



# XIV. A sketch of the structure of the austrian alps, &c. &c.

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XIV. *A Sketch of the Structure of the Austrian Alps, &c. &c.*  
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[With a Plate.]

§ I. *Introduction.*

WE believe that several years have elapsed since any account of the structure of the Alps has proceeded from the pen of an English geologist. A paper by Professor Buckland, published in the *Annals of Philosophy* of 1821, threw a new and unexpected light on the geological relations of the whole chain; showing, by many striking details, the analogy between some of its formations and a part of the English series; and proving that the great northern and southern calcareous zones belong exclusively to the secondary period. About the same time Mr. Bakewell was employed in making a series of observations on different parts of the Alps, which led him to similar conclusions†. Of the many excellent memoirs published on the same subject by the geologists of the Continent, we are not now called upon to speak.

The elevation of the Alps during the tertiary period, first asserted by Dr. Boué, has been confirmed, with innumerable details, by the successful labours of MM. de Buch and Elie de Beaumont, and is now generally admitted. A large series of strata on the southern flank of the chain, once regarded as primitive and afterwards elevated to the transition

\* Read before the Geological Society, May 21, 1830; and communicated by the Authors.

† See "Travels in the Tarentaise." 2 vols. 1823.

class, has been finally referred to the age of the lias. Numberless strata, formerly described as primitive or transition, have also been successfully compared with the green-sand and the newer secondary formations. These discoveries belong to the recent history of geology\*. Many new and careful observations must, however, be made before the great deposits of the Alps can be brought into a rigid comparison with the secondary formations of the North of France, of the North of Germany, and of the British Isles. The peculiar mineral structure of the Alpine limestone—the great mountain masses of it, so modified by crystalline power as to lose the traces of depository origin—the frequent absence of organic remains, and of those well-defined beds of clay and sandstone which form the best subdivisions of the English secondary groups—the enormous faults and dislocations produced during the different epochs of elevation—all these causes have greatly obscured the minuter subdivisions of the different systems of the chain: so that in the Geological Map of Germany (only finished last year, under the superintendence of one of the greatest naturalists of Europe) nearly the whole of the secondary calcareous zones are still represented by one colour, and described as the *Calcaire indéterminé des Alpes*†. Under these circumstances we have ventured to throw into a connected point of view our own observations, made in the summer of 1829 during several traverses among the eastern parts of the chain. We offer them as nothing more than an imperfect sketch, filled up in some instances by materials derived from others: we are anxious to state matters of fact correctly; and we wish that in every instance they should be carefully separated from any theoretical conclusions we may have derived from them.

The following are the principal directions in which we made traverses through the eastern portions of the Alps. 1st, From Vienna to Gratz over the Sömring: 2nd, From Gratz to Laybach, over a portion of the primary axis and the southern calcareous zone: 3rd, From Laybach to Capo d'Istria, over the calcareous chain, which is a prolongation of the Julian Alps, and forms the water-shed between the basin of the Danube and the Adriatic: 4th, A complete traverse by the gorges of the Tagliamento and the crests of the Tauern Alp to the valleys of Salzburg: 5th, Through the lateral valleys of the northern calcareous zone between Salzburg and Inspruck: 6th, Across the calcareous zone by the Seefeld pass to the

\* We here refer to various memoirs of MM. Elie de Beaumont, Boué, &c. &c.

† Geological Map of Germany, published by S. Schropp and Co., Berlin. plains

plains of Bavaria. To these may be added, a complete transverse, made by one of the authors of this paper in the summer of 1828, from the subalpine plains of Italy, over the Brenner and Seefeld pass, to the plains of the Danube.

In all these regions the structure of the Alps, when considered only in a general point of view, is of great simplicity; the chain being composed of an axis of primary and transition rocks, chiefly of a slaty texture, flanked and surmounted by the two great secondary calcareous zones; which are in their turn surmounted by the tertiary sandstones and conglomerates, descending on one side into the plains of Italy, and on the other into the elevated plains of the Upper Danube. We have endeavoured to show, in papers read at former meetings of this Society, that the chain of the eastern Alps has been elevated at successive epochs; and (agreeably to the views first published by Dr. Boué) that it has undergone a great movement since the tertiary period. By these successive elevations the relative position of its subordinate parts has been greatly deranged; the northern and southern calcareous zones being in many places completely rent asunder, and having their component strata thrown into the most violent contortions.

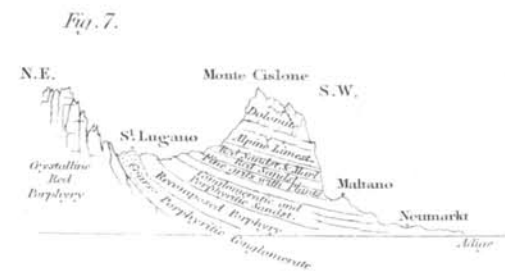
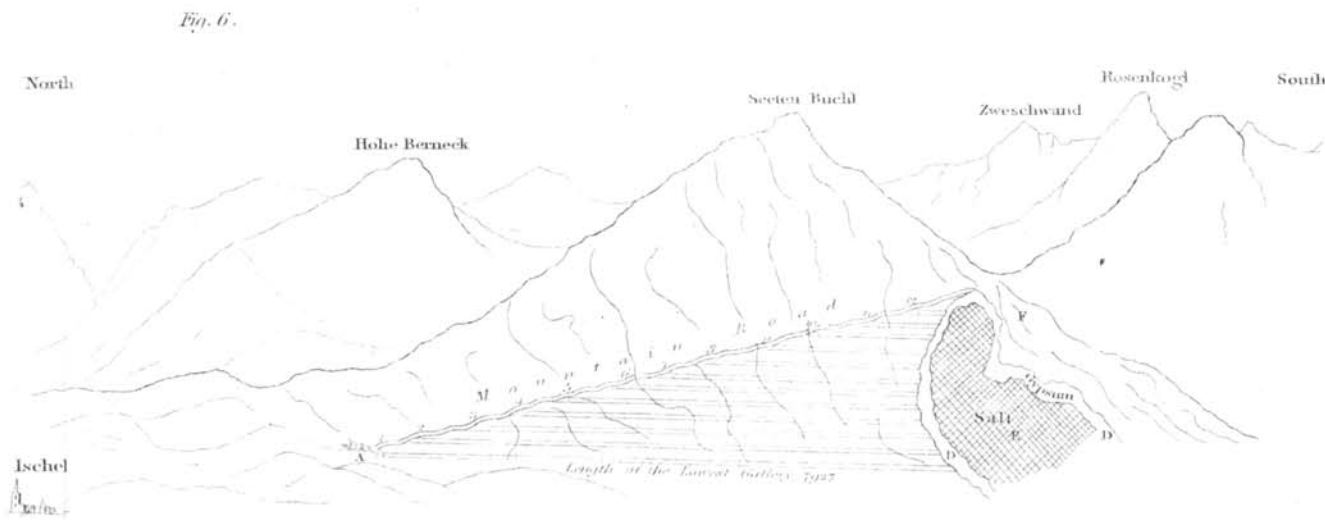
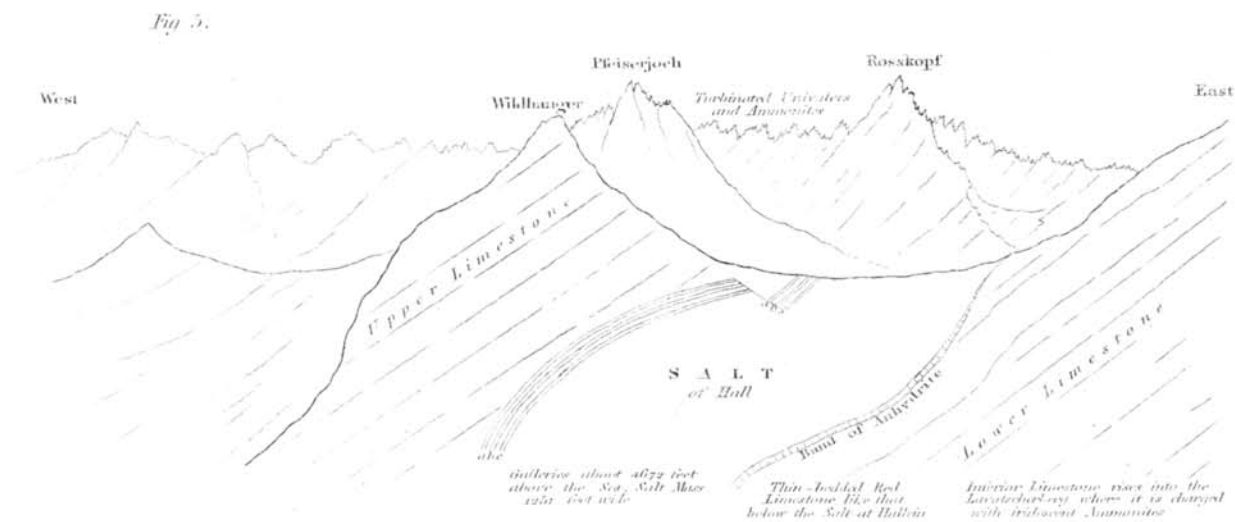
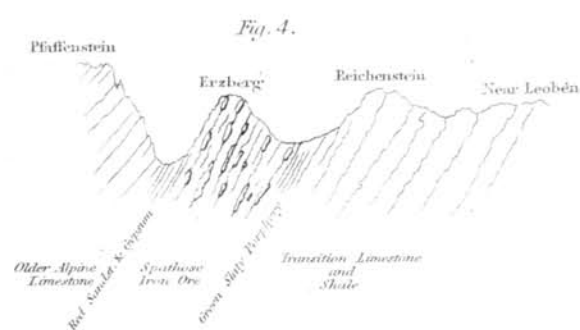
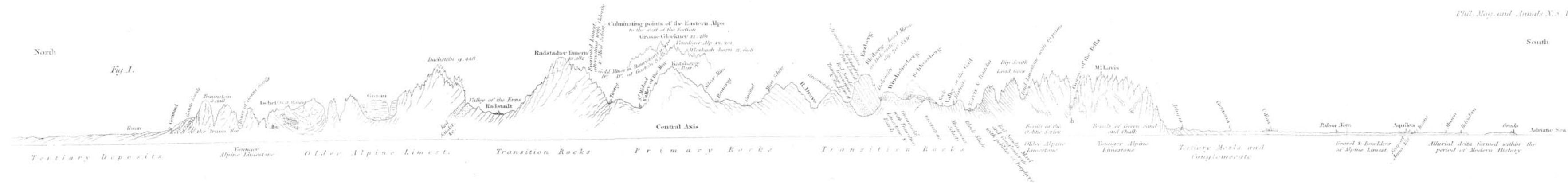
To the east of that part of the valley of the Inn which intersects the Alpine limestone, the derangements of the chain are, we believe, in no instance so great as to produce an entire inversion in the order of the calcareous formations; and the transition rocks and red sandstone series on the flanks of the central axis are uniformly surmounted by the lower part of the system of Alpine limestone. But on the west side of the great chasm through which the Inn escapes into the plains at the northern foot of the Alps, the dislocations are more complex; as there appear to be two distinct axes of elevation ranging nearly parallel to each other; one along the true geological central line of the Alps; the other through the centre of the northern calcareous zone. The effect produced by the second axis is such, that some of the higher members of this zone are carried, with an inverted dip, directly against the central chain, and appear to pass under it. This singular derangement of the strata passes through the dolomitic peaks of the Rhetian Alps at Mittenwald; but how far it ranges towards the west, we had no means of ascertaining: we have been informed, however, that similar derangements may be traced into the heart of Switzerland.

Having thus noticed the general position of the great mineral masses of the eastern Alps, it may be expedient briefly to explain the transverse section which forms the chief basis of our observations, and to which nearly all the subdivisions

of the several formations will be referred\*. This section commences in the marshes on the shores of the Adriatic, passes through the plains of Udina to the foot of the Alps, intersecting the tertiary marls and conglomerates on the left bank of the Tagliamento: then traverses the calcareous chain (connected with the Julian Alps) to the longitudinal valley between Tarvis and Ponteba, in a part of which is the outcrop of the sandstone, red marl, and conglomerate inferior to the Alpine limestone. It then crosses a low longitudinal ridge of doubtful character, but based upon, and partly composed of transition rocks, and is continued through the secondary, dolomitic ridges of Bleiberg to the valley of the Drave, which here, like so many of the longitudinal valleys of the Alps, forms the boundary between the primary and secondary ridges of the chain. It will be seen by the general section, that the Bleiberg dolomites rest on red sandstone and red gypseous marls; and that the secondary system is based on grauwacké, which contains beds of limestone with fossils resembling those of transition limestone. From the Drave the section is continued through the primary region of the Alps, over the Katsberg, to the valley of the Mur at St. Michael. These primary ridges are chiefly composed of micaceous schists, the beds generally ranging parallel to the principal chain, and dipping nearly due south. From the valley of the Mur the section is prolonged over the crests of the Tauern Alp to the longitudinal valley of the Enns at Radstadt. This part of the line cuts through a great succession of mineral masses, some of which, though eminently crystalline and primary in external character, contain a few subordinate beds of limestone with organic remains. The dip of these transition beds is irregular; but on the northern flank of the Tauern Alp, and in the ridges near Radstadt, the strata become less crystalline, and the prevailing dip is unequivocally towards the north. From Radstadt the section crosses some of the newer transition rocks graduating insensibly into the conglomerates, red sandstone, and gypseous marls; which here, as on the Italian side, form the base of the whole Alpine limestone system. The line is then continued through the great precipices of the older Alpine limestone; through the middle system with the subordinate saliferous marls; and through the younger Alpine limestone, flanked by the sandstones, marls, and conglomerates of the tertiary formations.

The principal section is drawn in such a direction as to show the position of the unconformable beds of Gosau, and the commencement of the tertiary system at the foot of the Traunstein.

\* See Plate II. fig. 1.



To explain more fully the structure of this part of the Alps, we have added another parallel section (fig. 2), about thirty miles west of the former, from the primary rocks at Gastein across the transition formations of the Upper Salza, the red sandstone series of Werfen, the older Alpine limestone of the Tannen Gebirge, the saliferous deposits of Hallein, the younger Alpine and hippurite-limestone of Untersberg, to the tertiary plains of Bavaria.

After these introductory remarks, we may proceed to notice each of the successive deposits seen on the line of transverse section, and on other corresponding parallels of the eastern Alps. They may be subdivided into the following natural groups in the ascending order. 1. Primary crystalline rocks forming the central axis. 2. Crystalline rocks with calcareous beds containing a few traces of organic remains; the system graduating into rocks agreeing with the ordinary transition type. 3. Red marl, sandstone, and gypsum, &c.; containing in parts of their range large, subordinate masses of magnesian limestone. 4. Older Alpine limestone. 5. Alpine limestone with subordinate saliferous deposits. 6. Younger Alpine limestone. 7. Tertiary formations.

## § II. *Successive Formations of the Eastern Alps.*

### 1. *Central Axis of primary Rocks.*

The primary rocks of the central axis have their culminating peaks on the eastern borders of the Tyrol, where the Grosse Glockner and the Venediger Alp rise to the respective elevations of 11,775 and 11,698 Vienna feet\* above the level of the sea. To the east of these peaks the central ridges diminish gradually in elevation; separating, in their range, Carinthia on the south from the Salzburg country on the north. Following the direction of the Mur for a considerable distance, they are finally divided into two irregular branches; one of which is prolonged in a south-easterly direction into the Bacher Gebirge, and forms the south-western boundary of the tertiary basin of Gratz; the other is continued in the direction of the principal axis of the Alps, and forms the great boundary between the tertiary basins of Vienna and Styria. This latter branch, after disappearing under some of the recent deposits connected with the Vienna basin, emerges near Presburg, and is said finally to die away in the low ridges extending thence towards the north-east†.

It

\* 12,281 and 12,201 English feet.

† The gradual diminution in the elevation of the central axis, as it ranges from

It forms no part of our object to give any detailed account of the mineral structure of the central axis; we may however observe, that as it decreases in elevation in its range towards the east, its prevailing character of granitoid gneiss seems to give way to that of mica-schist and some other primary slaty rocks.

In the higher part of the valley of Gastein the principal rocks we observed were the following: (1) Granite; (2) Granitoid gneiss, alternating near the highest waterfall with thin beds of white, granular marble; (3) A very feldspathic variety of mica-schist, here and there containing garnets; (4) The same variety often passing into white-stone, also here and there becoming quartzose and graduating into slaty quartz-rock; (5) Mica and chlorite slates, &c. &c. Some of these varieties below Hof Gastein, and close to the transition series, alternate with thin beds of a beautiful greenish, striated marble resembling *cipollino*.

Above Gasteiner Bad several of the slaty masses contain small disseminated crystals of auriferous pyrites; and in one of the precipices in the highest part of the valley, gold mines have been worked at the height of 7800 Vienna feet above the level of the sea. Similar mines have been worked in the adjoining peaks of the Raurisberg at the height of 9080 feet above the same level\*.

In the traverse we made through the primary system over the Katsberg, from Spital on the Drave to St. Michael on the Mur, the prevailing rocks were mica-schist; and we have already remarked that for many miles along the great longitudinal valley of the Drave they have a decided dip to the south, carrying them unequivocally under the transition rocks, hereafter to be noticed, which form the base of the Bleiberg ridge.

Between Gmünd and Rennweg the rocks contain abundance of garnets; and not far from the latter place there are subordinate masses of serpentine in the mica-schist. On the south ascent of the Katsberg, the prevailing rock is a beauti-

from the higher peaks of the Tyrol towards the east, and the great expansion of the southern calcareous zone of the Alpine chain, produce an effect upon the hydrography of the whole region which deserves notice. The calcareous zone not only becomes greatly expanded; but near the commencement of the Julian Alps gives off a second chain, extending into the provinces on the eastern shores of the Adriatic. The consequence is, that the parting of the waters between the Black Sea and the Adriatic takes place, in all the country east of the Adige, among the higher elevations of the secondary calcareous system. West of the Adige, the parting of the waters takes place among the crests of the central axis.

\* In English feet the respective heights are 8135 and 9470.



ful chloritic slate; alternating here and there with thin bands of light blue and green, laminated and granular limestone, somewhat resembling the *cipollino* of the Italians; sometimes also alternating with thin quartzose bands, identical with the beautiful green, quartzose, slaty masses which abound in a corresponding part of the pass of the Brenner. With the beds of the Katsberg terminates what we consider the primary system of our transverse section. It is not however possible to draw any precise line of demarcation between this and the superior transition system; for here, as well as in the valley of Gastein (see Pl. II. fig. 1, 2), the two classes of rocks seem, through the intervention of chloritic schist with thin bands of limestone, to pass insensibly into each other. We have thought this fact worth stating, although it is probably a mere local accident of structure, and of no real importance in the history of the successive formations\*.

2. *Crystalline Rocks containing calcareous Beds with traces of organic Remains, graduating into Rocks conforming to the ordinary Transition Type, &c. &c.*

The prolongation of the section over the Tauern Alp, from St. Michael on the Mur to Radstadt on the Enns, is through the lower transition system of the Alps. Near St. Michael, beds similar to those of the Katsberg alternate with large masses of crystalline limestone; and for some miles north of that place, the abundance of limestone among the other crystalline rocks begins to give a new character to the country. In our passage through it, we however thought that we were still in the primary system of the chain; and we can hardly express the surprise we experienced when we first discovered, near the village of Tweng, mica-slate with garnets, and chlorite-slate with thin layers of white crystalline limestone, alternating with, and passing into a more thick-bedded limestone, part of which was of a dark blue colour, of less crystalline texture, and contained many encrinital stems.

In ascending the mountain above the last-mentioned village, we found the same dark-coloured encrinite-limestone

\* In using the terms *primary* and *transition*, we have only endeavoured to conform to the language current among geologists. The two classes of rocks cannot, perhaps, in any case be precisely separated from each other. It is true that among the stratified rocks of a considerable part of the central axis there are no traces of organic remains: but they may once have existed, and have been obliterated by subsequent crystalline action: and the central peaks of true granite are (at least in their present form) probably among the most recent mineral masses of the chain.

repeatedly

repeatedly alternating with chlorite and mica-schist, also with fine, glossy clay-slate containing crystals of pyrites. Higher up the mountain are great masses of thin-bedded white crystalline limestone overlaid by thickly bedded, blue limestone; and the whole system passes into a series of lofty calcareous peaks, the highest of which, in the Radstadter Tauern, is 9762 Vienna feet above the level of the sea. The highest point of the calcareous peaks belonging to this system, east of the Weiss Eck, is 8360 Vienna\* feet above the same level†. We had no opportunity for examining any of these elevated peaks of the chain; but from their mode of weathering we were led to suppose that some of them were of dolomitic structure.

On descending the north flank of the Tauern Alp we found the same blue, thick-bedded limestone alternating with, and graduating into micaceous and chloritic schist, and appearing by a north-easterly dip to be carried under the peaks of the Radstadter Tauern.

When we first found the organic remains in the calcareous rocks above described, we supposed that the whole system was probably an outlier from the great northern calcareous zone, altered in structure by its contact with the primary formations. The sections from the foot of the Tauern to the banks of the Enns, proved that this opinion was untenable. The rocks above described are not only interlaced with the central system of the chain, but are inferior to a long series of strata, considered, if we mistake not, as transition by all the geologists who have described the Alps.

This conclusion is made still more clear by the sections laid bare in the gorge between Hof Gastein and Lend; and on the banks of the Salza between Lend and Werfen‡. The primary rocks of the valley of Gastein are supposed to terminate above the gorge with some great masses of micaceous and chloritic schist containing subordinate, thin beds of crystalline limestone. These masses are succeeded, in the ascending order—(1.) By an enormously thick calcareous series, generally of slaty texture, but obscurely stratified, often arranged in great vertical masses with an irregular cross cleavage: the limestone is here and there so mixed with dark shale as to

\* In English feet the respective heights are 10182 and 8708.

† In the Geological Map of Germany (published by Simon Schropp and Co. of Berlin), all the region of the Alps between St. Michael and Radstadt is erroneously represented as mica-schist. The calcareous chain connected with the Radstadter Tauern extends westwards to Scheideck and Dragstein. The Weiss Eck on the south, and Kalk Spitz on the east, are detached masses belonging to the same system.

‡ See Plate II. fig. 2.

become argillaceous and of earthy texture; the strongest beds of limestone are sometimes highly crystalline, generally of a dark blue colour, and contain innumerable white, contemporaneous veins running in irregular lines transverse to the beds. (2.) Micaceous and chloritic slates with a nearly vertical cleavage, having in many places the structure of primary rocks. (3.) Similar slaty masses, but of more incoherent texture, irregularly mixed with calcareous matter, and with calcareous beds generally of a dark blueish colour and of a close subcrystalline texture. This system extends to the bottom of the gorge, and is continued for some way below Lend on the right bank of the Salza. (4.) Fine talcose slate mixed with and passing into serpentine. (5.) A series of beds composed of coarse micaceous slate, sometimes of nearly incoherent texture, mixed irregularly with beds and masses of blueish gray, subcrystalline limestone, which pass in some instances into a fine, white, crystalline dolomite. (5.) Great masses of *grauwacké* slate, here and there becoming earthy and passing into shale. (6.) Great beds of limestone, some of them white and crystalline, plunging at a high angle into the valley above St. Johann.

We found no traces of organic remains in this long series of deposits, from their commencement above the gorge in the valley of Gastein: but we are convinced, both from their mineral structure and range, that they are prolonged into, and form a part of the system of the Tauern Alp.

On the banks of the Salza, between St. Johann and Werfen, there are some repetitions of mineral structure similar to those above described; but on the whole the beds gradually present a coarser and more mechanical texture: the shales are less micaceous and chloritic, and the slaty masses alternating with them often pass into *grauwacké*. With this change of structure there is a much greater regularity in the dip; the whole of this upper system being carried, by an undeviating inclination towards the north, under the great precipices of secondary limestone.

A still higher series of rocks on the banks of the Salza are of such a character that it seems uncertain whether they should be referred to the transition or secondary class. They consist of variously coloured shales passing into *grauwacké*-slate, alternating with greenish gray or reddish fine-grained sandstone; and subordinate to them are some beds of highly calcareous shale and of limestone, in texture resembling some varieties of our transition or mountain limestone. The sparry iron ore of Winterwald, a little south of Werfen, appears to be associated with these ambiguous strata.

We did not examine in detail any of the great deposits of sparry iron ore which characterize the eastern Alps. Although not, perhaps, on the same exact parallel, they chiefly occur under the system of secondary, red, gypseous marl and sandstone, along with a fine grit or *grauwacké* which is more or less calcareous. According to information which we owe to His Imperial Highness the Archduke John, who from personal examination is most intimately acquainted with the mineral structure of every part of the eastern Alps, the following are among the most important localities where the ore has been extracted for use:—Freisnitz near the Sömring; Rickenau; Neuberg; Veitsch; Niedereibl; Goldrath near Marianzell; Eisenerz; Radmar; Admont; Lietzen near Aussee; and Winterwald south of Werfen\*. To the south of the iron ore runs a low chain of limestone more or less argillaceous, which between Neuberg and Admont is said also to contain several small veins of iron spar. In two localities, one near Aussee, and the other at Imlau Graben near Marianzell, the ore is said to overlie red gypseous marls. From all these facts we conclude, that the greatest part of these remarkable deposits are close to the confines of the lowest secondary group of the Alps, and perhaps in some instances enter partially into its composition†.

It would be incompatible with our present object to enter into any longer details respecting the structure of the great series of rocks above described: but it may be asked how we prove them to be of the transition class, since the organic remains imbedded in them exhibit no specific characters. Considering the crystalline structure of some of the secondary formations of the western Alps, it would be difficult to meet this objection, had we not found an answer to it in the facts exhibited by our transverse section on the south side of the central axis.

On the right bank of the Drave below Paternion the formations of crystalline slate are surmounted by *grauwacké*, shale, and red sandstone, forming the base of the Carinthian lead hills. These formations are not so well exposed, but the order appears to be precisely the same, as on the north side of the axis. A great fault ranges up the valley of Bleiberg, between

\* To the same Illustrious Personage we are indebted for many other details connected with the immediate objects of this paper. The section Pl. II. fig. 4, which we owe to Professor Rippl, shows that the geological relations of the great deposits of sparry iron ore near Eisenerz are similar to those above described.

† This conclusion is, we believe, in accordance with the opinion of Dr. Boué.

the Schlossberg and the Erzberg, producing an upcast to the south-east, in consequence of which the red sandstone and red gypseous marl forming the base of the metalliferous dolomites, are once more brought out, and the whole secondary system is seen to rest unconformably upon inclined beds of grauwacké passing, in some places, into a millstone conglomerate, in others, into a grauwacké slate which is here and there calcareous, and contains subordinate, thin beds of dark-blueish coloured limestone.

In the calcareous grauwacké slate there are many stems of encrinites; and the beds of limestone contain innumerable fossil shells chiefly of the three genera *Producta*, *Spirifer*, and *Terebratula*. Hand specimens of these rocks could not be distinguished, either by their structure or by their fossils, from English mountain or transition limestone: and it deserves remark, that in one of the sections below the village of Bleiberg, thin calcareous bands full of transition fossils mark the dip and bedding of the rock; while its slaty cleavage (precisely as in some of the calcareous transition slates in the north of England) is transverse to the stratification.

The fossil shells collected by ourselves are:

*Producta hemisphærica*;

*Producta latissima*;

*Producta*, a species resembling *P. Martini*;

*Pecten*, resembling a species in the transition series of Cork.

And to this list may be added,

Encrinites, fragments of *Spirifers*, &c. &c.

These facts appear to decide the question respecting the age of the system of beds we are describing, as far as regards the country south of the central axis: and to place the corresponding beds on the north side of the axis in a different system, would be a violation of the plainest rules of analogy. It seems therefore to follow, that certain important inferences, recently drawn from the non-existence of transition rocks with organic remains in some portions of the western Alps, have no application to the eastern parts of the chain here described\*.

\* By reference to M. Rengger's memoir in the *Denkschriften der allgemeinen Schweizerischen Gesellschaft* (Zürich 1829), it will be seen that transition rocks form an equally important band in a part of the western Alps, and that on their southern or inferior limit they graduate downwards from grauwacké slate into mica-slate and gneiss; whilst in an ascending series they pass through iron ore deposits into red sandstone and conglomerate. So that in the western division of the chain, as well as in the eastern, they separate the Alpine or Jura limestone (synonymous terms) from the primary rocks.

3. *Red and variegated Sandstone and gypseous Marl; sometimes with subordinate Beds of fetid Limestone, Rauchwacké, &c. &c.*

This deposit is, we believe, found nearly throughout the whole extent of the eastern Alps overlying the transition series, and forming the base of the great precipices of the older Alpine limestone. Its characters are so peculiar, and its continuity is so remarkable, that, independently of its importance as a term of comparison with other regions, it would well deserve a separate notice.—On the northern side of the transition system of the Alps, the red sandstone is exposed in a series of longitudinal valleys, and overlies nearly all the principal deposits of sparry iron ore, of which we have already pointed out the general range.

From Werfen on the Salza to Häring on the Inn, it ranges in the position we have indicated, forming a succession of red terraces; and, in consequence of a great increase in the thickness of the subordinate fetid limestone, spreads out into a succession of low ridges of hills ranging parallel to the escarpment of the Alpine limestone. On the west side of the Inn it is no longer visible, in consequence of the great dislocation pointed out above, which brings the higher beds of the calcareous zone into contact with the central axis.

On the south side of the central axis the deposit has the same position, and we believe also the same continuity; and it is well exposed in the valley between Ponteba and Tarvis; also on both sides of the Bleiberg hills, as is indicated in our transverse section.—In order to convey some notion of the structure of this formation, we proceed to notice one or two sections on both sides of the chain, where it is well exposed.

In describing the succession of deposits on the banks of the Salza, we have already pointed out certain beds of close-grained grauwacké sandstone and variegated marls, which seemed to form a passage between the true transition system and the red sandstone. About half a mile south of Werfen are some quarries in the secondary series, exposing the following succession of beds in the ascending order:

(1.) Irregular masses of red conglomerate with rounded pebbles of the older rocks. (2.) Black, calcareous shale passing into dark smoke-gray, fetid limestone, the whole irregularly traversed by veins of gypsum. (3.) Argillaceous beds striped with parallel, red bands of gypsum. (4.) A thick, irregular cellular bed with much hydrate of iron, thin veins of gypsum forming reticulations through the mass. (5.) A mass composed of several beds of gypsum, finely granular, but not fibrous,

fibrous, and at its upper surface alternating with gray gypseous marls. (6.) Thin beds of dark fetid limestone surmounted by beds of gypsum lost under the alluvium of the hill. The aggregate thickness of these beds is fifty or sixty feet, and their dip is north. Near the same place is another quarry exposing red and variegated gypseous marls, alternating with beds of red sandstone perfectly like the new red sandstone of England.

On the whole, the formation we are describing is ill exposed, the greater part of it being obscured by the accumulations of alluvial matter near the foot of the great calcareous precipices; and we have only pointed out the previous sections for the purpose of conveying some notion, however imperfect, of its internal structure. Its thickness is very considerable, but its lower limit is very ill defined. Its upper portion seems to pass into the Alpine limestone through the intervention of dark calcareous shales with subordinate beds of fetid limestone.

On the right bank of the Drave, south-east of Paternion, the red sandstone is much concealed, but the order is as follows: (1.) Grauwacké; (2.) Red sandstone; (3.) Shale and fetid limestone; (4.) Dolomite of the Erzberg.

The great fault which brings up the red sandstone series under the Schlossberg, on the left bank of the rivulet below the village of Bleiberg in Carinthia, exposes the following succession of phenomena\*: (1.) Contorted and broken beds of shale and bands of compact limestone. Some of the limestone is fetid; many of the beds of shale are meagre and micaceous, of a gray and blueish gray colour; others are red or variegated, more argillaceous, and contain irregular and earthy, nodular masses of gypsum. This system is traversed by one of the adits to the lead-works, which intersects many beds of stinkstone like those under the dolomites on the north side of the Erzberg.

(2.) Red sandstone alternating with red and variegated gypseous marls, not to be distinguished from the most characteristic beds of new red sandstone. This system rises from beneath the contorted shales, and in its prolongation abuts against some highly inclined beds to be next enumerated.

(3.) Highly inclined beds composed of coarse grauwacké, passing here and there into a conglomerate with rounded pebbles of quartz and primary rocks. The cementing principle is close-grained and micaceous, and so hard that the masses are quarried for millstones.

(4.) A second mass of red marl and sandstone overlying and

\* See Plate II. fig. 3.

abutting

abutting against the preceding group; also in its prolongation abutting against highly inclined beds of grauwacké slate.

(5.) A series of highly inclined beds of grauwacké slate, succeeded or cut off by an irregular mass of trap.

(6.) Trap, which traverses the ravine and occupies the banks of the rivulet for several hundred feet. It is close-grained, of a dark greenish colour, and breaks into irregular fragments at a number of earthy ferruginous joints. We have no specimens of this rock; but it may we think be regarded as a variety of the black porphyry, or *melaphyre* of De Buch. It contains several fragments of white crystalline limestone, and here and there passes into a conglomerate with a cement of iron clay.

(7.) The trap is immediately succeeded by grauwacké slate, with the subordinate thin beds of limestone above described, containing Encrinites, Spirifers, Productæ, &c. Further down the valley, and at the south base of the Schlossberg, the red sandstone series is seen for several miles overlying the grauwacké series and underlying the Alpine limestone.

The great faults, which have not only brought out the red marl and sandstone, but have made the dolomite of the Erzberg to abut against the grauwacké of the Windischerberg\*—the singular contortions and breaks of the formations—the appearance of the trap and trappean conglomerates, not merely the accompaniments but probably the causes of the disruptions—the unusual occurrence of organic remains decidedly of the transition class—the clear relations (notwithstanding the local confusion) of the transition and secondary systems—all these circumstances together make the sections in the neighbourhood of Bleiberg the most instructive we have seen in the Alps.

On the south side of the chain, porphyry is said to be in many instances subordinate to the red sandstone. In the valley above Ponteba we found red sandstone passing into conglomerate with pebbles of porphyry; and in the range of the formation, towards the west, porphyry becomes so extremely abundant as to predominate over, and in some instances almost to take the place of, the red sandstone†.

It

\* Plate II. fig. 1.

† The range and extent of this porphyry is well marked in M. Ployer's Map of the Tyrol. One of the sections which best exhibits its relations and intimate connection with the gypseous red sandstone, was well seen between Neumarkt and Cavalese, in a traverse, from the valley of the Adige to Predazzo and the Val di Fassa, made by one of the Authors of this paper in 1828. (Pl. II. fig. 7.) The lowest beds observable in ascending from Egna or Neumarkt, on the Adige, to the pass of St. Lugano leading to the Val d'Avisio, and thence to Predazzo, consist of red sandstone with greenish marls



It remains for us to notice the sections on the right bank of the Inn, through the red sandstone series; especially as we have there a good exhibition of that expanded portion of it which contains great subordinate beds of limestone. We have in a former paper noticed the masses of red marl, red sandstone, and conglomerate, which on the right bank of the Inn rise from beneath the Alpine limestone and form the support of the unconformable tertiary deposits of Häring. The sandstone passes, near the coal-works, into a very close-grained, thick-bedded, micaceous rock; and alternates with masses of limestone resembling rauchwacké, some of which are bituminous and extremely fetid. From this place to Schwatz (a distance of more than two posts), there are, on the right bank of the Inn, a great succession of sections showing alternations of fetid limestone and red marl or sandstone\*.

South-

marls and reddish gray calciferous grits. By following these on their rise towards the north-east, they are found to repose upon a sandstone, which passes downwards into a recomposed porphyry, and finally into a coarse conglomerate. This conglomerate at Lugano is seen to rest against the mountain masses of crystalline porphyry, from which it has been derived, and to which it appears to have precisely the same relations as the older conglomerates of Foyers, Trefad, and the Ord of Caithness, have to the granitic and syenitic rocks of the Highlands. (See Geol. Trans. 2d Series, vol. iii. p. 139.)

In an ascending order, these conglomerates, graduating into sandstones and grits, exhibit in one part a fine-grained whitish grit, like some of the best freestone of the Scotch coal-measures; and these beds contain impressions and detached portions of plants, and thin laminæ of carbonaceous matter. The red marls and red sandstone which succeed, immediately support the Alpine limestone of Monte Cislone; and the highest members of that mountain assume the prevailing dolomitic aspect and shivery structure of all the peaks of Alpine limestone in this part of the Tyrol. The same relations of red sandstone, marls, and grits, supporting the Alpine limestone, are seen well exposed in the adjoining valleys of Avisio and Fassa, wherever the general range and structure of these formations is not obscured by the trap dykes abounding in that region, many of which have a syenitic and granitic character. In the higher part of these valleys, and particularly near Predazzo, these dykes frequently burst through the regular strata, which in many instances are altered in their mineral character, dislocated, and frequently overwhelmed by bulging masses of the igneous and intrusive rocks. At the Canzocoli, the Alpine limestone in contact with the trap, is changed into a crystalline, white marble, which is now quarried for statuary purposes; the edges of the limestone presenting bands of serpentine, and the whole forming a beautiful and direct analogy to the altered lias (described by Dr. Macculloch) in the Isle of Skye, where that deposit comes into contact with syenite.

The red sandstone and marl which have been derived from the pre-existing porphyry, and which so uniformly support the Alpine limestone, contain subordinate protuberances of anhydrite and gypsum near Cavalese; and the rock-salt, recently discovered in the adjoining valley, is probably subordinate to the same deposit.

\* The transverse section from Häring to Schwatz makes a very acute angle

South-west of Schwatz this system terminates in red conglomerates, and is seen distinctly to rise up to, and repose upon, the older formations.

In this part of the range the limestone greatly predominates in the exposed sections; for the red marls and sandstones being more destructible, do not form precipices, but occupy small longitudinal valleys. The contortions of some of the limestone beds, and the nature of their alternations with the sandstone, are well exposed in sections south of Rattersberg. We believe that the greatest number of these limestone beds are magnesian, some of them are metalliferous, and nearly all of them are fetid\*. Their structure is extremely various. Some of them are compact, some white and crystalline, some yellow and earthy, and some cavernous. When struck with the hammer, some of the masses shiver into innumerable fragments; and one of these varieties, of a beautiful white colour, has externally the small columnar structure of dried starch, and when struck falls into minute grains with trapezoidal faces. The name of *rogenstein* has been given to this variety, which however presents no analogies to the *rogenstein* of the Hartz.

This limestone series has often been called transition. We have allowed the difficulty of drawing a line between the secondary and transition systems of the Alps; and in this instance we derive no assistance from organic remains, for a few casts of *Terebratulæ* are the only fossils we saw in the beds we are describing. They are, however, too much interlaced with the lower part of the red sandstone to be separated from it; we agree therefore with Dr. Buckland in considering them secondary: and if the red sandstone of the Alps be identified with the new red sandstone, they approach both in position and in mineral character, much nearer to the *zechstein* or magnesian limestone than to any other formation with which we are acquainted. At the same time we wish carefully to distinguish them from the great zone of older Alpine limestone, from which they are separated by the red sandstone and gypseous marls, and to which, according to our views, they are in no respect subordinate.

#### 4. Older Alpine Limestone.

By the term Alpine limestone we mean the limestone found in any part of the great secondary calcareous zones superior

angle with the range of the red sandstone system, and therefore convey an erroneous idea of its thickness; which, however, after every deduction, must be very considerable.

\* Most of the old works below Schwatz were, we believe, in veins of argentiferous galena. They are now deserted.

to the red sandstone. The calcareous beds described in the preceding section are not therefore included under this term; which has undoubtedly led to some mistakes, having been applied to the *zechstein*, to the oolitic series, and to true transition rocks. It is not well that the same name should designate formations so widely separated from each other; but limiting the term Alpine limestone as we have done, we think that it may be used with advantage, and that it can lead to no confusion. This great deposit admits, as we have already stated, of three natural subdivisions, which we proceed to notice in order\*. It is, however, entirely foreign to our purpose, to give many details respecting a formation so well known, and so often described by those who have possessed incomparably better means than we had of studying the details of its mineral structure: we shall therefore in a great measure confine ourselves to a brief notice of some of the phenomena on our lines of section.

The first division, the older Alpine limestone, appears on our transverse section in the dolomites of the Bleiberg and the great escarpments of the Tannen Gebirge. We have before noticed the marls and thin beds of fetid limestone below the village of Bleiberg, which seem to form a passage into the superior limestone series. The thin-bedded, fetid limestone also appears in great force near the northern base of the Erzberg, overlying the red sandstone, and passing into the superior dolomites.

Near Werfen the order observed at the base of the calcareous zone was as follows:

1. Thin, dark, bituminous beds with calcareous veins; some of them fetid, and the masses shivering into angular fragments.
2. Light-gray limestone, breaking into similar fragments.
3. Dark, fetid beds, alternating with dark, micaceous shale throwing out copious springs of water.
4. Beds of limestone of compact texture, much traversed by calcareous veins, and used for marble. The beds separated into vertical masses by many great perpendicular clefts.
5. Gray limestone and shale.
6. Dark beds of limestone, traversed by contemporaneous veins, alternating with dark shale, into which they pass in-

\* The subdivisions of the Alpine limestone here adopted, were we believe first given by M. de Lill, of Hallein, a gentleman whose investigations have thrown great light on the natural history of the secondary formations of the chain. The Geologists of the French school seem disposed to reject the term Alpine limestone altogether, and to substitute in its place the term Jura limestone. We are unwilling to exclude the term Alpine limestone from what we think its proper place, and are only anxious to give it a consistent meaning, which may lead to no mistakes.

sensibly, and become of earthy texture.—This system is surmounted by the great, gray, bare precipices of lower Alpine limestone many thousand feet in thickness. It appears, therefore, that in the structure of the lowest beds of the Alpine limestone there is, to say the least of it, a very strong analogy between certain parts of the great northern and southern zones.

Dark, bituminous, slaty beds are not, however, confined to the base of the series, but in some instances, for example in the Seefeld pass, compose whole mountain masses. In consequence of the very complex dislocations of that part of the calcareous zone, it is difficult to ascertain the exact place of the bituminous ichthyolites of Seefeld. But placing the dolomites of Mittenwald as the mineralogical centre, we think that the Seefeld schist is considerably inferior to the saliferous deposits of Hall, and that some of the beds of the system descend far down into the lower Alpine limestone.

It would be useless for us, after all that has been written on the subject, to attempt any general description of the dolomites of the Alps. The metalliferous hills of Bleiberg are chiefly composed of this variety of rock, arranged in great irregular beds dipping south at an angle of 70°. The lead ore of these hills is arranged in masses which appeared to us parallel to the beds of limestone: but our persevering and skilful young friends, Messrs. J. and R. Taylor (who had previously visited the mines and examined them with great care) have since convinced us that the ore is deposited in true veins; which, though they for considerable spaces range parallel to the strata, cut obliquely through them at certain intervals. In the dolomitic beds of the hill above the village, are a few casts of shells and other obscure fossils; and we were happy to recognize among them two or three specimens of the *Gryphæa incurva*. Immediately behind the village are some beds of shale and limestone (fire-marble), with many fossils; among which are the celebrated iridescent *Ammonites*, which Dr. Buckland, we believe, identified with the fossils of the lias. Considering, then, that in this single locality we have *grauwacké* with beds of limestone containing transition fossils, surmounted by red sandstone and gypseous marls; and this latter series again surmounted by fetid limestone, dolomites, &c. containing the *Gryphæa incurva*, and by other beds containing *Ammonites* and *Belemnites*—there can, we think, be no doubt to what part of the secondary series we should refer the lowest division of the lower Alpine limestone as it is developed in the Bleiberg Hills.

Notwithstanding the magnificent scale of the sections in the  
Salzburg

Salzburg country, the geological evidence on that side of the chain is not so complete as in the neighbourhood of Bleiberg. Ammonites and Belemnites have been found, though rarely, in the lower part of the great precipices which surmount the red sandstone series near Werfen; but we are not aware that the *Gryphæa incurva* has ever been seen along with these fossils. The argument from analogy is, however, sufficiently convincing where we have nothing to oppose to it. We therefore venture to conclude, that the great system of the older Alpine limestone, overlying the red sandstone, commences on both sides of the chain with the lias. Its precise superior limit we are not able to indicate; but we believe, from its enormous thickness, as well as from some of its fossils, that it ascends considerably into the oolitic series\*.

5. *Limestone with subordinate saliferous Marls, &c. &c.*

No mines of salt have, we believe, been worked in the formation of red sandstone and gypseous marls which underlies the older Alpine limestone. All the principal deposits of that mineral are in a much higher position; being incased in the calcareous system of the Alps, and distinctly overlying the older Alpine limestone. This fact appears to be incontestably proved in the memoirs of M. de Lill de Lilienbach†; to whose kind assistance and instructions we were greatly indebted during our visit to the Salzburg Alps.

\* Along the line of our transverse section, we in vain looked for that structure which is so characteristic of many of the secondary rocks of England; and in no instance did we discover a single specimen of true oolite. In the range of the calcareous zone along the southern flanks of the Bacher Gebirge, and from thence towards the lower regions bordering on the Danube, the rocks, however, occasionally exhibit the external characters of a part of our oolitic series. Thus, near Gonowitz, we found beds of a yellow colour, and a coarse open texture, somewhat resembling cornbrash, and containing many well preserved fossils. At the time, we were not aware of the rarity, and consequent interest, of these phenomena; which are well deserving of a much more careful examination than we bestowed upon them.

On the great road from Cilly to Laybach, there are some highly interesting sections, especially near Fränz and St. Oswald, where great beds of shale alternate with coarse, reddish sandstone resembling millstone grit; the whole being surmounted by masses of rauchwacké and other modifications of dolomite. In the same neighbourhood are several beds of coal, which we wished to visit, as we supposed them analogous to the coal deposits we had seen, subordinate to the newer secondary system, south-west of Vienna. We were however disappointed in our hopes of seeing them; and we have been since informed that they all belong to formations of tertiary brown coal. We mention these facts, not in the expectation of throwing any light upon the structure of this portion of the Alps, but in the hope of directing the attention of future observers to the interesting phenomena of the calcareous chain between Gonowitz and Laybach.

† *Zeitschr für Mineralog.* No. x. 1828; and *Bulletin des Sciences*, Mai 1829, &c. &c.

In several parts of the chain the older Alpine limestone is succeeded by a great series of beds, composed of limestone, calcareous gritstone, sandstone, and shale. The calcareous beds are often nearly compact, sometimes cherty, commonly separated by thin bands of marl, and offer many varieties of colour and structure. The other members of the system are liable to like variations. The beds of marl, shale, and sandstone sometimes become greatly expanded; and the whole system frequently becomes contorted to such a degree, that great masses of brecciated sandstone, shale, &c., are rolled up and enclosed in mountain masses of the limestone we are now describing. To what causes the phenomenon may be due we do not inquire; but it is, we believe, among such brecciated and contorted masses that all the rock-salt of the eastern Alps has been discovered. The several deposits, commencing at Hall, and ranging through Berchtholsgaden, Hallein, Halstadt, Ischel, and Aussee, are certainly not now, and probably never were, continuous; but they have all been formed under nearly similar circumstances, and are all nearly on the same parallel. We proceed briefly to notice one or two sections where the true position of the rock-salt is indicated; and for fuller details we must refer to the papers of M. de Lill and other writers on the structure of the eastern Alps.

(1.) *Salt deposit of Hall.* (Pl. II. fig. 5.)—The accompanying section (for which we are indebted to M. Pöhringer, *Ober Bergmeister* at Hall) shows the true position of the rock-salt among the calcareous mountains on the left bank of the Inn. The whole system has a regular dip of about  $30^{\circ}$  towards the S.W., and belongs to that part of the secondary chain which, in consequence of an enormous dislocation, seems to plunge under the central axis (see above p. 83). The lowest beds of limestone in the section rise into the peaks of the Lavatscherberg, in which are found many iridescent Ammonites. They are succeeded by some compact, red beds resembling those immediately below the salt in some other localities. These red beds are surmounted by bands of anhydrite, forming the base of a great saliferous mass, composed of green, red, gray, and variegated marls, brecciated masses of sandstone, fetid limestone, &c., in which all appearances of stratification are entirely lost\*. The whole thickness of this mass, measured in the direction of the section, is about 1250 English feet; and

\* This position of the anhydrite seems to be nearly similar to that which has been noticed by Charpentier, Bakewell, and other writers on the gypsaceous and saliferous masses in the Alps.

galleries have been opened in it at the height of 4480\* Vienna feet above the level of the sea: but, like all the other corresponding deposits, it appears soon to thin out, so as not to be continued through the neighbouring mountains. The brecciated saliferous mass is surmounted by three beds of the united thickness of fifty feet. The lowest (*c*) is chiefly composed of marl; the middle bed (*b*) of gypsum; and the highest (*a*) consists chiefly of a gray and white concretionary limestone, the nuclei of the concretions being often composed of small *Terebratulæ*. To this rock the term *rogenstein* has been applied, as well as to the singular concretionary magnesian rock near Schwatz (*supra*, p. 96); but they both differ essentially, in their structure and relations, from the *rogenstein* of the Hartz, which is a coarse oolite subordinate to the new red sandstone. Over these beds come the upper strata of limestone containing many fossils; among which we recognized *Ammonites*, *Belemnites*, *Buccinites*, *Pectens*, *Terebratulæ*, &c. &c.

The whole of the beds here described, both from their position in the chain and from their fossils, belong evidently to the middle system of Alpine limestone; and notwithstanding the brecciated structure of the saliferous mass, they seem to be less disturbed than in the other analogous deposits of the Alps.

(2.) *Salt formations of Berchtholsgaden and Hallein.*—These two deposits, though very near together, are not continuous; probably in consequence of the great dislocations and contortions of the neighbouring portions of the chain. The relations of the salt mass of Hallein are extremely clear and may be seen even in our very reduced section (Pl. II. fig. 2). It is in a lenticular form, being about 1520 toises in length, 600 in breadth, and 220 † toises in its greatest thickness; and it is imbedded, or rather enclosed, in the contorted strata of limestone. The limestone below the salt is thin-bedded and compact; in colour gray, red, or variegated; alternates with bands of green and red marls, and contains here and there considerable portions of chert. It is surmounted by dark-coloured, gypseous marls which form the lining of the salt deposit‡. The saliferous masses are made up of green, red, and variegated gypseous clays, much mixed with brecciated masses of red micaceous sandstone, and with fragments and concretionary masses of dark-coloured limestone. The whole system is surmounted by twisted beds of light-gray, compact limestone, some of which contain many fossils. These relations are proved, not only by the

\* 4672 English feet.

† 9722, 3837, and 1407 English feet.

‡ In the galleries through the dark-coloured gypseous marls there is an extraordinary efflorescence of sulphate of magnesia.

general structure of the whole region, but also by numberless internal traverses through every part of the saliferous mass. It is therefore obvious, that the salt of Hallein is subordinate to strata separated from the lower red sandstone and gypseous marls, above described (p. 92), by many thousand feet of the older Alpine limestone\*.

3. *Saliferous mass at Ischel.*—The salt deposits of Halstadt, Ischel and Aussee are, we believe, very nearly on one geological parallel; and in their structure and relations to the nearest portions of the chain, they seem to be almost identical. The accompanying plan of the Ischel works†, which we owe to the kindness of M. Dicklberger the *Ober Bergmeister*, will convey a correct notion of the position of the salt mass among the beds of limestone. The neighbouring hills to which the salt is subordinate, in consequence of a great flexure, dip to the south-west. The beds under the salt are argillaceous, and contain some bands of dark-coloured limestone with casts of Ammonites and some bivalves. Over these beds, and immediately under the salt mass, are some thin, compact, cherty beds of limestone. The salt mass is a confused, irregular compound of gypseous and saliferous marls, &c.; which has been worked, at the lowest level, through a breadth of about 500 Vienna feet, and through a depth, between the highest and lowest levels, of about 1500 feet. These different levels are approached by means of 12 horizontal galleries cut through the inferior beds, as represented in the plan. It deserves remark, that here, as at Hallein, the saliferous mass (E) is separated from the surrounding limestone by bands of dark-coloured gypseous marls (D) not saliferous. The superior beds of limestone (F) are hardly to be distinguished, either by their structure or their fossils, from those which underlie the salt.

These details are sufficient to explain the nature and position of the great saliferous deposits of the eastern Alps, which evidently occupy an intermediate position between the older and younger portions of the calcareous zones; and may therefore, along with the accompanying strata, be conveniently regarded as one of the natural subdivisions of the Alpine limestone, in which so many of the distinctive characters of secondary formations are almost entirely wanting.

\* The relations of the saliferous beds of Berchtesgaden are not so obvious; but we have little doubt that they are nearly in the same geological position: for the system is continued northwards across the valley, and passes finally under the ridge which is a prolongation of Untersberg. On this account we think that the saliferous beds of Berchtesgaden cannot, by any complex series of faults, be brought into comparison with the marls inferior to the older Alpine limestone.

† Plate II. Fig. 6.



If it be asked in what part of the secondary series we place the salt deposits above described, we are unable to give any very definite answer to the question. In the limestone beds associated with the salt are many fossils; among them are Ammonites, of which the concamerations are marked by simple or undulating lines, and Orthoceratites. Both these fossils might be supposed to indicate strata older than any part of the oolitic series. Along with them are however near Hallein, oval Ammonites, and spheroidal masses resembling organic remains of the green-sand; also several casts of shells resembling oolite fossils, and a singular body, found in our Kimmeridge clay, to which the name *Tellinites solenoides* has sometimes been given. At Aussee, in the beds of limestone containing the saliferous marls, there are, along with other fossils, corallines of the genera *Tubipora* and *Astræa*, and *Pentacrinites*. On the whole we are disposed to place the salt formations of the Alps high in the oolitic series.

The preceding conclusion might appear strange to one who had only studied English geology; but it cannot now be considered anomalous, as recent discoveries have established the existence of salt among rocks of almost all ages. In the Crimea it is said to be daily accumulating in inland lakes. In Poland it probably exists among tertiary deposits. In the Austrian Alps we have placed it among the upper oolites. In Switzerland Mr. Bakewell places it in the lias. In Wirtemberg Alberti has proved it to be both in the *Keuper* and *Muschel-kalk*. In England, though all the great salt mines are in the new red sandstone, there are two or three copious salt springs in the coal-measures. Lastly, in certain parts of the United States, salt springs are stated by Mr. Featherstonehaugh to issue from old transition slate rocks\*.

#### 6. *Younger Alpine Limestone.*

Under this designation we include all those portions of the northern secondary chain which are superior to the saliferous deposits of the Alps. As we were unable to define the upper limits of these deposits, we are necessarily unable to define the lower limit of the formation we are now attempting briefly to describe. We, however, suppose that it commences somewhere in the middle or upper system of the oolitic series; and it terminates on the outskirts of the chain, in ridges of indurated shale, sandstone, and limestone; in some places containing many characteristic fossils, and now supposed, by most of the geologists who have visited the region, to be the equivalents of the green-sand and chalk.

\* See Phil. Mag. and Annals, N.S. vol. vii. p. 200.—EDIT.

Our examination of the calcareous zone on the south flank of the Alps was much too hasty to enable us to establish the three subdivisions we are now attempting to illustrate. We believe however that they may be traced, and that the zone may in many places be distinctly divided into older Alpine limestone and younger Alpine limestone, separated from each other by a system of strata composed of thin-bedded limestone, alternating with shales, gypseous marls, &c. One or two sections, kindly shown to us by Professor Rippl, exhibited this succession: and if these gypseous marls be considered as the representatives (in a somewhat altered form) of the saliferous system of the northern Alps, the subdivisions of the two great calcareous zones will be in perfect accordance.

In the southern Italian Alps, the younger formation of limestone has been examined with great care by MM. Maraschini and Catullo; and the latter gentleman has, by the help of a great suite of organic remains, proved the existence of beds of the age of the green-sand, overlying rocks containing many organic remains of the oolitic series. Near Belluno, Feltri, Canal di Brenta, &c., the system terminates in a red and white fissile limestone (*scaglia*) containing many flints; which, from its structure, position, and fossils, has been indentified with the chalk.

Between Adelsberg and Trieste the limestone beds contain many fossils, and among them are innumerable Nummulites. How far these fossils descend in the secondary series, we are not able to determine. In the ascending order, the formations, before they reach the Adriatic, undergo a great change in external character. The calcareous beds (chiefly composed of a compact, light-gray limestone full of Nummulites) no longer predominate; but become subordinate to great masses of blueish gray micaceous shale, and of sandstone generally of a gray or greenish gray colour, and here and there containing a few traces of carbonaceous matter. Along the shores of the Adriatic, for several leagues south of Trieste, the micaceous shale is so abundant as to produce a succession of ruinous cliffs, apparently held together only by the subordinate bands of sandstone and nummulite-limestone. We believe that this system is now generally regarded as the representative of the green-sand or chalk—a conclusion which is in perfect accordance with our views of the structure of the district.

It is not our intention, in such a sketch as this, to attempt any detailed description of the younger secondary formations of the Austro-Bavarian Alps; we must, however, notice some of their varieties of structure, and some of the masses which are subordinate to them. Occasionally they pass into dolomites,

mites; in which case they generally rise into peaks, weather into peculiarly fantastic forms, and lose all traces of stratification. From this it would seem, that their mineral structure has originated in some great crystalline action, which commenced after the deposition of the calcareous mass. We must however observe, that the same external forms, the same crystalline texture, and the same obliteration of all traces of depository origin, may be found in numberless parts of the chain where the rocks contain no magnesian earth.

Gypsum is found, in several places, subordinate to the younger Alpine limestone: for example, at Faulenbach near Fussen, where it is extensively quarried. The same mineral is found, near the head of the Kochel See, high in the series, and close to the tertiary plains of Bavaria. It is there associated with black, blue, and red fetid marls, and with fetid, porous rauchwacké, not to be distinguished in external character from the magnesian limestone of England. We mention this to show the hopelessness of attempting to determine the age of the different portions of Alpine limestone by mere mineral structure. We may further remark, that gypsum is found in the Alps among secondary rocks of all ages, and is therefore, by itself, no test of the age of any of them. We have already shown, that it exists in the marls inferior to the older Alpine limestone, in the superior saliferous marls, and also among beds high in the series of the younger Alpine limestone: and in former communications we have shown that the same mineral is also found, in considerable abundance, among the tertiary formations of Salzburg and Bavaria\*.

In the extreme prolongation of the calcareous zone into the ridges which terminate the chain a few miles south-west of Vienna, coal-works have been opened, in one or two places, under the direction of Professor Rippl. The coal is of bad quality, and is subordinate to shale alternating with the Alpine limestone. We obtained no fossils from the neighbourhood of the works which we visited; but we suppose, from their position in the chain, that they are in the higher part of the system we are describing.

One of the most abundant rocks of this series is a peculiar, light-gray, compact limestone, well known to every one who has visited the Alps; but entirely unlike any secondary rock

\* On the north-western bank of the Walcher See, near the side of the great road from Inspruck to Munich, are traces of some works which were opened about twenty years since in search of quicksilver. We were informed that some traces of that metal had been found among the argillaceous masses which there alternate with the beds of younger Alpine limestone.

of England. It is well exhibited in some of the beds of Untersberg; which on the north-west flank of that mountain contain innumerable Hippurites of the same species with those found, both in Provence and the Pyrenees, among rocks supposed to be of the age of the green-sand\*.

The Hippurite beds, in their prolongation towards the east, pass under a great series of white and red indurated marls, containing, we believe, some chalk fossils. These are surmounted by gypseous marls, with bands of calcareous grit containing Nummulites; which are in turn surmounted by a great system of beds, composed of sandstone (*molasse*), conglomerate, shale, and marl; some of the highest of which (in ravines below Schweiger Mill, &c. &c.) contain fossils similar to those in the overlying beds of Gosau. (See Pl. II. fig. 1 & 2.)

We think these highest beds, from their position in the section as well as from their fossils, are superior to the chalk; and on that account we in a former paper called them tertiary. We at the same time stated that we regarded them as a term of an undefined series, to be interpolated between the *calcaire grossier* and the chalk, and that we did not pretend to draw any well-defined line between them and the secondary system.

We have already mentioned the ridges of hills, composed of shale, sandstone, and limestone, developed on the outskirts of the Salzburg and Bavarian Alps close to the tertiary system. Being more thin-bedded and of less firm texture than the older parts of the chain, they have been exposed to extraordinary breaks and contortions; sometimes dipping towards the mineralogical axis, and sometimes from it; in one place being vertical, in others twisted into saddle-shaped masses; and, if we mistake not, being in some instances absolutely inverted. This series appears to be greatly expanded near the eastern termination of the Alps, and has been described by Dr. Boué, with many excellent details, under the name of Vienna sandstone (*grés Viennois*). In the maps and memoirs of M. Keferstein, it is designated by the name of *Flysch*.

From the outskirts of the calcareous zone near Reichenhall to the valley of the Rhine, it forms, in the position we have pointed out, a nearly continuous succession of ridges, easily distinguished from the inner portions of the chain. In some parts of the system the beds of limestone almost disappear, and it then passes into a formation of sandstone and shale, hardly to be separated, without the help of fossils, from the superior

\* We have the authority of Mr. Lyell, for stating that near Cape Passero in Sicily, Hippurites occur in a tertiary formation newer than the Sub-apennine: but most frequently they seem to occur in the newer secondary formations.

tertiary groups. In other places the calcareous beds of these outer ridges are of much greater thickness, and they then exhibit all the usual mineralogical characters of Alpine limestone.

The Kachelstein (immediately south of the iron works of Kressenberg, near Teisendorf) exhibits the following characteristic succession. (1.) Light-gray, calcareous marls with indurated bands resembling *planer-kalk*. (2.) Blueish, micaceous marls with calcareous bands, some of which are composed of calc-grit; others of compact, argillaceous limestone resembling blue and white lias. (3.) A great series of blueish gray flag-stones, alternating with marls, generally blue, but here and there of red or greenish red colours. (4.) Micaceous sandstone, mostly thin-bedded, and of a greenish gray colour, but containing some thick beds extensively quarried for building. Some of the calcareous bands of this lofty ridge contain Ammonites, and Belemnites; and it appears to be separated by a double system of faults, on one side from the metalliferous mountains of Alpine limestone, and on the other from the newer ferriferous strata of the Kressenberg\*.

In the Alpen Spitz immediately south of Nesselwang, beds of compact limestone, with many Belemnites, occasionally passing into a more earthy texture (like indurated *planer-kalk*) and containing balls of pyrites, alternate with bands of calc-grit and thick beds of dark-coloured shale.

In some instances the rocks of this system exhibit the ordinary characters of the green-sand of England. Thus at Sonthofen the iron-sand is not distinguishable in mineral character from the lower green-sand of the Kentish denudation; and it contains many fossils, among which we may enumerate Ammonites, Belemnites, Inocerami(?), Nummulites, Pectens, Terebratulæ, numerous crustacea, &c. &c. We had no hesitation in considering this deposit as subordinate to the higher part of the younger Alpine limestone, and therefore secondary†.

At Haslach, a few miles south of Bregenz, there is a deposit of red oxide of iron in beds of calcareous shale, alternating with beds of calc-grit and limestone, some of which are of a bright green colour. The series seems to pass under great precipices of Alpine limestone much charged with Nummulites. At Oberdorf, in the immediate neighbourhood, is a

\* We have the authority of the *Berg-Meister*, who has many years superintended the iron works, for asserting (in confirmation of the published statements of Count Munster), that the Kressenberg beds contain no Ammonites or Belemnites. In our opinion the formations of the Kachelstein and Kressenberg, though in close contact, ought not to be confounded.

† Dr. Boué has erroneously stated, in different journals, that we had considered the Sonthofen deposit as tertiary.

nummulite-limestone, apparently subordinate to great beds of indurated marl resembling *planer-kalk*. The geological relations at the last-mentioned places are rather obscure; but the deposits are we think unquestionably secondary, and nearly on the same parallel with those at Sonthofen.

On the whole we concluded, that the different portions of the ridges above described, which appear on the outskirts of the Alps, were nearly of the same age with the green-sand and chalk formations of England. The conclusion seems to be borne out by the position of the subordinate beds, as well as by their fossils, and is in some instances also confirmed by their mineral contents.

It was our wish in this sketch of the structure of the Eastern Alps, to avoid mere matters of detail, as being incompatible with our object. But the short abstracts of some of our former communications having been misunderstood, and consequently misrepresented; it became necessary, in this account of the younger Alpine limestone, to explain our views, more at length than we first intended, by referring to two or three specific localities.

### 7. Tertiary Deposits\*.

Having in two papers, read last year before the Geological Society, explained our views respecting the tertiary deposits of the Austrian Alps; we should not have added anything to what we have already stated, had it not been necessary to notice certain comments on these communications which have been published by Dr. Boué †.

1. He is mistaken in supposing that we confounded the iron sand of Sonthofen with rocks of the tertiary age. We distinctly stated that it contained Ammonites and Belemnites, and alternated with beds of the younger Alpine limestone; from which we concluded that it was secondary; and this conclusion is given, though very shortly, in the published abstract of our paper (Phil. Mag. and Annals, N.S. vol. vii. p. 53). On the age of the Sonthofen beds there appears therefore to be no difference of opinion between ourselves and Dr. Boué: but he has been led to misrepresent our meaning, from knowing nothing of our communications except through the medium of abstracts, which from their brevity may be easily misunderstood.

\* By tertiary deposits we mean all regular beds, of whatever age, newer than the chalk.

† See New Edinburgh Philosophical Journal, Jan. 1830, p. 176; *Bulletin des Sciences*, Février 1830, p. 228—Juin 1829, p. 328; Abstract of the Proceedings of the Geological Society (Phil. Mag. and Annals of Philosophy, for the last month, p. 64-67), &c.

2. He states that the tertiary formation of Häring is entirely of freshwater origin. We prove that it contains several species of marine shells; from which we conclude (contrary to the opinion of Dr. Boué, but on evidence we think not short of demonstration,)—that the marine tertiary deposits of the Alps do sometimes ascend far up the transverse secondary valleys.

3. He contends that the tertiary formations on the flanks of the Austrian Alps commence with the superior divisions of that class of rocks, the lower divisions being entirely wanting. We, on the contrary, have shown, both by transverse sections and suites of fossils, that some of the inferior groups of the tertiary deposits in the Gratz basin are of the age of the London clay. So far there is a difference between Dr. Boué and ourselves on what we consider questions of fact.

4. We also differ from him considerably on questions of opinion. For example: he describes great masses of calcareous conglomerate in the Salzburg Alps, which he compares with a part of the *nagelfluh* of Switzerland, and places in the secondary system under the green-sand. We have not examined the *nagelfluh*, and can therefore offer no opinion respecting its age; but of late years it has been generally considered tertiary. In the Salzburg Alps, the great masses of calcareous conglomerate are chiefly found on the outskirts of the chain, and form the base of a new series of deposits which are physically and zoologically separated from the older system; and are, if we mistake not, newer than the chalk. Occasionally, as in the valley of Gosau, they appear far within the chain: but in that case they are unconformable to the rocks which surround them; and there is then no means of determining their age, except by the help of their fossils, or by comparing them with the corresponding beds on the outskirts of the chain. After making use of both these means of comparison, we concluded that the overlying conglomerates of Gosau were newer than the chalk: and in our examination of other parts of the eastern Alps we did not find any large masses of coarse, calcareous conglomerate subordinate to the newer secondary system.

5. M. Boué seems to attribute much greater importance, than we do, to mere mineralogical distinctions. We know numberless instances in which green-sand above the chalk cannot be distinguished from green-sand below the chalk. Some of the lacustrine formations of central France have been mistaken for old secondary deposits. We have found, on the outskirts of the eastern Alps, fossils of the London clay alternating with rocks resembling our coal grits, and masses of conglomerate like those subordinate to the oldest secondary rocks;  
and

and we have shown, that the youngest tertiary shells of Lower Styria are sometimes associated with a beautiful oolite, undistinguishable in hand specimens from the great oolite of Bath. On these accounts we think that mineral character alone is nearly useless in comparing the ages of tertiary formations widely separated from each other.

6. He appears to identify the two deposits of iron ore at Sonthofen and Kressenberg. They both occur in a ferruginous green-sand with many Nummulites, and their mineralogical resemblance is nearly complete. But Nummulites by themselves prove nothing; and it may be asked whether all the circumstances of these two deposits are such as to justify this identification. We think not. For the Sonthofen iron ores contain Ammonites and Belemnites, and (if we rightly understood the plans of the works) are interlaced with the secondary system of the Alps. On the contrary, the Kressenberg deposit contains no Ammonites or Belemnites, and is entirely on the outskirts of the secondary system; so that its age can only be made out by its internal structure and its fossils. Now there is nothing in the mere structure of the Kressenberg beds to prove that they are secondary; and an elaborate examination of their fossils by Count Munster gave the following results.

(1st.) Of 172 species of these fossils, 42 exist in, and are characteristic of, the tertiary formations of Germany, England, France, and Italy.

(2nd.) There are 3 species, 2 of which resemble, and one of which (*Ostrea semiplana*) is identical with, certain fossils of the chalk.

(3rd.) Of the remaining 126 species, some are new and others indeterminable; but for the most part they belong to such genera as are commonly found in tertiary formations.

(4th.) Of the characteristic chalk-fossils, (viz. Ammonites, Belemnites, Hamites, Scaphites, Turritulites, &c. &c.,) there is not the least trace. Neither are there any traces of the *Gryphæa columba*, of *Inocerami*, plicated *Terebratulæ*, &c. &c.

(5th.) The only fossils (excepting the three above mentioned) which at the first glance seem to belong to the chalk, are a *Plagiostoma* and a *Gryphæa*. But on a closer examination, they not only differ from fossils of the chalk, but are of the same species with certain fossils found in the tertiary formations of Ortenburg and Sternberg.

Such are the statements of Count Munster. And no reply has been, or can be, given to them; unless it can be shown that the fossil species have been erroneously determined. But this has not been attempted. We therefore adopt the conclusion



clusion of Count Munster, that the iron-sand of Kressenberg is a formation newer than the chalk\*.

With the same spirit of generalization, of which we have been speaking, formations widely separated from each other, in the Alpine and Carpathian chains, have been brought under comparison; sometimes by the help of mineralogical characters, almost unassisted by a single organic fossil. Nor do we complain of this where no better evidence is to be had. On the contrary, we owe the greatest obligations to MM. de Lill, Boué, and other writers who have thrown much light on the structure of parts of Europe which have been seldom visited. At the same time, in all questions of doubt, we must take care not to allow ourselves to be misled by mere words; and in settling any difference of opinion, we must never apply to one formation the properties of another in a distant region, because it passes under the same name. For example; in arguing respecting the age of the overlying beds of Gosau, we have no right to transport the reader over 150 miles of Alpine limestone, and then to assert, that (at Grünbach, Piesting, &c.) the *same deposit*, as that at Gosau, contains Belemnites and certain other secondary fossils. In the present state of our information, and on questions of doubt, such an argument is nothing better than a direct inversion of the rules of induction.

7. After the preceding remarks, we are prepared to enter on the question of the age of the overlying deposit of Gosau. Let it be borne in mind—that it is identical with formations at the base and outskirts of the chain, and that it is equally difficult to account for its present position among the serrated Alpine peaks, whether it be considered secondary or tertiary—that the chain has undergone great movements of elevation within the tertiary period—that the older divisions of the tertiary groups do exist in certain portions of the eastern Alps—

\* M. Boué appears to assert that Ammonites and Belemnites are found in the Kressenberg deposit (*Bulletin des Sciences*, Juin 1829, p. 329.). On the authority of the *Berg-Meister*, who has spent many years in excavating this deposit, as well as from our examination of the spot, we doubt the correctness of this assertion; and it would be to no purpose to tell us that these fossils are found at Sonthofen. M. Boué also states, generally, that the fossils of the green-sand make a near approach to those of tertiary formations: and that some fossils of the oldest secondary rocks at Hall, Bleiberg, and Maibeln in Carinthia, have also a tertiary appearance (*Bulletin des Sciences*; and abstract of the proceedings of the Geological Society, July 1830). We do not wish to oppose all parts of this statement; but we think that at least the Bleiberg fossils offer no support to it.—If such suites of fossils, as those described by Count Munster, really occur in the green-sand below the chalk, there is an end of any zoological distinction between secondary and tertiary formations. † See our last Number, p. 65.—EDIT.

that

that we have, consequently, no right to exclude them, at least hypothetically, from the Salzburg valleys; and lastly, that the tertiary deposits do sometimes ascend (e. g. at Häring) far up the transverse valleys of the neighbouring portions of the chain. If all this be admitted, we must allow—that there is no great *a priori* improbability, much less any impossibility, that the Gosau beds should be of some age newer than the chalk. If it be further considered—that there is a great break between the *calcaire grossier* and the chalk, which has not yet been filled up—that in the neighbourhood of Maestricht, beds have been found superior to the chalk, and containing a mixture of secondary and tertiary shells\*—and that the portion of the chain we are describing, underwent its last elevation since the commencement of the tertiary period; we must then also conclude—that the regions bordering on the eastern Alps are the very places where we ought to look for the presence of ancient tertiary formations.

If the eastern Alps have been elevated at so recent an epoch, may there not have been on their flanks a continuous succession of deposits, between the newer secondary and the older tertiary periods? And is it not further probable, that the older tertiary rocks, having been deposited in deep water, may contain a mixture of pelagian shells not commonly found among the fossils of more shallow basins? All this is undoubtedly nothing but hypothesis: but it has reference to existing facts, and tends to bring the perplexing phenomena of the Alps under those laws by which the development of successive formations appears to have been generally governed.

After all, the age of the Gosau beds must be determined by their relations, structure, and fossils. There is nothing in their relations and structure which, in our opinion, proves them to be older than the chalk: and on examining the Gosau fossils on the spot, it is impossible to deny, that from their state of preservation, the great preponderance of univalves over bivalves, and the incredible abundance of shells of certain genera, seldom found except in the newest formations, the whole group has a decidedly tertiary appearance. At the same time, there are a few shells (*Hippurites*, *Gryphites*, *Plicatulæ*, &c. &c.†) which forcibly reminded us of the fossils of the newer secondary strata.

Since our collection of Gosau fossils reached England, it

\* See the abstract of a paper by Dr. Fitton, *Phil. Mag. and Annals of Philosophy*, Feb. 1830, p. 140.

† The *Hippurite* of Gosau, is not of the same species with that found in the secondary rock of Untersberg; and we have before remarked that *Hippurites* are not confined to secondary formations.

has been carefully re-examined; and we are enabled, through the kind assistance of our friend Mr. J. de C. Sowerby, to give the following results.

Out of more than one hundred different species (collected by ourselves on the spot) there are from thirty to forty bivalves; and of those capable of being identified, nearly equal numbers are referrible to the youngest secondary, and the oldest tertiary formations\*. The univalves are much more numerous, especially in the quantity of each species; a fact seldom remarked in secondary deposits. Among upwards of fifty species, three only are found in the chalk or green-sand, whilst seven species are identical with known tertiary fossils; and several of the genera, such as *Volvaria*, *Pleurotoma*, and *Voluta*, have, we believe, seldom if ever been found in any deposit below the surface of the chalk†.

After all these facts and observations, we venture to reaffirm those conclusions which in previous memoirs we have endeavoured to establish.

1. That in association with different parts of the eastern Alps, is a fine succession of tertiary deposits, commencing with some of the oldest and ending with some of the newest which have hitherto been described.

2. That the older tertiary deposits of the Austrian Alps sometimes ascend far within the transverse valleys, and in such cases rest unconformably upon the beds of secondary limestone.

3. That the same deposits are developed, in many places, on the outskirts of the chain; and do in such cases pass under, and graduate into, those newer deposits to which alone M. Boué would restrict the name of tertiary.

We now return to the southern extremity of our transverse section (Pl. II. fig. 1.) Although there is a general accordance in the successive zones of secondary rock on each side of the central axis, it will be seen, even on the minute scale of our section, that the tertiary deposits of the Friuli form only inconsi-

\* The secondary species are: *Mya plicata*; *Corbula elegans*; *Trigonia scabra*; *T. alaeformis*; *Pecten quinquecostatus*; *Exogyra lævigata*; *E. conica*; *Terebratula dimidiata*; *Cucullæa carinata*. The tertiary species are *Sanguinolaria Hollowaysii*; *Cytherea lævigata*; *Cardium hippopæum*; *Pectunculus nummarius*; *P. auritus*; *P. pulvinatus*; *P. brevisrostris*; *Nucula similis*.

† The three univalves, identical with species in the chalk or green-sand, are: *Auricula incrassata*; *Cirrus granulatus*; *Rostellaria emiclarata*. The seven tertiary species are: *Pleurotoma prisca*; *Fusus bulbiformis*; *F. intortus*; *Rostellaria macroptera*; *Mitra pyramidella*; *Voluta citharella*; *V. coronata* (?).

derable hills, very unlike the elevated masses of the same age in Salzburg and Bavaria. Not far from the gorge of the Tagliamento we found tertiary molasse, conglomerate, and marl, dipping from the nearest precipices of Alpine limestone towards the south; but we could not discover the exact representatives of those tertiary groups described, by one of the Authors of this paper, as occupying the neighbouring district between the Brenta and Piave\*. Indeed these groups seem to thin off gradually towards the east: and we lose all vestiges of them beyond the great delta formed by the rivers Piave, Tagliamento, and Isonzo†. In the neighbourhood of Trieste, all the mountains are composed of the younger secondary strata, which in many places come down to the coast and form bold promontories, standing out into the deep sea of the Adriatic.

*Description of Plate II.*

- Fig. 1. Transverse section of the eastern Alps, from the alluvial and tertiary plains of the Friuli on the south, to the valley of the Traun and the tertiary plains of Salzburg on the north.
- Fig. 2. Transverse section (parallel to Fig. 1.) from the primary mountains of Gastein to the tertiary plains of Bavaria.
- Fig. 3. Red sandstone, grauwacké, transition limestone, &c., as seen on the banks of the rivulet below Bleiberg in Carinthia.
- Fig. 4. Position of the spathose iron ore N.W. of Leoben; from a section by Prof. Rippl.
- Fig. 5. Section of the salt deposit of Hall near Inspruck.
- Fig. 6. Sectional plan of the salt-works of Ischel.
- Fig. 7. Section, showing the relations of the Alpine limestone, red sandstone and porphyry, between Neumarkt and Cavalese in the southern Tyrol.

XV. *On the Shortest Distance between two Points on the Earth's Surface.* By JAMES IVORY, Esq. M.A. F.R.S. &c.‡

IT may not be improper to illustrate the series in the Magazine for last month by applying it to an example; and I shall take the one given by M. Puissant, at p. 42. of the Additions to the *Conn. des Temps* for 1832.

\* See Phil. Mag. and Annals, N.S. vol. v. p. 401. — EDIT.

† We had no opportunity of studying the interesting phænomena of this delta; but some notion may be formed, even by ours mall section (Pl. II. fig. 1.), of its rapid increase during the last 1400 years

‡ Communicated by the Author