good example of this structure is seen on the Kamithor, where the dark sandy marls, containing many of the characteristic fossils, are very much contorted.

Farther to the north, and separated by another fault, we have the perfectly distinct upper Alpine limestone, followed by a long and regular band of the lower Lias, the whole underlied by an extensive mass of the dolomites.

Another fault, running in the same east and west direction, occurs on the left side of the valley of the Ferchenbach. An observer might at first think here, that the Lias marls must regularly underlie the dolomites; but the great line of fault, entirely separating the two formations, is most distinctly traceable all along the bare escarpments of the Stegreif. The rocks of the lower Lias then cover, with various anticlinal dips, a broad low mountain ridge, and they are underlied in a regular succession, on the right bank of the Valley of the Kankerbach, by the dolomites of the lower Alpine limestone of

the Eckenberg. One of the most remarkable of all these faults is this, which extends on the foot of the high escarpments of the Wetterstein, running from east to west, and to the W.S.W. All along this line we find isolated patches of the lower Lias, enclosed in various and most irregular manner between the white limestone strata of the Upper Alpenkalk; I have endeavoured to lay down on the map these Lias patches as accurately as possible. On these lines of dislocation are seen in different points masses of gypsum, and of a cavernous dolomitic breccia and a very cellular and evidently altered limestone (*Cargneuile*). This phænomenon is perfectly analogous to the occurrence of gypsum and cargneuile on the long lines of dislocation in Switzerland, which MM. Studer and Brunner have so well described.

B. *Structure of the Mountains between the Loisach and the Amper.*—The dolomites of the lower Alpenkalk form, on the Brunstelkopf and the Schafkopf, with a dip to the S.S.W., the regular base of the dark marly limestones of the lower Lias. Farther north, and more in the interior of the broad dolomitic range, we find several changes in the dip of the strata, evidently produced by different upheavals and contortions of the rocks. A most striking structure of the mountains is disclosed if we follow the line of section more to the south, through the Lahnewiesgraben, to the Kramerberg. There are seen large masses of well stratified dolomites, reaching the summit of the Kramerberg, at 6085 Fr. feet, which clearly rest upon the strata of the Lias. In examining the environs of the Kramerberg solely, it seems at first impossible not to consider these superposed dolomites as being younger than the underlying marly limestones; but, in following attentively the rocks of the Kramer in their western prolongation, it is quite evident that these strata must be identical with the dolomites which form generally the lower Alpenkalk and the base of all the other formations in this mountain. The dolomitic range, which occupies a considerable breadth on the Kramer, becomes narrower towards the west. The same strata pass on the right bank of the Loisach, and farther still, on the Eibsee and on the Thörlen, they form the base of the Lias and of all the mass of the Zugspitze.

The dolomite of the Kramer has, therefore, been pushed over the younger formations along an extended fault, by a very strong lateral pressure. This supposition is also corroborated by the many violent contortions and modifications in the strike and dip of the red lias strata, near the line of junction with the dolomites. The former stand at very steep angles, often nearly vertical, whilst the dolomites which follow above them are inclined at angles of only from 30° to 47°.

By the dolomites having been pushed over in so irregular a manner on the younger formations, we may also account for another remarkable phænomenon. It is seen on the map that the upper Lias and Jura formations, which occur on the Hirschbühel, become more and more narrow as we follow their eastern prolongation, whilst the dolomites have been advancing farther to the north. I nowhere succeeded, in the lower parts of the Lahnewiesgraben, in finding the characteristic

red marly limestones of the upper Lias and Jura, or the fossil remains which accompany them. The dark fossiliferous marls of the lower Lias are here continued to the limits of the dolomite, which is seen immediately resting upon them.

§ Remarks upon the Diluvial and Erratic Phænomena.

The diluvial and the alluvial deposits could not be indicated by different colours on the map. Mere alluvial and detrital accumulations in the higher parts of the mountains were not separately marked.

It may be of some interest to advert to the two diluvial terraces in the valleys of the Loisach and of the Tsar. They consist of hard conglomerates, containing pebbles of the different sedimentary rocks of the Alps, mixed with erratic pebbles, which go down to the very lowest visible beds. The terraces attain a height of 120 and 180 feet above the level of the rivers. They show us the great thickness of the diluvial beds with which the Alpine valleys had been covered before the denudations by the present rivers took place.

One of the most interesting phænomena which occur in the study of the Alpine diluvium is offered by the erratic blocks. I have endeavoured to indicate on the map the highest points on which the erratic rocks are found, and to ascertain the heights by direct barometric observations.

In the lower parts of these mountains, below 4000 and 3500 feet, the erratic rocks are seen everywhere scattered about in more or less abundance.

I may be allowed to mention some points which seem to me of importance for forming an estimate of the way in which these remarkable erratic rocks have been transported.

The erratic pebbles in the mountain chains under consideration generally reach an elevation of 4000 and 4400 Fr. feet, in some cases even 4600! Even on these highest limits we generally find rounded pebbles of 5 to 20 centimetres diameter. Hornblende rocks, with many massive and schistose varieties, are prevalent; there are also found mica-schist and gneiss, as well as some fragments of granite.

Even on the isolated summit of the Peissenberg, nine English miles distant from the Alps, at an elevation of 3005 Fr. ft., thick layers of diluvial boulders occur, with rolled erratic rocks. Further it is to be remarked, that the erratic rocks are not only deposited on the surface of the older diluvial boulder beds, but that they are also disseminated in their interior, and that they are found in their very lowest beds, down to the surface of the miocene tertiary deposits.

The deep valleys which have been cut through the thick boulder beds of the Bavarian plateau by the greater rivers, for instance by the Tsar, afford very excellent opportunities for the study of these phænomena. In the Valley of the Tsar, in the environs of Munich, the erratic pebbles in the lower beds are all rounded, and do not generally exceed the size of the fist. Erratic blocks of very considerable dimensions are not very common on the plateau around the Tsar and

the Ammer, which I have more especially examined. In those localities where blocks of larger size appear in greater number, they are sometimes more numerous, especially in the upper parts; but they are always imbedded between the other diluvial boulders, and are in part rounded, and in part they have preserved fresh angles. But it would be quite erroneous to suppose that these larger blocks are necessarily only limited to the upper beds; I have convinced myself by repeated careful examinations that they also occur, though generally less numerous, in the lower beds, and I have seen very large blocks which have sometimes been brought up from considerable depths in the excavation of wells.

The occurrence and the distribution of the erratic rocks on this part of the Bavarian Alps, and plateau bordering them to the north, seem evidently to show that here at least they must have been transported, and deposited in the same mode and at the same time as all the rest of the diluvial limestone and sandstone boulders amongst which they lie, and which cover to so great an extent and with so great a thickness the Bavarian plateau.

I need scarcely add, that the facts and the remarks which I have now brought forward relate only to that part of the Bavarian Alps which forms the subject of this paper. The erratic and diluvial phænomena all around the Alps are so extended, and they present such remarkable differences in various parts of this chain, that they must, in my opinion, be studied minutely in different districts before we can venture on general conclusions. But I may be allowed to say, that, generally speaking, the erratic rocks which occur on the plains all around the Alps have been too much regarded as merely a superficial deposit; and that, by examining different good sections, erratic pebbles are found to descend more or less deeply into the interior of the diluvial boulder beds.

The occurrence and the distribution of the erratic blocks on the extensive diluvial formations of the basin of the Lake of Constance, are, according to the minute observations of Prof. Fromherz*, very analogous to the phænomena which I observed on the Bavarian plateau.

These very remarkable heaps of enormous and angular erratic blocks principally occur in Switzerland and on the slopes of the Jura. Every one who has studied the present physical conditions of glaciers, and who has seen the great oscillations to which these ice-masses have been often subjected, even in historical times, will perfectly agree, that in former geological periods,—when the Alps were surrounded by large masses of water, when there was a greater amount of moisture in the atmosphere, and a greater quantity of snow-fall,—the glaciers may very probably have undergone most considerable changes of extension. The transport of debris from the central crystalline portions of the Alps may have been in some places, as in the valleys of the Rhone, of the Aar, of the Inn, &c., particularly favoured by that greater extension of the glaciers.

It is further very essential to recollect the importance of large

* Leonhard und Bronn's Jahrbuch für Geognosie, 1850, p. 641–656.

masses of ice floating about in rivers, or on the surface of lakes, in the transport of great angular rocks. Even in the present time large rocks are transported on the shores of the Arctic seas from one point to another; and the great masses of fine granite blocks which cover the plains of northern Germany, up to the foot of the Harz and the Silesian mountains, came very probably on similar icebergs and ice-floes from the Scandinavian peninsula.

On Polished Rock-Surfaces.

In relation to the erratic phænomena and their connexion with ancient glaciers, I propose to add a few remarks upon the polished and striated rocks, which have been considered, I think in some instances with too little hesitation, as general evidences of the presence of ancient glaciers.

There can be no doubt whatever, that the glaciers have the faculty of extensively producing by their movement polished and striated rock-surfaces on their borders. These interesting phænomena can be traced sometimes at very great distances from the present glaciers. They are seen very well developed in the environs of the glaciers of Macugnaga and of Gorner, especially on the lower termination of the Gorner glacier*.

But there are still many other agencies which can produce similar phænomena in a very deceptive way. I will not dwell on the polished and striated rocks produced by land-slips, so very common in the Alps; or on the striæ resulting from a small amount of sliding of sedimentary strata one along the other, which I clearly observed in several quarries: but I will merely call the attention of the Society to the fact, that the gneiss as well as the granite of the Alps very often shows a concentric exfoliation; and that all these concentric laminæ, having very different dimensions and very various degrees of curvature, offer on their surfaces a fine polish and fine parallel striæ, which are not limited to the superficial surface, but are repeated on all the laminæ in the interior of the rock.

It is quite evident that in such a case the polish and the striæ of the rocks cannot be attributed to the action of glaciers, which could but have affected the very surface of the mountains, never the interior laminæ of the rock. It seems that these phænomena are here intimately connected with the process of the concentric exfoliation itself; and that a limited sliding and displacement of the different folia or laminæ have taken place, which produced the fine parallel striæ and scratches so generally observed in these instances.

Leopold von Buch† was the first to show the importance of these polished concentric laminæ in Sweden and in the Alps: guided by his directions, I have endeavoured more fully to work out the subject in the Alps, and to represent some of the most characteristic forms of these concentric exfoliations on the three plates now exhibited to the Society.

* Lithographic illustrations of these phænomena (prepared for the Author's larger Memoir) were laid before the Meeting.

† Ueber Granit und Gneiss; Abhandlungen der Berliner Akademie für 1842.

In the vicinity of the Aar glacier, in the Bernese Alps, the rocks of granite and gneiss offer a curious and instructive exemplification of these phænomena.

On the mountains on the left side of this glacier are seen numerous small systems of these concentric foliations; the mountains being covered with little rounded bosses (*roches moutonnées*). In this instance these *roches moutonnées* cannot have been produced, as is indeed the case in other places, by the action of glaciers; for, by investigating their structure more closely, and by following the different ravines which disclose the interior of the rocks, we clearly see that these rounded bosses are produced by concentric exfoliations, and that the lowest visible laminæ are equally well polished as those on the very surface of the rocks. An additional proof of this conclusion is seen in the higher parts of the Aar glacier. We have there the limits between the granite and gneiss rocks and the stratified chlorite and mica slates, which latter do not show any of the concentric exfoliations. As soon as the granite appears, we find these very remarkable rounded bosses, which are wanting farther east in the schists. Had the glacier produced these rounded rock-surfaces, both formations would equally have been rounded and smoothed.

In comparing well-preserved polished rock-surfaces resulting from the action of glaciers, with the polished surfaces due merely to the process of the concentric exfoliation of gneiss and granite, it is quite possible to find some distinctive characters. On the polished surfaces produced by glaciers the striæ run generally pretty parallel to the longitudinal axis of the valley; whilst on the surface of the concentric layers the striæ follow generally the line of the maximum of the inclination of the laminæ. It is also very often to be observed that the polished concentric surfaces have a somewhat greater lustre, which may probably have been produced by small exudations of siliceous matter during the process of concentric exfoliation. These few remarks will be sufficient to show how desirable it is that the interior structure of rocks should be examined with the greatest care, and at different places; so that we may not confound, in all the extensive gneiss and granite districts of the Alps, the striæ and polishings of glaciers with other phænomena, very similar at first sight, but which have been produced by quite different causes.

May 3, 1854.

John Petherick, Esq., and John Coode, Esq., C.E., were elected Fellows; and M. Joachim Barrande was elected a Foreign Member.

The following communications were read:—

1. *On some* Intrusive Igneous Rocks *in* Cawsand Bay, *near* Plymouth. By Leonard Horner, Esq., F.R.S., F.G.S.

Several of the principal features in this locality are described by Sir Henry De la Beche, in his "Report on the Geology of Cornwall,