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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY,

ESTABLISHED NOVEMBER 13, 1807.

VOLUME THE FIRST.

Quod si cui mortalium cordi et curæ sit, non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant; ut omissis naturæ atriis, quæ infiniti contriverunt, aditus aliquando ad interiora patefiat.

Novum Organum, Præfatio.

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1811.

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ELECTED FEBRUARY 1, 1811.

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PREFACE.

THE Members of the Geological Society, to whom the arrangement of its papers for publication has been deputed, conceive that it may be satisfactory to prefix to the First Volume of the Society's Transactions a short account of the origin and progress of the Institution, and some cursory remarks on the objects which its plan embraces.

The few individuals, who were the founders of the Society, met in consequence of a desire of communicating to each other the result of their observations, and of examining how far the opinions maintained by the writers on Geology were in conformity with the facts presented by nature. They likewise hoped, that a new impulse might, through their exertions, be given to this science; and with this view, shortly after their establishment, they drew up and distributed a series of inquiries, calculated in their opinion to excite a greater degree of attention to this important study, than it had yet received in this country; and to serve as a guide to the geological traveller, by pointing out some of the various objects, which it is his province to examine.

The rapid and unexpected augmentation in number, which the Society has experienced, is the most satisfactory proof of the extended and increasing interest which is felt in geological studies; and the continued support which it has obtained, in the accession of new and highly respectable Members, is the best testimony in favour of its pursuits, and of the principles upon which it is founded.

It is unnecessary to dwell on the advantages, which may be derived from individuals acting in combination for the advancement of particular departments of science. It may indeed be asserted that there is no object of research in which this co-operation is more necessary than in Geology. In this science, less perhaps has been done, and more that is important remains to be ascertained by future inquirers, than in any other branch of natural knowledge; while the variety of attainments, and the degree of leisure requisite for the prosecution of it, can seldom fall to the share of one individual. But as the attention of different Members of the Society has been long occupied in the investigation of several of the particular objects which claim the notice of the Geologist, it was reasonable to hope, that their combined exertions would be productive of more immediate and important additions to the general stock of geological knowledge, than could probably be derived from the unassisted labours of any one observer, whatever might be his zeal or opportunities. Again, the remarks which are made by separate inquirers, however interesting in themselves, are less valuable from being unconnected; and are, moreover, in this state not unfrequently lost to the public: but could such individuals be induced to record their observations, and to place these collections of facts in a repository, easily accessible to themselves and to others, the progress of Geology would be materially accelerated. In offering to be contributors to and guardians of so valuable a deposit, the Members of the Society, without any partiality towards their own claims to the notice and encouragement of their countrymen, felt satisfied, that there was a peculiar propriety in making the metropolis of the empire the centre of such an institution, on account of the many mineralogical cabinets that it contains, as well as of the superior opportunities for mutual intercourse, which it presents to persons engaged in geological pursuits; and they have experienced sincere gratification in observing, that even their most sanguine expectations have been greatly exceeded by the early and progressive advancement of the Institution, towards the accomplishment of the objects which it had in view.

By the liberality of different individuals a considerable collection has already been formed, which comprises not only many of the mineral productions of the British islands, but likewise several series of foreign rocks; and arrangements have fortunately been made, by which the Society's cabinet will receive still more important additions. There is therefore reason to think, that it will at no distant period be sufficiently extensive to illustrate the mineral history of this country, and at the same time to afford great facilities to persons desirous of becoming acquainted with the elements of geological science.

The attention of the Society has likewise been directed to the highly useful instruction, which mineralogical maps, plans, and sections, are calculated to convey. In recording the donations, which have been made to this department of the Society's collection, the Editors of this volume feel no hesitation in expressing, on the part of the Members, a hope that it may continue to increase; both on account of the intrinsic value of such information, as laying the foundation of a general geological map of the British territory, and on account of the material assistance which it may afford to future inquirers. For, they are persuaded, nothing is more consonant to the wishes of the Society, than that every mineralogist, purposing to visit any part of the kingdom, should have free access to all documents which may happen to be in its possession.

The Editors also take occasion, on behalf of the Society, to acknowledge the valuable presents, which have been made to its library.

It would be superfluous to enumerate the many advantages which may be derived from Geology: it is sufficient to observe, that it offers to scientific research a field of inquiry, rich in the beautiful and sublime productions of nature; and that, practically considered, its results admit of direct application to purposes of the highest utility. It may also be remarked, that the means of acquiring such information are peculiarly great throughout every part of the British islands. No country contains, within an equal space, a greater variety of mineral substances; while our long and broken line of coast, and our numerous mines, furnish the most ample opportunities of making geological observations.

In the present imperfect state of this science, it cannot be supposed that the Society should attempt to decide upon the merits of the different theories of the earth that have been proposed. In the communications, therefore, which are now submitted to the public, every latitude has been allowed to authors, with regard to their theoretical inferences from the observations which they record; it being understood, according to the rule of Literary and Philosophical Societies in general, that the writers alone are responsible for the facts and opinions, which their papers may contain.

In the selection which the Editors have made from the communications read at the Society's meetings, they have been influenced by a desire of laying before the public new and important information in the different departments of geological research.

The periods, at which the subsequent volumes of the Transactions of the Society may appear, must depend upon the zeal and exertions of the Members at large; and upon the contributions which may be received from individuals, devoted to geological pursuits, and who, though not immediately connected with the Society, may yet feel disposed to promote its objects.

House of the Geological Society,
No. 3, *Lincoln's Inn Fields, London,*
June 28, 1811.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY.

I. *Account of Guernsey, and the other Channel Islands, by*

J. Mac Culloch, M.D. F.L.S. Member of the Geological Society.

THE few following notes may help to explain the maps on which I have sketched the leading features of the mineralogy of the Channel Islands. The specimens which I collected having been mislaid, I am unable to give a more particular description of the stones which I have noticed.

These islands are situated in St. Michael's Bay, and from the general direction of the land, the form of the bottom, and the numerous rocks which are scattered around, may possibly have once been more intimately connected with the Coast of Normandy. Of this however, any further evidence, arising from continuity or similarity of strata, is, for the present at least, inaccessible.

It will be seen that they are chiefly formed of granitic rocks. The Islands of Chozè, which lie deeper in the Bay, are of similar formation, and I am informed that Mont St. Michel is also a mass of granite. Excepting this, I have not been able to obtain any information with regard to the Coasts of Normandy or Brittany, from the Islands of Brehat to La Hogue. But from the Seven Islands to l'Isle de Siecle, including Morlaix and Treguier, I have had opportunities of ascertaining that granite is the predominant rock; and more extensive observation may possibly prove, that a chain of granitic rock extends from Cape La Hogue to Ushant, a line parallel to that granitic chain, which runs in a WSW direction, from Dartmoor to the Scilly Islands. This is rendered further probable, from the rockiness of the bottom of the sea, and the quartzose gravel and sand which are brought up by the sounding line.

The average depth of water in the neighbourhood of the islands is thirty-five fathoms; it is scarcely any where more than forty, and with the exception of a few shoals, the bottom is tolerably uniform.

Numerous rocks beset these coasts, some of which form large chains lying in an east and west position. A variety of currents is the consequence of the particular position of these islands in the Channel stream, and the intricacy and rapidity of them, tend to form a very difficult navigation, and a strong natural defence, to the islands.

The tides on these shores rise to a considerable height, though not nearly equal to their elevation in the bottom of the bay, where the check to the Atlantic wave is greatest. The height which they attain is from thirty to forty feet: at Guernsey it is thirty-two feet. At St. Maloes it is said to exceed sixty.

The great wave which enters from the Atlantic, striking directly against the projecting Coast of Normandy, first fills the bay, and then continues its course along the islands, and round La Hogue, up the English Channel. Where its passage is narrowed, and diverted by the land, it forms those currents of which the variety and intricacy is so great, and of which the rapidity is such, as in some places to amount (it is said) to six miles in an hour.

Neither from my own observations, nor from the traditions of the inhabitants, nor from ancient records, have I been able to trace much alteration in the level of the sea, or any considerable change in the positions of the harbours, or the depths of the soundings. Indeed, the shores in general being high, small changes of level are more likely to escape notice; and the rocks being of a firm constitution, and belonging to a country without rivers, and almost without ice, escape some of the ordinary causes of decay.

ALDERNEY.

THE approach to this island is somewhat dangerous, from the rapidity and perplexity of the tides, and the number of the rocks which surround it.

Its eastern end is only seven miles distant from Cape La Hogue, and the passage between them, Raz Blanchard, is known to English navigators by the name of the Race. Here the tide wave undergoes its first violent contraction, and here the rapidity of the current is greatest. Its course is on the NNW rhumbline.

The high rocky shores which are subjected to the constant action of this current, do not appear to have suffered materially from it; apparently, because they are formed of a rock so inclined, as to avert the effects of its action.

This part of the island is also beset with rocks, but there is deep water in mid channel. About six miles to the southward of it lies the Banc de la Chole, extending in a WSW direction about the same length, and having only two fathoms water on it at low tides.

On the other side of Alderney to the north-west, is the passage of the Singe, which, although narrow, contains water for ships of great burthen. It is formed by the shores of Alderney and the little island Burhou, and like the other passage, is subject to a short and turbulent sea.

The Island of Alderney shelves to the NE, but it is also intersected by deep vallies. Its length is about three miles and a half, and its greatest breadth one and a half.

The whole of the southern and western part, from La Pendante to La Clanque, is bounded by cliffs from one hundred to two hundred feet in height, presenting various picturesque and striking scenes. The northern and eastern sides consist of low cliffs, alternating with small bays and flat shores.

This part of the island is formed of a reddish grit, and the western side of porphyry; in which respects Alderney differs from the others of the group; which do not contain either of those rocks, at least, in large masses.

The boundary of this grit to the south-west, may be determined by a line drawn from l'Etat to Braie, or nearly. It is an aggregate formed from a *detritus* of granite, regularly varying in its texture and colour. At the NE part of the island it is a red coarse-grained grit; but it becomes gradually whiter, and of a finer texture, towards the west, till it ceases; resembling there, the finest sandstone. It is stratified through its whole extent, in parallel and equal strata, of about a foot in thickness. These strata are straight and continuous wherever I have observed them, and are almost every where inclined in an angle of 45°, dipping towards the east. Here and there, are some strata of a more horizontal tendency. Their equality and the regularity of their position gives them in some places, where their edges are exposed, a form so apparently columnar, that they might at a distance be mistaken for basalt: and when a succession of these ribs appears cropping through the grass, the appearance as of the skeleton of a mountain is exhibited. The cliffs give no opportunity of observing on what bottom this sandstone rests, as the tide flows high round them. I have remarked that it becomes finer and whiter as it approaches the south-west, that is to say, the strata which in their original horizontal position were undermost, are the whitest and finest. They, here also, approach nearer in their nature to a sandstone flag ; acquiring a schistose fracture, though incapable of being raised in large masses. The stone is however easily quarried, and breaks naturally into masses having their sides slightly inclined, or absolutely rectangular. It is therefore well calculated for architectural purposes ; and abundance might be procured at a small expense, very nearly adapted for squared building without the assistance of the chisel. The few inclosures which are used in the island are built of this stone without mortar.

The principal varieties of the stone that I have been describing are the following.

1. White—very coarse—the quartz cemented by a clay the produce of the felspar.

2. The same—red—and with distinct grains besides, of felspar imbedded in it.

3. Dark red—and containing mica.

4. The felspar so distinct as to reapproach to a fine-grained granite.

5. A variety consisting of very minute grains, and to the magnifying glass exactly resembling a granite.

6. A granitel, consisting of quartz and felspar in equal proportions.

7. A similar stone with a much less proportion of felspar.

8. No felspar at all—a fine white sandstone.

All these varieties are evidently the produce of the disintegration and reunion of more ancient granites.

At a point on the southern shore, is a rock called La Pendante, resembling a square tower of masonry, and inclined at a considerable angle. It consists of portions of the strata I have been describing, and appears about twenty feet high.

Where the strata of grit cease, a vein, or an inclined stratum, of black granitel, composed of hornblende and quartz, is found; which appears to run straight, and in contact with them, in a N and S direction across the whole island, from l'Etat to Braie. This is a thick mass, but I could neither discover its dimensions, nor its points of contact with the grit. It is in some places accompanied by a fine-grained sienite of a compact nature; and by another, much disintegrated and shot with iron. Here and there also, are fissures filled with red and purple hornstone, and more rarely, fissures, or what appear such, filled with sandstone-schist and mica, and often assuming the appearance of micaceous schist. The grit, which is cut off by this mass of granite, does not here absolutely disappear; but various strata of it and the granitel, succeed each other, till the whole ceases, and is replaced by a mass of porphyry.

Of the mass of porphyry, the remainder of the island is formed. And it is the broad and perpendicular fracture of this rock, which causes the picturesque appearance of the western extremity of the island.

It appears to have a great tendency to wear before the effects of time. At the western point in particular, where it is exposed to the undiminished force of the wind and the sea, it has undergone considerable changes, and many detached rocks of rude forms are the consequence. And on this side it is in many places so thoroughly decomposed, as to have formed a white, powdery, siliceous soil, much resembling tripoli.

The whole of this porphyry has a hornstone basis, and is either red, grey, or white. Together with the felspar, it frequently contains imbedded grains of quartz. On the beach I picked up flints, and pebbles of different coloured hornstone. It is a necessary consequence of such an arrangement of rocks, that a great part of the soil of Alderney should be sandy. It is nevertheless well supplied with water, and produces good crops of grain and vegetables. Its valuable breed of cows is well known.

The precipitous rock Ortac lies a mile and a half to the westward of Alderney. It is about an hundred feet high, and connected with a chain of rocks that stretches from Burhou. And at the distance of seven miles in the same direction are the Casquets, remarkable for their well-known lighthouse, and consisting of many high and sunken rocks. I had no opportunity of visiting any of these, but was informed that they consisted of the same grit as the eastern end of Alderney. The figure of Ortac would however lead me to think that it was formed of porphyry, as its precipitous appearance is not so consistent with the tendency of the grit I have described. No organic remains have, as far as I know, been found in Alderney.

GUERNSEY.

The approach to Guernsey is also full of danger, from the number of the rocks, and the rapidity of the tides which surround it.

This island is of a triangular shape, its extreme length being seven and a half miles, and its greatest breadth about four. Its gross circuit is twenty-one miles.

The inclination of the land bears some resemblance to that of Alderney, as it is elevated to the south, and shelves towards the north. The southern coast is bounded by high cliffs, which also extend along part of the eastern coast. The remainder of the eastern and the northern sides, consists of a series of flat bays, divided by interposed ridges of high rocks.

The whole island is readily divided by a line drawn from the Town to Pezeries. To the north of this imaginary boundary is a level tract, interrupted only by cairns and rocky hillocks. And in this tract is an inundation of about sixty years standing, which covers three hundred acres ; but whether this has arisen from any change in the level of the sea, or the failure of some natural barrier does not appear. It is quite dry long before the time of low water.*

To the south of the line I have supposed, the country forms a higher stratum, or stair, but every where intersected by narrow vallies and deep glens, of which the direction is exceedingly various. The high cliffs which bound this southern tract are continuous, with the exception of two or three narrow coves, the mouths of small vallies intersecting the high land.

On this part of the coast there are but few detached rocks ; the northern shore is beset with them.

The Island of Guernsey is almost entirely of granitic formation, the southern division consisting entirely of gneiss, and the rocks which form the northern part exibiting various kinds of granite or granitel.

To descend to a more particular description, the rock on which

* Since this paper was written, the tract in question has been drained and embanked.

Castle Cornet is built is a gneiss, often approaching so near to granite as to render its place in a nomenclature doubtful. It is every where crossed and intersected by veins of quartz, of trap, and of felspar, curved and mixed in various ways, but tending, upon the whole, to the north or north-east. More rarely there are found in it veins of brick red and bright green felspar, and pebbles of the same substance, or with hornblende imbedded, are found on the beach, as well as coarse agates passing into quartz and hornstone.

Proceeding from the Castle southwards, gneiss is found to constitute the cliffs on the eastern side, often in a state of decomposition, and covered with a great depth of *debris*. These strata, which extend all along the south coast to Rocquaine Bay, seem to tend from NE to SW; and have various inclinations, but most generally 10° or 15°, dipping to the south. On the southern side of the island they are intersected by veins of white, flesh-coloured, and red felspar, of various breadths. In some places the felspar veins pass into granite. Veins of quartz, and veins of a granitel consisting of quartz and felspar, also traverse it. A few veins of trap are also found intersecting it at Rocquaine, which are occasionally superseded by trap porphyry, or by the same substance containing minute grains of quartz. In this tract there are wrought two or three quarries of a black granitel, consisting of hornblende and quartz, and very hard.

The constitution of this stone varies much through the extent which it traverses. In some places it is a true granite, in others the mica disappears, in others again this latter ingredient becomes so abundant, that the stone passes into micaceous schistus. Occasionally also hornblende enters into its composition, as has been noticed by others: when this is the case it sometimes loses the foliated structure and passes into sienite. Sometimes all the other ingredients are excluded, and felspar alone remains. There may also be traced gradations into mere quartz; and I further observed some varieties consisting of wavy mixtures of quartz and hornblende only.

This stone has a considerable tendency to decomposition, the felspar and mica being both very ferruginous. It is consequently found in all states, from that of a friable rock, to a gravelly clay, and finally to a perfect soil; constituting the gravelly or sandy loam which predominates through the Island.

No where is it more easy to remark the process by which in nature rocks are converted into earth; and as in this case by the action of an oxide of iron. Nests of yellow mica which seem to have arisen from the decomposed rock, are found in many places.

This stone is used for rough masonry.

A ledge of rocks called the Hanois extends from the westernmost point of the island, and from its apparent geographical continuity is probably of the same structure. Against this point the whole strength of the western ocean is first directed. And it is from hence I doubt not, that a large ridge of rounded masses of stone has been rolled, so as to form a natural barrier near Rocquaine.

In quitting the elevated part of the island, and with it the southern shore, the gneiss disappears; and its place is supplied by other granitic formations. Besides the trap and trap porphyry which I remarked at Rocquaine, there are masses of micaceous schist, having the appearance of veins; and a stratum of argillaceous schist may also be observed at the lower parts of the bay, incumbent on the granitic foundation.

At l'Erée and Lihou the rocks are composed of quartz and felspar, the foliated texture having disappeared. A granitel is thus formed, which in some places receiving an addition of hornblende, passes into sienite. This is traversed here and there by veins of the same red and green felspar, which are found at Castle Cornet. The same highly coloured felspars are also occasionally intermixed so as to form a constituent part of the granite, which thus becomes exceedingly beautiful.

Among the various pebbles which I picked up on the beach, I observed a black siliceous schistus and hornblende slate, but from whence they had been detached I could not discover: the latter however is known to be common in gneiss as well as in granite rocks.

At Grande Rocque are large masses of sienite, which are quarried to form building stones. It is the only rock of this nature on the island, and its produce is fully equal in beauty to that of the celebrated quarries of Mont Mado in Jersey, although it cannot be raised in such large masses. The felspar is the predominant ingredient, and it is either white or flesh-coloured. It is traversed by veins of a similarly constituted stone, but more minutely compacted and of a brick red colour. In some places indeed the veins seem to consist of a felspar basis, with grains of quartz and hornblende imbedded, approaching in its nature to a petunse porphyry. It is here an universal rule that where the granites are traversed by veins of a similar nature, the vein is the most compact of the two. As the hornblende is sometimes wanting in these stones, and as mica is sometimes present, we meet with many other granitic varieties. I observed in one place lumps of argillaceous porphyry stuck in granite, as has been noticed by Baron Born.

The predominant rock towards the bay of St. Sampson's, is a grey or black granitel, consisting of quartz and hornblende mixed in various proportions. Detached masses of this rock are also found in the higher grounds, as well as among the gneiss of the southern coast.

The hornblende in some places predominates so as to give a sort of hornblende porphyry, and in others, every other ingredient is excluded, and a hornblende rock alone remains. I observed some specimens, traversed by a derivative rock of the same composition, interspersed with minute grains of pyrites; the only trace of the kind I perceived in this island.

This stone is very hard and sonorous, and admirably adapted for building, as it easily breaks into squared masses before the hammer. It is more particularly fitted for paving, from its extreme hardness and toughness; and for that purpose it is exported in large quantities to London and to Portsmouth, by the name of Guernsey stone, or St. Sampson's stone.

A similar succession of rocks occupies the remainder of the coast to the town.

Such, as far I had opportunities of remarking, is the mineralogical structure of this island. The discovery of lime was much desired by the inhabitants, but there is no appearance of limestone.

Although the principal rocks are of a metalliferous nature, no metallic traces have at any time been observed.

It has been a common belief in England that emery was a product of this island, but of this I could neither obtain physical nor historical evidence.

The soil which is the produce of the decomposed gneiss is abundantly fertile, the ground being well watered, in a climate exposed to the first arrival of the Atlantic clouds. Springs and rivulets are therefore plentiful, and as is usually the case in siliceous countries, the waters are remarkably pure and free from saline impregnations.

Of Herm and Jedhout which are detached prolongations of the same rocks, nothing can be said which would not be a repetition of what I have remarked concerning Guernsey. The inaccessible ridge of the Anfroques is probably of a similar structure, and this is somewhat pointed out by their granitiform outline.

SERCQ.

The little Island of Sercq lies six miles to the east of Guernsey, and is rather more than three miles in length. Its extreme breadth is not more than a mile and a half, and its average breadth not quite a mile. In one part, it is not many yards wide, being nearly divided into two portions, connected only by a high and narrow ridge. A small island, l'Isle des Marchands, lies on the west side of it, and sundry detached rocks surround it on other sides. Though of such small dimensions, it is more interesting to a mineralogist than the other islands, not only from the greater variety of its rocks, but from the more perfect exposure of its formation that is afforded by the abrupt cliffs which bound it on all parts. Unlike Guernsey or Alderney, it is a table land, having no declivity to the sea at any part, except a small descent at its northern extremity. The cliffs by which it is bounded are from one hundred to two hundred feet high. Except the Isle des Marchands which I mentioned, the western shore is so abrupt that large ships may range it very near without hazard. The eastern shore is less clean, and is beset with ridges of rocks running far out into the sea. The bottom is rocky. The eastern side of the land is also pretty uniformly about one third lower than the western, or it has a tendency to rise towards the west. In a general view the western side is of a trap and schistose formation, and the eastern of a granitic. It is intersected by veins of greater magnitude, and a more decided character than Guernsey, Alderney, or Jersey. The surface of the island though high, is every where intersected by deep vallies;

conducing much to its picturesque appearance, and contributing to its fertility: in which, on a comparison with Alderney, it very much excels. It is well watered, and produces trees of tolerable growth and vigour; a circumstance denied to the former.

Although there are five landing places about the island, there is no harbour where ships can lie, and but one beach where small boats can be wintered. Such is the nature of the cliffs, that except at the Creux, where a tunnel is cut through the rock, there is hardly any entrance to the land, but by climbing. It is a very strong natural fortification, and might at a small expence be rendered impregnable.

The rocks which compose the shores, being of various and generally fine forms, afford a variety of singularly grand and picturesque scenery.

Havre Gosselin, which is formed between the land and l'Isle des Marchands, is the nearest landing place to Guernsey. This is bounded by cliffs of trap formation, near two hundred feet in height, in many places very hard and compact, as is particularly the case where it is in contact with granite. The rock of which they are formed seems to have a N and S direction, consisting of indistinct strata, and dipping to the east under an angle of about 40°. These cliffs are divided by many large and deep fissures, out of which the materials have been washed, thus leaving large caverns. Some of these veins which I was able to examine, are filled with granitic stones, ironshot, and in a state of decomposition. In some parts I observed dark siliceous iron stone; and in some, were mixtures of black mica and quartz, resembling micaceous schistus. Smaller intersections are formed of green, and red jaspers, and many coarse agates are found among them, consisting of similar materials, and mixed with hornstones and quartz of different colours. Many veins are inaccessible, but the substances found on the beach which seem to have been washed out of them, are, coarse yellow, brown, red, and green jaspers, sometimes containing veins of iron ochre, or crystals of hornblende, or passing on the one hand to quartz, and on the other to hornstone. Sometimes they are veined with quartz, and striped and waved of various colours, with mixtures of quartz and calcedony, resembling agates.

The Peninsula of Little Sercq is connected with the main island by the high narrow ridge before mentioned. This is about three hundred yards in length, and has a precipitous face to the sea on the eastern side ; to the weſt it is also partly rocky and precipitous, and the remainder is a steep declivity of broken rocks and rubbish. It is called the Coupée, and on the top of it is a rugged path of frightful appearance, being in many places not above a yard or two in breadth, and in most without boundary on either hand. By this, the communication between the two parts of the island is kept up.

This narrow neck is traversed by a vein of porcelain clay at its widest part, ten or twelve feet in thickness, and lying E and W across it.

In most places this vein is much contaminated by purple, red, and yellow oxides of iron, and intersected by reticulations of quartz, which are probably the remains of veins running through the granite, from the decomposition of which the porcelain clay appears to have originated. Grains of quartz are also found dispersed through it, and indeed in many places it seems to be little altered from its original granite. Towards the bottom of the vein various substances are found, among which are coarse approaches to calcedony and agates ; but the greater and apparently the most interesting part of the vein was inaccessible to me, in consequence of huge masses of fallen rocks.

In some places are veins of quartz having a slaty fracture, and becoming earthy, or much discoloured with iron, or containing nodules rudely approaching to ocular agates. These are accompanied by veins of mica and felspar in various states of decomposition, apparently from the failure of the mica, and by veins of chlorite containing here and there pyrites, together with talc and quartz, and talcaceous schistus, and a mixture of greenish steatite, felspar, and quartz. The rocks here also are of trap formation, and the beach is covered with jaspideous pebbles as at Havre Gosselin.

Such is Grande Havre, and the number of the soft veins here existing may serve to account for the great waste the land has undergone. The Coupée is becoming daily lower to the eye.

The southern point of the island is formed of a sienite, but there is no opportunity of tracing its connexion with the trap of the western shore; for, from the Coupée to l'Etat there is no access, unless under circumstances of weather which rarely occur.

The Etat very much resembles in shape the Mewstone of Plymouth, and from its appearance and inclination is probably of the same formation as that I have been describing. The felspar of the sienite is invariably white, and not nearly so beautiful as that of Guernsey before mentioned. It is intersected by various trap veins, one of the most remarkable of which near Paregorois runs N and S, inclining about 3° to the W, and is about six feet in thickness. This vein consists of trap porphyry and amorphous trap; and besides these, regular hexangular blocks, the sides alternately large and small, are quarried out of it. I was unable to find in what position they lie, as the vein was only accessible at low water, but from what I observed in a similar vein at Experquerie, I am inclined to think that the columns lie across it. Their joints are flat. Some veins of a brick red felspar are also here to be observed, and in some places the sienite passes into greenstone; but as this part of the coast is almost inaccessible, it is difficult to say what varieties may exist in it. The sienite which I have been describing seems to be continued as far round the eastern coast as les Burons, where trap is again found. Of this part of the coast I can say nothing more particular. Those shores which are not impracticable are very difficult of access; and that which was accessible was sufficiently various to occupy more time than I was able to appropriate to its examination.

Further to the north, and on the eastern side, is the port of the Creux. This is a pry beach, in a cove formed by high cliffs of argillaceous rock, of which the faces are absolutely perpendicular in most parts, and as smooth as a wall. Being inaccessible from the land, and at the same time the only secure beach on the island, a communication was formed in 1588 by De Carterets, who excavated a tunnel through the rock; taking advantage of a loose vein which traverses it. This passage is occupied by a gate, and thus the chief landing place is rendered defensible by a very small force. The whole is strikingly picturesque and singular.

Bridges of detached rocks stretch out to sea from this point, which from the peculiar form of their outline appear to be granite.

There is a small funnel on the coast resembling the Buller of Buchan or Tol Pedn Penwith: it is called Creux terrible. I did not see it.

From hence to la Noire is an inaccessible promontory, but on the other side of it, is a steatitical vein containing asbestus, and which is probably the continuation of a vein I shall have occasion to notice on the western side of the island at Port des Moulins.

I also observed a large vein of black porphyry, of a beautiful texture, and capable of a high polish, containing distinct and large concretions of white and pale green felspar. An inaccessible vein is also here visible, of which the lower part has been washed out so as to form a cavern. The upper part which remains, shows blocks of stone lying transversely and resembling masonry. I supposed it to be a vein of columnar trap similar to that I noticed at Paregorois. From Experquerie to Port des Moulins I could not examine the coast.

The descent into Port des Moulins is through a narrow pass of wild rocks, and the scenery of it is of the most picturesque class. Detached masses of rock surrounded by the sea, and relieved by the broad cliffs which bound it, constitute its peculiar feature. The whole of these rocks are of grauwacké schist and grauwacké. The strata are nearly horizontal, and are occasionally intersected by veins of quartz, as is common elsewhere. It is no where of a foliated fracture producing roofing slate, but in many places breaks into pieces well adapted for square masonry. In some places where it lies near to granite it seems to undergo an alteration of texture, and to become more siliceous. It is intersected in one or two places by wide and perpendicular veins of the magnesian class of stones; and where it is in contact with those veins, it appears to pass into schistose talc, and indurated steatite.

The veins I have mentioned contain various kinds of steatite, often so contaminated with iron and clay, and so indurated, as to be difficultly distinguished from the argillaceous tribe.

Talc, talcaceous schist, and asbestus, are found in the same veins; and with the asbestus are slender veins of argentine spar.

Lapis ollaris is also found there, as well as in the land lying above the cliffs, from which I guess that this vein extends across the island. It is applied by the natives to economical uses.

A very large wall of a redish granite, the end of a vein from which the schistose strata have been washed, stands far out on the shore, forming a natural arch. Where the arch is formed, a softer cross fissure seems to have existed from which the looser materials have been washed away. This vein intersects the grauwacké, and is nearly perpendicular, running in an east and west direction. Parallel and near to it, is a similar vein, but not standing out from the cliff, and between these two granite veins is contained a vein of argillaceous stone about fifteen feet thick, the whole forming a singular kind of stratified vein lying in the grauwacké.

I have to regret that the flowing of the tide prevented me from making a more accurate examination of this interesting spot. This is particularly desirable as it is said that De Carteret about one hundred years ago wrought a copper mine here. The researches however of Mr. Le Pelley, the lord, have not confirmed this report, nor could I distinguish any metallic traces. Their existence however is not improbable, as it is well known that the rocks I have been describing are very productive of metals, and that copper ore among others is frequently found in similar situations.

From this place to l'Isle des Marchands, the coast appears to consist of the same materials. I had no time to examine it, and I believe it is every where inaccessible.

The small island itself is precisely of the same nature as the opposite coasts.

JERSEY.

The island of Jersey is in the form of a parallelogram, being about ten miles long and on an average about five broad. Its inclination is precisely the reverse of that of Guernsey, it being much elevated to the north and shelving away to the south. It is every where intersected by narrow vallies, of which the most common direction is across the island, or north and south. The soil is not unlike that of Guernsey: it is equally well watered, but being better sheltered and of more extent eastward, is far more productive of trees.

The cliffs which form its northern shore are in general about an hundred feet in height, though in many places they attain twice that elevation. The whole of this side is indented by small coves and bays. The western, southern, and part of the eastern sides, are formed of shelving shores, and wide sandy bays, separated by high rocks. Sundry rocks are dispersed round these coasts. On the northern side of the island lies a large and long ridge stretching east and west, consisting of the Paternostres, the Dirouilles, and the Ecreho. The depth of the sea is more variable round Jersey than round any of the other islands, there being many banks and shoals about it.

In a general view the whole of the high and northern tract may be said to consist of granitic rock, and the southern and flatter part of the island of a mass of schistus incumbent on it. The high rocks which stretch away to sea all round Jersey seem to be of granitic formation.

The Bay of St. Ouen is a large flat sandy tract occupying the whole western side of the island, and bounded by a ridge of sienitic rock, of which species all the granite of Jersey appears to be. A few rocks of grauwacké schist are seen emerging from the sand. This coast is subject to a sandy inundation, but it does not appear to spread rapidly: no precautions are taken to prevent it.

The ridge I have been describing terminates at the Corbiere, in an assemblage of rocks which stem the current of the Atlantic tide, forming a rapid and boisterous sea about this point, well known to seamen. From here to St. Aubyn's we find a succession of points formed of the same rock, their sides being every where covered with schistus. The castles of St. Aubyn and Elizabeth are built on similar rocks.

The history of this shore is the history of the whole coast as far as Mont Orgueil, where the granitic rock becomes more continuous. The castle itself is situated on a high promontory of it.

From Mont Orgueil to Rosel harbour, with the exception of a flat shore in St. Catharine's bay, is a continuous cliff, affording no variety of structure, and not intersected by any remarkable veins.

But at Rosel a very singular rock commences, which appears to occupy the whole of Bouley Bay from Rosel to Belle-Hougue. At a distance it so much resembles the forms of the granites in Cornwall, that I should have set it down as such had I not examined it at hand.

It is an argillaceous breccia consisting of large and small scraps of schistus cemented by a basis of the same nature, but having entirely lost its tendency to a schistose fracture. I found some veins of a white hornstone porphyry which run in it. How it is connected with the granitic rock I could not find, but I traced it two miles into the country towards the church of St. Martin.

The whole remainder of the northern coast consists of rocks of sienite of various elevation, exhibiting generally broad and perpendicular faces to the sea. They are every where intersected by perpendicular veins running N and S, forming many remarkable caverns where they have been exposed to the action of the waves.

These veins wherever I saw them seemed to consist of granite, of which the felspar was commonly of a brick red colour. The sienite itself is in general white, consisting of variable mixtures of quartz, felspar, and hornblende, and varying therefore in colour. Most commonly the felspar is predominant.

In the rocks of Mont Mado the felspar is particularly abundant, and is of a flesh colour, constituting a very beautiful variety, which is also susceptible of a fine polish.

There are quarries established on this spot from whence stone is raised for the use of the island: it is also exported to Guernsey and to England. In times of peace it has been carried to France.

The quarries are inexhaustible; the cliffs for a long space and an elevation of an hundred feet or more, consisting entirely of this stone, in large masses apparently undisturbed by a single fissure. Shafts for columns of considerable length have been taken from the quarries, and were the demand sufficient to call for new openings, I have no doubt that columns of twenty feet and upwards might be raised.

No metallic traces, except of iron, have ever been observed in Jersey.*

There is no trace of lime, a substance so much wanted.

The schistus, though spread wide over the island, has not hitherto afforded any slate.

I wish that my knowledge and my time had enabled me to make these notes somewhat more than a mere sketch of mineralogical topography.

* I have just been informed by Mr. Lowry that manganese has been lately found; but I have not learnt the particulars.

II. *A Description of the Red Oxyd of Copper, the production of Cornwall, and of the Varieties in the form of its Crystal, with Observations on the Lodes which principally produced it; and on the Crystallization of the arseniated Iron.*

By William Phillips, Member of the Geological Society.

THE Mine called Huel Gorland, in the parish of Gwennap and county of Cornwall, is in a hill whereon is situated the town of St. Day, to which it is immediately contiguous eastward. In this mine there are seven lodes; one of tin, the others of copper; but as only three of the latter have produced the red oxyd of copper, it will not be important further to notice the others. These three lodes are known by the names of the North Lode, the Great Gossan Lode, and the Muttrell Lode. The latter, is that noticed by the Count de Bournon, as having produced the arseniate of copper, in a paper published in the Transactions of the Royal Society, in which he has so ably and scientifically described that mineral.

In the North Lode which runs eighty fathoms north of the Great Gossan Lode, the red oxyd of copper was occasionally found with fluate of lime; though, compared with the quantities produced by the other two lodes, very sparingly.

The Great Gossan Lode averages about four feet in width; the Muttrell Lode about three feet. The former runs eight degrees from the north of the west, meeting the latter, which runs four degrees from the south of the west, at a certain point, whence they run together for about fifty fathoms. The united lode is about twelve feet wide, and takes a direction nearly east. The underlay* of these lodes is north; the Great Gossan Lode about two feet, the Muttrell Lode one foot ten inches, and the united lode one foot nine inches, in the fathom. The two lodes are about thirty-seven fathoms apart at fifty fathoms west of the point where they meet; from which place they have been worked, respectively, the Great Gossan Lode about two hundred and thirty fathoms, and the Muttrell Lode seventy fathoms, at the adit level.† They afterwards run on together about forty fathoms in Huel Gorland mine, and further east form a valuable part of the rich and extensive mine called Huel Unity. Huel Gorland is in granite.

In that part of the mine where the two lodes are separate, the adit is fifty fathoms from the surface, but after they have run together some distance, it is only forty fathoms, the descent of the hill being towards the east. The adit being nearer on a level than the surface of the country, it is, therefore, in noticing the depths of different parts of a mine, most correct to date from the adit level, as is the practice of miners. The depths hereafter given are so dated.

In the two lodes, the red oxyd of copper was found under very different circumstances. In the Great Gossan Lode it occurred

* The generality of the lodes in Cornwall run nearly east and west; their downward direction is not quite perpendicular, but generally more or less inclining to the north or south. This inclination is called the underlay of the lode.

† It is the first object of a miner, in the working of a mine, to drive a passage or adit from the nearest low ground or valley to meet the shaft, for the purpose of conveying off the water, which is raised to the adit level by the means of the steam engine. It will therefore be obvious that the depth of the adit from the surface of the mine, must depend on the height of the ground in which the mine is, and the depth of the neighbouring valley.

principally between the sixty-six and eighty-six fathom levels, in considerable quantity, often in well-defined crystals, and occasionally intermingled with native copper. Above it, the lode abounded with fluate of lime, frequently very solid, and so pure, that they, whose business it is to assay copper for the miner and the purchaser, preferred it as a flux to that of any other mine. Among this fluate of lime, and sometimes intimately mingled with it, considerable quantities of the yellow copper ore were found, and some arsenical pyrites containing 4 or 5 per cent. of copper, though comparatively little of that gossan, which, as will presently be noted, constituted the greater part of the Muttrell Lode; nor was the arseniate of copper discovered in any part of this lode, west of the junction of it with the Muttrell Lode.

The Muttrell Lode is one, to which no other lode hitherto discovered in the County of Cornwall bears any analogy. Throughout almost the whole length of its working, but particularly in that part, above, below, and in which was discovered the great deposit of red oxyd of copper, with the beautiful varieties of which this mine has enriched the cabinet of the mineralogist, this lode abounded in an ochreous substance, frequently accompanied by quartz, which from its appearance may be termed an argillaceous oxyd of iron; and which, sometimes for a considerable length and depth, constituted alone the great body of the lode. This substance is always considered by the miner as an indication of neighbouring riches; it is technically called *gossan*, and is denominated *kindly*, or *very kindly*, in proportion to the darkness of its hue, and the looseness of its texture. Through this gossan they sunk in the Muttrell Lode forty-six fathoms, and almost as many above the adit, before they arrived at any considerable quantity of the red oxyd of copper, which afterwards continued through a space ten fathoms in depth, and about six fathoms in length; being disposed in bunches, the largest and richest of which were about fifteen feet in length, by as many in depth.

In this lode, the red oxyd of copper was accompanied occasionally by vitreous copper ore, black oxyd of copper, arseniate of copper, arsenical pyrites, quartz, and fluate of lime. Native copper also occurred in considerable quantities, generally in contact with the red oxyd, and more or less intermingled with it. It was sometimes remarkably brilliant, and occasionally occurred regularly crystallized. There were however considerable masses of the red oxyd unaccompanied by any of the above substances, hollow within, and presenting, on being broken, perfect and varied crystallizations. From the depth of fifty-six fathoms, the search for this mineral was continued for forty fathoms lower, with but little success; bunches of a few tons in weight, and smaller quantities were occasionally discovered, but these became less frequent; so that, at ninety-six fathoms under the adit, the further working of this lode was abandoned. At this depth one part of the vein consisted only of gossan, and was six feet in width, forty fathoms from which it narrowed to three feet, and was there composed of yellow copper ore and quartz.

Further east than the principal body of the red oxyd of copper, and at different depths in the Muttrell Lode; that is, nearer the junction of it with the Great Gossan Lode, were found the interesting varieties of the arseniate of copper, and occasionally that substance which in the paper before alluded to has been described by the Count de Bournon, and by him called Cupreous Arseniate of Iron. These substances were also found in considerable abundance at the line of junction of the two lodes, and in its immediate neighbourhood eastward, at various depths, but with scarcely a trace of the red oxyd of copper until the depth of fifty-six fathoms, at which place this mineral also was found in the Gossan before described, occasionally intermingled with arseniate of copper. The latter occurred, besides, in great abundance in the same lode in Huel Unity; indeed, I believe it is to that part of the united lodes which passes through this mine, that mineralogists are chiefly indebted for the fine varieties of the arseniate of copper.

That beautiful mineral, the cubic arseniate of iron, was also found at and near the junction of the Great Gossan and Muttrell Lodes; but occurred in greatest quantity in the latter, thirty fathoms west of the junction, about the adit level; being forty-six fathoms higher, though perhaps not immediately above the part in which the first discovery of the red oxyd took place. The cubic arseniate of iron was also found in the Gossan before described.

Since the publication in the Philosophical Transactions of the paper by the Count de Bournon, containing a description of this mineral, I have obtained some varieties in the form of its crystal, not described in that paper. In addition to the perfect cube (fig. 1.) and that modification of it, by which four of its solid angles are replaced by an equal number of equilateral triangular planes (fig. 2.) as described by the Count de Bournon, I possess some in which each angle so modified has received an additional modification, by three triangular planes placed on the edges, and inclining to the axis of the crystal. This variety however rarely occurs in the perfection in which it is represented by fig. 3. for, generally, the two modifications are so blended together, as to give a roundness to the whole as in fig. 4. I possess also others in which the edges of the cube are replaced by planes (fig. 5.); others in which the modifications described in figs. 3 and 5 are combined, as in fig. 6: others again, where the same modifications occur, but in which each of those angles that are not replaced by the two modifications as in fig. 3.

are replaced by three triangular planes as shown in fig. 7. I have also others which have the edges replaced, and in which each of the angles is also replaced by both modifications (fig. 8.) The crystals above described vary in colour from light and almost transparent green, to dark green, sometimes having a brownish tinge: others are of a resinous appearance and are almost transparent. It may be remarked that the crystals of this substance are generally more or less, though not regularly striated on the surface, and that the striæ constantly take the directions described in fig. 2: they do not however admit of a fracture in that direction, nor have I satisfactorily obtained it in the direction of the faces of the cube. Some crystals of a dull green colour, on being broken, have been found to enclose other cubes of a darker colour, and iridescent on the surface. I have to regret the impossibility of giving the admeasurements of the various angles formed by the modifications and varieties of the crystal of the arseniate of iron, on account of their minuteness.

Description of the red Oxyd of Copper.

This substance, which during the last ten years, has been found in Cornwall in great abundance, was previously of very sparing occurrence in that county. I am not aware of its having been mentioned as a production of that district, by any foreign mineralogist, until very lately: even the celebrated Haüy has not quoted it in his *Traité de Minéralogie* as a Cornish mineral. Many cabinets however now abound with it. Previously to the labours of Mr. Chenevix on this substance its composition was by no means well understood. From the analysis by that able chemist it appears to contain copper 88,5, oxygen 11,5, and is therefore a sub-oxide of copper, and "exists in a state hitherto unknown in nature." In reference, doubtless, to that analysis, it has been called by Brongniart, Cuivre oxidulé.

The colour of this mineral varies from carmine red to metallic grey, occasionally inclining to black.

Its lustre is considerable—very considerable in the more translucent crystals.

It is not very brittle.

It easily cuts calcareous spar, but will not scratch fluor spar.

It gives, when rubbed on paper, a slight red streak.

It emits no smell when rubbed.

When powdered it is of a brick-red colour.

It emits in that state no light when thrown on a hot iron.

Its specific gravity is 5,6.

It is soluble with effervescence in nitric acid, to which it imparts a greenish tinge.

The fracture of the crystals, particularly of the more translucent ones, is very smooth and inclines to conchoidal; but is frequently uneven, and inclining to shattery, in those of a darker hue. I have met with some octohedrons that admitted a fracture in the direction of their faces, but have not found any of a cubical form in which a division parallel to the circumscribing planes was practicable.

The form of the primitive crystal, according to Haüy, is the regular octohedron (fig. 1.) and of the integrant molecule, the regular tetrahedron.

The crystals of this substance are mostly well defined, but do not in general exceed a line in length. The largest in my collection is nearly half an inch; I have seen others somewhat larger. They are however frequently so small, as to appear to the naked eye a mere point, but by the assistance of the lens, the perfection of their geometrical forms may easily be discovered: a perfection rarely observable in the larger crystals. They are generally of a considerable external lustre, occasionally approaching to metallic; and are sometimes, though rarely, iridescent on the surface. In some of the most recent specimens afforded by Huel Gorland, the crystals exhibit a singular external brilliancy, occasioned, apparently, by a deposition, after the formation of the crystal, of small thin facets which cannot be detached by the knife, of the same form as the faces of the crystal itself. The crystals of this substance are mostly aggregated, and frequently confusedly grouped: it is by no means common to find one in which all the solid angles are disengaged. A singular variety was found in small quantities in Huel Jewell mine, of a dark red colour and remarkable lustre, in hollow octohedrons, formed by very minute crystals, each arranged in the same direction, and attached at the solid angle. This variety is sometimes accompanied by uranium in small tabular crystals of a light green colour.

The compact red oxyd of copper, usually denominated tile ore, which by Brongniart is called Cuivre oxidulé ferrifère, has been found in several mines in Cornwall. In Huel Gorland, this red oxyd often occurred massive, sometimes with portions of native copper passing through it; and in this state, as well as when crystallized, passing into black oxyd. Crystals were frequently found deposited on native copper, the irregular crystallizations of which formed, as it were, the nuclei of the superimposed crystals; and these were generally varieties, the primitive form being rarely found so circumstanced. Crystals also occasionally enclose minute portions of native copper.

Specimens of this substance occur, consisting almost wholly of a pure mass of aggregated crystals; it is however usually accompanied by quartz, and occasionally by a compact and very hard substance, apparently composed of quartz, in intimate mixture with the Gossan before described. It has also been found with fluor spar in Huel

Jewell; in chlorite, and in brown and almost pulverulent mica in Huel Gorland. The crystals enclosed in the latter substance, it may be observed, are always of remarkable brilliancy and in well defined varieties. In the latter mine it also occurred with blue and green carbonate of copper; with fibrous arseniate of copper; in cubes with the green cubic arseniate of iron; with mispickel and pyrites. I possess one specimen from Cornwall, but from what mine is uncertain, in which it is accompanied by vitreous and yellow copper. It has been found in capillary crystals in Huel Gorland, Carharack and Tol Carn mines; in the latter in recomposed granite though but very sparingly. I have one specimen from Tin Croft mine, in which the red oxyd is intermingled with native copper, and with jasper of a fine red colour.

There are perhaps but few minerals that exhibit so many beautiful and regular forms, although the modifications of its primitive crystal, hitherto noticed, are only six in number. Of these forms, four have been given by Haüy, which, with two or three delineated by Sowerby in his British Mineralogy, constitute the whole of what has been published relative to the crystallographical history of this interesting substance. My own attention has been particularly directed to this subject, by the possession of a large collection of specimens, chiefly from Huel Gorland mine; from which have been selected the principal varieties in the form of the crystal, which are here presented in a regular series. The number of these will doubtless be increased by future research. It does not seem requisite to offer detailed remarks on each individual crystal; it will suffice to make some occasional observations, and to note some peculiarities that might not be perfectly intelligible by the assistance of the figures alone.

The primitive Crystal and its varieties.

Fig. 1 is the primitive crystal; the angle formed by the meeting of the two faces PP has been ascertained by Haüy to be 109d. 28′. 16″. Fig. 2 is the result of a * decrease on one face of the upper, and on the opposed face of the lower pyramid. This crystal has aptly been called the segment of the octohedron, as the explanatory fig. 3, will evince. Fig. 4 is the primitive crystal elongated; this elongation arises, as is obvious, from a regular increase of the crystalline laminæ on one face of the upper pyramid, and on that face of the lower to which it is united at their common base. Fig. 5, is the same occurring in capillary crystals. Fig. 6 differs from fig. 4 in the upper pyramid only; on the already increased face of which, a still further increase of laminæ has taken place, as well as a similar deposition on the opposite face of the same pyramid. Fig. 7 is produced by an increase on one face of the upper, and on one face of the lower pyramid of fig. 4, as will be obvious on consulting fig. 8. Fig. 9 is the consequence of an increase on two opposed faces of the upper, and on the other two opposed faces of the lower pyramid of the primitive crystal, as will be seen by fig. 10. Fig. 11 is the result

* In the present imperfect state of mineralogical language, it is difficult on every occasion to find terms by which even facts can be accurately defined. For instance, in that modification of the octohedron, where the solid angle is wanting, and which though differing in form from the primitive Crystal, can scarcely be called an imperfection in crystallization, there is no term in use justly descriptive of the fact. The terms *truncation* and *decrease* are obviously inaccurate. I have used the latter as perhaps the least exceptionable. It is with deference to the opinions of the Count de Bournon, I venture to observe that the term *retrogradation* lately adopted by him seems equally objectionable with either of the preceding.

of an arrangement that may not be allowed strictly to come within the meaning of the term *macle*, in the sense in which it is used by Romé de l'Isle, being simply two crystals of the last variety, uniting by one of the four hexagonal faces of each crystal, so as to form in appearance but a single crystal. I possess also another, in which two crystals of the succeeding variety are in like manner attached.

Fig. 12 is a highly interesting variety of the primitive crystal, as it forms the passage of it, as fig. 13 will shew, into the acute rhomboid, fig. 15, of which fig. 14 is the intermediary stage. This rhomboid, I have not, from the minuteness of the crystals, which, though numerous, exceed not in size the extremity of the smallest pin, been able to submit to the goniometer. This form also exists in the Spinelle ruby and in the diamond ; which, as well as the red oxyd of copper, have for their primitive form, the regular octohedron, and give an acute rhomboid of 60 and 120d.

THE FIRST MODIFICATION.

This modification consists in a decrease on the six solid angles of the primitive crystal, so that each is replaced by an equilateral quadrangular plane, perpendicular to the axis that passes through the angle, and forms the passage of the octohedron into the cube. The angle caused by the meeting of the faces P and 1, Fig. 16, is, according to Haüy, 125°, 15′, 52″. Fig. 24 shews the direction of the laminæ of the cube. Fig. 25 may rather be considered an accidental circumstance, than as forming an important part of this series. That the triangular face formed by the decrease of crystalline laminæ on the solid angle of the cube (fig. 24.) corresponds with the face P of the primitive crystal will be obvious. I could not therefore hesitate to delineate this interesting combination, of which several instances occurred on the same specimen. Fig. 29 represents the cube in capillary crystals, of which I possess a specimen from Tol Carn mine, in recomposed granite, and of the most lively carmine colour. Fig. 32 is an octohedron formed of minute cubes, of which there are several on the same specimen. Fig. 33 shews the passage of the cube into the rhomboidal dodecahedron by the deposition of the cubic facets, progressively diminishing in size, on each face of the cube. This interesting crystal at first excited the suspicion that the cube is the primitive form of the red oxyd, which abated on reflecting that the octohedron will admit a fracture in the direction of its faces, and that the cube will not, as has been already noticed: the direction of the laminæ in both cases is shewn by figs. 24 and 37. These circumstances indeed prove the octohedron to be the form of the primitive crystal.

SECOND MODIFICATION.

This modification arises from a decrease along the edges of the primitive crystal, which replaces each by a plane perpendicular to the axis that passes through the middle of the edges. It shews the passage of the primitive form into the rhomboidal dodecaedron. The angle formed by the meeting of the face P with the plane 2, Fig. 34, is 144d. 44′, 8″ as given by Haüy. The striæ on fig. 37, which shews the passage of the primitive form into the rhomboidal dodecaedron, denote the direction of the laminæ. In fig. 41, which resembles in its general form the crystallization of the oxyd of tin, the decrease on the edges formed by the meeting of the two pyramids is so considerable, as to give the shape of a parallelogram to the four planes which replace the four solid angles, also formed by the meeting of the two pyramids.

THIRD MODIFICATION.

This modification is the result of a decrease on each of the solid angles of the octohedron, and on its edges, which replaces each of the solid angles by four planes inclined on the axis, and placed on the edges of the octohedron.

Fig. 61, which represents this modification uncombined with any other, is here delineated in order to shew it in that state, but I have not so seen it. It is however probable that it may hereafter be discovered.

This modification is extremely rare. The crystals on which I have hitherto observed it scarcely exceed half a line in length. It is perhaps, therefore, impossible to determine with accuracy the admeasurement of the angles.

FOURTH MODIFICATION.

This modification is the result of a decrease along the edges of the octohedron, as well as the second modification, but with this difference, that, in this, each edge is replaced by two planes inclined on the axis passing through the middle of the edge (fig. 64.)

The planes 4, 4, on fig. 67, may be considered as resulting from an after-deposition of those planes on a crystal formed as fig. 39. I possess a specimen on which there are many of these singular crystals. This species of deposition may frequently be observed. I have repeatedly noticed it on the plane 2 of fig. 39, not exceeding one half the length or breadth of the plane; and again, in distinct laminæ so disposed as to produce a triangular pyramid on each face of the primitive crystal, which respectively formed the base, as in the instance of fig. 70, but much more acute.

FIFTH MODIFICATION.

This interesting modification is found in combination with each of the preceding, but is rarely seen displayed by itself on the primitive crystal as in fig. 74. It arises from a decrease of the crystalline laminæ on that part of each face forming the solid angle, by which each is replaced by an obtuse quadrilateral pyramid; the faces of which incline on the axis that passes through the angles. The angle formed by the meeting of P and 5 is about 160 d. and of 1 on 5 about 144 d.*

Fig. 78 seems to be the result of a partial after-deposition on the faces of the primitive crystal, by which each face of it (such parts of of them excepted as contribute to form the solid angle,) is brought in form to resemble fig. 77, except only that in this the solid angles of the primitive crystal remain.

It may perhaps be imagined that some of the latter figures in the series of this modification, exhibiting its combination with some of the preceding modifications might have been omitted; but as the term variety is used to signify combination of two or more modifications, as well as those differences in crystals which arise from the various proportions of the faces to each other, by which variations in the form of the face are produced; and as each of these differs in one or more of these respects, and actually exists, it seemed proper not to omit them.

* There are other modifications, and their combinations delineated in the series of the crystallization of this substance, the angles of which it would have been desirable to have given; in most, if not all of which, it is, from their exceedingly small size, to be regretted that it would have been difficult, if not impossible, even for the most skilful and practised hand, to have subjected them to the goniometer.

SIXTH MODIFICATION.

This modification is the result of a decrease, by which each solid angle is replaced by eight triangular planes, two on each face of the primitive crystal, and inclining on the axis that passes through the angles. Fig. 106; I have not seen this modification as thus described, but only, as in the following figures, in combination with other modifications. The crystal represented by fig. 108 contains all the modifications of the primitive crystal of this substance, which, I believe, have hitherto been noticed.

III. *A Sketch of the natural History of the Cheshire Rock-Salt District.*

By Henry Holland, Esq. Honorary Member of the Geological Society.

THE vast beds of fossil or rock-salt, which are found in different parts of the County of Chester, form undoubtedly the most important and peculiar feature in the mineralogy of this district. In offering to the notice of the Geological Society some remarks upon these mines, it may be proper to premise, that in a Survey of Cheshire, which I had the honour of drawing up for the Board of Agriculture, I entered at considerable length upon the subject of their natural history, and upon the manufacture of white salt from the brine springs to which they give rise. It will be my present object to consider more especially the mineralogical situation and characters of the Cheshire rock-salt; and though the repetition of some statements must necessarily occur; this, in the case of a work only partially known, can, I conceive, be attended with little disadvantage.

Character of the country surrounding the salt mines.

In speaking of the general situation of the Cheshire salt mines, it will be proper to state some facts with respect to the nature of the surrounding country, that their mineralogical relations may more clearly be understood, and an opportunity given to speculate upon the probable origin of these important strata. The southern parts of Lancashire, the northern extremity of Shropshire, and the whole of the intervening County of Cheshire, form in conjunction one vast tract of plain country, interrupted by few elevations, and these inconsiderable in size and extent. The area of this plain may be regarded as extending nearly fifty miles from north to south, and as having an average breadth of twenty-five or thirty miles. Its eastern boundary, as more immediately regards the County of Chester, is a high range of sandstone hills, stretching from north to south along the borders of Derbyshire and Staffordshire; connected on the north with the hills in the West Riding of York, and on their eastern side passing into the limestone hills of Derbyshire. The sandstone, in a considerable part of this range, is slaty in its structure, and would seem to belong to the Independent Coal-formation of Werner, some pretty extensive beds of coal being found and worked under it. The southern boundary of the plain, which is the one approaching most nearly to the rock-salt, is irregularly formed by ridges of limestone and calcareous sandstone, leaving open some communications with the level country in the middle of Shropshire. To the west its limits are marked by the sandstone and limestone hills in the adjoining part of Wales, and by the sandy æstuaries of the Mersey and Dee.

The only ridge of hills, properly speaking, within the Cheshire plain, is one on the western side of the county, extending with a few interruptions from Frodsham to Malpas, and including in its progress from north to south, the high grounds of Delamere Forest, the Hill of Beeston, and the Peckforton Hills. This range, which no where attains an elevation of more than four or five hundred feet, is composed entirely of sandstone. A small quantity of copper ore has been found in the Peckforton Hills, which form its southern extremity. Another ridge of land, possessing a small and irregular elevation above the adjoining plain, may be traced from the hills on the eastern border of Cheshire, in a westerly or north-westerly direction to Halton and Runcorn. At this point, where it attains its greatest height, it is separated from the northern extremity of the former ridge, only by the intervention of the valley of the Weaver, which valley is here about two miles in width. Towards the eastern extremity of this range, we meet with a singular sandstone hill, called Alderley Edge, in which have been found ores of lead, copper and cobalt, and masses of sulphate of barytes.

This distribution of the high grounds in the Cheshire plain is traced out in the annexed map, and it will be seen, by a reference to this, that they form three distinct divisions of its area: one to the west of the higher sandstone range; another to the east of this, and south of the lower range; and a third lying north of the latter, and including the southern parts of Lancashire. With the exception of a very few instances only, the existence of the rock-salt appears to be exclusively confined to the southern or central plain.

The marl beds form the most peculiar feature in the alluvial strata of the Cheshire plain. These occur in great abundance in every part of the district; being found not only under the common soil, but occasionally, as on the borders of Delamere Forest, interposed between layers of sandstone rock. The Cheshire marls are also very frequently met with in large detached masses, twenty or thirty feet in thickness, in the working out of which, it is not unusual to find large assemblages of fragments of the older rocks. Portions of granite, often of large size, and shewing on their surface evident marks of attrition, are among the most common appearances in these collections: no granitic rocks are found within fifty or sixty miles of this district.

The divisions which I have pointed out in the Cheshire plain are still further marked by the course of the streams in this tract of country. The Dee is the great river of the western plain; the Weaver and its subordinate streams receive all the waters of the southern division; while the Mersey and its tributaries do the same in the northern portion. From their local relation to the great beds of rock-salt, the streams of the southern or central plain possess a peculiar importance.

The Weaver rises in the Peckforton Hills, near the Shropshire border, runs for some miles towards the south-east, then making a sudden flexion to the north, continues in this direction, by Nantwich and Winsford, to Northwich, about thirty miles further. Here it takes a north-westerly course to Frodsham, where it expands into a sandy æstuary, connected with the channel of the Mersey. It receives its principal accessions at Northwich, where it is joined by the united streams of the Dane and Wheelock from the south-east, and by a stream called Witton-Brook from the east. At Anderton, a little below Northwich, the valley which has hitherto been comparatively wide and flat, is suddenly contracted by the approach of two ranges of high ground; that on the western side of the river connecting itself by a gradual rise with the heights of Delamere Forest; the opposite one passing by a series of irregular elevations into the range of high land, which separates the southern from the northern plain. At Frodsham the river flows, as I before mentioned, between the termination of this high ground and that of the ridge which crosses the county from north to south, the hills thus opposed corresponding perfectly in appearance and structure. We have thus two distinct contractions in the valley of the Weaver below Northwich; a circumstance in some degree worthy of notice.

Situation of the brine springs, rock-salt mines, &c.

I have dwelt thus minutely upon local facts from their connection with the situation of the rock-salt, which, with few exceptions, has yet been ascertained to exist only in the vallies of the Weaver and its tributary streams; in some places manifesting its presence by springs impregnated with salt; in other places being known by mines actually carried down into the substance of the strata. A reference to the map will shew the several situations where brine springs occur, or where mines have been sunk, in the course of these vallies. Between the source of the Weaver and Nantwich, it will be seen that many brine springs make their appearance; and in the latter part of this course, it would seem that brine might be obtained by sinking to some depth in any place near the banks of the Weaver. Proceeding down the stream, salt-springs occur again at Winsford, and in several situations between Winsford and Northwich. At Moulton, between these two places, a mine has been sunk into the body of rock-salt, and another also between Winsford and Middlewich. At Northwich the brine springs are very abundant, and here also many mines have been sunk for the purpose of working out the fossil salt. The springs occur again in several places further down the river, but none have been met with below Saltersford, about two miles from Northwich. At Whitley, however, two miles north of the Weaver, and six miles from Northwich, a body of rock-salt is stated to have been met with in boring for coal.

On the course of the river Wheelock, brine springs have been found at Lawton, Roughwood, Wheelock, and again at Middlewich, where this stream unites itself with the Dane. At Lawton a mine has been sunk into the rock-salt. In the valley of the Dane, no salt springs actually appear, but several circumstances indicate that brine has at some former period been discovered there, and this as high up the stream as the neighbourhood of Congleton. No springs have been found in the valley of Witton Brook, except at the part of it immediately adjoining the Weaver at Northwich.

The evidences of the presence of rock-salt occur, as I before stated, in very few places out of these vallies, and even some of the excepted instances appear to have a local relation to the southern or central plain. This is the case with the salt springs of Dirtwich, in the south-western angle of Cheshire; with a spring of very weak brine lately found at Adderley, in the northern extremity of Shropshire; and probably also with other saline springs which occur in the contiguous parts of Flint and Denbighshire. At Dunham, however, in the north of Cheshire, we find a weak spring, which cannot strictly be considered as connected with the formations of the southern plain. At Barton and Adlington, in the southern parts of Lancashire, brine springs likewise appear; and it is not improbable that other instances of the same kind may occur in the northern portion of the great plain. It appears possible, however, that these weak springs may derive their saline contents, not from distinct subjacent beds of the fossil salt, but merely from beds of clay or argillaceous stone, strongly impregnated with particles of the muriate of soda.

Manufacture of white salt.

It would be foreign to the object of this paper to enter with minuteness into the natural history of the salt springs, or into the processes employed in the manufacture of white salt. Those members of the Society, who may wish for further information on these subjects, I beg leave to refer to the Survey of Cheshire before noticed.

It may be sufficient here to state a few of the most general and important facts.

The brines met with in this district are very generally formed by the penetration of spring or rain waters to the upper surface of the rock-salt, in passing over which they acquire a degree of strength, modified by several circumstances, which it would be needless to detail. Their average strength, however, appears to be much greater than that of the springs met with in Hungary, Germany, or France. At Winsford, Northwich, Anderton, Lawton, Roughwood, Wheelock, and Middlewich, where all the principal salt works are situated, the brine springs contain between 25 and 26 per cent. of the pure muriate of soda; and in some of the springs at Anderton, the proportion stands as high as 26.566 per cent. a very near approach to the perfect saturation of the brine. The earthy salts held in solution together with the muriate of soda are principally muriate of magnesia and sulphate of lime; the quantity of these varying from $\frac{6}{10}$ per cent. to 2 or to $2\frac{1}{2}$ per cent. in different springs. The brine being pumped out of the pits, is first conveyed into large reservoirs, and afterwards drawn off as it is wanted, into evaporating pans, made of wrought iron. Here heat is applied in a degree determined by the nature of the salt intended to be manufactured, and various additions are made to the brine, with a view either to assist the crystallization of the muriate of soda, or to promote the separation of the earthy salts. The latter exist in a very small proportion in the manufactured salt, and cannot be supposed in any degree to affect the uses to which it is applied.* The importance of the Cheshire

* In reference to the chemical character of the different varieties of salt, an excellent paper by my friend Dr. Henry will be found in the Philosophical Transactions for the year 1810. Part I.

salt manufacture will be sufficiently obvious from the statement, that besides the salt made for home consumption, which annually amounts to more than 16,000 tons, the average of the quantity sent to Liverpool for exportation has not been less than 140,000 tons.

General situation, thickness, &c. of the beds of rock-salt.

Though springs impregnated with salt occur in several parts of the Cheshire plain, it may be remarked that the rock-salt itself has only been worked into near the banks of the Weaver and its tributary streams. It was first discovered at Marbury near Northwich, about one hundred and forty years ago, in searching for coal. This bed of rock was the only one worked for more than a century, when, in the same neighbourhood, a second and inferior stratum was met with, separated by a bed of indurated clay from the one previously known. This lower stratum was ascertained to possess at a certain depth a great degree of purity and freedom from earthy admixture; on which account, and from the local advantages of Northwich for exportation, the fossil salt is now worked only in the vicinity of this place.

This local limitation of the mines precludes the possibility of many comparative remarks which might be interesting to the geologist; and in giving a particular description of the rock-salt formation, I must confine myself in great measure to the facts which present themselves in the neighbourhood of Northwich, explaining first the circumstances of general position, &c. and then entering into the more minute particulars of the mines which have been sunk into these important strata.

The rock-salt of Northwich occurs, as I have just mentioned, in two great strata or beds, lying nearly horizontally, but on different levels, and separated, the superincumbent from the subjacent stratum, by several layers of indurated clay or argillaceous stone. These intervening beds possess in conjunction a very uniform thickness of ten or eleven yards, and are irregularly penetrated by veins of the fossil salt. Though the evidence on the subject is not entirely of a positive nature, there seem strong grounds for believing that the beds of rock-salt at Northwich are perfectly distinct from any others in the salt district, forming what the Germans would call *liegende stöcke*, lying bodies or masses of the mineral. It will readily be conceived that there is much difficulty in acquiring precise information with respect to the extent and limitation of these great masses, and that there are many sources of error to which such an inquiry is liable. There are, however, a few leading facts upon which dependence may be placed, and which will be admitted to furnish fair grounds for deduction.

It would appear that the great beds of rock-salt at Northwich assume a general longitudinal direction from north-east to south-west, the line which has been traced upon them in this direction being a mile and a half in length, and no direct evidence existing that they may not extend further in these points; while their transverse extent, as measured by a line at right angles to the former, is much more limited, probably not exceeding in any place one thousand three hundred or one thousand four hundred yards. Several circumstances concur in giving probability to this statement. Let two parallel lines, drawn from NE to SW, with an intervening distance equal to about half their length, be employed to designate the supposed extent of the subjacent rock-salt. In a mine which approaches very nearly to the eastern limit of the area thus formed, the upper bed of rock-salt was actually worked through in an horizontal direction on this side, and discovered to be going off with a very rapid declivity. A similar fact has been stated with respect to another pit further to the south on the same line of boundary, but as the mine was destroyed many years ago by the ingress of fresh water, this statement is considerably more doubtful than the former. It may be remarked too, that in sinking for brine a little beyond, or out of the area, on this side, the brine met with is of a very weak and inferior kind, and at a short distance altogether disappears. Appearances leading to the same conclusion of the sudden termination of the body of rock-salt occur on the opposite side of the area marking its extent. In a mine at the northern extremity of the western line of boundary, a shaft situated nearer to this line is fifteen yards deeper than another shaft immediately contiguous, apparently in consequence of the rapid sinking of the rock-salt at this point. In most of the pits on this side, the upper bed of rock is met with at a depth of from thirty to forty yards; yet at Barnton, a mile further to the west, and on the same or a lower level, none was met with in a sinking of one hundred and fifteen yards.

Corresponding appearances have been observed in the body of rock-salt which occurs at Moulton, between Winsford and Northwich, where in two sinkings on the same level, and at the distance of one hundred yards from each other, the difference in the depth at which the rock was found, was nearly twenty yards, a circumstance from which the limitation or going off of the bed at this particular point may reasonably be inferred. As nothing further, however, is ascertained with respect to the extent and direction of this particular body of rock-salt, I merely mention the fact to corroborate the statement given of the limitation of the great beds at Northwich.

Another important observation with respect to the Northwich rock-salt, is, that there seems to be a progressive thinning of the upper bed of salt from NW to SE, or in a direction nearly at right angles to the longitudinal extent of the stratum. Though much uncertainty exists with respect to the rate and progression of this decrease, the general fact seems to be sufficiently confirmed by observations taken from different mines. In those which have been sunk near to the western or north-western side of the area before described, the thickness of the upper bed has been very generally twenty-eight, twenty-nine, or thirty yards. Proceeding towards the east or south-east, we find this thickness decreasing to twenty-five yards, and in the mines near the eastern boundary, the bed of rock-salt comes down to twenty, eighteen, and even seventeen yards in thickness. It will be observed that this thinning takes place in a general direction *from* the nearest sea coast; the thickest part of the body of rock being situated furthest down the Weaver, and just above the contraction which takes place in the valley of the river at Anderton.

Besides this general variation of surface in the superior stratum of rock-salt, it has been found that there is a considerable irregularity of level on its upper surface. In one of the mines, in which a tunnel was carried one hundred yards along this surface, many small risings and depressions were met with; and similar appearances have been observed in the other mines near Northwich.

The depth at which the upper bed of rock-salt is found, though varied by several of these circumstances, depends principally, of course, upon the surface of the ground above, which at Northwich, from the confluence of streams there, is somewhat irregular. In the greater number of the mines, it is met with at a depth varying from thirty-five to forty yards. The smallest depth, at which it has been found, is in a mine situated close to Witton Brook, about half a mile above the entrance of this stream into the Weaver. Here it appears at twenty-nine yards from the surface; and a general estimate of level from this mine shews that the upper surface of the salt is at least twelve or thirteen yards below the low-water mark of the sea at Liverpool; a fact perhaps not wholly unimportant as regards our ideas of the formation of this mineral.

The thickness of the upper bed of salt at Northwich has been already stated to vary from twenty to thirty yards: that of the lower bed has never yet been ascertained in any one of the mines in this district. The workings in this lower stratum are usually begun at the depth of from twenty to twenty-five yards, and are carried down for five or six yards, through what forms, as will afterwards be mentioned, the purest portion of the bed. In one of the mines a shaft has been sunk to a level of fourteen yards still lower, without passing through the body of rock-salt. We have thus an ascertained thickness of this bed, of about forty yards, and no direct evidence that it may not extend to a considerably greater depth.

Though only two distinct beds of the fossil salt have been met with at Northwich, it has been ascertained that the same limitations do not exist throughout the whole of the salt district. At Lawton, near the source of the river Wheelock, three distinct beds were found, separated by strata of indurated clay; one, at the depth of forty-two yards, four feet in thickness; a second, ten yards lower, and twelve feet thick; and a third, fifteen yards still further down, which was sunk into twenty-four yards, without passing through its substance. Coal is found and worked within two or three miles of this place, and the only limestone known in the County of Chester, is got from the hills which here form the southern boundary of the plain. In no other parts of the salt district, than at Northwich and Lawton, has the upper bed of rock been worked through.

The strata passed through in going down to the upper bed of rock, are nearly horizontal in position, and very uniform in their structure, consisting in every instance of beds of clay and marl; and these, with the exception of a few of the most superficial, appearing in similar progression in each mine. The clays, or argillaceous stone, of which these beds are composed, are indurated in different degrees, tinged with various shades of red, blue, brown, &c. and usually contain a portion of sulphate of lime. They are known to the miners by the general name of *metals*; a distinctive appellation being given to each from the shade of colour which it assumes. In the section of strata, annexed to this paper, these appearances are noted with some degree of minuteness; and that they may more accurately be known, I have sent a few specimens, illustrative particularly of the induration of the clay strata, and of their admixture with the sulphate of lime. It will be observed that, though these clays in general possess a considerable degree of induration, there are some of them sufficiently porous to admit the passage of water through their substance. Where this structure of the clay occurs it goes by the name of the *shaggy metal*, and the fresh water which makes its way through the pores has the expressive appellation of *Roaring Meg*. This term will not appear too strong, when it is mentioned that in the mine from which the section of strata was taken, and where the *shaggy metal* was found at the depth of twenty-six yards, the quantity of water, ascertained to issue from its pores in one minute, was not less than three hundred and sixty gallons; a circumstance greatly enhancing the difficulties of passing a shaft down to the body of rock-salt.

A portion of salt, sufficient strongly to affect the taste, is found to exist in many of these beds of argillaceous stone: and this saltness increases, as might be expected, as we approach the body of the rock-salt. In the strata or layers immediately above the rock, which in all the mines are perfectly uniform in their appearance and structure, it is particularly remarkable. It may be observed, however, that there are not in these strata any veins of rock-salt, connected with the great mass below: on the contrary, the line of division between the clay and rock-salt is drawn with great distinctness in every instance, and presents none of those inequalities which would arise from a mutual penetration of the strata.

It may, I believe, be considered as a decided fact that no marine exuviæ or organic remains are found in the strata situated over the rock-salt. I have indeed heard it asserted that there are a few instances in opposition to this statement; but upon minute inquiry, I do not find that the accuracy of these alleged exceptions is in any degree to be depended upon.

The general, I believe universal, occurrence of gypsum, in connexion with beds of fossil salt, is a fact worthy of observation. This connexion appears in the salt mines of Hungary, Transylvania, and Poland, as well as in those of Cheshire, and it has led Werner to assign to the rock-salt and flœtz gypsum a conjunct situation in his Geognostic System. The gypsum, contained in the clays over the Cheshire rock-salt, occurs in varying proportions, and under different appearances in the several beds passed through. It is found both in large masses and in small granular concretions. The compact, foliated, and fibrous varieties are all met with; the last of these occurring in very considerable proportion. According to Werner, the first or oldest flœtz gypsum is that which has the most immediate relation to rock-salt. I am not enabled to say whether the gypsum appearing above the Cheshire salt would be considered as belonging to this particular formation. The presence of the fibrous variety of the mineral would rather seem to place it with the second flœtz gypsum where this species is particularly abundant; but no positive distinction can be derived from this circumstance. I may remark that gypsum has been met with in several other parts of the Cheshire plain, in situations and with appearances very similar to those in which it occurs above the rock-salt.

Interior character of the beds of rock-salt.

Having stated the several facts which regard the extent, thickness, and other general characters of the beds of rock-salt at Northwich; I shall now mention more particularly the appearances exhibited in their internal structure, in relation to which some interesting observations occur.

The fineness or purity of the rock is a circumstance very important to the interests of the mining proprietor, and in this point considerable varieties appear in different parts of the strata. The great body of the rock-salt, both in the upper and lower stratum, is composed of crystals of muriate of soda, intimately mixed with certain proportions of clay and oxide of iron, giving to the mass a red or reddish-brown tinge; and in addition to these constituent parts, contains likewise certain earthy salts, the sulphate of lime, and the muriates of lime and magnesia, but these in small proportion. In every part, however, of this compound rock, we find separate crystalline concretions of muriate of soda, variously disposed, sometimes occurring distinctly in the cubical form; in other places in masses of larger size, and irregularly shaped. The colour of these concretions, which are of the foliated species of fossil salt, is usually a greyish or milk-white; they are always translucent, and often attain a considerable degree of transparency. It would appear that they contain the muriate of soda in its purest form; the sulphate of lime in specimens of this kind being scarcely distinguishable by the delicate tests applied to its discovery.

This finer rock-salt occurs not only in separate concretions, but also in veins intersecting the coarser mass, and in the rims or borders of the polyhedral figures which will afterwards be mentioned. Its proportion varies both in the two great beds of rock, and likewise in different parts of the same bed; and it is a regard to this circumstance which determines the situation and extent of the workings in the several mines. In the upper bed this variety is less considerable than in the lower: but here the substance of the rock-salt is evidently purer three or four yards above the lower surface than in other parts of the same stratum, and continues so for about four feet. In the lower bed, the first twenty or twenty-five yards passed through contain a proportion of earth as large as in the upper stratum: at this depth, however, a greatly increased degree of purity appears, which is continued for five or six yards further down, when the proportion of earthy admixture again becomes as large as before.

It is invariably this purer portion of the lower bed which is at present worked in the Northwich mines, and the rock-salt obtained from it, being principally exported to the Baltic, obtains the name of *Prussia Rock.* The extent of the cavity formed by the workings varies in different mines; the average depth may probably be taken at about sixteen feet. In some of the pits, where pillars six or eight yards square form the supports of the mine, the appearance of the cavity is singularly striking, and the brilliancy of the effect is greatly increased, if the mine be illuminated by candles fixed to the side of the rock. The scene so formed, would almost appear to realize the magic palaces of the eastern poets. Some of the pits are worked in aisles or streets, but the choice here is wholly arbitrary. The methods employed in working out the rock-salt offer nothing worthy of notice. The operation of blasting is applied to the separation of large masses from the body of the rock, and these are afterwards broken down by the mechanical implements in common use. The present number of mines is eleven or twelve, from which there are raised, on an annual average, fifty or sixty thousand tons of rock-salt. The greater part of this quantity is exported to Ireland and the Baltic: the remainder is employed in the Cheshire district in the manufacture of white salt by solution and subsequent evaporation.

It is very doubtful whether in any instance the body of rock-salt can be considered as stratified, or disposed in distinct layers. A perpendicular section does sometimes indeed present irregular appearances of this kind, and more especially in the purer part of the lower bed, but the great body of the rock offers to the eye merely a confused red mass, varied here and there by the occurrence of the crystalline portions of salt.

One of the most striking facts connected with the internal structure of the Northwich rock-salt, is the appearance observable on the surface of an horizontal section of the rock, as viewed in any of the mines. On this surface may be traced various figures, more or less distinctly marked, and differing considerably in the forms which they assume; some appearing nearly circular, others perfectly pentagonal, and others again having an irregular polyhedral form. The lines which form the boundary of these figures are composed of extremely pure white salt, forming a division between the coarse red rock exterior to the figure, and the equally coarse rock included within its area. These bordering lines or rims vary from two to six inches in width. The figures themselves differ greatly in size; some of them being less than a yard in diameter, others as much as three or four yards; and they very frequently are observed, one within another, gradually diminishing in size to a centre. Professor Playfair, in his Illustrations of the Huttonian Theory, has stated, that the compression of these figures is always mutual; the flat side of one being turned to the flat side of another, and never an angle to an angle, nor an angle to a side. This remark, as far as my observations have gone, is perfectly founded in fact. From the mode of working the mines, it is difficult to ascertain the progressive appearance of these figures in a perpendicular plane. It has been stated to me that their form is a pyramidal one, the area enlarging by a determinate ratio of increase as they are traced downwards; but several circumstances induce me to consider this statement as a very doubtful one, and certainly founded upon insufficient evidence.

One very important negative fact remains to be mentioned with respect to the internal structure of the Cheshire rock-salt, viz. that no organic impressions or remains have ever been met with in any of the beds of the mineral, which have been worked in this district. This fact rests on evidence of a satisfactory kind, and I am not aware of more than a single instance adduced in opposition to it, and that of a very dubious nature. The same remark may be applied to the strata of argillaceous stone between the two beds of rock-salt. The veins of rock-salt intersecting these intermediate strata contain principally the fibrous variety of the fossil. It may be remarked too of these strata, that at their junction with the upper and lower beds of rock-salt, the lines of division are nearly as distinct, as that between the upper bed of rock, and the superincumbent layers of argillaceous stone.

Comparative View of the Cheshire and Continental Salt Mines.

The want of sufficient materials with respect to the history of the continental salt-mines prevents me from entering into circumstances of comparison so minutely as I could have wished; considering such comparison to afford the best foundation for inquiries into the origin of the fossil-salt. The best, or rather the only memoir on this subject which I have had the opportunity of seeing, is one by M. Hassenfratz, contained in the eleventh volume of the Annales de Chimie. From this memoir it would appear that the general situation of the Rock-salt in Transylvania and Poland is very similar to that which it occupies in Cheshire ; the beds of this mineral being disposed in small plains, bounded by hills of inconsiderable height, forming a kind of basin or hollow, from which there is usually only a narrow egress for the waters. The situation of the Austrian salt-mines near Salzburgh is however very different. The mineral here appears to be disposed in beds of great thickness, which occur near the summit of limestone hills, at a great elevation above the adjoining country.* This fact is a singular one ; and if we admit the idea that rock-salt is formed from the waters of the sea, makes it necessary to suppose the occurrence on this spot of the most vast and wonderful changes. M. Hassenfratz states it as a general fact, that in countries where salt-mines occur, fragments of primitive rocks appear in great abundance over these beds. It does not seem, however, that any deduction of importance can be connected with this fact.

The disposition of the beds of salt in the continental mines seems to be very generally a horizontal one, and as in the English mines, they are separated by strata of clay of a varying thickness. It would appear, however, with respect to extent of dimensions, that they are in general greatly inferior to the bodies of rock-salt met with in our own island. In Hungary and Poland these beds do not present a thickness of more than one or two feet, and are separated by layers of

* I am informed by Mr. Greenough that the *lapelsgraben*, which is the highest gallery of the salt mine at Halstadt, is stated in Von Buch's Travels through Germany and Italy to be two thousand nine hundred and seventy-five feet above the sea, and that the salt mines at Hall in the Tyrol are at a much more considerable elevation.

clay a few inches in thickness. Much, however, it is evident, must depend upon the number of the beds thus disposed, but this I do not find any where noticed. The earthy saline contents of the foreign rock-salt very exactly resemble those of the Cheshire; the gypsum existing in much larger proportion than the other earthy salts, and appearing in considerable masses, both distinctly, and in mixture with the beds of clay. It is an important fact, however, that sea-shells and other marine exuviæ are found in these beds of clay and gypsum; a circumstance which, as I before stated, never occurs in the Cheshire mines. It would seem that the portion of oxide of iron combined with the clay in the substance of the English rock-salt does not exist in the mineral as found abroad, or at least in a proportion not so considerable.

The comparative commercial value of the English and Polish mines is best ascertained by the fact that many thousand tons of rock-salt are annually sent from Cheshire to the parts of the Prussian coast most nearly adjacent to the salt-mines; independently of the large supplies of the English manufactured white salt which are exported to the same country.

Considerations on the Origin of the Cheshire Rock-salt.

With respect to the theory of the formation of rock-salt, as applicable particularly to that of Cheshire, I shall not venture to say much, and that little will be of a general nature. Though it must be acknowledged that there are some difficulties connected with the suppotion, little doubt can exist of the general fact, that the beds of this mineral have been formed by deposition from the waters of the sea. Such an opinion acquires much probability from the situation in which these beds usually occur; occupying the vallies and lower parts of plains which are so surrounded by hills of secondary formation, as to leave only a narrow egress for the waters collected on their surface. This structure of the plain constituting the salt district of Cheshire, I have particularly described; and, regarded in its general character, it leads strongly to the conclusion that the waters of the sea must, at some former period, have occupied the lower parts at least of the basin thus formed, which at that time had a level eighty or one hundred yards lower than the one now appearing.* To account for the great depositions of salt in the lower parts of this basin, it is necessary to suppose that some barrier must have been afterwards interposed to prevent the free communication of the waters of the sea with those thus collected, and the general course of the streams, the position of the beds of rock-salt, and the contractions in the valley of the Weaver, which appear below Northwich at Anderton and Frodsham, point out with some distinctness the place where these obstructions may probably have occurred.

To explain the appearance of the strata of indurated clay, intermediate between the beds of salt, we must suppose that the obstruction still continued, when the deposition of salt from the waters first confined, had nearly ceased; and that at this period, the deposition of clay, which had hitherto been going on in conjunction with that of the salt, proceeded in a great measure alone; the salt which remained in the water being merely sufficient to form small veins in its substance. When these strata had been deposited to a thickness of ten or eleven yards, it would appear that the barrier preventing the access of the sea to the basin or plain, was again so far removed as to allow the

* This general character of the Cheshire salt district was remarked to me by my friend Sir John Stanley, in reference to the formation of the rock-salt; on which subject he obliged me by some very interesting observations, which are inserted in the Cheshire Report.

entrance of a fresh body of sea water ; from the gradual evaporation of which, the formation of the upper bed of rock-salt took place ; and there being then no further admission of sea water to the plain, the superincumbent strata of clay and marl were successively deposited in the order in which they at present appear.

This is a general sketch of the probable mode of formation of the Cheshire rock-salt ; but as it would seem very doubtful whether any single accumulation of sea water could contain the materials of depositions possessing so great a thickness, the theory might perhaps be successfully modified, by supposing the barrier before noticed, to have had such an elevation in the progressive stages of the deposition of the salt, as to allow the very frequent ingress of sea water into the basin. Admitting this idea, we must suppose that the formation of the strata of indurated clay between the beds of rock-salt took place, either during some intermission of these overflowings, or when there was a great predominance of this earth in the water, from which the depositions were made. It seems probable too that the veins of salt intersecting these strata were formed rather by the penetration of water holding salt in solution, from the upper bed of rock-salt, than by a direct deposition from the waters of the sea. With respect to the sources of the clay, combined with the substance of the rock-salt, or found in intermediate and superincumbent beds, little doubt can exist that it has been derived from the decomposition of more ancient rocks, of the situation and precise characters of which no vestiges now remain.

This general idea of the formation of the Cheshire rock-salt derives confirmation from the fact that, with the exception of the sulphate of magnesia, the same earthy salts occur together with the muriate of soda in these strata, as are met with in the waters of the sea. The circumstance of the beds decreasing in thickness as they recede from the sea, may perhaps be admitted as another argument in behalf of the opinion.

The principal objection to the theory undoubtedly is, the non-existence of marine exuviæ either in the rock-salt, or in the adjacent strata of clay ; a fact very difficult to connect with the idea of a deposition from the waters of the sea. Other objections, though perhaps of less moment, arise from the appearance of the earthy salts in smaller proportion in the rock-salt than in sea water ; from the apparently partial deposition of the beds, and from the difficulty of explaining the formation of the figured appearances which occur in the substance of the rock. These circumstances, however, will by no means authorize us to reject the general idea which has been given of the origin of this mineral, strengthened as it is by the situation and appearances observed in the foreign salt mines, where the proofs of marine deposition are still stronger than those presented in the Cheshire district.

I confess I see no sufficient reason for supposing the action of subterraneous or internal heat in the formation of the beds of fossil salt. It appears probable that a deposition of muriate of soda from the confined waters of the sea might have taken place without the intervention of this agency, and there are no appearances either in the beds of salt, or in the clays accompanying them, which render it necessary to have recourse to the supposition in question. It must be acknowledged, however, that it is difficult to give a satisfactory account of the consolidation of the beds of salt ; nor do I know any opinion on this subject, which can be considered altogether free from objection. A more enlarged discussion of these theoretical points may be found in the Appendix to the Report of Cheshire, before alluded to.

In dwelling thus minutely upon the natural history of the Cheshire rock-salt district, I am not aware that I have gone further than was requisite to a complete view of the subject. The prosecution of such enquiries is much assisted by the comparison of facts observed in different situations; and as the neighbourhood of Droitwich, in Worcestershire, is with the exception of the Cheshire salt district, the most considerable source of brine springs in this kingdom, some information with respect to the situation and natural history of these springs, as connected with a subjacent body of rock-salt, may be considered a desirable and important object. Such information I have not the means of giving, but it is more than probable that the Geological Society will be enabled to procure it, by the assistance of some of its corresponding members.

Section of the Strata sunk through to the second Bed of Rock-Salt, at Witton, near Northwich.

No.	Nature of the Strata.	yards	feet	inch.
1	Calcareous Marl	5	—	—
2	Indurated red Clay	1	1	6
3	Indurated blue Clay with Sand	2	1	—
4	Argillaceous Marl	1	2	—
5	Indurated blue Clay		1	—
6	Red Clay, with Sulphate of Lime irregularly intersecting it	1	1	—
7	Indurated blue and brown Clay, with grains of Sulphate of Lime interspersed	1	1	—
8	Indurated brown Clay, with Sulphate of Lime crystallized in irregular masses, and in large proportion	4	—	—
9	Indurated blue Clay, laminated with Sulphate of Lime	1	1	6
10	Argillaceous Marl	1	1	—
11	Indurated brown Clay, laminated with Sulphate of Lime	1	—	—
12	Indurated blue Clay, with laminæ of Sulphate of Lime	1	—	—
13	Indurated red and blue Clay	4	—	—
14	Indurated brown Clay, with Sand and Sulphate of Lime irregularly interspersed through it. The fresh water (360 gallons per minute) finds its way through holes in this stratum, and has its level at sixteen yards from the surface	4	1	—
15	Argillaceous Marl	1	2	—
16	Indurated blue Clay with Sand, and grains of Sulphate of Lime	1	—	9
17	Indurated brown Clay, with a little Sulphate of Lime	5	—	—
18	Indurated blue Clay, with grains of Sulphate of Lime		1	6
19	Indurated brown Clay, with Sulphate of Lime	2	1	—
20	The first Bed of Rock Salt	25	—	—
21	Layers of indurated Clay, with veins of Rock Salt running through them	10	1	6
		76	2	9
22	The second Bed of Rock Salt, which has been sunk into thirty-five or thirty-six yards.			

See the engraved Section in the Agricultural Report of Cheshire.

IV. *Account of the Pitch Lake of the Island of Trinidad.*

By Nicholas Nugent, M.D. Honorary Member of the Geological Society.

BEING desirous to visit the celebrated Lake of Pitch, previously to my departure from the Island of Trinidad, I embarked with that intention in the month of October, 1807, in a small vessel at Port Spain. After a pleasant sail of about thirty miles down the Gulph of Paria, we arrived at the point la Braye, so called by the French from its characteristic feature. It is a considerable headland, about eighty feet above the level of the sea, and perhaps two miles long and two broad. We landed on the southern side of the point, at the plantation of Mr. Vessigny: as the boat drew near the shore, I was struck with the appearance of a rocky bluff or small promontory of a reddish brown colour, very different from the pitch which I had expected to find on the whole shore. Upon examining this spot, I found it composed of a substance corresponding to the porcelain jasper of mineralogists, generally of a red colour, where it had been exposed to the weather, but of light slate blue in the interior; it is a very hard stone with a conchoidal fracture, some degree of lustre, and is perfectly opake even at the edges; in some places, from the action of the air, it was of a reddish or yellowish brown, and an earthy appearance. I wished to have devoted more time to the investigation of what in the language of the Wernerian school is termed the geognostic relations of this spot, but my companions were anxious to proceed. We ascended the hill, which was entirely composed of this rock, to the plantation, where we procured a negro guide, who conducted us through a wood about three quarters of a mile. We now perceived a strong sulphureous and pitchy smell, like that of burning coal, and soon after had a view of the lake, which at first sight appeared to be an expanse of still water, frequently interrupted by clumps of dwarf trees or islets of rushes and shrubs: but on a nearer approach we found it to be in reality an extensive plain of mineral pitch, with frequent crevices and chasms filled with water. The singularity of the scene was altogether so great, that it was sometime before I could recover from my surprize so as to investigate it minutely. The surface of the lake is of the colour of ashes, and at this season was not polished or smooth so as to be slippery; the hardness or consistence was such as to bear any weight, and it was not adhesive, though it partially received the impression of the foot; it bore us without any tremulous motion whatever, and several head of cattle were browsing on it in perfect security. In the dry season however the surface is much more yielding, and must be in a state approaching to fluidity, as is shewn by pieces of recent wood and other substances being enveloped in it. Even large branches of trees which were a foot above the level, had in some way become enveloped in the bituminous matter. The interstices or chasms are very numerous, ramifying and joining in every direction, and in the wet season being filled with water, present the only obstacle to walking over the surface; these cavities are generally deep in proportion to their width, some being only a few inches in depth, others several feet, and many almost unfathomable: the water in them is good and uncontaminated by the pitch; the people of the neighbourhood derive their supply from this source, and refresh themselves by bathing in it;

fish are caught in it, and particularly a very good species of mullet. The arrangement of the chasms is very singular, the sides, which of course are formed of the pitch, are invariably shelving from the surface, so as nearly to meet at the bottom, but then they bulge out towards each other with a considerable degree of convexity. This may be supposed to arise from the tendency in the pitch slowly to coalesce, whenever softened by the intensity of the sun's rays. These crevices are known occasionally to close up entirely, and we saw many marks or seams from this cause. How these crevices originate it may not be so easy to explain. One of our party suggested that the whole mass of pitch might be supported by the water which made its way through accidental rents, but in the solid state it is of greater specific gravity than water, for several bits thrown into one of the pools immediately sunk.* The lake, (I call it so, because I think the common name appropriate enough) contains many islets covered with long grass and shrubs, which are the haunts of birds of the most exquisite plumage, as the pools are of snipe and plover. Alligators are also said to abound here, but it was not our lot to encounter any of these animals. It is not easy to state precisely the extent of this great collection of pitch ; the line between it and the neighbouring soil is not always well defined, and indeed it appears to form the substratum of the surrounding tract of land. We may say, however, that it is bounded on the north and west sides by the sea, on the south by the rocky eminence of porcelain jasper, before

* Pieces of asphaltum are, I believe, frequently found floating on the Dead Sea in Palestine, but this arises probably from the extraordinary specific gravity of the waters of that lake which Dr. Marcet found to be 1.211. Mr. Hatchett states the specific gravity of ordinary asphaltum to vary from 1.023 to 1.165, but in two varieties of that of Trinidad it was as great as 1.336 and 1.744, which led Mr. Hatchett to form a conjecture which I shall afterwards notice.

mentioned, and on the east by the usual argillaceous soil of the country; the main body may perhaps be estimated at three miles in circumference; the depth cannot be ascertained, and no subjacent rock or soil can be discovered. Where the bitumen is slightly covered by soil, there are plantations of cassava, plantains and pine-apples, the last of which grow with luxuriance and attain to great perfection. There are three or four French and one English sugar estates in the immediate neighbourhood; our opinion of the soil did not, however, coincide with that of Mr. Anderson, who in the account he gave some years ago, thought it very fertile. It is worthy of remark, that the main body of the pitch, which may properly be called the lake, is situated higher than the adjoining land, and that you descend by a gentle slope to the sea, where the pitch is much contaminated by the sand of the beach. During the dry season, as I have before remarked, this pitch is much softened, so that different bodies have been known slowly to sink into it; if a quantity be cut out, the cavity left will be shortly filled up; and I have heard it related, that when the Spaniards undertook formerly to prepare the pitch for economical purposes, and had imprudently erected their cauldrons on the very lake, they completely sunk in the course of a night, so as to defeat their intentions. Numberless proofs are given of its being at times in this softened state: the negro houses of the vicinage, for instance, built by driving posts in the earth, frequently are twisted or sunk on one side. In many places it seems to have actually overflown like lava, and presents the wrinkled appearance which a sluggish substance would exhibit in motion.

This substance is generally thought to be the asphaltum of naturalists: in different spots however it presents different appearances. In some parts it is black, with a splintery conchoidal fracture, of considerable specific gravity, with little or no lustre, resembling particular kinds of coal, and so hard as to require a severe blow of the hammer to detach or break it; in other parts, it is so much softer, as to allow one to cut out a piece in any form with a spade or hatchet, and in the interior is vesicular and oily; this is the character of by far the greater portion of the whole mass; in one place, it bubbles up in a perfectly fluid state, so that you may take it up in a cup, and I am informed that in one of the neighbouring plantations there is a spot where it is of a bright colour, shining, transparent, and brittle, like bottle glass or resin. The odour in all these instances is strong and like that of a combination of pitch and sulphur. No sulphur however is any where to be perceived, but from the strong exhalation of that substance and the affinity which is known to exist between the fluid bitumens and it, much is, no doubt, contained in a state of combination; a bit of the pitch held in the candle melts like sealing wax and burns with a light flame which is extinguished whenever it is removed, and on cooling the bitumen hardens again. From this property it is sufficiently evident that this substance may be converted to many useful purposes, and accordingly it is universally used in the country wherever pitch is required; and the reports of the naval officers who have tried it are favourable to its more general adoption; it is requisite merely to prepare it with a proportion of oil, tallow, or common tar, to give it a sufficient degree of fluidity. In this point of view, this lake is of vast national importance, and more especially to a great maritime power. It is indeed singular that the attention of government should not have been more forcibly directed to a subject of such magnitude: the attempts that have hitherto been made to render it extensively useful have for the most part been only feeble and injudicious, and have consequently proved abortive. This vast collection of bitumen might in all probability afford an inexhaustible supply of an essential article of naval stores, and being situated on the margin of the sea could be wrought and shipped with little inconvenience or expense.* It would however be great injustice to Sir Alexander Cochrane not to state explicitly that he has at various times, during his long and active command on the Leeward Island station, taken considerable pains to insure a proper and fair trial of this mineral production for the highly important uses of which it is generally believed to be capable. But whether it has arisen from certain perverse occurrences or from the prejudice of the mechanical superintendants of the Colonial Dock Yards, or really, as some have pretended, from an absolute unfitness of the substance in question; the views of the gallant admiral have I believe been invariably thwarted, or his exertions rendered altogether fruitless. I was at Antigua in 1809 when a transport arrived laden with this pitch for the use of the dock-yard at English Harbour: it had evidently been hastily collected with little care or zeal from the beach, and was of course much contaminated with sand and other foreign substances. The best way would probably be to have it properly prepared on the spot, and brought to the state in which it may be serviceable, previously to its exportation. I have frequently seen it used to pay the bottoms of small vessels, for which it is particularly well adapted, as it preserves them from the numerous tribe of worms so abundant in tropical countries.† There seems indeed no reason why it should not when duly pre-

* This island contains also a great quantity of valuable timber, and several plants which yield excellent hemp.

† The different kinds of bitumen have always been found particularly obnoxious to the class of insects; there can be little doubt but that they formed ingredients in the Egyptian compost for embalming bodies, and the Arabians are said to avail themselves of them in preserving the trappings of their horses. Vide Jameson's Mineralogy.

pared and attenuated be applicable to all the purposes of the petroleum of Zante, a well-known article of commerce in the Adriatic, or that of the district in Burmah, where 400,000 hogsheads are said to be collected annually.*

It is observed by Capt. Mallet in his Short Topographical Sketch of the Island, that " near Cape la Brea (la Braye) a little to the south-" west, is a gulph or vortex, which in stormy weather gushes out, " raising the water five or six feet, and covers the surface for a consi-" derable space with petroleum or tar;" and he adds that " on the " east coast in the Bay of Mayaro, there is another gulph or vortex " similar to the former, which in the months of March and June " produces a detonation like thunder, having some flame with a " thick black smoke, which vanishes away immediately; in about " twenty-four hours afterwards, is found along the shore of the bay, " a quantity of bitumen or pitch, about three or four inches thick, " which is employed with success." Capt. Mallet likewise quotes Gumilla, as stating in his Description of the Orinoco, that about seventy years ago, " a spot of land on the western coast of this " island, near half way between the capital and Indian village sunk " suddenly, and was immediately replaced by a small lake of pitch " to the great terror of the inhabitants."

I have had no opportunity of ascertaining personally whether these statements are accurate, though sufficiently probable from what is known to occur in other parts of the world; but I have been informed by several persons that the sea in the neighbourhood of La Braye is occasionally covered with a fluid bitumen, and in the south-eastern part of the island there is certainly a similar collection of this bitumen, though of less extent, and many small detached spots

* Vide Aikin's Dictionary of Chemistry, quoted from Captain Cox in the Asiatic Researches.

of it are to be met with in the woods: it is even said that an evident line of communication may thus be traced between the two great receptacles. There is every probability, that in all these cases the pitch was originally fluid, and has since become inspissated by exposure to the air, as happens in the Dead Sea and other parts of the east.

It is for geologists to explain the origin of this singular phenomenon, and each sect will doubtless give a solution of the difficulty according to its peculiar tenets. To frame any very satisfactory hypothesis on the subject, would require a more exact investigation of the neighbouring country, and particularly to the southward and eastward, which I had not an opportunity of visiting. And it must be remembered that geological inquiries are not conducted here with that facility which they are in some other parts of the world; the soil is almost universally covered with the thickest and most luxuriant vegetation, and the stranger is soon exhausted and overcome by the scorching rays of a vertical sun. Immediately to the southward, the face of the country as seen from la Braye, is a good deal broken and rugged, which Mr. Anderson attributes to some convulsion of nature from subterranean fires, in which idea he is confirmed by having found in the neighbouring woods several hot springs. He is indeed of opinion that this tract has experienced the effects of the volcanic power, which, as he supposes, elevated the great mountains on the main and the northern side of the island.* The production of all bituminous substances has certainly with plausibility been attributed to the action of subterranean fires on beds of coal, being separated in a similar manner as when effected by artificial heat, and thus they may be traced through the various trans-

* Vide 79th vol. Philos. Trans. or Ann. Register for 1789.

formations of vegetable matter. I was accordingly particular in my inquiries with regard to the existence of beds of coal, but could not learn that there was any certain trace of that substance in the island, and though it may exist at a great depth, I saw no strata that indicate it. A friend indeed gave me specimens of a kind of bituminous shale mixed with sand, which he brought from Point Cedar about twenty miles distant, and I find Mr. Anderson speaks of the soil near the Pitch-lake containing burnt cinders, but I imagine he may have taken for them the small fragments of the bitumen itself.

An examination of this tract of country could not fail, I think, to be highly gratifying to those who embrace the Huttonian theory of the earth, for they might behold the numerous branches of one of the largest rivers of the world (the Orinoco) bringing down so amazing a quantity of earthy particles as to discolour the sea in a most remarkable manner for many leagues distant,* they might see

* No scene can be more magnificent than that presented on a near approach to the north-western coast of Trinidad. The sea is not only changed from a light green to a deep brown colour, but has in an extraordinary degree, that rippling, confused and whirling motion, which arises from the violence of contending currents, and which prevail here in so remarkable a manner, particularly at those seasons when the Orinoco is swollen by periodical rains, that vessels are not unfrequently several days or weeks in stemming them, or perhaps are irresistibly borne before them far out of their destined track. The dark verdure of lofty mountains, covered with impenetrable woods to the very summits, whence, in the most humid of climates, torrents impetuously rush through deep ravines to the sea; three narrow passages into the Gulph of Paria, between rugged mountains of brown micaceous schist, on whose cavernous sides the eddying surge dashes with fury, and where a vessel must necessarily be for some time embayed, with a depth of water scarcely to be fathomed by the lead, present altogether a scene which may well be conceived to have impressed the mind of the navigator who first beheld it with considerable surprise and awe. Columbus made this land in his third voyage, and gave it the name of the *Bocas del Drago*. From the wonderful discoloration and turbidity of the water, he sagaciously concluded that a very large river was near, and consequently a great continent.

these earthy particles deposited by the influence of powerful currents on the shores of the gulph of Paria, and particularly on the western side of the island of Trinidad; they might there find vast collections of bituminous substances, beds of porcelain jasper, and such other bodies, as may readily be supposed to arise from the modified action of heat on such vegetable and earthy materials as the waters are known actually to deposit. They would further perceive no very vague traces of subterranean fire, by which these changes may have been effected and the whole tract elevated above the ordinary level of the general loose soil of the country, as for instance, hot springs, the vortices above mentioned, the frequent occurrence of earthquakes, and two singular semi-volcanic mounds at Point Icaque, which, though not very near, throw light on the general character of the country. Without pledging myself to any particular system of geology, I confess an explanation similar to this appears to me sufficiently probable, and consonant with the known phenomena of nature. A vast river, like the Orinoco, must for ages have rolled down great quantities of woody and vegetable bodies, which from certain causes, as the influence of currents and eddies, may have been arrested and accumulated in particular places; they may there have undergone those transformations and chemical changes, which various vegetable substances similarly situated have been proved to suffer in other parts of the world. An accidental fire, such as is known frequently to occur in the bowels of the earth, may then have operated in separating and driving off the newly formed bitumen more or less combined with siliceous and argillaceous earths, which forcing its way through the surface, and afterwards becoming inspissated by exposure to the air, may have occasioned such scenes as I have ventured to describe. The only other country accurately resembling this part of Trinidad of which I recollect to have read, is that which borders on the Gulph of Taman in Crim Tartary: from the representation of travellers, springs of naptha and petroleum equally abound, and they describe volcanic mounds precisely similar to those of Point Icaque. Pallas's explanation of their origin seems to me very satisfactory, and I think it not improbable that the River Don and Sea of Azof may have acted the same part in producing these appearances in the one case, as the Orinoco and Gulph of Paria appear to have done in the other.* It may be supposed that the destruction of a forest or perhaps even a great Savanna on the spot, would be a more obvious mode of accounting for this singular phenomenon; but, as I shall immediately state, all this part of the island is of recent alluvial formation, and the land all along this coast is daily receiving a considerable accession from the surrounding water. The Pitch-lake with the circumjacent tract, being now on the margin of the sea, must in like manner have had an origin of no very distant date; besides, according to the above representation of Capt. Mallet, and which has been frequently corroborated, a fluid bitumen oozes up and rises to the surface of the water on both sides of the island, not where the sea has encroached on and overwhelmed the ready-formed land, but where it is obviously in a very rapid manner depositing and forming a new soil.

From a consideration of the great hardness, the specific gravity, and the general external characters of the specimens submitted a few years ago to the examination of Mr. Hatchett, that gentleman was led to suppose that a considerable part of the aggregate mass at Trinidad was not pure mineral pitch or asphaltum, but rather a porous stone of the argillaceous genus much impregnated with bitumen.

* Vide Universal Mag. for Feb. 1808, Mrs. Guthrie's Tour in the Tauride, or Voyages de Pallas.

Two specimens of the more compact and earthy sort, analysed by Mr. Hatchett, yielded about 32 and 36 per cent. of pure bitumen: the residuum in the crucible consisted of a spongy, friable and ochraceous stone, and 100 parts of it afforded, as far as could be determined by a single trial, of silica 60, alumina 10, oxide of iron 10, carbonaceous matter by estimation 11; not the smallest traces of lime could be discovered, so that the substance has no similarity to the bituminous limestones which have been noticed in different parts of the world.* I have already remarked, that this mineral production differs considerably in different places. The specimens examined by Mr. Hatchett by no means correspond in character with the great mass of the lake, which, in most cases, would doubtless be found to be infinitely more free from combination with earthy substances; though from the mode of origin which I have assigned to it, this intermixture may be regarded as more or less unavoidable. The analysis of the stone after the separation of the bitumen, as Mr. Hatchett very correctly observes, accords with the prevalent soil of the country; and I may add, with the soil daily deposited by the gulph, and with the composition of the porcelain jasper, in immediate contact with the bituminous mass.

All the country which I have visited in Trinidad is either decidedly primitive or alluvial. The great northern range of mountains which runs from east to west, and is connected with the Highlands of Paria on the continent, by the Islands at the Bocas, consists of gneiss, of mica slate containing great masses of quartz, and in many places approaching so much to the nature of talc, as to render the soil quite unctuous by its decomposition, and of compact bluish grey limestone, with frequent veins of white crystallized carbo-

* Vide Linnean Trans. vol. 8.

nate of lime. From the foot of these mountains for many leagues to the southward there is little else than a thick, fertile, argillaceous soil, without a stone or a single pebble. This tract of land, which is low and perfectly level, is evidently formed by the *detritus* of the mountains, and by the copious tribute of the waters of the Orinoco, which being deposited by the influence of currents, gradually accumulates, and in a climate where vegetation is astonishingly rapid, is speedily covered with the mangrove and other woods. It is accordingly observed, that the leeward side of the island constantly encroaches on the gulph, and marine shells are frequently found on the land at a considerable distance from the sea. This is the character of Naparima and the greater part of the country I saw along the coast to la Braye. It is not only in forming and extending the coast of Trinidad, that the Orinoco exerts its powerful agency; co-operating with its mighty sister flood, the Amazons, it has manifestly formed all that line of coast and vast extent of country, included between the extreme branches of each river. To use the language of a writer in the Philosophical Transactions of Edinburgh, " If " you cast your eye upon the map you will observe from Cayenne " to the bottom of the Gulph of Paria, this immense tract of swamp, " formed by the sediment of these rivers, and a similar tract of shallow " muddy coast, which their continued operation will one day elevate. " The sediment of the Amazons is carried down thus to leeward (the " westward) by the constant currents which set along from the " southward and the coast of Brazil. That of the Oroonoko is de- " tained and allowed to settle near its mouths by the opposite island " of Trinidad, and still more by the mountains on the main, which " are only separated from that island by the Bocos del Drago. The " coast of Guiana has remained, as it were, the great eddy or resting " place for the washings of great part of South America for ages;

" and its own comparatively small streams have but modified here
" and there the grand deposit."*

Having been amply gratified with our visit to this singular place, which to the usual magnificence of the West Indian landscape, unites the striking peculiarity of the local scene, we re-embarked in our vessel, and stood along the coast on our return. On the way we landed, and visited the plantations of several gentlemen, who received us with hospitality, and made us more fully acquainted with the state of this island: a colony which may with truth be described as fortunate in its situation, fertile in its soil, and rich beyond measure in the productions of nature; presenting, in short, by a rare combination, all which can gratify the curiosity of the naturalist, or the cupidity of the planter; restrained in the developement of its astonishing resources, only by the inadequacy of population, the tedious and ill-defined forms of Spanish justice, and the severe, though we may hope transient, pressure of the times.

* Vide Mr. Lochhead's Observ. on the Nat. Hist. of Guiana. Edin. Trans. vol. 4.

V. *Memoir on the Laumonite.*

By M. Le Comte de Bournon, F.R. & L.S. &c.

Foreign Secretary of the Geological Society.

[Translated from the original French Manuscript.]

THIS substance, which has been long known under the name of efflorescent zeolite, has been termed Laumonite by Werner, in honour of M. Gillet de Laumont, to whom we are indebted for our first knowledge of it, as well as for many other important contributions to the science of mineralogy.

The former name of this mineral (efflorescent zeolite) was given to it, in consequence of the property it has of not being able to bear, even for a short period, exposure to the air without undergoing disintegration and finally falling into powder; and the opinion most generally entertained with respect to it was, that it belonged to the species of mesotype. It is however altogether different from that substance, nor does it belong to any of the numerous series of zeolitic minerals, which have hitherto been made known to us.

Highly calculated however as this substance is to excite the interest and the curiosity of the mineralogist, we have as yet had but very slight and imperfect descriptions of it. The author who has spoken of it most in detail is the Abbé Haüy.

In the first appendix to his "*Traité de Minéralogie*," that celebrated mineralogist, who was then disposed to consider it as a variety of the mesotype, states that he was induced to regard its primitive crystal as a rectangular tetrahedral prism, having indications of subdivision in the direction of its two diagonals; but since in his subsequent work, entitled, "*Tableau comparatif des resultats de la Crystallographie et de l'Analyse chimique*," &c. p. 49. he has changed his opinion, and has declared its primitive crystal to be a rectangular octohedron, having its faces unequally inclined. The observations, which I have myself made on this substance, prevent my assenting to either of these two forms as its primitive crystal; and they have enabled me at the same time to present to the Geological Society a more complete examination and description of it. The possibility of my doing so I owe to the friendship of M. Gillet de Laumont, who lately sent me several specimens, among which was one of very considerable magnitude. On its way to me it was broken. Chance, which very frequently assists the observer when he is prepared to profit by it, produced by that accident what I should certainly never have attempted myself: it furnished me with an immense number of fragments, and of perfectly regular crystals, and at the same time by exposing to view the central part of the mass, which had never yet been acted upon by the atmosphere, and had therefore been preserved entirely unaltered, it enabled me to examine this substance before it had undergone any kind of change, a circumstance which must of necessity be but of very rare occurrence.

Specific Characters of the Laumonite.

Essential Characters.

A. CRYSTALLOGRAPHICAL.

1. *Primitive Crystal.* A rhomboidal tetrahedral prism with rhombic bases, the sides of the prism meet at angles of 92° 30′ and 87° 30′; the bases are inclined upon the edges of 92° 30′, so as to form with them angles of 55° and of 125°, fig. 1. The height of the prism is to the edges of the terminal faces, in the ratio of eight to seven. This prism divides in a direction parallel to all its planes, but much more easily longitudinally than on its terminal surfaces; this division takes place also with greater facility on two of the opposite sides than on the two others. It is likewise more readily effected, but at the same time less neatly, when the substance has undergone alteration.

2. *Integrant Molecule.* This slightly rhomboidal tetrahedral prism is besides divisible parallel to its axis, and to the greater diagonal of its rhombic terminal planes. I have not perceived any natural joints in the direction of the other diagonal. This second division shews that the integrant molecule of the laumonite is a trihedral prism, the exact half of the rhomboidal tetrahedral prism, fig. 2.

3. *Fracture.* Lamellar.

B. PHYSICAL CHARACTERS.

1. *Specific gravity.* Taken with a piece slightly changed, but still preserving in some degree its transparency 22,34.* The variety

* Water being considered as 10,00.

in which disintegration had commenced, having a dull white appearance, and opaque, but not sufficiently changed to break and divide of itself, did not shew any sensible difference with respect to this character.

2. *Hardness.* When the laumonite has not been altered, it cuts glass with ease ; but in proportion as it becomes disintegrated, this hardness diminishes, and ultimately the least pressure reduces it into small delicate prismatic fragments.

3. *Electricity by friction.* None.

C. CHEMICAL CHARACTERS.

1. *Action of acids.* This substance is reduced to the state of a jelly by the action of acids.

2. *Action of heat.* Under the blowpipe, and without addition, the laumonite is fusible with a slight degree of ebullition, and affords a perfectly opaque and beautifully white enamel.

3. *Analysis.* As far as my knowledge extends, no analysis has yet been made by which the constituent parts of this substance have been determined.

4. *Natural alteration.* This character is so peculiar, so striking, and so constant in this substance, that it is perfectly entitled to be placed in the number of its essential specific characters. From the moment that the laumonite is exposed to the atmosphere, it begins to alter, and this alteration, as well as the progress of it, is proportional to the warmth of the air ; it advances with such rapidity when the temperature is high, that having inadvertently undertaken during a very hot day the examination of its crystals, many of these, in which the alteration, although begun, was not yet very considerable, so quickly disintegrated that it became impossible, even in

the short space of time necessary for their examination, to touch them without reducing them to powder. By this mere inattention I have to regret the loss of many very beautiful crystals. As this alteration proceeds, the mineral loses its transparency and at length becomes of a shining white appearance; then the faces which belong to the longitudinal planes of the primitive tetrahedral prism, assume a slightly pearly aspect. In proportion to the extent of this alteration the degree of cohesion subsisting between the crystalline molecules diminishes. The effect of this first state of alteration is to render the natural joints of the laminæ, which are parallel to the longitudinal planes of the prism, much more evident; and sometimes also, but more rarely, those which are parallel to their terminal faces. The alteration increasing, the diminution of cohesion between the molecules becomes more considerable; and the separation of the laminæ of crystallisation may be easily produced by simple pressure between the fingers. The crystal at length separates spontaneously according to this direction into prismatic fragments, of which many are perfectly regular; these again subdivide, and ultimately reduce the crystal to a mere powder. This alteration may be prevented, or arrested, by lightly covering the surface of the crystals with gum or with varnish, or by preserving the specimen in distilled water.

D. SPECIFIC CHARACTERS NOT ESSENTIAL, AND ADMITTING OF VARIATION.

1. *Colour.* When it is not altered, this substance has hitherto occurred perfectly colourless. The alteration which it undergoes, renders it opaque, and of a shining white aspect, giving it at the same time a slightly pearly lustre on the longitudinal faces of the prism.

2. *Transparency.* The laumonite in its perfect and unaltered

state is beautifully transparent, but it is extremely rare to meet with it in this condition, in consequence of the great facility and rapidity with which its alteration proceeds.

3. *Phosphorescence.* This substance does not possess any sensible phosphorescence ; however, as it is accompanied, and even intermixed, with a highly phosphorescent lamellar carbonate of lime, the luminous appearance of which is a bright reddish yellow or orange, it is liable to have some portions of this carbonate of lime interposed throughout its substance, which is the cause of its being sometimes observed, that fragments of it when submitted to trial give traces of a slight phosphorescence.

Observations on the crystallisation of the Laumonite.

If this substance offer a striking peculiarity, and one very proper to entitle it to a distinct place in the classification of mineral substances, by the facility with which simple exposure to the atmosphere causes it to undergo disintegration, and finally to fall into powder ; its crystallisation, which cannot be referred to that of any other known mineral, adds still more to the singular characters which the laumonite exhibits. This crystallisation generally appears in the state of crystalline masses, often of considerable size, and which at first sight present only a deeply striated or fasciculated surface ; but these same masses, which apparently have no determinate crystalline forms, on being broken become immediately a rich field of observation by the great quantity of extremely perfect and diversified crystals, which the portions into which they divide, afford. They are therefore, at least with regard to a great number, merely a confused aggregation (arranged however in the direction of their prisms) of crystals perfectly formed, and of different shapes, piled one above the other on their ends. This structure, if I may be allowed the comparison, is like the bud of a flower, in which the form of the petals cannot be seen except by tearing it open and unfolding them. May it not be the same in many other substances which occur also in fascicular masses of more or less considerable size, such as tourmaline, thallite, prehnite, analcime, stilbite, &c. May not also the irregularity of the interior of these masses be at the same time owing to the difference in the variety of forms which these aggregated crystals present? and if it were possible to separate in these masses each of the component crystals, with as much facility as they are separated in the masses of the laumonite, might we not obtain the same result?

There is a striking irregularity in the manner in which the planes of substitution are situated on the laumonite, an example of which may be seen in fig. 3, with respect to those by which the edges of 92° 30′ in the prism are replaced. The same irregularity occurs in the position of the planes which are the result of the other modifications; for example, in the crystal delineated in fig. 28, there occurs in the place of one of the two obtuse angles of the terminal faces, a plane belonging to the 9th modification, whilst the plane of substitution for the other angle belongs to the 8th. In fig. 30. there exists a still greater irregularity in the planes of substitution of these two angles, one of them being replaced by two planes, which belong to the 8th and 9th modifications, and the other by a single plane of the 10th. This fresh example, if it were necessary, might serve to shew the difference which exists between the retrogradations on primitive crystals, where the geometrical form is one in which all the parts are perfectly symmetrical, and those on primitive crystals, in which the parts are not so circumstanced. A symmetry is established between the new planes produced on the first, while the planes which occur in the second, are more or less distant from it.

The difference which exists between what has been said by the Abbe Haüy in his " *Tableau Comparatif, &c.*" with regard to the form of the primitive crystal of the laumonite, and that which I have myself established respecting it, will no doubt excite surprise. This difference for a long time detained me. The estimation, in which this celebrated mineralogist is so justly held, made me redouble my attention and care in the examination of this substance, but the several results of my inquiries have always afforded me the fullest confirmation of what I have said of the form of its primitive crystal, and of the measure which I have given of its angles. The circumstances that probably led the Abbé Haüy into an error, are the different varieties of crystals I have mentioned as forming the aggregations to which the fasciculated masses of the laumonite belong, but which, when this substance has undergone any alteration, are detached with much facility, producing so many isolated crystals, a great number of which present varieties differing one from the other. He would without doubt have obtained in this way a crystal analogous to that represented in fig. 14, as I have myself done, and which in reality presents a rectangular octohedron with its faces unequally inclined, and, regarding all the faces of this crystal as arising from a natural cleavage, he may have adopted it as being the primitive form of this substance. But two of the faces of this crystal are by no means primitive; they belong to the sixth modification. In no instance could the angles of this crystal be such as the Abbé Haüy has given them: the four faces which belong to the longitudinal ones of the primitive rhomboidal tetrahedral prism, meet each other two by two at an angle of 92° 30′; and the other four, of which two belong to the terminal faces of the primitive crystal, and the two others to the planes of the sixth modification, meet at an angle of 127° 40′; but these angles are never 98° 12′ and 121° 34′ as is said in the work which I have just noticed. The rhomboidal tetrahedral prism of 92° 30′, and 87° 30′ of this substance, approaches so nearly to the rectangular form that it is extremely easy to conceive how the Abbé Haüy in his first determination of the primitive crystal of the laumonite (a determination which he has given us to understand was merely a first glance of the subject) might have been led to consider it as being in reality rectangular; but he certainly would not have committed that error, if the angles of this prism had really differed more than eight degrees from a right angle. It is on the supposition of the octohedron being the primitive form, that the Abbé Haüy has stated, that the crystal, fig. 40, pl. III. of his "Tableau Comparatif," is a variety produced from that figure. This form is the only variety which he has given. I have represented it at fig. 33, keeping on its planes the letters of indication which he employs. In this figure the planes M belong to the longitudinal planes of the primitive rhomboidal tetrahedral prism; one of the planes P to the terminal face of this prism, and the other to the plane of the sixth modification. The plane l belongs to the first modification, and that indicated by S, which I have never perceived in any of the crystals that have come under my own observation, would belong to a fifteenth modification, which would be the result of a retrogradation by a single row along the edges of 87° 30′ of the prism.

This difference in opinion between the Abbé Haüy and myself with regard to the true primitive form of the laumonite may perhaps again give rise to the unjust reproaches which a similar diversity under circumstances nearly alike has already occasioned. By rendering the science responsible for the errors which those who cultivate it may commit, an attempt has been made to insinuate its uncertainty and even its inutility. But what science is there which would not be annihilated the moment that we made its truth and its usefulness to depend on the exact degree of correspondence that might subsist between the opinions of those philosophers who make it the subject of their study? If there exist some difference in the opinions entertained by the AbbéHaüy and myself on certain points in crystallography, what conclusion ought to be deduced from this circumstance? simply that this science, which on the one hand is supported by physics, and on the other by mathematics, and will perhaps at some future day become equally exact with the latter, has not yet obtained that certainty. Let us allow it to proceed towards this point, without obstructing its course. Difference of opinion when maintained with candour and decorum is perhaps not without advantage to the security and promptitude of its progress.

General observations on the Laumonite.

The laumonite has never hitherto been discovered except in a crystallized state, either in separate crystals, which is the most common appearance, or in an aggregation of crystals, forming masses of more or less considerable size for the most part irregular, and deeply striated externally.

Till the present time the laumonite had been observed only in the lead mine of Huelgoet in lower Brittany, in which it was discovered about twenty-five years ago by M. Gillet de Laumont.*

* It lines the walls of the vein, conjointly with a lamellar carbonate of lime belonging to that variety in which the rhomboidal fragments are striated in the direction of the greater diagonal of two of the opposite faces. This carbonate of lime, which is perfectly colourless, is one of the most phosphorescent which I have ever seen. If I may judge

But on further examination I find this substance occurring in specimens from various other places. I have in my possession a specimen from the Island of Ferröe, in which pretty large crystals, of a dull white aspect, and almost pulverulent, but of which the figure is still perfectly discernable, are grouped with stilbite in larger crystals, and not in the least altered, on a layer of quartz about three lines thick, enclosing a nucleus of that sort of argillaceous and earthy rock, well known as the gangue of the zeolites of Ferröe, and from which it is separated by a thin layer of green ferruginous earth. The exterior surface of this quartzose layer, on which the crystals of laumonite are placed, is covered by a vast quantity of small crystals of stilbite, differing in figure from those of the same substance that accompany the laumonite, the forms of both of which belong to the very numerous series of crystals of this substance, that have not yet been described.

I have another small group of laumonite also from Ferröe, the crystals of which, unmixed with any other substance, are placed on a small layer of granular quartz of a loose texture, the grains of

of the rock from the portions of it remaining attached to the pieces which I have examined, the walls of the vein, to which this substance, with the carbonate of lime which accompanies it, adheres, consist of a ferruginous argillaceous schist of a deep blackish-grey colour, of a very loose texture, and traversed by small veins of carbonate of lime. A moderate action of the fire changes this colour to a reddish-brown, and at the same time renders this schist extremely attractable by the magnet; its texture likewise becomes more loose, and when examined with a glass and by the light of the sun, this substance appears to be formed of a mass of small and extremely thin scales: its aspect is then much like that which wonld be presented by a mass of chlorite of the same colour, and of a fine grain. I am indebted to M. Gillet de Laumont for another very fine specimen of this mineral which I have received since that mentioned in the first part of this paper, in which the crystals of laumonite are very large and regular and beautifully grouped with crystals of carbonate of lime. The base of this specimen bears very evident marks of its having been detached from the schist which I have just described.

which are all hexahedral prisms, terminated at each extremity by a hexahedral pyramid. These crystals, all of which belong to the elongated variety of the primitive crystal, are placed edgeways on the quartz, and though this specimen has been several years in my collection, several of the crystals of laumonite still retain some degree of transparency.

In the collection of Mr. Richard Phillips I have seen a very fine specimen from Paisley in Renfrewshire, in which the laumonite is grouped with analcime, and I have a small specimen from Portrush in the County of Antrim, in which it occurs with stilbite and analcime.

I possess a specimen of amygdaloid having a very argillaceous and earthy base, from the Venetian States, the nodules of which are all hollow, and have their interior surface lined with very small crystals of this substance, of a dull white appearance, and very friable.

Lastly, I have a specimen of prehnite, of a slightly yellowish green colour, the crystals of which are grouped together and penetrate each other in such a manner as to form spheroids; these have their surface covered by a dull white and pulverulent laumonite. This specimen, which was given me as coming from China, has for its gangue an earthy argillaceous rock of a greenish grey colour.*

Thus, with this, as with many other mineral substances, it has ceased to be found the exclusive production of a peculiar district, as soon as attention has been particularly directed towards it. It may be observed however, from what I have stated, that the laumonite affects the zeolitic rocks more than any others; and that wherever these exist, we may hope to meet with it.

I have said, under the head of specific characters, that the laumo-

* In all the above specimens, however, of this substance the rapidity of its spontaneous efflorescence is less remarkable than in those from Huel-goet.

nite had not exhibited to me any sensible difference with respect to its specific gravity, whether this was taken whilst this substance had experienced only a very slight change, or whether when it was much more considerably altered. This fact which I did not expect, attributing, according to the opinion generally entertained, its disintegration or efflorescence to the loss of its water either of composition and consequently combined with it, or of crystallisation, and in that case simply interposed between its particles, this fact, I say, greatly surprised me. But is it true that in the laumonite, as well as in all the salts which effloresce on exposure to the atmosphere, this phenomenon is to be attributed to the loss of water? as far as the laumonite is concerned it appears to me very probable that this destruction is in reality, as I have said, nothing more than the simple result of disintegration. That this is the case will appear from the changes which occur in this mineral, and principally from the greater or less regularity of the primitive form which many of the smallest fragments preserve, when this alteration has even arrived at such a point that the substance divides of itself. If it is to be attributed to the loss of its water, this can only be the case with respect to that of crystallisation or of simple interposition. But if so, ought not this substance, as happens with regard to hydrophanous bodies, at some period during the loss of its water to have, in consequence of the same affinity which placed it there originally, a great tendency to resume it, and thereby, re-establishing the refractive power which belongs to it in its unaltered state, to recover its transparency, which it never does? may not its alteration rather be occasioned by a strong attraction of its integrant molecules for caloric, and by the separation produced between them from the introduction of this fluid in larger quantity? I do not mean this as an assertion, but propose it simply as a question.

TABLE OF THE MODIFICATIONS OF THE PRIMITIVE CRYSTAL OF THE LAUMONITE.

Primitive Crystal. A tetrahedral prism slightly rhomboidal of 92° 30′ and 87° 30′, with rhombic bases inclined on the edges formed by the meeting of the sides of the prism at an angle of 92° 30′, so as to form with them angles of 125° and 55°. The height of the prism is to the edges of the terminal faces in the ratio of 8 to 7.

Retrogradations along the edges of the prism formed by the meeting of its sides at an angle of 92° 30′.							
Number of the modifications.	Figure of the Crystal.	Angles formed by the meeting of the new planes with the side of the prism on which they are inclined.	Angles formed by the meeting of the new planes with the sides opposite to those on which they are inclined.	Angles formed by the meeting of the new planes with those of the 1st modification.	Angles formed by the meeting of the new planes with those of the 2d modification.	Angles formed by the meeting of the new planes with those of the 3d modification.	Nature of the Retrogradations.
1st.	Primitive crystal with planes of substitution on the edges of 92° 30′.	. 136°, 15′ .	. . 136° . .	. . . .	. . . .	. . . .	Retrogradation by a single row.
2d		. 144°, 2′ .	. 128°, 28′ .	. 172°, 18′ .	. . . .	. . . .	Retrogradation by 4 rows in breadth, and 3 laminæ in height.
3d		. 168°, 48′ .	. 103°, 42′ .	. 147°, 27′ .	. 155°, 14′ .	. . . .	Retrogradation by 5 rows.
4th		. 171°, 55′ .	. 100°, 35′ .	. 139°, 52′.	. 147°, 44′ .	. 176°, 23′ .	Retrogradation by 7 rows.

Retrogradations upon the acute angles of the terminal faces, answering to the acute solid angles of the primitive crystal.

Number of the modifications.	Figure of the crystal.	Angles formed by the meeting of the new planes with the terminal faces.	Angles formed by the meeting of the new planes with the edges of 87°,30′.	Angles formed by the meeting of the new planes with those of the 5th modification.	Angles formed by the meeting of the new planes with those of the 6th modification.	Nature of the retrogradations.
5th.	Primitive crystal with the planes of substitution on its acute solid angles.	.. 98°, 5′ ..	.. 136°. 55′ ..	....	....	Retrogradation by a single row.
6th.		.. 124°, 56′ ..	.. 110°, 4′ ..	.. 153°, 4′ ...	....	Retrogradation by 5 rows in breadth, and 3 laminæ in height.
7th.		.. 134°, 22′ ..	.. 100°, 38′ ..	.. 143°, 26′ ..	.. 170°, 34′ ..	Retrogradation by 2 rows.

Retrogradation on the obtuse angles of the terminal faces.

Number of the modifications.	Figure of the crystal.	Angles formed by the meeting of the new planes with the terminal faces.	Angles formed by the meeting of the new planes with the edges of 92°, 30′.	Angles formed by the meeting of the new planes with those of the 8th modification.	Angles formed by the meeting of the new planes with those of the 9th modification.	Nature of the Retrogradations.
8th.	Primitive crystal with the solid angles answering to the obtuse edges of the prism replaced by a plane.	.. 105°, 7′ ..	.. 164°, 53′ ..	....	....	Retrogradation by 1 row in breadth, and 2 laminæ in height.
9th.		.. 118°, 22′ ..	.. 151°, 28′ ..	.. 166°, 45′ ..	....	Retrogradation by a single row.
10th.		.. 148°, 28′ ..	.. 121°, 37′ ..	.. 136°, 44′ ..	.. 156°, 9′ ..	Retrogradation by 3 rows.

Retrogradations along the edges of the terminal faces formed by the incidence of these faces on the sides of the prism, at an angle of 66° 38′.

Number of the modifications.	Figure of the crystal.	Angles formed by the meeting of the new planes with the terminal faces.	Angles formed by the meeting of the new planes with those of the prism.	Angles formed by the meeting of the new planes with those of the 11th modification.	Nature of the retrogradations.
11th.	Primitive crystal having the edges of its terminal faces of 66° 38′ replaced by a plane.	. . . 139°, 10′	. . . . 107°, 28′	. . . .	Retrogradation by two rows.
12th.		. . . 145°, 9′ . . .	. . . . 101°, 29′	. . . . 174°, 1′	Retrogradation by three rows.

Intermediate retrogradations upon the acute angles of the terminal faces that concur in the formation of the acute solid angles of the primitive crystal.

Number of the modifications.	Figure of the crystal.	Angles which the edge uniting the new planes forms with the terminal faces.	Angles which the edge uniting the new planes forms with the edges of 92°, 30′.	Angles of incidence between the new planes.	Angles of incidence between the new planes, and the terminal faces.	Nature of the retrogradations.
13th.	Primitive crystal having its acute solid angles replaced by two planes.	. . 98°, 26′ . .	. . 136°, 34′ . .	. . 136°, 58′ . .	. . 110°, 20′ .	Retrogradation by a single row, which while it takes one molecule from one of the sides of the acute angles, takes two from the other.
14th.		. . 81°, 59′ . .	. . 153°, 1′ . .	. . 134°, 84′ . .	. . 82°, 32′ . .	Retrogradation by a single row in breadth, and two laminæ in height which, while it takes one molecule from one of the sides of the acute angles, takes two from the other.

VI. *Observations on the Physical Structure of Devonshire and Cornwall.*

By J. F. BERGER, M. D. of Geneva,

Honorary Member of the Geological Society.

[Translated from the original French Manuscript.]

IN venturing to lay before the Geological Society the following observations made in the course of a journey through Devonshire and Cornwall,* I do not presume to think that I have by any means comprehended all that is interesting in the physical structure of these counties; many observations, not only of detail, but of higher importance, have no doubt escaped me: all I pretend to do is, to give a general outline of what I have seen, and to connect those observations with such as I have made in the other countries of Europe which I have also visited.

Among the several formations † which the greater part of geologists recognize, (understanding by this term not only the

* I had the pleasure of making this tour in 1809, in company with Mr. Louis Albert Necker of Geneva, who has since presented to the Geological Society, of which he is an honorary member, a series of specimens, with a descriptive catalogue of the rocks he had collected.

† The word *formation* implies the idea of *time* or *epoch*.

nature of the rocks of a district, but likewise the general disposition of the strata, and their relation in point of position to the surrounding country) one of the most interesting undoubtedly is that of flint in chalk, which is subordinate to the secondary formation in the great and generally admitted division of rocks into *primitive*, *transition*, and *secondary*.

Whatever be the country, where the formation of flint in chalk or marl occurs, it is worthy of remark:

I. That it occupies a considerable extent.

II. That it belongs to flat countries stratiform or alluvial: and what appears to me a more striking circumstance is, that as far as I know, it is to be met with chiefly on the skirt of some great chain of mountains at some distance; as if it made one of the links of a complete system of formations. Thus, in France, it prevails on the skirt of the western boundary of Mount Jura, extending nearly in a direction from S. E. to N. W. and covering a space of at least two hundred and ten miles long, by about one hundred and fifty broad.* In Poland, on the borders of the chain of the Carpathian mountains, from the shores of the Baltic, comprehending the plains of the Pilica, of the Bug, and of the Vistula, as far as the first heights where these rivers have their source.† In England, to the east of the mountainous part of Devonshire and Cornwall, and stretching across to the German ocean. This formation is also found in Ireland, Saxony, Spain, Denmark, and Sweden; but I do not sufficiently know in what particular situations, to enable me to notice them in a less general manner.

From the nearly exact correspondence of the meridians under

* Journ. de Physique, Mars, 1807.

† Geologie des Montagnes de l'ancienno Sarmatic (Pologne d'aujourdhui) par M. l'Abbé Staszie. Journ. de Physique, Août, 1807.

which this formation lies in France and in England, some persons have been led to consider it as one and the same, and consequently to conclude that the British channel, which separates these parts which are now opposed to each other, has been formed after the chalk had been deposited. I shall not however enter upon the discussion of the merits of that opinion, which if examined in detail, would offer several difficulties, as I do not think that it is necessary to adopt it, in order to account for the facts which present themselves.

One of the distinctive characters of this formation, is the disposition of the flint in beds or layers, nearly parallel to each other, though at unequal distances, so that whatever be the shape of the country at the surface, whether it be hilly or flat, the beds of flint preserve a nearly uniform parallelism with the surface of the ground; this is tolerably well seen in Dorsetshire, a county, the outline of which is very undulated. This kind of hilly ground is known in England by the name of *downs*. In Hampshire, in the western part of it especially, there are elevated plains, and occasional depressions, but these last are not sufficiently deep nor do they succeed to the former so rapidly as to entitle that district of country to the name of downs.

Flints near their original situation do not always appear in the form of pebbles, but often in masses of a more or less considerable size, and of a shape sometimes flatted and irregular. It is chiefly in alluvial ground formed of a slightly aggregated gravel, that flints are found in the state of pebbles, of different sizes, according to the friction they have undergone, and consequently, according to the distance from which they have been brought: hence, the individual pebbles of which gravel consists, become in general smaller and smaller as they approach the sea.

This cause has operated not only on flints, but also on every kind of rock, forming detached masses or entire mountains, which have been worn down either in whole or in part, and the fragments afterwards transported, and deposited in the plains by currents of water.* It is principally the same agent which has accumulated the heaps of quartz pebbles, which are found at the extremities of some primitive countries,† on elevated plains, to the nature of which they are quite foreign: it is however much more difficult to trace with any certainty the original locality of this quartz, than of flint gravel.‡

With regard to the formation of flints in chalk, if we adopt the explanation of Werner, that they have been produced by infiltration, I should be as much disposed to attribute the void spaces in the chalk to a natural contraction of its own substance, as to the disengagement of air. We know that chalk divides by drying, into compartments which are sometimes very regular, nearly in the same way as marl. According to this hypothesis we may suppose, either that the chalk and the flints are of contemporaneous formation, that the elements of the flint were mixed with those of the chalk, and that they separated from each other by elective affinity, or that the siliceous matter has been afterwards introduced, and has filled up the cavities left in the chalk.

But whichever of these opinions we may adopt, I do not see, how in any case we can possibly admit the conversion of chalk into flint,

* Saussure, Voyages aux Alpes, §§. 1315. 1327. 1329. 1334.

† For example, at the entrance of the great valley of the Rhone, in the neighbourhood of Lyons.

‡ Sir Henry Englefield has pointed out in the Isle of Wight, a very remarkable fact relative to the state of the flints imbedded in the chalk. Transact. of the Linnæan Soc. vol. vi. p. 103 and 303. See also for a fact nearly similar to the preceding, Geographie Physique de Bergman. Journ. des Mines, No. xvi. p. 39.

or *vice versa*, that of flint into chalk. The following reflections of Saussure on this subject are strongly in point.—"These observations "and these experiments appear to me to prove that the intermediate "species which have been sometimes considered as forming the gra-"dation from one genus to another, or as limestones partly trans-"formed into flint, are very often merely mechanical mixtures of the "two. In fact there is no mineral hitherto known which we might "not assume as the commencement of a series, and thence proceed to "establish by insensible shades a circuit comprehending the whole of "those which have been already determined, and the more extensive "our acquaintance with mineralogy the more will the truth of the "observation become apparent, in consequence of the more nume-"rous varieties and shades of difference which will be discovered."*

It would appear however that the chalk in which flints occur, although subordinate to the calcareous rocks, must, according to Brongniart, belong to a formation anterior to that of the limestone which he denominates *grossière*. He asserts that the fossils found in chalk are almost all species of extinct genera, and that the situation of chalk is always inferior to that of the *calcaire grossière*.† It is probably this species of limestone of which the quarry of St. Eutrope, near Aix in Provence consists, where the Chevalier de Sades affirms, *eleven beds have been formed since the existence of man in a civilized state?*‡

The western border of Dorsetshire is nearly the limit of the occurrence of flints in the chalk. This last, however, extends on the road to Axminster, to within four miles of Honiton in Devonshire, where

* Voyages aux Alpes, § 1537. Werner, without going so far as Saussure in strictness of language, is of the same opinion. Nouvelle Théorie de la Formation des Filons, 55. 91.

† Brongniart, Elemens de Minéralogie, tome i. p. 209.

‡ Traité de Minéralogie, par M. le Comte de Bournon, vol. ii. p. 402.

it is totally lost, so that setting out from London, and going in a direct line from east to west, this formation extends one hundred and fifty miles between these two boundaries. The structure of the cliffs on the sea-shore, it is true, changes several miles eastward of the western boundary now stated. Thus the Island of Portland furnishes a grit, having a calcareous cement; and Lyme Regis, a little farther west, a shell limestone ;* this last I did not see *in situ*, but from the specimens I procured in that neighbourhood, it appeared to me rather to deserve the name of a shelly-calcareous grit. It is of a bluish colour, of a fine grain, and the particles distinct. It contains petrifactions, particularly very beautiful ammonites, which are semi-transparent. This rock, in many respects, very much resembles that which forms the cliffs of Tracy on the coast of Bayeux in Normandy.†

Immediately upon quitting the chalk district, we enter upon a transition country, of which Exeter may be considered the centre, and as it is yet little known in a geological point of view, it deserves a more particular examination.

The red sandstone, having an argillo-ferruginous cement, first succeeds the chalk and flint. Towards Honiton, it is in the state of a coarse-grained gravel, almost entirely disintegrated. It contains rounded pebbles, some of which are two or three inches in diameter : it then approaches to a conglomerate puddingstone, but near Exeter, it assumes the character of an arenaceous sandstone, and becomes more compact and uniform in its texture and composition.

* There is also along the coast of Dorsetshire, a range of argillaceous hills, belonging to a kind which, according to M. Brongniart, are to be observed either on the boundaries of primitive countries, or on the passage to the secondary countries. Traité Elémentaire de Minéralogie, tom. i. p. 527.

† Journ. de Physique, Mars 1807.

This conglomerate is in nearly horizontal strata, which probably extend eastward below the chalk, while to the westward they lie upon rocks of a different nature, of which I shall afterwards speak.

The town of Exeter is situated in a sort of hollow encircled by hills not very elevated, nearly all of the same height, and which become gradually lower as they approach the coast. I found one of these hills, situated eight or nine miles N. N. W. of Exeter, near the village of Thorverton, to be seven hundred feet above the level of the sea. This basin opens to the S. S. E. and, as is frequently the case in England, a river, which at the distance of a few miles from its mouth would deserve rather the name of a brook, suddenly enlarges near the sea to a considerable width. The Ex at the place where it flows into the open sea, suddenly again contracts, and forms a very narrow strait.

There are several quarries opened in the neighbourhood of Exeter, deserving the attention of the geologist: some of these I shall now enumerate.

The quarry of Heavitree is situated about a mile and a half from Exeter, on the road to Honiton. It is worked to the extent of a quarter of a mile in length, and at present, to the depth of about ninety or a hundred feet, in a plane intersecting that of the strata. The rock worked in this quarry is a conglomerate evidently stratified; the strata are from six to eight feet in thickness, and dip S. E. at an angle of about 15°. As long as this rock preserves the character of conglomerate, it is compact and tenacious, and according to the workmen employed in the quarry, it hardens more and more by exposure to the air. But as soon as it passes to the state of an arenaceous sandstone, it becomes tender and friable. It is very common to see blocks of it in this last state, and sometimes of great size, included in the middle of the conglomerate. The cement of this rock is argillo-ferruginous,* and by itself does not effervesce with acids, as it is easy to prove by making use of pieces of the pure sandstone for that purpose; but it produces so brisk an effervescence from the intimate mixture of calcareous particles, that it might be very easily mistaken for limestone. The substances which enter into the composition of this conglomerate are numerous; and it may first be remarked, that these pieces are of very different sizes and forms, sometimes rolled and rounded, sometimes pointed with sharp angles, from very minute grains to the size of several inches in diameter. There are found in it rhomboïdal crystals of calcareous spar, and crystals of felspar, most frequently of an opaque white, and decomposed; pieces of flint; grauwacke; yellowish limestone; rolled masses of a species of porphyry somewhat resembling the antique, the base of which is of a reddish brown colour, not effervescing with acids, and containing numerous, small and well-defined crystals of felspar imbedded in it; pieces of a rock which is itself compounded, having the appearance of a porphyry, the base earthy, and including small grains of quartz, crystals of felspar, and pieces of bluish carbonate of lime; and a whitish tender steatite, in small angular fragments.

Poucham quarry is situated about two miles N. N. W. of Exeter. It is of much less extent than that in the parish of Heavitree. I was not able to determine either the direction or inclination of the

* May not the presence of iron in this conglomerate be owing to the disintegration of the granite of the low chain of Cornwall, the mica of which contains so great a proportion of it in the state of oxide?

The Count de Bournon appears even disposed to believe, that the primitive rocks have been the only source from which the iron has come, that is spread over the whole surface of the earth. Traité de Min. vol. I. p. 62.

strata. The rock itself is an amygdaloid, the nodules of which are chiefly calcareous, small and uniform ; the base does not effervesce with acids, and when breathed upon, it has the smell peculiar to clay. It is much stained by oxide of iron, which tarnishes the lustre of the calcareous nodules and veins contained in it.

Thorverton quarry is seven or eight miles north of Exeter. In going to it by Cowley Bridge, on the summit of a hill which overlooks Exeter, and is almost close to the town, the grauwacke is met with *in situ*. It is of a greyish colour, with very distinct and separate grains, breaking spontaneously into rhomboidal fragments ; it is harder in some places than in others ; when tender, it splits in the manner of slate, and assumes quite the character of that species of rock. It occurs in strata, dipping N.W. at an angle of about 70°. The same grauwacke formation is met with to the N.N.E. of Exeter, on the road to Bickleigh, Silverton, Rew, and Cross-hill ; at Cross-hill the direction and inclination of the strata are very distinctly seen. From Cowley Bridge the grauwacke extends as far as the neighbourhood of Upton Pyne, but in this district it can only be distinctly seen on the summits of the hills ; it is lost in the bottom of the vallies, and is there succeeded by the red argillaceous sandstone. This is particularly the case at Upton Pyne, a village five miles north of Exeter on the right bank of the Ex. As there is a mine of black oxide of manganese worked in open day at this place, I had an opportunity of making pretty accurate observations on the strata, and on the nature of the rock. The red argillaceous sandstone, at the place where the mine is excavated, forms a stratum several feet in thickness from the surface ; below this is a conglomerate puddingstone, the same that is found in the parish of Heavitree, but quite disintegrated : then, a reddish compact felspar in mass, containing a few laminæ of calcareous spar, and some crystals of quartz. This last rock forms the roof of the mine, the *saalbände* * consists of a calcareo-manganesian amygdaloid. As to the floor of the mine, it is not known of what it consists, as the vein, which appears to be of considerable magnitude, has not been cut through. Its direction is from E. to W. dipping N. with an inclination of three feet in six. Of the black oxide of manganese, several varieties are met with, together with ferriferous carbonate of lime. The red argillaceous sandstone occupies the surface of the country from Upton Pyne to Thorverton.

There are three or four quarries at Thorverton, and these not far distant from each other. They are all in the same rock, viz. a calcareous amygdaloid, the nature of which, however, varies considerably in different places. In some places, the nodules are small, and very closely united in clusters in the base, forming nearly a homogeneous mass, with here and there nodules of a much larger size than the rest imbedded in it. In other places the nodules are about the bigness of a pea, all of the same size, and consist of rhomboidal sparry laminæ. There are other places where the base of the amygdaloid has the appearance of a sand stone in which a small number of calcareous nodules are imbedded, externally coloured green by the steatite, and exactly resembling those which enter into the composition of some of the amygdaloids of Derbyshire, and of the Pentland hills near Edinburgh.

The country between Exeter and Plymouth by Chudleigh, Ashburton, and Ivy-bridge, is quite hilly, the whole being a continual

* The term *saalbände,* for which we have no corresponding scientific expression, is frequently denominated in some of the mining districts of this country, *pasting* or *sticking*. Tr.

ascent and descent as far as the neighbourhood of Ivy-bridge. The red argillaceous sandstone continues from Exeter for some miles on that road; it is succeeded near Chudleigh by a vast number of flint pebbles, which appear to be scattered over the surface of the ground: I was not able to stop to examine them more attentively: but between Chudleigh and Ashburton, there occurs a blue compact limestone, traversed by numerous veins of calcareous spar. At every step the extremities of the strata of this rock may be seen cropping out, and fragments of it are mixed with the soil. In the neigbourhood of Ivy-bridge a formation commences, which as will afterwards be shewn, occupies a prodigious extent in this part of England: I mean the slaty and compact grauwacke. At Plymouth, however, the cliffs on the shore are of limestone; which as I examined them leisurely, and as they appear to me to excite some degree of interest, I shall describe more minutely.

The range of tolerably high cliffs, which extends from Stonehouse Pool, between Plymouth and Plymouth Dock, and thence along Catwater, ascending the right bank of the Plym as far as the Flying bridge, together with Mount Batten, and probably also the Island of St. Nicholas, are formed of a compact limestone. It occurs in strata rising N.N.W. at an angle of about 65°; it breaks with a semi-conchoidal fracture into large flakes, is of a yellowish-white colour, and, when quarried, is blasted with gunpowder. I did not discover in it any impressions of organic bodies, and I did not hear that they have ever been found in it; at least, if any do exist, they are very scarce. It contains several cavities lined with calcareous spar, or with stalactites, and filled with an ochreous earth. It is frequently also traversed by veins of calcareous spar of a wedge shape, wider at the bottom than at the top, and which generally occupy the whole height of the cliffs. On the side of Catwater, this limestone is of a bluish colour and a crystalline grain ; it is here also frequently intersected by veins of calcareous spar. The cliffs near Stonehouse being much exposed to the action of the sea, afford very distinct proofs of its effect on the most tender parts of the rock. It has made in several places erosions or crevices of various extent, which have been afterwards filled by a gravelly sand thrown up by the sea, and which has, by drying, become so coherent, that one might be led into error, by conceiving that the sand alternates in beds with the limestone.

But it is at the eastern end of the Flying bridge, on the left bank of the Plym, that the transition limestone is found in its true character. I have no where seen it so well characterized, not even at Meillerie in Savoy, on the borders of the Lake of Geneva. The strata have the same direction and the same degree of inclination as those at Catwater. There is a quarry belonging to Lord Borringdon, which is an excellent spot for studying it. This limestone is blackish-brown, several rhomboidal plates of calcareous spar may be seen disseminated through the mass, and it suddenly assumes in the same stratum, all the characters of a shining slate; the rock in this last state effervesces less briskly with acids.

On quitting the coast, and advancing into the interior of the country, there is seen on the road from Saltram to Plymptom Earle a slaty amygdaloid, the base of which is of a purplish-brown colour, the nodules calcareous, and the greater part of them very minute. I found in the same neighbourhood, on the surface of the fields, in adventitious blocks and pebbles, another species of amygdaloid, the base of which is greenish-grey, and has the lustre of satin; several of the nodules being completely decomposed, had left corresponding empty spaces.

I cannot say what formation is found on the shore to the east of

Plymouth, by Dartmouth, Torbay, and Teignmouth. I am inclined to believe that it is the same limestone which I saw at Chudleigh and Ashburton, and which extends thus far into the interior of the country. The observations of Dr. Maton seem to support this conjecture,* as do those subsequently made by Lord Webb Seymour and Mr. Playfair.†

Nor do I know what rocks are found *in situ*, on the road from Exeter to Oakhampton. I can only say, that at a few miles to the east of that town, the extensive grauwacke formation commences.

Before proceeding further westward, where more constant and uniform formations will be found to exist, it may not be amiss to make here some general remarks, pointed out by the subject itself, on the nature and succession of the different formations which have been already noticed, and on what they seem to offer in the way of analogy with other countries.

It has been seen, that leaving on the borders of Dorsetshire the chalk and flint formation, and afterwards the shell limestone, a red sandstone succeeded, in strata slightly inclined, which as well as those of the conglomerate into which it passes, rest in some places on amygdaloid, in others on grauwacke, and finally on transition limestone. It is an object of inquiry which demanded more leisure than I was able to bestow upon it, to determine whether it is on one of these rocks in particular, that the argillaceous sandstone rests: but it is, I presume, a matter of secondary importance. There is another general fact of some consequence to observe, which is, the elevation of the strata the further they proceed to the westward, and the great angle of inclination they make with the horizon. Let us

* Observations on the Western Counties, vol. i. p. 122.

† Illustrations of the Huttonian Theory, p. 55, 189.

now compare these appearances with those met with in other countries, and we shall find, that upon a diminutive scale, they coincide for the most part with each other, and that they lead us very strongly to believe that we are approaching a primitive country, or rather, that we are upon the verge of it. Thus, upon the skirts of the primitive mountains, where the Rhine rises, and at the opening of the great valley through which that river flows, enormous masses of conglomerate breccia are found. I have followed them for the space of several miles, from the borders of the lake of Wallenstadt, on the road to Zurich. It is also upon the same line, but a little more to the eastward, and on the skirts of the chain of mountains of St. Gothard, that are found those masses of pudding-stone which form mountains of so great an elevation as the Rigiberg,* the Ruffiberg, and the Albisberg; and turning W.N.W. extend into the Entlibuchthal, where I have seen mural precipices of it, of a considerable height between Schoepfheim and Hochstetten. I have also seen those mentioned by Saussure at Valorsine in the valley of Trient;† on the left bank of the Rhone, between Martigny and St. Maurice in the Valais;‡ as well as those which are found in the beautiful valley of Loch Ness in Scotland.

* Mr. Kirwan considers the Conglomerate of Rigiberg as a calcareo-argillaceous breccia, which he calls *Farcilite.* Geol. Essays, p. 252.

I believe he might have equally comprehended it under the same head as the aggregate which he has called Semi-Protolite (Geol. Ess. p. 256), for fragments of granite are included in it, though in small quantity. I have seen some at least in the detached blocks of breccia of the Ruffiberg, near the village of Steinen in the valley of Goldau; and what is remarkable, it is a granite, having the felspar of a brick-red colour, a variety very rare in the high Alps.

† Voyages dans les Alpes, §§ 687, 688, 689.

‡ Ibidem, § 1053.

Ramond has likewise met with this breccia in the Pyrenees.* He describes it by the name of " *bandes* " formed of a heterogeneous mixture in irregular veins, occurring between the fundamental granite, and the secondary and tertiary mountains. Other travellers have observed it in similar geological situations, in the Palatinate, Saxony, Bohemia, and particularly in Siberia, where it is stratified, and where jasper constitutes one of the principal elements of it.†

An indefatigable artist, the beauty of whose descriptions is not inferior to the graphic charms of his pencil, has proved, that a traveller, without being a profound mineralogist, may, if guided by a spirit of observation, collect materials very useful to those who know how to employ them. Vivant Denon, in noticing the mountains on the road from Keneh to Cosseir on the red sea, says, " at day-" break we found the appearance of the country changed; the " mountains that we had passed the day before were rocks of free-" stone; these were of puddingstone, being a mixture of granite, por-" phyry, serpentine, and other primitive species, aggregated in green " schistus. The vallies continued to grow narrower, and the rocks " on every side more lofty. At noon we had reached the first half " of our journey, in the midst of fine rocks of breccia, which would " be very easy to work if it were not for the great distance from any " supplies of provisions: the portions of this granite, of which this " breccia is composed, shew, that the primitive mountains are not far " distant."‡

With regard to the elevation, and abutting of the secondary and tertiary strata as they approach the primitive rocks, Saussure and

* Voyages au Mont Perdue, p. 197, 359, 205, &c.

† Kirwan's Geological Essays, 229.

‡ Voyage dans la basse et haute Egypte, tome I. p. 292; or English Translation, vol. II. p. 340.

Pfyffer are, I believe, the first, who paid attention to this circumstance: Saussure in the mountains of Meillerie and St. Gingouph, in Savoy, Pfyffer in the Alps bordering on Lucerne.* The neighbourhood of Plymouth affords an example of it in this part of England.

As the physical structure of the western part of England, from the banks of the Tamar as far as the Lands End, offers little variety in geology, and as the great masses consist of a small number of different rocks, it will, I think, be convenient, to give, at first, a sketch of the chain of mountains which traverses this part of the country, such at least as I conceive it to be. It will be an outline, which may afterwards be more easily filled up by future observations. Besides, as the grauwacke constitutes one of the most essential component parts of this chain of mountains, and as it is susceptible of numberless modifications, it will be better to give, in the first place, some details on the nature of this rock in the different states which it assumes.

General Observations on the low Mountain-chain of Cornwall.

The chain of low mountains, which forms the county of Cornwall, extends nearly into the centre of Devonshire, comprehending the elevated and irregular mountain plain, called Dartmoor Forest.

Like all primitive chains, it stretches from N.E. to S.W. or, more correctly, from E. N. E. to W. S. W. extending in this direction from 115 to 118 miles.

Its line of direction is pretty accurately represented by a line passing through the following places, viz. Two Bridges, Launceston,

* Voyages dans les Alpes, § 325.

Bodmin, Indian Queen, Redruth, Camborne, Tregonin-hill near Marazion, St. Burien, and Sennen.

The central and highest part of the chain is granite, which extends into a narrow mountain plain at the north eastern extremity, and as it approaches the south-west gradually contracts into a ridge, and is flanked on the right and left by grauwacke. The outline of the range is not altogether continuous, several of the rounded summits which compose it are separated by small vallies or ravines of various depths. Thus, the Tamar, which flows to the eastward of Dartmoor forest, seems quite to detach that mountain plain from the hilly country to the west of Launceston; but it is easy to see, that such a separation does not exist in reality, Brown-Willy, the most elevated point of the whole chain,* being in the parallel which passes directly through the middle of Dartmoor forest. The whole chain may be said to be formed of downs, and to be in some places interrupted, but no where entirely broken off. I have little doubt, that in the lower parts of the country, where the granite appears to be wanting, it would be found under the rocks, which I believe cover it, whatever these may be, if wells sufficiently deep were sunk in those places.

The water-shed of the chain is to the north and south, and both sides have nearly the same degree of inclination: the waters on the one side run into the British, and on the other into the Bristol Channel. The whole range has a gradual slope towards the west, but on the east the terminations are rather abrupt. The greatest breadth of the chain, is a little to the east of the middle point in its longitudinal extent. On the west it contracts into a narrow tongue of land, which is almost entirely granitic. The highest part of the

* According to the trigonometrical measurements of Lieut. Col. Mudge, this mountain is thirteen hundred and sixty-eight feet above the level of the sea.

chain is also very near its centre.* Brown-Willy, in the neighbourhood of Bodmin, is, as has been said, one thousand three hundred and sixty-eight feet above the level of the sea, while the granitic cliffs at the Lands-end do not exceed sixty or one hundred feet. It is however possible, that the neighbourhood of Craw-Mere-Pool in Dartmoor forest, not far from the eastern extremity of the chain, may be nearly as high as Brown-Willy. But it is rare to find any general rule without some exceptions: thus, according to André de Gy and Ramond, the highest points in the Vosges† and in the Pyrenees are out of the central chain.

The low range of Cornwall presents a regularity in its composition, rarely found in great chains. Saussure has shewn the dissimilarity between the two opposite sides of the Alps: on the northern side, he informs us, the whole of the exterior range is composed of mountains of limestone of considerable height and extent; on the south side, on the contrary, the schistose rocks, and even the granite reach the plains, and if limestone do exist on this side, it is of very rare occurrence, and does not form broad and continuous chains as on the northern side.‡

Pallas has also observed in Russia and in Siberia, essential differences between the opposite sides of the same chain of mountains. Ramond remarked the great dissimilarity between the two sides of the Pyrenean chain, the sandstones are rarely met with on the north-

* This appears also to be the case in North Wales. "The county of Caernarvon, from Bardsey island, in a north-easterly direction, to the promontory of Penmaen-bach in Conway bay, is occupied by a range of mountains the highest of any in Wales. They gradually ascend from each extremity of the chain towards the centre, which is occupied by Snowdon, the loftiest of all." Arthur Aikin's Tour through North Wales, p. 97.

† I have recognized in the Vosges, the truth of the observations of André de Gy.

‡ Voyages dans les Alpes, § 981.

ern skirts, while they form a great part of the mountains to the south. The phenomenon of twisted and arched strata is much more common on the northern side, where the marine fossil remains are generally calcareous, as on the southern they are siliceous.

Among the small number of general facts, to which few exceptions have yet been found, in the structure of mountains, as stated by Saussure, the following appear very applicable to the mountains of Cornwall.

1. Mountain chains are generally directed from east to west, or from north-east to south-west.

2. The strata of mountains of newer formation generally incline towards, and rest upon the mass of those which are more ancient.

3. Great quantities of *debris*, in the form of *detached* blocks, of breccias, of pudding-stones, of sandstones, and of sand, are found either accumulated in the form of mountains, or scattered over the borders of the Alps, and even extend into the plains. This observation applies equally to all primitive countries.

General Observations on Grauwacke.

I give the name grauwacke to a rock composed of separate siliceous particles united by an argillaceous cement, with a little magnesia and iron. It might be called a sandstone, having a base so fine that the rock appears homogeneous; but the name grauwacke, made use of by the school of Werner, has been generally adopted.

Though formed by a mechanical precipitation, grauwacke is one of the oldest of the secondary rocks. I have never found in it any impression of organic bodies, and I am not aware that it has ever been found to contain them. It is divided into two species, common grauwacke, and grauwacke slate.

The structure of the first is compact, dividing by natural joints into rhomboids or parallelipipeds: it is harder, not so fine in the grain and of a darker colour than the other variety. This last quality depends, no doubt, on its containing a greater proportion of iron. I believe that common grauwacke is a *cornéenne trap* of the French mineralogists. In Cornwall it is always found higher than the grauwacke slate: it may be supposed to have been precipitated more slowly, and under a less powerful pressure, whereby the mass has been allowed to contract, and assume a kind of crystallisation. It rests immediately upon the granite,* and, at its junction with that rock, it is very frequently accompanied by veins or beds of quartz, which is also often found in detached pieces or blocks.† It is much less rich in ores than the grauwacke slate.

The structure of grauwacke slate is schistose, and the laminæ become thinner, as they are further removed from the junction with the granite. The base is exceedingly fine, smooth to the touch without being unctuous; the colour of the mass varies from dark grey to white; its lustre is silvery, sometimes that of satin, especially when the fractures are fresh, but that fine lustre soon goes off when it is exposed to the air. It is to this variety exclusively that the Cornish

* The rock which Ramond calls *Cornéenne*, and describes as interposed between the fundamental granite of the chain, the primitive limestone and the porphyritic rocks, in the Pyrenees, is very likely grauwacke. Voyages au Mont Perdu, p. 4, 25, 206, 265, &c.

† It is probably also found in the mountains of Wales, according to the description given by Arthur Aikin—" All the mountains from Bala to Aberystwith are primitive " schistus, sometimes intersected by large veins of quartz, and of a coarse texture, some- " times forming slate." Journal of a Tour through North Wales, p. 42.

miners give the name of *Killas.** Here, as in the Hartz, it is very rich in ore, and for this reason, Klaproth proposed to call it *Saxum Metalliferum Cornubiense.*†

In low situations especially, grauwacke-slate has a very great resemblance to clay-slate;‡ in other places it decomposes, and passes into the state of marl.§

The grauwacke formation occupies a very considerable extent in Cornwall. Without having traced it step by step throughout, I believe I may safely say, that it prevails without interruption on the southern side of the chain from the mouth of the Hamoaze (the name given to the river Tamar after its junction with the Tavy) to that of the river Hel, thus occupying a space of about forty miles from east to west. It may possibly happen that in this course some other rock belonging to the same formation may be found in subordinate beds, but whatever it is, I do not think it can be of any great extent.||

* It is also this variety which has been analysed by Kirwan, and which he classes with the Hornstones. He found that 100 grains contained

Silica .	60
Alumina	25
Magnesia	9
Iron .	6
	100

† Klaproth's Mineralogical Observations on Cornwall, p. 7.

‡ *La fermentation* (qu'on me permette, dit M. de Trebra, de designer sous ce nom, cette force de la nature qui met tout en mouvement dans le regne minéral) peut transformer la *grauwacke* en un schiste argileux qui peut durcir et devenir un jaspe, si cette fermentation cesse ou diminue. Nouvelle Théorie de la formation des filons, par Werner, p. 54.

§ In some parts of Cornwall this marl mixed with sea sand and sea weed is used as a manure.

|| The Rev. Mr. Gregor of Creed, with whom I conversed on this subject, informed me, that going along the coast from Grampound to Fowey, a limestone is found, which

In Cornwall, as in the Hartz, the covering of grauwacke never rises very high, and we find that here, the more elevated points, although their absolute height be not very considerable, are left bare.

Here also, as in other countries,* the two varieties of grauwacke are uniformly found connected with one another: they in general cover the transition limestone, whereas secondary greenstone and clay-slate occur in it in subordinate beds, and perhaps the formations of serpentine, of diallage with felspar, and of talcose slate, of which I shall afterwards speak, are similarly situated.

Though the cliffs at Stonehouse are of limestone, nevertheless Mount Edgecumbe, which is only separated from them by the Hamoaze, belongs to the grauwacke formation. We here find that rock passing from the state of a coarse argillaceous sandstone, of a reddish colour, not effervescing, and stained by oxide of iron, to that of a fine-grained grauwacke-slate, with red veins, giving it the appearance of ribbon jasper. It occurs in strata, dipping S.S.E. at an angle of about 65° or 70°, which is nearly the same as that of the limestone cliffs of Plymouth harbour. The stratification is best seen on the south side of Mount Edgecumbe about half way up; and especially from the *great terrace* to the *arch*, and beyond that on the way to the zig-zag walk. At the top of the hill the grauwacke becomes less distinctly stratified, and begins to separate into rhomboidal pieces. Maker Heights,† Rame Head, Higher Blarick in

appeared to him like that of Plymouth: he added, that it had been excavated in some places by the sea, and that the fissures had since been filled up with a gravelly conglomerate.

* Brochant, Traité de Minéralogie, tome ii. p. 588.

† The altitude of this place, computed from the Trigonometrical Survey, is four hundred and two feet above the level of the sea.

White-sand Bay, the point where my excursion to this part of the coast ended, and precisely in the meridian of the Eddystone light-house, all belong to the grauwacke formation. In White-sand Bay this rock, forming the cliffs, separates by very regular rhomboidal joints. It is of a whitish colour, of a friable texture, like that of the *grès-molasse*, and might pass for a corneous trap in a state of decomposition. It is accompanied by a rock, having a reddish argillaceous base, containing much oxyd of iron, and fragments of compact limestone, and which effervesces with acids.

There is at Peter Point in St. John's Creek, very near Torr Point, a bed of greenstone, in the composition of which there is a good deal of steatite, completely included in the grauwacke. Though of small extent, it is quarried for building. Not far from this place, on the banks of Lyhner Creek, and on the estate of Sir Henry Carew, there is another bed of greenstone: it is immediately adjoining the ferry. This bed extends from one bank to the other; and on the right or south side of the creek there is a large quarry of it. Very remarkable differences may be observed in the texture of the greenstone, though the specimens be taken from the same bed. The base is sometimes so close, so homogeneous, that single unconnected specimens of it might pass for *corneous trap*,* with pyrites dispersed through it: other specimens, however, taken quite close to the preceding, are of a composition and grain, between that of corneous trap and greenstone: these are in my opinion sufficient reasons for comprehending all the varieties of this substance, under the common denomination of greenstone.

* It is, more properly speaking, what the German mineralogists call *graustein* (grey-stone) which they describe as having nearly a homogeneous base, of an ash-grey colour, and of a dry aspect. Brochant, Traité de Minéralogie, tom. ii. p. 608.

It is difficult to account for these differences in the same rock, but though they certainly do exist, I do not think they are sufficient to constitute distinct species. I conceive that in the nomenclature o rocks especially, we ought strictly to adhere to the principle laid down by Saussure—" To determine genera and species from those " individuals in which the characters are most distinct, and to qualify " by the name of transitions, those which are doubtful or indistinct."*

From Lynher Creek, directing our course northward towards Callington, by Saltash and St. Mellion, the grauwacke continues uninterrupted, but as the country rises, and we approach Kitt-hill, situated about a mile N. E. of Callington, the quantity of quartz met with on the road in blocks and pebbles becomes very remarkable: this indicates our being near the termination of the grauwacke, and we accordingly find it cropping out to-day on the side of Kitt-hill, at about two-thirds of the ascent. Kitt-hill is the nearest place to the sea from the mouth of the Hamoaze, where granite is found *in situ.* This little hill, though insulated, must be considered as a dependance of the mountains of Dartmoor: it is situated on the southern skirt of the granitic mountain-plain of the low range of Cornwall.

The sides of Kitt-hill are gently inclined; that on the east is the most abrupt. The north and south sides are the most extended, and may be considered as the water-sheds. The upper part of the hill is a true granite, composed of crystals of white felspar, quartz and mica. Mr. Necker found in the neighbourhood of Kitt-hill an adventitious mass of tourmaline of a cylindrical form, and of a brownish-green colour, which the Comte de Bournon, to whom I shewed it, considers a new variety of form. From Callington to Plymouth, by Beer Alston, Beer Ferris, and Tamerton Folliet, as far

* Voyages dans les Alpes, §. 1915.

as the point where the high road to Tavistock joins, the grauwacke-slate continues. Its stratification is very distinctly seen at the passage of the Tamar near Calstock, and of the Tavy near Beer Ferris.

At Calstock, the strata are cut more abruptly on the left bank, and at Beer Ferris on the right bank, from which we may infer, that the depth of the Tamar and the Tavy is not the same at both banks, the depth of a river being in general increased as its banks become more precipitous.

The grauwacke-slate also continues in the road from Plymouth to Ivy-bridge. On approaching the latter place we find pebbles and even adventitious blocks of granite, which being brought down into the plains, by the rivers which flow from the high land of Dartmoor, shew that that district is formed of primitive rocks.

Of the Mountain-plain of Dartmoor Forest.

When we trace up the courses of the rivers which flow through Devonshire, we find they all rise in an elevated and extensive plain situated nearly in the middle of the county, and upon which the adjacent rocks, gradually rising as they approach it, are found to rest. The south and north sides are the water-sheds of the mountain-plain. The Tavy, the Plym, the Yealme, the Erme, the Avon, and the Dart, flow down the southern side; the two Oakments and the Taw run to the north: there is only the Bovey on the south-east, and the Lyd on the west, and these are both very small streams.

I entered Dartmoor forest, by the valley of the Erme, which opens at Ivy-Bridge. This little valley is at first contracted and deep, with a rapid ascent. The general direction is nearly from

N. to S. which is the same with the course of the river flowing through it. Thus it appears that these vallies, which are all similar to each other, are perpendicular to the mountain plain.*

Leaving the bed of the river Erme to the left, about five minutes walk from Ivy-Bridge, we pass some farm houses at the bottom of a small detached hill, the name of which I did not learn, nor do I find it laid down in the common maps of the county: it is situated N.N.E. of Ivy-Bridge, and from thence to the top of the hill is about two miles and a half by the nearest road. This small hill, the only abrupt face of which is towards the south, is situated on the exterior line of the mountains of Dartmoor, on the first plain they form from the sea coast. The upper half is composed of a rock which I call a porphyritic granite,† and the lower part as well as the base is of grauwacke. I found the summit to be one thousand one hundred and thirty feet above the level of the sea, and the greatest height to which the grauwacke rises on its sides is six hundred and thirty-one feet.

There is on the right bank of the Erme another small hill, facing the latter, equally rounded in its outline: both have that appearance which Saussure calls *moutonnée*,‡ an expression in my opinion peculiarly applicable to the low granite mountains of the *ci-devant* Forez.

* In the Alps, the vallies are longitudinal and transverse; in Jura, they are almost all longitudinal; in the Vosges, the greater part are oblique; in the Pyrenees, they are nearly at right angles. Journal des Mines, No. 126.

† The base of this porphyritic granite is a beautiful kind of felspar of a brick-red colour, confusedly crystallized, in which are imbedded crystals of vitreous quartz, hornblende and tender steatite of a greenish yellow. I found on the summit several adventitious blocks of amethystine quartz.

‡ The mountains which Saussure designates by this expression *(moutonnée)* are composed of an assemblage of rounded tops, covered sometimes with wood, but more fre-

Kit-hill is situated farther in the interior of the country than the small hill above Ivy-Bridge. The distance of the latter from the coast is, in a direct line, scarcely nine miles, whereas Kit-hill is at least thirteen.

In proportion as the valley of the Erme rises, it continues to open, insomuch, that at three miles and some furlongs from Ivy-Bridge northward, the river is no longer confined in a narrow channel, but flows over a plain gently inclined towards the south.

This mountain plain, at Harford church, which is six hundred and fifty-eight feet above the sea, is entirely granitic. We leave the grauwacke behind, about half a mile nearer the sea, and in ascending the valley of the Erme, the point of termination is very distinctly seen, particularly on the left bank. At the junction, there are veins or shoots of granite of different lengths and breadth, and they appear to penetrate into the grauwacke. The two rocks are certainly contiguous, and in immediate contact the one with the other.

The grauwacke near its termination loses its slaty character, as may be seen on the sides of the hill above Ivy-Bridge, where it attains nearly the same height as in the last mentioned place.

The primitive rock of this district is a true granite, composed of felspar, quartz, and mica, and the crystals of felspar are sometimes two or three inches long.

From Harford church the country assumes quite a bare and alpine appearance, presenting a vast plain extending beyond the

quently with shrubs or brushwood. These rounded tops being contiguous and in frequent succession, have on the great scale, the appearance of a thick fleece, or of one of those wigs which are called *moutonnées*. The mountains which assume that form are almost always composed of primitive rocks, or are at least steatitic; mountains of limestone or slate have never that appearance. Voyages dans les Alpes, § 1061.

visible horizon. The face of the country is formed by swellings and undulations gradually overtopping each other without ever forming very distinct mountains. There is neither vegetation nor any human dwelling; we tread upon a boggy soil of very little depth, and scarcely furnishing sufficient food to support some dwarf colts, wild as the country they inhabit.

The Erme rises about nine miles north of Ivy-Bridge, and one thousand one hundred and thirty-one feet above the level of the sea; the land gradually rising as we approach its source. This however is not the most elevated point of this part of Dartmoor forest; as far as I can judge, that point is near a place three miles south-east of Two-Bridges, where some tin mines are worked, and where that metal is found disseminated in the granite, as one of its integrant parts.

Two Bridges is fourteen miles to the north of Ivy-Bridge. There is but one house, and that an inn,* which stands nearly in the middle of this vast mountain plain, which contains, I believe, nearly three hundred and fifty square miles of surface.† Two Bridges is one thousand one hundred and forty-eight feet above the level of the sea. To the north of this place, the granitic country appears to extend as far as the neighbourhood of Oakhampton, but I cannot speak of that with certainty, as I did not trace it myself over the whole of that extent; I can only say, that according to the course of the rivers, the only mountain of any consequence

* There has been lately erected in the neighbourhood, a vast stone building, where it is intended to convey the greatest part of the French prisoners now confined in Mill prison at Plymouth. There are also at some distance from the inn at Two Bridges some houses on the high road from Tavistock to Ashburton, and Moreton Hampstead, which crosses this part of Dartmoor forest.

† It contains about 80,000 acres. Maton's Survey of the Western Counties, vol. I. p. 299.

which appears to me to rise above this mountain plain, and which is, without doubt, the highest point of all that part of the country, is Craw-Mere rock, where the two rivers Oakment and Dart have their source.

I bent my course from Two Bridges to Launceston, by St. Mary Tavy, Brentor, and Lifton, making a circuit of the exterior boundary of that part of Dartmoor forest. As long as the mountain plain continues, the country preserves the same appearance, and all along the road between Two Bridges and Tavistock, for the first six or seven miles, we find on the surface of the ground great numbers of granite-blocks; these probably come either from the tors, or are produced by the rock on the surface splitting in that manner, in consequence of the continued action of external agents. Several of these blocks are so firmly fixed in the ground from which they project, and are besides so uniformly spread over the surface in every direction, that they cannot be supposed to have been transported by a current to the place which they now occupy.

At the distance of three miles and a quarter from Tavistock the grauwacke begins to re-appear in a very distinct manner, and at the height of one thousand one hundred and twenty-nine feet above the level of the sea, which is rather considerable for this formation.

From this place, the country lowers with a pretty quick descent towards Tavistock, and this change of rock is accompanied by so complete a change in the vegetation, that it is impossible not to be struck by it. Nothing can be more remarkable than to see on the skirt of this mountain plain, towards St. Mary Tavy and Brentor, highly cultivated vallies, succeeded by rich pastures, which rise as high as the line of superposition of the secondary rocks, above which there is nothing but bare and naked rock.

About a mile from St. Mary Tavy, near the place where the roads join which lead from Plymouth to Oakhampton, and from Tavistock to Two Bridges, there is a bed of greenstone of some feet in thickness, in the grauwacke slate; it decomposes into a green earth. With regard to the grauwacke itself, the direction and inclination of its strata continue the same, it only contains more quartz as we approach St. Mary Tavy, and becomes at the same time less slaty.

St. Mary Tavy is six hundred and forty-eight feet above the level of the sea. A copper mine is worked here at a great depth, and amongst the rubbish I found grauwacke and schistose limestone,* heaped one above the other; which shews that the epochs of formation of these two rocks are nearly coeval, since we find beds of the one included in those of the other.

From St. Mary Tavy to Launceston by Brentor and Lifton, we cross successively the Lyd and the Tamar, continuing in the grauwacke slate formation to within a mile of Launceston. The strata of the grauwacke slate are very distinctly seen at the ferries of these two rivers. It is succeeded by a schistose limestone having a very fine paste of a dark blue colour and dull lustre, dividing into large flags, which are put to the same use as slate, and which I should have taken for such, if I had not found that it effervesced with acid.† Besides, it is here only in subordinate beds, and I do not believe that it extends very far.

I saw at the house of the Rev. William Gregor of Creed, two rolled pieces, one of which appeared to me to be idocrase (vesu-

* Similar to that at the mouth of the Plym.

† It is in fact, what some German geologists call transition, *thonschiefer*, and which they say alternates with transition limestone. Brochant Traité de Mineralogie, tome II. p. 587.

vian) and the other actinolite. Both had been given to him as having been found on Dartmoor.

From Launceston to Bodmin the distance is twenty miles, and between these towns, the highest part of the county of Cornwall intervenes. In the course of this tract of country, we quit, and again enter upon the grauwacke formation. It is exactly at the distance of seven miles and a quarter from Launceston, that it is lost at a height of nearly eight hundred feet above the level of the sea: the nearest village to this place is called Five Lanes. Here the grauwacke is succeeded by a granitic plain, where several rivers, flowing to the right and left, have their source: the Inny, the Fowey, the Camel or Alan, &c.

Brown Willy and Rough Tor do not rise much above their base, not more than other hills of much less absolute height, which are seen in the horizon. The grauwacke is again found exactly at the fourth mile stone from Bodmin, very near *New London Inn*, at a height, which upon that side of the chain appeared to me considerably greater than upon the northern side, but I was not able to determine the point more accurately. The land afterwards falls with a rapid descent to Bodmin, which is only one hundred and eighty-eight feet above the level of the sea. The soil of that granitic ridge is boggy, and quite like that of Dartmoor Forest.

From Bodmin to Truro, by the Indian Queen and St. Michael, is twenty-two miles: the grauwacke formation continues the whole way, becoming more slaty as we approach Truro, that is to say, as we get lower down. It then very nearly resembles clay-slate. The most elevated point on this road, and from which the whole of the Bristol Channel may be seen, is in the neighbourhood of St. Michael. From that place to Truro, the vegetation is very luxuriant, but from St. Michael to the Indian Queen, and from thence to within three miles of Bodmin, the soil is composed of peat and produces absolutely nothing. It is almost entirely a country of mines, especially in the neighbourhood of St. Austle. The inn called the Indian Queen is four hundred and ninety-one feet above the level of the sea: the most considerable branch of the river Fal rises in this neighbourhood. From the Indian Queen to Grampound, we continue for nine miles in grauwacke-slate, without its offering any thing remarkable. It is however very far otherwise, if from Grampound we direct our course N. N. E. towards the parish of St. Stephens.*

On quitting Grampound, the road leads for a short way towards the north, until we reach a small valley, which at its opening runs nearly east and west; it afterwards turns towards the north, and very soon takes a direction due north and south. A branch of the Fal flows through it, and the water, which on the heights near its source has been employed in washing porcelain earth, retaining the white colour of the earth, has at a distance the appearance of milk, which produces a very singular effect.

In proportion as we ascend, the grauwacke slate disappears, and in the neighbourhood of St. Stephen's church, it passes into the state of *cornéenne*, or of common grauwacke. It is stained with oxide of iron, and accompanied by numerous veins and pebbles of quartz. All these appearances indicate that we are approaching towards its limit. And although we cannot exactly point out the very spot of the transition itself, we may, without any material error, fix that point at Step-aside, a hamlet situated two or three furlongs from St.

* The pleasure and instruction I derived from this excursion, were particularly augmented by my having the advantage of the company of the Rev. Wm. Gregor, a gentleman equally modest as well informed, and whose name I have already had frequent occasion to mention.

Stephen's Church, and which is about six hundred and thirty-five feet above the level of the sea.

From Step-aside, we enter upon a mountain-plain of decomposed granite in the state of kaolin, which is famous for the porcelain earth it affords, and which is sent to Worcestershire. This plain is some miles in extent, and belongs to the southern boundary of the chain. One of the most elevated points of it, and which is in the neighbourhood of the principal quarry of the porcelain earth (China pit) is eight hundred and thirty feet above the level of the sea. This granite, the felspar of which forms two-thirds of the mass, appeared to me to be less decomposed near the borders of the plain, than in the central part. In this last place it has rather the appearance of a porphyry with a pulverulent base, of a whitish colour, in which crystals of quartz, and some plates of mica, are loosely included. It is used in this rough state in the manufacture of porcelain, in the same manner as the Chinese make use of petuntze, by mixing it in certain proportions with the porcelain earth that is obtained by washing and frequent precipitations. Crystals of a compact and earthy felspar are occasionally met with in this decomposed granite, of a much larger size than usual. We also find here another rock, the geological position of which is very interesting; I mean the *schorl rock*,* a binary compound of schorl and quartz, in which the first considerably predominates. We find masses of it of all sizes, generally of a rounded shape, and coated on the surface with the porcelain earth. There are also large blocks of it in the bed of the Fal,

* "The schorl rock of Cornwall is probably very intimately connected with topaz "rock." Jameson's Elements of Geognosy,

The same author adds in a note—"The geognostic relations and characters of schorl-"rock are not well ascertained, therefore I have declined saying any thing regarding it "in the text."

near St. Stephen's Church. This is not the only place in Cornwall where I found that scarce rock, of which I shall speak more particularly hereafter.

It is difficult to decide, whether the formation of this kaolin clay, (the *feld-spath argiliforme*, of Haüy) is connected with a particular texture of the felspar, dependent on some principle which is inherent in it in the places where this earth is met with ; or whether, as I should be more inclined to believe, we are to attribute it solely to the action of external agents, particularly of the water retained in the crevices of the native rock of the place, which produces a decomposition in one portion of the rock, then acts upon the adjacent parts, and so by degrees, in time extends its effects to a considerable distance.* Whatever be the cause, we know that kaolin is never found but in a primitive country, and forming beds or veins in granite, particularly in that species called graphic granite.

To the already pretty extensive enumeration of the places where kaolin is met with, such as China, Japan, different parts of Germany, of France, &c. I shall add another, which as far as I know has not yet been mentioned, viz. the *Culma d'Orta* in the Milanese, a granitic mountain, elevated one thousand four hundred and fifty-eight

* Ramond found granites in the high chain of the Pyrenees, corroded both externally and internally : not detached blocks alone, he informs us, but whole regions are attacked with this cariousness, the cause of which is still unknown. This corrosion is frequently met with on the northern confines of the chain, where beds of *cornéenne*, of porphyries, of hornblende in mass, and of serpentine spontaneously resolve into clays, fullers earth and marls: these still preserve the appearance and grain of the rock which has produced them, though they now only form an earth easily cut by the knife. Voyages au Mont Perdu, p. 17.

It is the carbonic acid according to Werner, which has changed the felspar into kaolin in granite and gneiss, as well upon the walls of veins as upon the surface of mountains. Nouvelle Théorie de la formation des filons. Journal des Mines, No. xviii. p. 84.

feet above the level of the sea, six miles east of *Varallo*, at the entrance of the vallies of *Sesia Grande* and *Piccola*.

From Grampound to Falmouth, by Creed, Tregony, Tregear, and St. Mawes, grauwacke slate continues the whole way, and the fertility of the country sufficiently indicates it, as that kind of rock is very abundant in springs. The granite ridge begins sensibly to lower, and consequently the grauwacke formation occupies less extent. It is found on the sea-shore, traversed by quartz veins, although it is stratified. I observed this, among other things, in crossing from St. Mawes to Falmouth, near a strong fort on the right, facing Pendennis Castle.

There is something very romantic in the view of the port of Falmouth from the heights of St. Just: it resembles very much the situation of Loch Long and Loch Fine in Argyleshire. There is at first some difficulty in believing that all those creeks which penetrate so far into the interior of the country, are basins of salt water.

I observed on this road, that near Pennare Point, a small promontory a few miles E. N. E. of Falmouth, the cliffs were high and precipitous.

The grauwacke slate still prevails from Falmouth to Menaccan: there is a fine quarry of it from Falmouth to Penryn, which skirts the bottom of the hill on one side, and the King's Road on the other. The beautiful river called the Hel flows over the same rock, at the ferry, near its mouth, from Mawnan to Helford. It is intersected there by a great number of quartz veins, and blocks of it of different sizes are found on the road from Penryn to Mawnan Smith. This very extensive formation at length terminates near a small sea-port called Port-hallo, or as the inhabitants pronounce it, Pralo, which is three miles S. S. E. of Menaccan, across the Dinnis. This river runs in the bottom of a valley, where the substance named menachanite by the the Rev. Wm. Gregor (the *Titane oxydé ferrifère* of Haüy) is found in a stream work.

Before arriving at Port-hallo, I observed in the village of Tregollis, in the parish of St. Kevern, a bed of greenstone of small extent, and this is the last place in Cornwall where I observed that subordinate rock of the grauwacke formation. According to the geological rather than specific characters, this greenstone ought to be considered as belonging to the transition rocks.*

The next formation in importance, which succeeds the grauwacke, is the serpentine. But although it may be seen for some miles before, in the form of large blocks scattered here and there in the fields, and forming part of the materials of the walls of the inclosures, it is not upon this rock that the grauwacke immediately rests, but on a kind of talcose slate, of a greenish grey colour at the surface, tender and shining, soft to the touch, and evidently stratified: it forms a bed of small thickness, the boundaries of which it is difficult to determine. The junction may be seen in the cliffs to the S.S.E. of Port-hallo, immediately upon crossing the brook which runs through that village in its passage to the sea.

A few paces beyond this bed of talcose slate, the serpentine appears in the form of large blocks of an irregular shape, detached one from another and projecting above the surface of the ground : these soon disappear, and on the way to St. Kevern's Church, on the S.S.W. we enter again, for a short time, upon the grauwacke, which shews that these rocks are included in an irregular manner one within the other; and in a cultivated country it is not easy to trace the line of demarcation. It is quite clear, however, that to the S.

* Secondary as well as primitive greenstone is composed of hornblende and felspar, but the grains of it are less crystalline, and less intimately blended. Brochant, Traité de Minéralogie, tome ii. p. 60.

of St. Kevern, there is no more grauwacke. Before coming to the serpentine *in situ*, a rock intervenes, composed of felspar and diallage which I traced very distinctly as far as Treleever, a hamlet about four miles S.S.E. of St. Kevern. The felspar of this rock is compact and opaque, with a tendency to crystallization: the diallage belongs to the variety called *diallage metalloïde* by Haüy: its colour varies from bronze green to a brilliant grey, and it presents very smooth rhomboidal joints; sometimes the felspar prevails in the mass, but most frequently the diallage. This rock is extremely tough, when struck it makes the hammer rebound. There is a quarry of it in the village of St. Kevern, where it is blasted with gunpowder. From what I have seen of the serpentine district, I believe that it is confined to that portion of the country, which lies to the south of a line stretching east and west, from the neighbourhood of Treleever, by Ruan Major, as far as Lower Pradanack; thus including the promontory, the extremity of which is called the Lizard Point. It is possible, however, that the serpentine may extend beyond these limits, or that it may be irregular, as we have found the grauwacke to be; but it is not an object of much importance whether it is so or not. I must not omit to mention, that in the space which the serpentine occupies, there are two formations of rocks in subordinate beds, and of different natures: the one mica slate, which is met with to the S.S.W. of the village of the Lizard, on the way to the light houses, where it forms the cliffs, and appears to extend into the sea, forming those dangerous reefs and sunken rocks, which are seen beyond the Lizard Point: the other is the soap-rock to the north of Kinance Cove.

The serpentine of the Lizard Point is not homogeneous in its composition; the colour of the base is usually leek green, and the fracture often conchoidal, breaking into large broad flakes with sharp edges; it is also frequently striped with red, which appears to be owing to the oxide of iron it contains; small threads of tender yellow steatite are seen running through it, and it is often traversed by veins of whitish asbestos. The course of these veins is very straight, and by their intersections they form nearly regular rectangular pieces, thus disposing the rock to break in those directions.* Sometimes this serpentine passes into a hard steatite, disposed in curved laminæ, and having at the same time a fibrous fracture.

The mica slate of the most southern part of the Lizard has a very brilliant lustre, is of a fawn colour, includes veins of quartz, and is evidently stratified. I was not able to discover any garnets in its composition.

By soap-rock is meant a kind of steatite, so tender that it may be cut as easily as new cheese. It is imbedded in the serpentine. Its colour is a pearly white or grey with red and blue veins, and when pure it has a sort of semi-transparence. On coming out of the quarry, it may be kneaded like a lump of dough, but after having been exposed to the air for some time, it becomes friable, owing, no doubt, to the evaporation of the great quantity of water it contains; it possesses the soapy feel in the highest degree, and pieces of hard stone are included in it, in pretty large quantity. It is used in the manufacture of porcelain for the same purpose as the kaolin, and on

* On the summit of the mountain *de la Garde* near Genoa, Saussure observed a granular serpentine, which divided naturally into polyhedral fragments, most frequently of a rhomboidal form. Voyages dans les Alpes, § 1342.

On the road from Nice to Fréjus, the same geologist found another kind of serpentine, which divided into irregular polyhedral masses. Ibidem. § 1434.

many accounts it might be said that soap-rock is to serpentine what kaolin is to granite.*

Kinance Cove, situated a mile and a half N.N.W. of the Lizard Point, is a kind of small valley *(combe)* in the serpentine formation, opening towards the sea, and exhibiting pillars or detached rocks of very rude forms and appearance, which recalled to my mind those of the high Alps. One of these obelisks projects into the sea; others have been so much excavated by the action of the sea, that fissures, or complete arches have been formed, under which you may walk at low water. When the sea, at the flowing of the tide, begins to rush through these excavations, the whiteness of the foam, contrasted with the brown colour of the rocks upon which it breaks, produces a very striking effect.

From the soap-rocks to Mullyan Church-town, where we re-enter the grauwacke slate, on the west side of the promontory, we walk over a common covered with turf, which prevents us from knowing what the nature of the rock is in that district, it was besides, almost dark when I passed over it.

Remarks on the serpentine formation, and on some rocks which usually accompany it.

Before I proceed to inquire to what formation the serpentine of the Lizard belongs, I shall briefly notice the geological position of

* Are we to refer to a species of kaolin or soap-rock, the white and unctuous clay which the ancients called *terra cimolia*, and which was employed by the inhabitants of the island of Argentiera, formerly Cimolis, instead of soap, for the purpose of cleansing cloth. Lettres sur la Grèce pour servir de suite a celles sur l' Egypte, par M. Savary, p. 370.

one or two rocks in different countries, which almost always accompany serpentine.

It is not in Cornwall alone, that diallage is found in the immediate vicinity of serpentine. It is found on Mount Musinet, two leagues west of Turin, a mountain almost entirely composed of a hard greenish serpentine. The mineral named after Saussure, which he himself calls smaragdite, is the green variety of diallage united with jade. The semiopal or hydrophane is found in a subordinate bed in the same mountain.* I am sorry to say that this last mineral becomes daily more rare: I was not able to procure on the spot a single well characterised specimen, after employing several hours in searching for it.

I found on *Monte Baldissero*, in the Circle of Ivrea, the metalloidal diallage, accompanied also with semiopal, nearly in the same geological position as on Mount Musinet; the only difference is, that the rock which forms the mass of the mountain approaches more to the nature of steatite than of serpentine. I also found in a vein on *Monte Baldissero* a white earth in rounded mamillated masses, which used to be taken for pure alumine, but which Giobert has shewn to be magnesia.† It is used in the manufacture of porcelain.

* Voyages dans des Alpes, § 1313.

† It contains according to this chemist,

Magnesia	68
Carbonic acid . .	12
Silica	15.60
Sulphate of lime .	1.60
Water	3
	100.20

Journ. des Mines, No. 118.

Viviani relates, that the lamellar metalloidal diallage, as well as the jade of Saussure, are found in the serpentine mountains of the Apennines between La Rochetta and Sassello, in eastern Liguria.* It appears to form a subordinate bed in the composition of those small insulated hills, which are for the most part of serpentine, and which are scattered here and there in the great valley which separates the southern extremity of the Alps from the Apennine chain.

I was very desirous of discovering from whence came the vast quantity of blocks, consisting of diallage united with the jade of Saussure, which are met with, not only in the great valley of the Rhone, but also in that distinguished by the name of the *Bassin de Genève*, and I had the good fortune to discover it in 1806, in company with Mr. William Maclure, in the *Visp-Klein-Thal* in the *Haut Valais* on the skirts of Mount Rosa, which is an assemblage of mountains of serpentine. The smaragdite, or green diallage, extends here for the space of several miles, from the village of Saass (eight hundred and eleven toises above the level of the sea) ascending the Vispach, as far as the neighbourhood of Mount Moro at Macugnaga, and very near Meigeren, the most elevated village in Switzerland and the Valais which is inhabited during the whole year. This rock is found in the form of enormous rounded blocks, adhering to the ground, and heaped close together; it is sometimes only a mixture of green diallage, jade, and a little red oxide of titanium; in other places it is green diallage mixed with primitive marble; but I did not find the metalloidal variety there. Serpentine is also the matrix of the schillerspar of the Tyrol, and of that found at Baste or Paste, near Harzburg, at Mezzebergen in Moravia, &c.†

* Journal de Physique, Octobre 1807.

† "I am disposed to consider the hornblende of Labrador, the variety called schiller-"spar, and the smaragdite of Saussure, as one and the same species, as well as the

If we now compare the analyses of these different rocks in order to ascertain, if in their chemical composition, there is the same analogy which their geological situations seem to indicate, the result of that examination will prove by no means so conclusive.

Although serpentine is in itself a simple rock, we find it so often mixed with foreign substances, that it is impossible to obtain by chemical analysis any uniform results. Thus Kirwan has found in one experiment, 0,18 of alumina, while Klaproth found none. Kirwan gives 0,23 as the proportion of magnesia, Bayen 0,33: but there are even greater differences in these analyses.*

With regard to the analyses we have of diallage, by Vauquelin, Drappier, Heyer and Gmelin, they all state a greater or less proportion of lime, a substance never found in serpentine. The smaragdite contains besides, according to Vauquelin, as much as 0,08 of oxide of chromium, and a little oxide of copper. There are also great differences in the proportions of the same principles in the green and metalloidal varieties. Vauquelin found in the first, 0,06 of magnesia, 0,21 of alumina; and Drappier found in the second, 0,29 of magnesia, and only, 0,03 of alumina.† Lime is also, according to Hœpfner and Theodore de Saussure, one of the component parts of jade, but the first finds in it as much as 0,38 of magnesia, while Saussure makes no mention of it. On the other hand, Saussure found soda and potash in jade, but Hœpfner does not seem even to have suspected their existence.‡

" *verde dei Corsica duro* of the Italians. Brochant, Traité de Minéralogie, tome i.
" p. 423."

* Brochant, Traité de Minéralogie, tome i. p. 483.

† Brongniart, Traité Elémentaire de Minéralogie, tome i. p. 442.

Brochant, Traité de Minéralogie, tome i. p. 422.

‡ Idem, tome i. p. 468.

Journal de Phyisque, Mars, 1807, Analyse de la Saussurite appelée lehmanite par De la Metherie.

Thus we find, that all those rocks which are geologically arranged with serpentine, contain in greater or less proportion, several substances quite foreign to it, and what is still less satisfactory, we find that the same rocks analysed by different chemists, frequently give very different results. I believe that upon full examination, we shall agree with the observation of Saussure, that substances of very dissimilar natures are often included in rocks which do not at all, or very slightly resemble them, although both may have been formed simultaneously; but that, in consequence of certain principles of affinity, the similar particles of the different materials suspended in the fluid, united and formed distinct rocks.*

In considering the steatite, a mineral which still more frequently than the diallage and jade accompanies the serpentine, I shall adopt the same method I have pursued in treating of these last substances.

Steatite is found not only intimately combined with serpentine, but frequently in masses forming subordinate beds in that rock; such are the soap-rocks at the Lizard.

There is in the valley of Sesia Grande, about half a league to the north of Alagna, and consequently, at the foot of Mount Rosa, a bed of true potstone in the serpentine. It is so soft as to be worked upon the lathe, and dishes are made of it which are known in the country by the name of *lavezzi*.† But I learned upon the spot, in 1806, that they had given over working the quarry, since it had been encumbered by the fall of an enormous block of serpentine. In the mountains of Chiavenna, and also in the valley of Chamouni, steatite, in scattered blocks is often met with, though, according to the observation of Saussure, less frequently on the side of the Alps than on the side of Italy.‡

Estner suspects, that the beilstein (a variety of steatite) must form

* Voyages dans les Alpes, § 1312. † Voyages dans les Alpes, § 2151. ‡ Ibid. § 716.

distinct beds in primitive mountains, included in rocks of serpentine with which it is closely connected, but he does not give any example.*

Of all the rocks allied to the serpentine formation, steatite is that, without doubt, which approaches nearest to it in chemical composition. The only analyses of these two rocks which I know, are, that of serpentine by Kirwan, and of the soap-rock of Cornwall by Klaproth, who calls it *seifenstein.* The coincidence of these two able chemists in the proportions of the component parts of these substances, renders the idea I had formed, relative to their common origin, more probable. I subjoin a comparative statement of the results of these two analyses. It is possible, that hereafter, when such experiments are multiplied, we may discover too many anomalies to allow us longer to consider these two rocks as nearly allied to each other, and that we shall be obliged to arrange soap-rock as a distinct species of steatite.

Serpentine analysed by Kirwan.		Soap-rock analysed by Klaproth.
Silica	0, 45	0, 48
Magnesia	0, 23	0, 20.50
Alumina	0, 18	0, 14
Iron	0, 03	0, 01
Water	0, 12	0, 15.50
	101	99

We see that with the exception of the silica and the water, which are most abundant in the soap-rock, there is in this last substance a diminution of about 0,03, or 0,04 of all the other component parts

* Brochant, Traité de Minéralogie, tome i. p. 471

of the serpentine, as if they had been destroyed in consequence of the disintegration of the rock, and carried off by the waters.

In what formation then, ought we to place the serpentine of the Lizard? does it belong to the older formation of Werner, or to that which is more recent? the distinctions are in my opinion so vague, that I am almost led to suspect, that the terms are designedly obscure, in order to avoid being more explicit in the definition. Notwithstanding that obscurity, I think I can understand so far, as to discover that the characters by which it is endeavoured to distinguish these two formations, are erroneous, or imply a contradiction, and that if they are followed literally, we shall not in the present instance be able to refer the serpentine of the Lizard, either to the one formation or to the other.

The oldest formation according to Brochant, is found in the vicinity of gneiss and of mica slate, is mixed with granular limestone,* and sometimes this last even predominates. It appears from what Brochant adds respecting the great extent of the newest serpentine formation, that the oldest is of least extent.† Brongniart says, that the oldest formation seldom rises to a very great height, and in noticing the potstones and the beds of iron ore (Fer oxidulé) found in the newest formation, he gives us sufficiently to understand that they are not found in the oldest; he also states, that the newest serpentine occurs in masses or balls, but does not say, whether this is the form in which the oldest is found.‡ Kirwan says, that although the oldest serpentine is not metalliferous, yet it contains magnetic iron, and veins of copper.§

* He does not say whether chemically or mechanically.

† Brochant, Traité de Minéralogie, tome ii. p. 577.

‡ Brongniart, Traité Elémentaire de Minéralogie, tome i. p. 487.

§ Geological Essays, p. 204.

It is easier to shew, that these characters are for the most part erroneous, than to substitute others more precise, and consequently better, in their stead: a negative truth is however in my opinion always of some value.

Monte Rosa is we know, next to Mont Blanc, the highest mountain in Europe; there being a difference of only ninety-six feet between them. All mineralogists and geologists agree that it is an assemblage of primitive mountains.* Brochant does not state the extent of that vast deposit of newer serpentine which he tells us exists at Zoeblitz in Saxony; I think however, that a circuit of mountains of serpentine, the internal diameter of which is thirty thousand feet, and which is bounded by walls, if I may so express myself, fourteen thousand five hundred and eighty feet high, cannot be considered as a deposit of very limited extent.†

As a cap of eternal snow completely covers the upper part of the mountain, it is only by analogy we can say that the serpentine reaches to the top, it can however be traced to a very considerable height. I have observed it myself at ten thousand four hundred and sixteen feet above the level of the sea, at the fort of St. Theodule, in the passage of Mont Cervin. This may serve as a reply to the assertion of Brongniart, that the serpentine of oldest formation does not rise very high. He does not omit, it is true, to mention Monte Rosa as an exception, but he has forgot to produce a single example in support of his opinion. The potstone which is found at Alagna at the foot of Monte Rosa, at the height of three thousand eight hundred feet above the level of the sea, may be considered, I think, by all

* Saussure compares the assemblage of mountains which form Monte Rosa to a tennis court.

† Voyage dans les Alpes, § 2140.

mineralogists, as occurring in the oldest serpentine, as much as that at Chiavenna and elsewhere.

There is a little way below the *Pass-d'Olen*, a ridge connected with the main body of Monte Rosa itself, a bed of magnetic iron* which is worked, though situated at the height of eight thousand eight hundred and fourteen feet above the level of the sea, so that without going out of the boundary of this mountain we find arguments supported by certain facts, proving that the characters which have been pointed out as distinguishing the two kinds of formation, are not well founded. Cornwall furnishes an example no less conclusive, as we find at the most southern point of the Lizard, the serpentine resting on mica slate, though it appears as if occurring there in mass.

Of all the characters which have been considered, I see only one, upon which we can rely in establishing a division in the serpentine formation, if such a division be at all necessary, viz. that the serpentine is found either stratified; or in mass, in balls, and forming subordinate beds. All the other circumstances which have been hitherto thought to characterize the one or the other of these formations, appear to me to belong to both indifferently. It is probable that there may be some reason for admitting a difference of age in the serpentine formation, but on what ground this distinction is to be admitted, does not appear. It is a subject which among a great many others ought to excite the attention of those who are interested in the study of the physical structure of our globe. Let us imitate the example of the most skilful geologists, of Pallas, and of Saussure, who without ever losing

* Brochant also mentions this mine; he calls the *Pass-d'Olen* the *Col d'Olingue*. Traité de Minéralogie, tom. ii. p. 278.

sight for an instant of general views, did not cease to collect in the most patient and judicious manner, observations of detail, which if not in sufficient number to enable us to explain all appearances, have nevertheless the immense value of serving as a compass, and thus preventing us from making retrograde steps in our researches after truth.

Though Mullyan is situated completely in the grauwacke slate, we find here and there in the neighbourhood loose blocks of serpentine, which indicate a transition country, and similar to that on the east side of the Lizard Point between St. Kevern and Menaccan. The cliffs from Mullyan to the neighbourhood of Loe Pool are the highest I have seen on the coast of Cornwall, especially near Pengwinian Point: they form a semicircular line, the regularity of which is broken by angular portions of the rock projecting in some places, and by fissures and indentations in others, exhibiting fine sections of the grauwacke. The continuity of the line is interrupted at Gunwalloe by the mouth of a small river; through this creek the sea-sand is carried at some distance into the interior of the country, covering the soil, and heaped together in some places so as to form little sand hills.

The cliffs become gradually lower as they approach Loe Pool, and the shore is covered with a very fine siliceous sand. At the mouth of the river Loe there is rather a curious fact, and worthy of some remark: the river forms a kind of reservoir at a little distance from the sea, which I found to be one hundred and sixty paces at low water, from which the water runs into the sea by a subterranean passage. The water in the pool is fresh, though the bar of sand between it and the sea is not more than twenty feet high. This shews that the tides do not rise very high, and the inhabitants assured me, that at no time of the year did they find the water in Loe Pool become salt. I tasted it repeatedly and found it quite fresh.*

The coast beyond Portlever rises abruptly, at the distance of a mile and a half from the sea, and at the height of three hundred and sixty feet, we leave the grauwacke and enter the granite, just before we reach the road leading from Helston to Marazion.

It will be recollected that the mountain chain of Cornwall dips to the west, that the land is contracted very much on that side by Mount's Bay, thus cutting off a great portion of the grauwacke formation, for although the road from Helston to Marazion runs nearly the whole way along the shore, it lies directly on the line of transition. The grauwacke rises to the height of three hundred and sixty feet on the side of Tregonning-hill,† from thence the granite continues as far as the sixth mile stone from Helston to Marazion. There, the land gradually lowering to the sea, we enter again on the grauwacke, near the village of Kennegy, but at what height I did not ascertain.

Antiquarians, after very laborious researches, have conceived, that they have found sufficient proofs in the testimony of ancient his-

* This was in the beginning of May.—We find in the History of New Holland, by the Right Honourable William Eden, a fact of this sort, which is nearly similar. "Part "of the Batavia's people were sent to look for water on one of the islands near the "spot where she was wrecked, and having landed there, had subsisted for near three "weeks upon rain-water, and what lodged in the cliffs of the rocks, not imagining that "the water of two wells which were on the island could be of any use, as they saw them "constantly rise and fall with the tide: for they concluded from this circumstance that, "having a communication with the sea, the water must consequently be brackish; how-"ever, upon trial, it was found to be very good, and the ship's company were thencefor-"ward plentifully supplied." p. 12.

† The top of this hill at the signal house is five hundred and eighty-four feet above the sea. Both channels may be seen from this station, which is the most elevated in this part of the country.

torians, that St. Michael's Mount, situated in Mount's Bay, at the distance of a quarter of a mile from the nearest land, (Marazion) had been separated from it at a period, apparently not very remote, since some carry their pretensions so far as to state the quantity of land and the number of churches, that were swallowed up. Dr. Maton has taken the trouble to collect together the different accounts of this matter.*

I do not presume to reject, or even to lessen, the degree of confidence which ought to be placed in historical records of very remote date, notwithstanding the general tendency of the human mind to receive with eagerness every thing that is at all extraordinary, especially if presented in a plausible shape. All that I can say is, that upon an examination of the place, I am satisfied, that if a separation did ever take place (an event certainly possible and even probable) it must have been previous to the deposition of the grauwacke formation, consequently at a period, which I presume is extremely remote from that of any historical record whatsoever. The strata of grauwacke, which all along the south slope of the mountain-chain of Cornwall, invariably dip S.S.E. have here, a direction exactly the reverse, viz. they dip N.N.W. This may be seen near the bottom of the northern side of the mount, which is the least abrupt, exactly in the meridian of Ludgvan Church-town, near a well of fresh water, the only water fit for drinking which the inhabitants have when they are surrounded by the tide.

The grauwacke extends westward, facing Penzance, and seldom rises above the eighth part of the absolute height of the mount ;†

* Observations on the Western Counties, vol. I. p. 197.

† I found by the barometer, the height of St. Michael's Mount to be two hundred and thirty-one feet from the level of the sea to the platform of the tower of the chapel.

it is common grauwacke, with quartz,* and at its junction with the granite, it is traversed by veins of this rock, similar to those I have already mentioned in the valley of the Erme in Dartmoor.† The southern side of the mount is nearly precipitous, and is composed from top to bottom of a granite split into irregular masses; at the bottom is a heap of large blocks, among which, I thought I observed some indications of copper ore, on their surface. Sometimes the felspar and sometimes the quartz predominates in this granite; when it is the quartz, it gives the rock a vitreous appearance: it contains also black tourmaline, and pinite is also said to have been found in it.

Admitting however that the mass of granite of St. Michael's Mount was detached from the land, before the grauwacke was deposited upon it, and conformable with it, the grauwacke could only have rested on the northern face, or that which is the least abrupt, as the southern face is almost perpendicular, which is shewn by the great depth of the sea at the bottom of the mount on that side. But without having recource to this hypothesis, to explain so partial a fact, it would perhaps be more reasonable to admit, that the epoch of the separation and transportation of St. Michael's Mount has been posterior to the deposition of the grauwacke which has remained adhering to the detached mass of granite; and that in settling it has taken such a degree of inclination, that the strata of grauwacke on the south have been completely concealed, and only exposed to view on the northern side. I should not have dwelt so long upon

* The large rocks lying on the bar between Marazion and the Mount, are also common grauwacke.

† Mr. Playfair has described this appearance, with a degree of precision proportionate to the importance he attaches to facts of this sort. Illustrations of the Huttonian Theory, p. 318.

an individual fact, and one of so little extent, were it not that it offers an exception to what I consider as a general law in Cornwall, I mean, the direction and inclination of the grauwacke strata.

A semi-circular beach, covered with fine sand, in front of which stands, in a magnificent bay, St. Michael's Mount, topped by its gothic castle, affords a delightful walk the whole way from Marazion to Penzance. The land rising on both sides, breaks the uniform though imposing grandeur of a horizon bounded by the vault of heaven, and the picture taken in its whole extent, forms one of the most beautiful landscapes that the human eye can contemplate.

At the entrance of Penzance, I remarked some rocks of common grauwacke, which were not I believe *in situ*. We find in the neighbourhood, indications of this rock, but only close by the sea, shewing, that its geological situation is the same throughout the whole extent of Cornwall. Thus, on leaving the village of Newlyn, on the road from St. Paul, it is seen distinctly *in situ*, but one hundred and fifty paces farther, the land rising, though but a little, the grauwacke is lost, and we enter upon the granite. From St. Paul to Mouse-hole, by the sea side, the land again falls, and we re-enter the grauwacke about two or three hundred paces from the church-yard of St. Paul. It is remarkable that the grauwacke, although in so low a situation, is no longer slaty, but compact; it is here, however, near the point of its junction with the granite, a circumstance which, more than its absolute height above the level of the sea, determines its particular structure. At the south end of the village of Mouse-hole, the granite lowers so much, that the grauwacke can only be seen at low water. It contains much quartz, and even felspar, and at the place of junction, there are several veins of granite seen shooting through it.

Of the Veins or Shoots of Granite, which traverse the Grauwacke Formation.

The last place in Cornwall where I met with veins or shoots of granite in the grauwacke, was at Mousehole near Penzance. As the attention of geologists, particularly the supporters of the Huttonian Theory, has been strongly directed to facts of this sort, I shall briefly state the observations I have made on this subject, confining myself to what I saw in Devonshire and Cornwall:* not that I am unacquainted with some of those places on the continent where similar facts have been pointed out,† but because I found them exhibited in this part of England in a manner much more striking and less difficult of apprehension.

1. We never find these veins or shoots of granite but at the point of junction of that rock with the grauwacke, whether that junction be in high situations or on the sea shore.

2. These veins are not independent or insulated, but by following their course we can always trace them to a main body of granite, without any interruption of continuity intervening between them.

* There is a remarkable example of this occurrence of granite veins at the junction with the grauwacke, in New Galloway in Dumfries-shire, on one of the estates of Sir James Hall. Vide third vol. of the Transactions of the Royal Society of Edin. Sir James Hall had a very interesting model of the place made on a pretty large scale, which he has deposited in the collection of the Geological Society.

Mr. Playfair also mentions some other facts of this sort, which he has observed in the course of his travels in England and Scotland. Illustrations of the Huttonian Theory, from p. 307 to 320.

† Voyages dans les Alpes, § 598, 599, 601.

3. In those places which have been thought to prove that granite veins were formed in the same way as metallic veins, they have always been at a considerable depth, such at least, as might reasonably induce us to suppose, that they were very near the main body of the granite.*

4. These granite veins, whether they are found at the surface or at a greater or less depth, are in Devonshire and Cornwall, invariably directed from north to south, which is a direction opposite to that of the metallic veins, but quite conformable with the mode of deposition of the grauwacke on the mass of granite which forms the low mountain chain of Cornwall.

5. These subterraneous granite veins are rarely metalliferous, but when they do contain a metal, it is always tin, which is known to belong to the oldest formation, and which sometimes forms one of the component parts of the granite.

* Granite veins have been found at a great depth in some of the mines in Cornwall, such as Dolcoath, Huel Providence, Huel Gorland, &c.—It is worthy of remark, that the prefix *Huel*, which is given to the greater number of mines in Cornwall, is the same as that by which they are distinguished on the opposite coast of the continent, in Brittany. These veins are called *lodes* by the miners, and divided into two classes, those of granite being called *growan*, and those of porphyry *elvan*. The following are examples of these two kinds :—

a. Vein of granite, found at the depth of one hundred and sixty-one fathoms in the mine of Dolcoath. This granite ought to be called porphyritic, as the particles which compose it are so far separated from each other, that they may be said to be imbedded in a base of common felspar, which is in a state of decomposition. The quartz is of a bluish appearance, and opalescent ; the plates of mica are few, as well as the crystals of felspar ; these last are very well defined.

b. Vein of porphyry in the mine of Huel Providence. This rock is more compact, or more sound than the preceding ; the base is a felspar, of a dirty grey colour, in which are imbedded small crystals of quartz, mica, and felspar of an opaque white colour.

In the Journal des Mines, No. xviii. p. 84, there are some observations on the causes which may have produced these alterations in the texture of granite.

6. The width of these veins does not always diminish as they recede from the main body of granite. Sometimes after a very slender beginning, they swell out, or divide into ramifications.

7. I did not find the veins extend very far, nor rise perpendicularly, on the contrary, I always observed those at the surface to be conformable with the planes of inclination of the ground.

8. At the point of contact of these two rocks I never found the one disseminated in small quantities through the other, the granite never mixes with the grauwacke, but both retain their distinct characters.*

9. In breaking a part of these veins with the hammer it generally happens that the grauwacke separates from the granite, which proves that there was no penetration, but only juxta-position, as if the one had been moulded in the crevices of the other.

Several of these facts appear to me not very easily reconcilable with the following assertion in the work of Mr. Playfair: I quote it in his own words, " It remains certain therefore, that the whole " mass of granite and the veins proceeding from it are coeval, *and* " *both of later formation than the strata.*"†

To the latter part of the above quotation, I cannot assent; I conceive, that at the time the grauwacke was deposited upon the granite, the water in which its particles were suspended, meeting with portions of the granite, a little more elevated than the general plane of the surface, left them exposed, and filled up the spaces between

* At least, if any thing of the kind has been observed, it has never been at such a distance as we might expect it to be, if produced by so considerable a force as that which the Huttonians suppose, but only at the edges; and in this case, it may have happened that the granite was softened by the grauwacke acting upon it as a solvent, so far as to permit pieces of that rock to amalgamate with it.

† Illustrations of the Huttonian Theory, § 82.

them.—If we are to attribute the origin of these veins, according to the Huttonian Theory, to the action of a force from below, and which has caused them to intersect the grauwacke posterior to its formation, how comes it that along the whole line of the superposition of the grauwacke on the granite, they occur in so few places? and how comes it that the grauwacke, without any exception, forms a covering upon the granite, which, as it approaches the junction between it and the primitive rock, continues diminishing in thickness?

From Mousehole to St. Burien, the road continues to ascend, and is now completely in the granite formation. Several projections or hillocks may be seen in the horizon as we advance into the interior of the country; they are all of little height, and to their partial disintegration may be attributed the great number of blocks which are spread over the surface of this plain; it extends to the west, and has that uneven rugged appearance peculiar to a low primitive country.

St. Burien stands, I believe, on the highest point in that part of the country; its height is four hundred and sixty-seven feet above the level of the sea. There is a very extensive view from the top of the church tower, commanding the whole range of the surrounding country, and it is even said, that in clear weather, the Scilly Islands may be seen in the horizon.* The soil in the neighbourhood of St. Burien is mossy, and characterized by that sterility which usually accompanies a granitic country, but it becomes more fertile in approaching the sea. There are two or three druidical barrows, in very good preservation, at a short distance from the town.

The plain on which St. Burien is situated preserves its height

* I did not see them however, the weather, though very fine, being rather hazy.

pretty far to the west, for Sennen, the most western village in England, which is three miles distant from it in a straight line, and only half a mile from the Land's-end, is, according to my observations, but seventy-six feet lower than St. Burien, that is, three hundred and ninety-one feet above the level of the sea.

The cliffs which bound this western shore of England, are nevertheless of small elevation. They are rather more abrupt and more lofty towards the north than towards the south. Mean Cliff and Cape Cornwall are higher than the Land's-end and the Logan rock.

The Logan rocks, or rocking stones, are a heap of blocks of granite on the sea-coast, beyond the village of Traen or Trereen, a little to the south of the road from St. Burien to Sennen, forming a kind of cliff more inclined than abrupt towards the sea. Though there may be to the south of these rocks, near the ancient castle of Trereen, some remains of fortifications, I am satisfied that the logan stones formed at one time only one complete mass of granite, which by the action of the atmosphere and other external agents, has split into irregular blocks: the greater part of these, though separated on all sides from each other, have remained in their original position, but now appear as if they had been placed one above another. It appears to me, that it is in this way granite disintegrates in low primitive countries, and this appearance has, I believe, been often mistaken for strata, and has given rise to the idea that true granite is stratified, an opinion which I cannot adopt, even after having visited those places where Saussure thought he had discovered the strongest proofs in favour of the fact.* Among these logan rocks, there is one which rests upon another by only one

* Observations sur les aiguilles ou pyramides de granit qui sont au sud-est de la vallée de Chamouni. Voyages dans les Alpes, tome ii. p. 62. Edit. 4to.

point, and it is so nicely balanced, that a child may move it with the greatest ease, although it is of a very considerable size. The interesting observations of Mr. Playfair on this subject, render it unnecessary for me to say any thing further concerning it.*

With regard to the nature of the granite itself, the crystals of felspar in it are numerous, very large, and often in an earthy state: the rock is crossed in many places by felspar veins of considerable length: black tourmaline, in large and small crystals, is also very common in the mass: taken in its whole extent, this granite is rough and uneven, furrowed on the surface, and may be said to bear very marked proofs of the hand of time.

At the point which may properly be called the Land's-end, the cliff is abrupt, but not more than fifty or sixty feet high. It is composed of granite, presenting very remarkable appearances, and which might be taken for the work of art, as well as the logan stones. In some places there are shafts which look as if they had been cut with the chisel, in others, regular equidistant fissures divide the rock into horizontal masses, and give it the appearance of a collection of basaltic columns:† in other places again, there are complete arches under which the waves of the sea roll—physical and undeniable proofs of the combined action of time and external agents.

> Sic igitur mundi naturam totius ætas
> Mutat, & ex alio terram status excipit alter.
>
> Lucret. de Nat. Rerum. lib. v.

The Islands of Scilly, nine leagues distant from the Land's-end, are said to be granitic, as well as the Islands of Jersey, Guernsey and

* Illustrations of the Huttonian Theory, § 354.

† What Ramond calls crystalline forms of granite, and which he describes and represents in a plate, in his "Voyages au Mont Perdu," are, in my opinion, only accidental splittings of the rock, though perhaps of a regular form. Page 342, plate i, fig. 1. C.

Alderney, and the adjoining coasts of France. If it were attempted to determine the epoch when the land of Cornwall was separated from the opposite coast of the Continent, and consequently the epoch of the formation of the British Channel, we must, in order to diminish the resemblance as little as possible, fix the date of that great event, immediately posterior to the deposition of the granite, a period lost in the darkness of ages.

Mean Cliff, situated a little to the E.N.E. of the Land's-end, is also entirely composed of granite, and is one hundred and eighty-eight feet high: at the bottom of it is a rock curiously shaped, called by the inhabitants, *the Irish Lady*.*

In descending from Mean Cliff to White-sand Bay, we passed a small village called Escales, at the north end of which we found the rocks laid bare by the sea at low water, to be compact grauwacke: that rock may be traced for some distance under the sea. The same common grauwacke again occurs on the sea-shore a little further to the north. The point of land called Cape Cornwall, stretching out to the west, and which may be considered as the western limit of the northern portion of the mountain chain, is entirely composed of grauwacke, although it is two hundred and twenty-nine feet high, while, at the cliffs east of the cape, the same rock does not rise higher than ninety-three feet.

Advancing from Cape Cornwall into the interior of the country by St. Just, many blocks of *schorl rock* are found scattered on this part of the granitic plain, particularly amongst the rubbish of some old tin mines, which are now scarcely worked. Though quartz be disseminated in small crystals through the mass, it sometimes also

* In the road from Two Bridges to Tavistock, in Dartmoor Forest, Mr. Necker remarked a rock of granite, of which he took a sketch, very much like an Egyptian sphinx in a mutilated state; the same resemblance occurred to us both at the same instant.

appears in the form of rounded nodules, giving the rock a porphyritic appearance. It is very common to find cavities in it, lined with crystallized tourmaline. I did not see this rock *in situ*, but it is so abundant in this district, that I suspect it forms a subordinate bed in the granite, perhaps as the matrix of an ore: in the vicinity of the Land's-end, the granite is often accompanied with masses of black schorl, both amorphous and crystallized.

From St. Just, which is four hundred and four feet above the level of the sea, the granite continues as far as the neighbourhood of St. Ives by Botallach, Morvah, and Zennor, though only at a short distance from the sea. It must however be observed, that the height of the granitic plain continues, and even increases as we advance. Thus, the highest point of that part of the road, in the neighbourhood of Mean Screefis, is six hundred and twenty-three feet above the level of the sea. The tors in that part of the country rise ins uccession, and form an almost uninterrupted boundary to the south of the road. Near St. Ives, the country suddenly lowers, and we enter the grauwacke, but at what place, or at what height, I cannot say.

Leaving St. Ives for Redruth, the road crosses a hill, the top of which lies to the right: it is granitic, but the common grauwacke having a very fine and close texture, appears on its side. The termination of this rock is pretty near the highest point of the road. Being in a hurry to pass the river Heyl, which can only be forded at low water, I had not time to determine the exact height.

The mouth of the Heyl lies in a small inclosed bay between St. Ives and Godrevy, situated N.N.E. of Mount's Bay. By these two bays this part of Cornwall is formed into a kind of isthmus. A great deal of sand is heaped up in St. Ives' Bay, particularly on the east side, forming small sand hills between Gwithian and Phillack.

The grauwacke slate appears on the right or eastern bank of the Heyl, and continues without interruption as far as Redruth. Nevertheless, we are upon its boundary near Camborne, and I should not be surprised if that place, which lies a little to the right of the road, were on granite, for the ground rises in that direction, and at a small distance the Tors make their appearance. I had already observed the grauwacke at several places on the Bristol Channel, but it was of so small extent, that I found it impossible to judge, whether, according to my expectations, the strata dipped N.W. on the northern slope of the chain. There was every reason to expect that this would be the case, as the strata on the opposite side of the chain, have, as I have shewn, the contrary slope; I was therefore much gratified when I found my expectation realized in the course of an excursion I made from Redruth to Portreth, the nearest seaport, and three miles to the N.N.W. I had at the same time a very agreeable walk, and it is the only place where, in this part of the country one could forget for an instant, being in the midst of a mining country, and I may also say in the midst of ruins, for between Camborne and Scorrier House, there is hardly any vegetation to be seen. The ground is on all sides torn up and covered with rubbish and excavations.

In order to go to Portreth, we follow the course of a brook, along the sides of which there are some *stream works:* the country gradually lowers, and the verdure of the meadows foretold the approach of the sea, which we very soon discovered, and as we went through a narrow and woody pass, it had quite the appearance of a lake. When we reached the bottom of the bay, we found the grauwacke fully displayed; the angle which its strata make with the horizon is nearly the same as that which was formerly mentioned.

A little to the south-west of Redruth is a *Tor*,* called *Carn-brea* or *Karn-breh*, with an old castle on the top. This hill forms a ridge extending from E.N.E. to W.S.W. and the highest point of it is six hundred and ninety-seven feet above the level of the sea. The northern side is covered with heaps of granite blocks, which are probably the *debris* of a part of the ridge. The rock appears to be of a very tender texture, and the water retained at the surface by the mould which covers it, contributes, no doubt, very powerfully to its decomposition.†

Carn Marth, another small hill, the summit of which is elevated eight hundred and forty-nine feet above the level of the sea, is distant two miles S.S.E. from Redruth. It is the highest point in the neighbourhood, and from it may be seen the two channels and the port of Falmouth, which is about seven miles distant in a straight line. The upper part of Carn Marth (about one-third) is granite; large blocks are strewed over this part of the mountain, and they appear to have been rolled from the summit. In general, all these

* The small round hills in this part of Cornwall seem to be better known by the name of *Karn* or *Carn*, than that of *Tor*.

† We are so apt to form our opinions on those of others, and to see things only as they have been seen before, that to speak of *Carn-brea* without immediately recognizing it to have formerly been a place consecrated to the worship of the Druids, is almost an insult offered to the greater number of those who have visited the place. Nevertheless, I must freely confess, that the Druidical barrows which are said to be here so distinctly marked, did not appear to me as such, and in my opinion are by no means to be compared to those in other parts of Cornwall, as well as in the north of Scotland. And I can never believe that those rocks which are distinguished by the pompous names of *Judicizing*, *Sirloin*, and *Sacrificing* stones, were ever excavated by the hand of men: indeed I never saw any thing which could more reasonably be attributed to the operation of time. If the Druids had ever made the Alps their habitation, there is no doubt that homage would have been paid to the *Table au Chantre*, the *Pierre ronde*, &c.

tors seem to have undergone great changes by the lapse of time, and they were probably higher at a former period than they now are.

The grauwacke covers the lower part of Carn Marth, and rises exactly to the height of five hundred and forty-three feet, which is about two-thirds of that of the mountain.

According to the mean of nine barometrical observations, the height of Redruth at Gray's Hotel, in the middle of the town, is four hundred and fourteen feet above the level of the sea; about two hundred paces beyond the first milestone from Redruth to Truro, the grauwacke disappears, and is superseded by a ridge of granite which continues exactly to the end of the first mile; there the land lowers, and we re-enter the grauwacke, on which formation Scorrier House stands.*

Porth Towan is another place on the Bristol Channel, four miles from Scorrier House, where the direction and inclination of the strata of grauwacke may be well observed. The cliffs are high and rather abrupt, and the rock has been very much excavated at the bottom by the action of the waters. Quartz abounds in it.

I observed that the grauwacke assumed a more slaty structure as it approached the sea from Scorrier House. The sands at Porth Towan extend pretty far into the interior of the country.

St. Agnes's Beacon is an insulated eminence of a pyramidal form, situated N.E. of Porth Towan, a short way in the interior; it has nearly the same degree of inclination on all sides, and is quite covered with *debris*. It is entirely composed of grauwacke, though six hundred and sixty-four feet above the level of the sea, and in

* Scorrier House, on the road from Redruth to Truro, is three hundred and seventy-seven feet above the level of the sea: it is a house, which mineralogists who visit Cornwall, and who seek instruction as well as good company, ought not to fail to visit.

the upper part this rock is compact. From this eminence there is a very extensive view of the coast, which presents a very irregular broken line.

In going from Redruth to Truro, by Carnon which is at the farthest extremity of Restronget Creek, we follow for some time the road to Falmouth, and for the first three miles at least there is only granite; a little before coming to the road from Penryn to Truro, and just before leaving the parish of Gwennap, the grauwacke formation begins and continues without interruption as far as Truro, its positions to the east of which town I have already described.

General Observations on the Mines of Cornwall.

I passed too short a time in Cornwall, and I am not sufficiently familiar with the practical part of mining to enable me to treat of this interesting subject in detail; I must leave it to those who are more capable. I shall confine myself to a few geological observations alone, and I shall, as may be expected, follow with most other mineralogists the opinions of Werner on the formation of veins.

All mineral beds or deposits whatsoever may, I believe, be referred to one of the three following divisions.

A. Mineral beds.

B. Mineral veins.

C. Alluvial depositions.*

* This denomination, which conveys a very good idea of what is meant here, was suggested by two friends, instead of the less correct French word "minèrais de lavage," (stream-works).

A. *Of Mineral Beds.*

A bed is the mass of a substance different from the rock or rocks of which the mountain is formed in which it occurs, but the direction and position of which are conformable with the strata of the mountain.

Mineral beds are of less extent and of rarer occurrence on the surface of the globe than mineral veins.

We seldom find mineral beds and mineral veins in the same district.

I know of no ores having been found in the form of beds in Cornwall.

There is at Torneo in Lapland, a mountain entirely composed of iron ore, and at Luleo in the same country, the mountain Gelliware is one mass of rich iron ore of a blackish blue colour, which extends like an irregular vein for more than a mile, and is three or four hundred toises in breadth.*

I saw in the valley of Brozzo in Piedmont, five leagues west of Ivrea, at the height of four hundred and fifty-five toises above the level of the sea, a mountain almost entirely composed of very rich iron ore, (the fer oxydulé of Haüy) covered only at the surface with a cap of gneiss or mica slate. Every inhabitant of the valley having the right of working this mine, by paying a very small sum of money to the *Commune*, it cannot be expected that the mining operations are conducted with that method which is the result of theoretical and practical knowledge combined. Every one endeavours to dig out the greatest possible quantity of ore with the least possible trouble and expense to himself. Nothing can be more curious than the appearance of those galleries, if galleries they can

* Geographie Physique de Bergman. Journal des Mines, No. xvi. p. 58.

be called; on entering them with a torch we discover vast chambers or excavations placed one above another, very much resembling the different stories of a house, with a common entrance.

The mine worked at Rammelsberg, and which is of so great an extent, does not appear to be a vein, but an immense mass of ore deposited in that place in the same manner as mountains are formed. Werner is also of opinion that the vein (spitaler hauptang) at Schemnitz, mentioned by Born, as well as two others of equally great thickness, worked in the same place, are rather banks of ore than true veins, judging from the uniformity of their direction and inclination, from their nearly horizontal position, and from what is said of their thickness.*

B. *Of Mineral Veins.*

Veins have originally been fissures in mountains, and intersect the strata or beds of which the mountain is composed. These fissures have been filled from above by substances differing more or less from those of which the mass of the mountain that they intersect is composed, and those substances have been precipitated from a liquid solution.

Werner has brought forward so many facts in support of these two fundamental positions, that his theory scarcely receives a greater degree of stability by any of the farther proofs which are daily discovered.

Two particular cases have come to my knowledge, which I shall, notwithstanding, briefly mention. The one proving that veins have

Journal des Mines, No. xviii. p. 79.

been empty spaces, and the other, that they have been filled from above.

I observed the first in the mine of Dolcoath, between Camborne and Redruth, where, at the depth of seventy fathoms *below* the adit level,* that is to say, according to my observations, one hundred and eighty-four feet *below* the level of the sea, there was found an empty space in the vein of some fathoms in length, and broad in proportion. The walls of it are smooth, which is seldom the case, as these cavities, called by the miners, *druses*, *creaks*, or *pouches*, are almost always lined with crystallisations ; Werner observes, that we find these druses in places where the vein is of greatest thickness. It often very distinctly appears that they have been much longer and wider, but that they have been partly filled up by a new substance having been deposited in them.†

The second fact, I have alluded to, I observed in a coal-pit at Littry in Normandy, two leagues S.W. of Bayeux. In sinking the pit St. George, there was found in a vein at the depth of two hundred and fifty feet from the surface, a conglomerate formed of rounded pebbles, the greatest part of them flints, although the *saalbande* and the rock are of stratified limestone. A branch of a tree was also found, with the ligneous structure preserved.‡ Werner mentions

* The adit level is twenty-seven fathoms below the surface of the ground, where the entrance to the mine is situated, and which is, according to my observations, two hundred and thirty-six feet above the level of the sea.

† Nouvelle Theorie de la formation des filons, p. 80. One of the most singular caverns of this sort, is that which exists at Joachimstal, at the depth of two hundred and fifty toises. This cavern, from which a vast quantity of water ran out, is said to be eleven toises in length and nine in breadth. Its height, which is not yet known, considerably exceeds twelve toises. Ibidem p. 115.

‡ Journal de Physique, Mars 1807, p. 225.

a fact nearly similar, observed in the coal strata near Hainchen. He also saw a vein at Joachimstal, entirely filled with pebbles.* Now, how is it possible that these stones could find their way into the interior of the veins, if these had not been originally open at the top?

Of the comparative Age of Beds and Veins.

Though according to the theory of Werner, the spaces of veins were immediately filled up by precipitations from the same solutions which, by previous precipitations, had formed the mountains, it does not, I think, follow as a necessary consequence that beds and veins are exactly of the same age. The difference which I conceive exists between them is in the mode of their formation.

Beds of ore being now covered by strata of rocks, in a manner conformable with those on which they have been deposited, it follows, that the elements of both were all held in solution at the same time, but that by a play of affinities, which tended to unite together similar particles, sometimes precipitates of the one, and sometimes of the other, took place, by causes which are yet unknown to us; but since they are deposited alternately we may safely say that they are coeval. Veins on the contrary, having been originally fissures, which could not be formed until after the retreat of the waters, when the mass of the mountain was in a soft or semi-indurated state, we may conclude, that at that time, the solutions from which the veins were filled up, were no longer mixed with those from which the mountains were formed, and consequently, that a vein is of posterior formation to a bed.†

* Nouvelle Theorie de la formation des filons, p. 74 and 81.

† It is said, that in the Bannat of Temeswar, the same formation is found in beds, which occurs in veins in Voightland, in Bayreuth, in the Hartz near Lauterbach, and in

C. *Of Alluvial Depositions of Ores.*

I agree with many mineralogists* in the opinion that these accumulations of ore have been originally true veins, worn down and removed by some cause or other from the place where they were formed; that they have been water-worn, and carried to a greater or less distance, where they have been covered by alluvial soil. These washed ores occur every where in similar situations, either in a plain, or in open and very low-lying vallies, in beds or strata, which are generally at a small depth below the surface of the ground, and often

Westerwalde. This formation consists of copper pyrites, red oxide of copper, malachite, brown compact testaceous iron ore, with quartz. Nouvelle Théorie de la formation des filons, p. 168.

Werner endeavours to prove by this, that an analogy exists between the age of veins and beds. But admitting the example just quoted (Werner does not give it as undoubted), does it follow that this formation of beds and veins in different countries is coeval? has not Werner himself told us, that veins of the same nature may be of different ages?

* Klaproth's Mineralogical Observations on Cornwall, p. 11.

Mr. Jars believes these fragments to be remains of heaps of refuse from the ancient unskilful working of the mines, which by inundations have been washed down from the mountains, and formed beds in the vallies. Ibidem, p 11.

Pryce, who was a practical miner, divided the alluvial ores of tin into different kinds. "The *shode* is disjunct, and scattered to some declined distance from its parent "lode, and it is pebbly or smoothy angular of various sizes, from half an ounce to some "pounds weight." *Stream tin ore* is the same as *shode*, but smaller sized, or arenaceous. "It is the smaller loose particles of the mineral, detached from the *bryle* or *back* of sundry "lodes, which are situated on hilly ground, and carried down from thence by the retiring "waters, being collected in large bodies or heaps in the vallies. In the solid rock of the "valley there is no tin ore, but immediately upon it is deposited a layer of stream tin of "various thickness; perhaps over that a layer of earth, clay, gravel, &c. upon that again "another stratum of tin ore, and so on successively, stratum super stratum according to "their gravity, and the different periods of their coming thither." Pryce Mineralogia "Cornubiensis.

accompanied with remains of marine animals or other organized bodies. At Poth stream-works, about four miles from Fowey, on the shores of Trewardreth Bay, tin in the form of round pebbles is found imbedded in a bluish marl, containing the remains of marine animals at the depth of twenty feet. The tin pebbles vary in size, from a grain to that of a small egg.*

At the head of Restronget Creek, not far from Falmouth, the tin-stone of Carnon is found under fifty feet of soil. I saw in the collection of Mr. John Williams, of Scorrier-house, deer's horns which were found in the same soil, and which were in no way mineralized. I was told that trunks of trees and small grains of gold had also been found in it.

The other places in Cornwall where stream tin has been met with, are at Perran Porth in the parish of Perranzabuloe, below the sea-sand in the form of large blackish grains, at Hallibesack in the parish of Wendron, at Frogmoor in the parish of Probus, at St. Dennis and St. Roach in larger, but angular fragments, at Swanpool in the parish of Ladock, often mixed with cubic galena;† at St. Austle Moor, at the average depth of eighteen feet, and at St. Blazey Moor at the depth of twenty-eight feet.‡

The menachanite, which is found in the form of sand in the small valley of Menaccan, at a short distance from the sea, and the iserine, which is also found in the state of sand in the beds of different rivers, as well as in the neighbourhood of volcanoes,§ belong probably to the formation of alluvial ores.

* Maton's Observations on the Western Counties, vol. i. p. 152.

† Klaproth's Mineralogical Observations on Cornwall, p. 13.

‡ Pryce's Miner. Cornub.

§ The iserine is a metallic sand, composed almost entirely of titanium and oxide of iron, and appears to differ very little from the menachanite. Dr. Thomson has analysed

D. *Of the Course of the Veins in Cornwall.*

Almost all the veins in this country, as well as those in Devonshire, belong to the class of oblique or inclined veins. Their degree of inclination varies, but according to the information I received on the spot, and from what I saw myself, I believe, that taking an average, they may be said to dip a foot and a half in each fathom. The point of the compass to which they dip varies. Some mineralogists think that the veins of copper generally dip to the north, and those of tin to the south: but we must look to practical miners for the most accurate information on this head.*

The position or direction of the *productive* veins is from east to west, or more correctly from E.S.E. to W.N.W. forming what used to be called in France *filons du matin.*† It is remarkable that in England, and also in Scotland, all veins of whatsoever age, or of whatsoever ore they may be composed, have nearly the same position, which would seem to indicate, that the cause to which they owe their existence, had acted in the same direction, though at different periods. It appears then that the veins run parallel to each other. The tin veins are not so long as those of copper, and they

that which is found in the bed of the river Dee in Aberdeenshire, and M. Cordier has analysed a great variety of different kinds gathered in volcanic countries. Journal des Mines, No. 124.

* Metallic veins in Derbyshire near Castleton, run from east to west, and are traced or discovered from the surface. They incline about one foot in ten, sometimes to the north, sometimes to the south. Mawe's Mineralogy of Derbyshire, p. 2.

† In Brittany, on the contrary, they consider as barren, all the veins which have a direction from east to west; the best run nearly from north to south, or at least do not vary much from that direction. Journal des Mines, No. xvi.

are even shorter than those which contain a mixture of copper and tin. This appears, at least, by comparing the number of the workings with the number of the veins. The respective length of the three species of veins may, I believe, be pretty accurately represented by the relative value of the following numbers.

Copper . . .	72
Copper and Tin	64
Tin	58

In the parish of St. Agnes, and at other places along the coast, but particularly at St. Agnes' Beacon, the distortion and irregularity in the course of the veins is very remarkable.* The width of the veins varies with the form they assume; when they divide into small ramifications they become poor; when, on the contrary, several small veins converge, and form a belly, then they become rich. I do not believe that there is any vein in Cornwall more than a fathom in thickness, at least if there are any of greater width, they are very rare. Some of the veins in Cornwall penetrate to a very great depth, to one hundred and forty fathoms in Huel Alfred, and one hundred and eighty-eight in Dolcoath, Cook's Kitchen, and Huel Virgin. The copper veins go deeper than those of tin.† There is another fact pretty well known to the Cornish miners, viz. that a change of the rock in which a vein runs, produces a change in the

* Pryce's Mineral. Cornub.

† It is very seldom that tin continues rich and worth the working beyond fifty fathoms deep; and it is absolutely certain, that copper is not often wrought in great abundance, till past that depth, to an hundred fathoms or more. It is also a fact, that most mines with us, both of tin and copper, are richer in quality near the surface. The richest state for copper is between forty and eighty fathoms deep, and for tin, between twenty and sixty. Pryce's Miner. Cornub.

degree of richness, for instance, if a vein was in grauwacke, it would be impoverished by entering the granite, and *vice versâ.*

It was formerly conceived, that the veins of copper belonged exclusively to the grauwacke, and that those of tin were chiefly confined to the granite; but there are now several copper veins worked in the primitive rock: it is however true, that they are near its junction with the grauwacke.*

Cross courses are veins of marl or clay which intersect the true veins in Cornwall nearly at right angles to their direction, that is to say, which run from north to south. The most considerable of these cross courses extends from sea to sea; it passes directly through the meridian of St. Agnes, leaves in the middle of its course the parish of Stythians, three quarters of a mile to the west, and terminates on the south in the neighbourhood of Pedn-Boar-Point: it varies from a few inches to some feet in thickness: the depth to which it penetrates is still undetermined. It not only intersects all the true veins, but it has thrown the western portion of those veins some fathoms to the north of the corresponding portion on the east side of it. These cross courses are evidently of posterior formation

* Mr. Kirwan has endeavoured to explain, why ores are found less frequently in granite than in all other rock formations. He says, "Hence we see why metallic veins seldom occur in granitic mountains or those of jasper, and the harder stones, as their texture is too close to permit the percolation of water, at least in sufficient plenty, and because their rifts were previously occupied and filled with stony masses, as being more soluble, and therefore soonest conveyed into them; thus silex sufficiently comminuted is soluble in about one thousand times its weight of water, or even less, whereas metallic substances require much more; but if the granitic stones are in a state of decomposition, as in the lower mountains they often are in Cornwall, &c. there they may be metalliferous. On the other hand, gneiss and schistose mica, argillaceous porphyry, and argillites being much softer, are the principal abodes of metallic ores." Geological Essays, p. 412.

to the metallic veins, since they cross them, as I had an opportunity of observing at different places in the mine of Dolcoath.

I do not know if there are any other true veins posterior to the cross courses, that is to say which cross them, and the direction of which would in that case be from east to west. Did these occur, it would point out three distinct periods at least, in the formation of veins in Cornwall. Ought the small metalliferous veins which run in the same direction with the cross courses, i. e. from north to south, to be considered of contemporaneous formation with them? It is in a vein of this sort that the arseniate of lead is found. This mineral has been lately discovered in the mine of Huel Unity, and has been analysed by the Rev. Wm. Gregor.*

Although the cross courses are barren veins,† they are nevertheless, always dug into on each side, to ascertain whether they contain any ore left behind by the older vein in the act of its being rent asunder. A metallic vein interrupted by a cross course is more generally impoverished than enriched.‡

* Philosophical Transactions, part. ii. 1809.

† Cross lodes, cross courses, cross flookans, cross gossans, and contres or caunters, are generally quite barren for tin and copper, but we have some few instances of cross gossans being wrought for lead, though not to any great profit. Some antimonial veins run also north and south. Pryce's Miner. Cornub.

‡ Charpentier thinks on the contrary, that a vein is sometimes enriched by meeting with another which is poor or even absolutely barren, or by meeting a vein that is slightly filled up, and sometimes quite empty. He gives as an example, the mining district, called *Le Prince Electoral Frederic Auguste*, at Gross-Schirma, where a large vein suddenly increases in richness, by meeting a very narrow vein, containing only a grey clay, and without any metallic substance whatever. *Journal des Mines*, No. xviii. p. 96.

E. *Estimate of the number of Mines in Cornwall, of the different kinds of ore they contain, and of their relative ages.*

Most of the data on which the facts comprehended in this paragraph are founded, I obtained from a MS map of the mines of Cornwall, executed by Mr. William Phillips in the year 1800. This map is very interesting, and ably executed in all respects, but there are several omissions in it, which may be easily accounted for, as the state of the mines varies from year to year. Old workings are given up, and new mines are daily opening; what follows therefore is to be understood in a relative and not in an absolute sense.

Without taking into account the tin stream-works already mentioned, and the mines of soap-stone, which is a particular object of itself, there were about the year 1800, ninety-nine mines worked in Cornwall.*

Of these, there were forty-five of copper, twenty-eight of tin eighteen of copper and tin, two of lead, one of lead and silver, one of copper and silver, one of silver, one of copper and cobalt, one of tin and cobalt, and one of antimony. To which we may now add, some mines of manganese which were not worked at that time.

Of the copper mines, eleven are in the parish of Gwennap alone, six in that of St. Agnes, five in Camborne, four in Gwinear, the same number in St. Hillary, three in Germoe, Crowan and Illogan, and two in St. Neot. The other mines are scattered singly in parishes more or less distant from each other.

Of the tin mines, seven are in the parish of St. Agnes, four in Wendron, three in Gulval, two in Lelant, Redruth, and Perranzabuloe, and only one in the parish of Gwennap, where most of the copper veins are found.

* According to Mr. Phillips's map.

Of the mines of copper and tin, there are four in each of the parishes of Redruth and Gwennap, three in St. Agnes, and two in St. Neot.

The two mines of lead marked in the above-mentioned map, occur in the parish of Sithney, in a situation which is nearly of the same elevation, as the lead mines of Beer-alston in Devonshire.

The mine of lead and silver is found in the parish of Wendron, and that of silver in the parish of Cubert.

The mine of copper and silver is in the parish of Gwinear; the antimony at St. Austle and Endellyon; copper and cobalt in Camborne; tin and cobalt in Madron; manganese near Launceston and the Indian Queen.

If we examine these localities it will appear, that the copper and tin which either singly or combined form four-fifths at least of the mines in Cornwall, *are met with near the junction of the granite and grauwacke:** but it also appears, that tin may, contrary to the opinion of Werner,† be sometimes found in secondary stratified mountains. It is true that at Kithill, and in the islands of Scilly,‡ it is found in the true granite.

When the tin is not combined with copper, it usually forms a constituent part of the granite, and in this case it is often accompanied by wolfram in the matrix of the vein.§

* Baron Born and Ferber have made the same observations, the former in the Bannat, the latter in the mountains of the Veronese and of the Vicentine. Ferber's Letters on Italy, to Baron Born, p. 36.

† Journal des Mines, No. xviii. p. 90.

‡ "The vestigia of any tin lodes, mines or workings, in the islands of Scilly, are "scarcely discernible; for there is but one place that exhibits even an imperfect ap-"pearance of a mine." Pryce's Miner. Cornub.

§ At Kithill near Callington.

A very singular and very anomalous combination of tin with sulphuret of lead is found in the mine of Heavas in the parish of St. Mewan. There is also a vein at Marienberg in Saxony, in one part of which ores of tin are found, and in another, ores of silver.* Are we to infer, that in some cases the tin veins already formed have been rent, and the new fissures filled with ore of a later formation; or are we to admit, that there are tin formations of different ages?

The cobalt united with tin, found in Wherry mine in the parish of Madron, belongs very probably to the oldest formation of cobalt, the same as that of Gieren in Silesia, which is in a mountain of mica-slate;† for the veins of cobalt in secondary mountains are of very recent formation.

The tin is accompanied with arsenical pyrites, copper pyrites, and even blende, as in the mine of Trevascus. Arsenical pyrites, according to Werner, is of very old formation, although produced at different ages; for we find it (he says) with tin, with galena, sometimes, though rarely, with copper pyrites, and also with arsenical silver ore.‡ It is not usual, he adds, to find copper pyrites with blende, but very frequently this last accompanies galena.

Copper occurs in various forms in Cornwall, independently of its combinations with tin, with cobalt, and with silver: viz. in the native state,§ in the states of red oxide, blue carbonate, green carbonate, sulphuret, grey antimoniated ore, and arseniate. The sub-

* Nouvelle Théorie de la formation des filons, p. 106.

† Ibidem, p. 179.

‡ Nouvelle Théorie de la formation des filons.

§ "Native copper is frequently found in our mines near the clay or surface, or "commonly but a few fathoms deep; though there are some few instances of its being "found very deep, particularly in the mine of Cook's Kitchen." Pryce's Miner. Corn.

stances that have been found to accompany the veins are, arseniate of iron in the mines of Carrarack and Huel Gorland, oxide of uranium in the state of ochre, in Tin Croft mine; bismuth and nickel at Dolcoath, spathose iron at Cook's-Kitchen, and native silver united with decomposed galena in the mine of copper and silver at Herland. Judging of this formation of copper from its being accompanied by bismuth and uranium, we should be led to consider it as very old. Uranium and bismuth being found in this district proves, that those metals may, contrary to the opinion of Werner, be met with in secondary mountains. The nickel, cobalt,* silver, and especially the spathose iron, would lead us on the contrary to refer that formation to a much more recent epoch,† insomuch, that we must perhaps admit, that in the deposits of copper in Cornwall, there are veins of different ages.

It may be possible also, and this idea seems to me the most probable, that the accompanying substances which contradict the uniformity of age in veins of copper, are met with in rents formed at a later period, or in the veins called *cross-courses*, of a still more recent date.‡ It is only however from practical miners, that we can hope to obtain information on this head.

" Native copper is found in very considerable quantity at Cape Lizard, between the " rocks near the sea shore, in filiform branches, and veins of some thickness, contained " in blackish serpentine, in Huel Virgin, Carrarach, at Poldory in the clefts of moun- " tains composed of killas." Klaproth's Miner. Observ.

* " At Huel Trugo also, a copper mine near St. Columb, some of the purest Cobalt " has been worked. Very good cobalt has been also discovered in Dudnan's mine in " Illogan parish." Pryce's Miner. Cornub.

† Ramond has also found in the Pyrenees indications of nickel and cobalt, at the junction of the veined granites with the *cornéennes*, i. e. in a geological situation very analogous to that of Cornwall. Voyages au Mont Perdu, p. 206 and 239.

‡ It is said, however, that bismuth never accompanies cobalt and nickel in deposits of new formation. Journal des Mines, No. xviii. p. 94.

The relative age of the different formations of silver, according to Werner, is not yet determined.* The vein which was formerly worked at Huel Mexico in Cornwall, was in grauwacke slate. The ore appeared to be mixed in it in the form of insulated masses or nests; besides the native silver, corneous ore (muriate of silver) was also met with. This last ore, of all the combinations of silver, is that which is most frequently found at the surface of veins.†

Silver united with lead in the state of galena is found in the mine of Huel Pool, and filiform native silver, with vitreous silver and decomposed galena, has been met with at Herland; we know that these two metals combine very readily, so much so, that we rarely find a mine of lead which does not contain more or less silver. The mines of Beer-alston in Devonshire, contain a pretty large proportion of it. The most important mineral deposit at Freyberg is of silver and lead.

Grey antimony ore (sulphuret) is sometimes found in primitive, and sometimes in secondary mountains. According to most geologists it belongs to the middle ages of our globe. It was formerly worked in different parts of Cornwall; among others at Padstow Harbour and Camelford near St. Teath, and more lately at Huel

Bismuth unaccompanied by any other metal does not form veins, but kidney-form masses. Thomson's System of Chemistry.

I do not know exactly under what form the bismuth has been found at Dolcoath, I believe in the kidney form.

* At Freyberg and in Norway, silver is found in gneiss, at Johanngeorgenstadt in clay slate, mica slate and hornblende. Nouvelle Théorie de la formation des filons.

According to Bergman, silver is found in quartz, limestone, and sometimes in petrosilex. It is often accompanied with blende, pyrites of different metals, among which may be particularly noticed, antimony, zinc, cobalt and lead. Journal des Mines, No. xvi. p. 25.

† At Frankenberg in Hesse, leaves of native silver have been found upon petrifactions. Nouvelle Théorie de la formation des filons, p. 185.

Buoys in the parish of Endellyon. All these workings are now given up.*

Manganese has only lately been worked in Cornwall, and it appears to afford considerable profit to the proprietors of those mines. The ore is shipped direct for Lancashire, where for some years it has been employed in the bleaching of cotton. I was informed of two mines of this metal, the one near the Indian Queen, on the road from Bodmin to Truro, the other at St. Mary Magdalene, a mile to the south of Launceston; both are consequently situated in the grauwacke formation. It is the pink siliciferous oxide of manganese, which is worked at St. Mary Magdalene, the same variety that is found in the mines of Nagyag in Transilvania. I have already given a detailed account of the mine of brown oxide of manganese at Upton Pyne in Devonshire, accompanied with ferriferous carbonate of lime, &c. Dr. Maton, at the time of his last visit to Exeter, was informed that the working of this last mine was abandoned, and that others had been opened at Newton St. Cyres, four miles N.W. of Exeter.†

Manganese usually accompanies iron stone mines.‡ The soil at Upton Pyne evidently contains a considerable quantity of iron in the state of red oxide; but whether it is found in the situations just

* There exists a small deposit of grey antimony accompanied with quartz, in the circle of Freyberg; it is considered as subordinate to an older deposit of antimoniated sulphuret of silver. Nouvelle Théorie de la formation des filons, p. 303.

According to Bergman, antimony is found in kidney-shaped masses, and in threads, in veins of galena and hematites. It is also found native at Carlson, and in the mine of Sala. Journal des Mines, No. xvi. p. 34.

† Observations on the Western Counties, vol. II. p. 74.

‡ Penzilly in Breage parish affords hematite of a liver brown colour, mixed with Manganese. This fossil is found in a vein of yellow friable iron ore, through which it runs in veins of different thickness and position. Klaproth's Miner. Obser. p. 31.

mentioned, I cannot say. Manganese as well as antimony occurs in primitive and in secondary mountains, and the different formations of it appear to belong to a middle age.

The lead formation is of very small extent in Cornwall, it is confined to the low parts of the county. This metal is known to occur particularly in calcareous countries, rarely in primitive rocks ; it is one of those metals most universally spread over the surface of the globe, especially in the state of galena. Werner conceives that the numerous formations of this metal are of very different ages.*

The ferriferous oxide of titanium belongs almost exclusively to primitive countries. The locality of the menachanite proves nevertheless, that it may also be met with in secondary countries. The naturalist, to whose accurate researches we are indebted for the discovery of the menachanite, has also observed it in a kind of sonorous petrosilex, which I consider as the clinkstone of Werner, and which had been picked up in the neighbourhood of south Brentor in Devonshire, where it is found in blocks on the surface of the fields. We know in fact, that the oxide of titanium exists in a great number of rocks, even in granite.

With the exception of platina, mercury, molybdena, tellurium, tantalium, columbium and cerium, Cornwall affords indications of all the other known metals, in one shape or other, in mass, forming deposits, or as adventitious substances in the veins.†

* Galena in large cubes is found at Treseavan, with copper pyrites : at Poldice mixed at the same time with cupreous and arsenical pyrites in quartz and killas : and at Penrose there is a rich vein of it which opens upon the surface. Klaproth's Miner. Obser. p. 30.

† Becher in his remarkable dedicatory epistle to the famous Boyle of his mineralogical alphabet which he wrote at Truro, says, The earth is here so abundant in different kinds of fossils that I believe there is no place in the world which excels Cornwall in the quantity and variety of them. Klaproth's Miner. Obser. Introd. p. 3.

It will have been remarked, that calamine or carbonate of zinc, so common in stratified limestone, is found in no part of Cornwall that I am aware of, although blende, or sulphuret of zinc, occurs pretty abundantly in the veins.

Those who know the geological situations of coal will not expect to find it in Cornwall. There is at Bovey in the eastern part of Devonshire, a kind of brown coal or bituminized wood *(braun-kohle)* which contains some very remarkable substances. I refer however for a full account of this substance to the interesting memoir of Mr. Hatchett.*

According to Klaproth, asphaltum or indurated bitumen has been found somewhere in Cornwall in granite, at the depth of ninety yards.† I am not acquainted with the locality, but I should suppose that the presence of this inflammable principle in that situation must be owing to some local and accidental cause.

Among the substances that are combined with the different metals of which the mineral deposits of Cornwall are composed, there are two which merit particular notice, both on account of their very general occurrence, and also because they appear in certain circumstances to act considerably upon the rocks with which they are in contact, altering their texture, and distintegrating them, as if they had been exposed to acid vapours. These two substances are sulphur and arsenic.

This change of appearance in the rock in contact with the veins, and which sometimes extends pretty far, takes place principally where the ore is strongly combined with sulphur. It is found to continue for some distance *from the actual contact of the ore*, so much so, that in following a barren vein, if we come to a place where the

* Philosophical Transactions, 1804, part 2.

† Miner. Obser. p. 32.

rock is decomposed, it may be concluded that ore will very soon be found.* The arsenic acid, according to Werner, produces a similar alteration upon rocks, and the carbonic acid also appears sometimes to contribute to this decomposition. It is in porphyritic rocks, sienite, gneiss, mica-slate, and clay-slate, that this alteration principally occurs, but it is still more distinctly seen, where felspar is found, as has been said above in noticing the veins of granite, which have been found at a great depth in some of the mines of Cornwall.†

F. *Of the different Matrices accompanying the mineral Deposits in Cornwall and Devonshire.*

By *saalbande* is understood a slip or band interposed between the vein and the rock which forms the body of the mountain. The

* Théorie des filons, 151. 156.

† The action of these substances is not confined to rocks alone; their effects seem to me to extend even to the workmen. The miners are affected in a somewhat similar manner as the unfortunate criminals who are employed in roasting the ore in the arsenic and cobalt mines of Saxony, where they live almost continually in an atmosphere of arsenical vapours, and are seen to languish at the end of a few years. This poison is, no doubt, infinitely less powerful in Cornwall, but there are many other circumstances which combine with it to destroy the health of the workmen. I was nevertheless very much struck with the pungent smell of garlic in the galleries after a blast, or when a vein has been worked for a long time with the pick-axe. A blow of the hammer alone, upon some parts of the ore, produces a very powerful smell. It is possible, however, that this smell of garlic may in part be produced by antimony, for we know that this metal, even in a pure state, when strongly heated, gives out a vapour, the smell of which is very similar to that of arsenic.

Whatever may be the respective effects of these various causes, it is certain that the miners never live to an advanced age: fifty-five is a very long life for them. I was anxious to consult the parish register of Redruth, in order to ascertain the average life of the miners compared with the husbandmen, but was prevented by want of time.

saalbande is in general of a different nature from the substances to which it is contiguous: it is sometimes composed of clay, sometimes of amianthus, of mica in layers, &c. It is not found in all veins, and those from which it is absent are said to be adherent. This is, I believe, generally the case in Cornwall.

Vein-stones are the different stony substances with which the ore is intermixed, and which as a whole constitute the vein. It is these vein-stones which I now propose more particularly to consider.

Werner is of opinion that in the same vein the parts of the vein-stone nearest to the saalbande are the oldest, those in the middle the most modern, and the intermediate parts of a middle age. But whatever may be the age of these different parts of the vein, they are all necessarily posterior to the rock of the mountain in which the vein occurs, and in the present case, to the granite and the grauwacke, the only two formations of any extent that are met with in Cornwall and Devonshire.

As the same vein-stones are found in different formations of veins, we must therefore admit, that the same rocks have been held in solution at different periods.

Massive quartz sometimes forms alone the greatest part of the vein-stone of certain veins. This is the case at Kithill near Callington: I believe that here the quartz is united to the granite without any saalbande intervening.

In the tin mines between St. Just and Cape Cornwall, quartz is united with black, massive, and radiated tourmaline. The quartz exists not only in the form of veins, but also in blocks. According to Bergman, there is in the mountain of Nasa, a block of quartz several hundred yards broad, and double that dimension in length.*

* Journal des Mines, No. xvi. p. 41.

Dodecahedral hyaline quartz is frequently found among the vein-stones of the lead mines at Beer-alston in Devonshire.

Swimming quartz is met with in the copper mine of Huel Gorland, and in that of Suit and Cloak, or Pednandrae, united with tin and calcedony. The same quartz is said to be met with at Nancothan.

Compact quartz, passing to quartz-agate and calcedony, is very common in the old mines of Beer-alston. It may be said to form the principal part of the vein-stones. It is combined with fluor, galena, and blende, which are disseminated through it in small masses.

Calcedony, in the form of stalactites, is found at Huel Sparnan and Trevascus. In the former place, it is combined with chlorophane, a variety of fluor, which was thought to be peculiar to Siberia.*

In the copper and tin mine of Tol-carn in the parish of Gwennap, a kind of flint, commonly known in England by the name of *chert*, has been found with semi-opal in a decomposed granite; and jasper-agate has been found in the tin mine called Ding-dong in the parish of Gulvall.

Pitchstone has been met with in the copper mine of Carrarach, one of the *consolidated mines*.†

* Fluate of lime does not usually enter into the composition of primitive rocks; it is said however, that the violet variety called clorophane is found disseminated in a granitic rock, in eastern Siberia; and Dandrada mentions having seen in Sweden, in the district of Norberg, extensive strata of mica-slate mixed with fluate of lime in compact masses, and with nodules of quartz. Brongniart, Traité Elem. de Minér. tome i. p. 246.

† In the island of Arran, there are appearances of pitch-stone in the form of veins traversing the granite, but as all veins are of posterior formation to the rocks which they traverse, this cannot be equally old with the granite or other rocks reckoned primitive.

From these several facts we may conclude, that although quartz is the oldest vein-stone, it has nevertheless been produced at different periods under various forms.

Spathose iron, though scarce, is however one of the vein-stones at Beer-alston.

But fluor appears to be by far the most common vein-stone in both Devonshire and Cornwall. It is more generally disseminated in particles, than occurring massive: it belongs almost entirely to the green variety, and differs in intensity of colour from a greenish-white to a bluish-green with a dull aspect. It is of a brittle texture, and slightly coherent: it is found, I believe, in the middle parts of the vein, and is therefore of the most recent formation. It chiefly occurs in the copper mines.

Perhaps the different colours of the fluor may, to a certain extent, have some connection with the different periods of its formation. Red or pink fluor, as far as I know, has never been found but in primitive countries: it has been met with in the valley of Chamouni, near the glacier of Talcul, in the valley of Urseren, not far from Mont St. Gothard, &c. The violet or blackish-green fluor is chiefly peculiar to the stratified limestone of Derbyshire, and the green variety would seem to characterize that of Devonshire and Cornwall.

Dr. Kidd mentions a bivalve shell in the mineralogical cabinet of Oxford, the interior of which is lined with imperfect crystals of transparent fluor,* shewing undeniably, that fluor is in some cases

These veins (of pitch-stone) traverse the common argillaceous sandstone in Morven, and are often of a great magnitude. In the island of Mull, it seems to lie between sandstone and basalt, but in Eigg it forms considerable veins traversing basalt. Jameson's Mineralogy of the Scottish Isles. vol. i.

* Kidd's Outlines of Mineralogy, part i. p. 74.

of very recent formation. This fact, which Dr. Kidd conceives to be unique in its kind, appears less extraordinary, since the discovery by Morichini of fluate of lime in the enamel of some fossil elephants' teeth, where it was mixed with phosphate of lime and gelatine.*

In the mine called Stony Gwynn, in the parish of St. Stephens, violet fluor is found combined with vitreous quartz, phosphate of lime, and yellowish foliated talc, forming a very hard and compact rock, which constitutes the saalbande. This rock is certainly not the same with that forming the mass of the mountain, although it resembles it, thus demonstrating its antiquity. The middle parts of the vein, in the same mine, although more recent, are however, in my opinion, of much earlier formation than the greater number of the other mines in Cornwall. It is a rock which has some resemblance to the topaz-rock of Werner; and is composed of a fine quartz, more or less granular, with yellowish or white foliated talc. In the middle part of the vein, there are frequent cavities, lined with rock crystal, and crystallized apatite. This assigns a pretty remote age to the last-mentioned substance as well as to the talc, which is conformable with the ideas of Werner. The schorl rock may perhaps be considered as a vein-stone, or rather as forming a saalbande.

Carbonate of lime is of very rare occurrence in Cornwall; I saw a very fine specimen of schiefer-sparth, (*slate-spar*, or chaux carbonatée nacrée of Haüy) in the collection of Mr. John Williams, which had been found, I believe, in the tin mine of Polgooth.

Such are the few observations I had to make on the ores and

* Brongniart, Traité Elem. de Minér. tome i. p. 246.

their matrices. Before closing this memoir, I shall venture to offer some conjectures on the causes to which some of the great phenomena in the physical structure of Cornwall may be attributed, and on the epochs of their occurrence, more particularly with respect to the formation of the veins and the *cross-courses.*

It appears to me, that the force which produced the fissures that now contain the veins must have acted upon the northern and southern slope of the chain: that at the time when the waters fell into the British Channel on the one side, and into the Bristol Channel on the other, the granite ridge, as well as the upper part of the strata of grauwacke, being left exposed and in a state of softness, must, when left to their own weight, have yielded on the sides where they were no longer supported, and that owing to this cause, fissures, or empty places, were formed on each slope, parallel to the length and to the direction of the chain, that is to say, from east to west; and that these spaces, being afterwards filled up with different materials held in solution, formed the veins such as we now see them.

But the body of water still serving as a support to the strata at the base, while they were deprived of it in the upper parts, it necessarily followed that the fissures were confined to the parts of the chain which were first left exposed; and we find, in fact, that the greater number of the mines are situated on a line which is a little below that of the junction of the granite and the grauwacke.

Farther, there must have been at an after period some great convulsion, which produced the falling down or hanging of the chain towards the west; the formation of the cross-courses, and consequently the breaking across of the true veins; and lastly, the dislocation of some portion of the chain, the fragments of which carried down into the plain on the eastern side,* were accumulated there, and again consolidated by the waters, thus affording those beds of conglomerate which have been already noticed in the course of this memoir.

* Does not the weight of the substances included in the conglomerate, described p. 98. seem to give some weight to this conjecture ?

Table of the different heights which indicate the line of superposition of the secondary on the primitive rocks in the low mountain chain of Cornwall.

Names of Places.	Heights in feet above the level of the sea.
DEVONSHIRE.	
Kithill, near Callington (on the slope)	700 by approx^{n}
Ivy-bridge Hill (on the slope)	631
Harford Church, Dartmoor Forest (neighbourhood of) . .	658
Dartmoor Forest, three miles and a quarter from Tavistock on the road to Two Bridges	1129
St. Mary Tavy (neighbourhood of)	648
CORNWALL.	
Bodmin Downs, seven miles and a quarter from Launceston .	800
Step Aside, a hamlet two or three furlongs from St. Stephen's Church	635
Carn Marth (slope of) one or two miles S.E. of Redruth .	543
Tregoning Hill (slope of) about five miles E.S.E. of Marazion .	360
St. Michael's Mount	It is at a very small elevation, but not having determined it accurately, I prefer omitting it.
Newlyn, a village about a mile S.S.W. of Penzance. . .	
Mousehole . . , ...	0
White Sand Bay, parish of Sennen	0
Cape Cornwall (cliff)	93

I ought to mention that I only mark the junctions of the grauwacke with the granite, which I observed myself; if it were desired to have the list complete, a great many other localities ought to be added.

*Table of the heights of different places in Devonshire and Cornwall, determined by the barometer.**

Names of Places.	Heights in feet, above the level of the sea.		Observations.
	By the Barometer.	By the trigonometrical measurement of Lt. Col. Mudge.	
DEVONSHIRE.			
Exeter . . .	123		Mean of four observations.
A hill, one or two miles north of the village of Thorverton . .	703		
Oakhampton . . .	423		
Ivy-bridge	310		Mean of four observations.
Summit of a hill to the N.N.E. of Ivy-bridge	1130		
Harford Church in Dartmoor Forest	658		
Source of the river Erme in Dartmoor Forest	1131		
Two Bridges in Dartmoor Forest . .	1148		
St. Mary Tavy . .	648		
Brentor Inn . . .	802		
CORNWALL.			
Whitesand Bay Cliff to the S. of Saint Germains . . .	338		
Saltash	173		
Hill on this side Saint Mellion, on the road to Callington . . .	436		
Hill beyond St. Mellion, on the common: the highest point in the road between Saltash and Callington . . .	675		
Callington	428		

* I made use of the portable barometer of Sir Henry Englefield, Bart. which seems particularly suited for the geological traveller. The heights have been calculated according to the formula of Sir George Shuckburg, which Sir H. Englefield recommends in the paper where he describes this instrument. Phil. Mag. Feb. 1808.

Names of Places.	Heights in feet above the level of the sea. By the Barometer.	By the trigonometrical measurement of Lt. Col. Mudge.	Observations.
Kithill Top . . .	942	1067	The weather was very variable on this day, and the only correspondent observation by the sea side that I had was the arithmetical mean between two, made at the distance of several hours from the time of my observation on Kithill. I am therefore inclined to think, that the trigonometrical measurement is in this instance most to be relied on.
Launceston . . .	591		
The Jamaica Inn, Bodmin Downs . .	825		
Bodmin	188		
Indian Queen . . .	491		
St. Stephen's Church .		605	
Granitic Mountain-plain, near the China pits	830		
Menachan	153		
St. Kevern's Church .	213		
Mullyon Church Town	280		
Tregoning-hill, Signal-house	548		
St Michael's Mount .	231		240 Maton's Observ. on the Western Counties, vol. i. p. 195. I do not know whether it was by the plumb-line, or by what other process, that this result was obtained.
Buryan	467	519	
Sennen	391	387	
Mean Cliff, parish of Sennen	188		
Cape Cornwall . .	229		
St. Just Church Town	404		
Highest point in the road between St. Just and Zennor, near Mean Screefis	623		
Redruth, Gray's hotel	414		Mean of nine Observations.
Carn Brea . . .	697		
Counting-house at Dolcoath . . .	372		Mean of two Observations. 360 Klaproth's Min. Observ. p. 27.
Redruth Church Parsonage	350		
Carn Marth . . .	849		
Scorrier House . .	377		Mean of two Observations.
St. Agnes' Beacon .	664	621	In this instance, the simple method, that is to say, the difference alone of the logarithms of numbers which express the heights of the barometer at each station (six hundred and sixteen feet), is more correct, or at least comes nearer to the trigonometrical measurement, than the method with the corrections.

N. B. The comparative experiment on the sea shore, and on St. Agnes' Beacon, were carefully made, there was a very short interval between each, and the observations were made in a line nearly vertical, between two and three o'clock, in the afternoon.

VII. *An Account of "The Sulphur," or "Souffrière" of the Island of Montserrat.*

By Nicholas Nugent, M.D.
Honorary Member of the Geological Society.

On my voyage last year (October 1810) from Antigua to England the packet touched at Montserrat, and my curiosity having been excited by the accounts I received of a place in the island called "The Sulphur," and which, from the descriptions of several persons, I conceived might be the crater of an inconsiderable volcano, I determined to avail myself of the stay of the packet to visit that place.

The island of Montserrat, so called by the Spaniards from a fancied resemblance to the celebrated mountain of Catalonia, is every where extremely rugged and mountainous, and the only roads, except in one direction, are narrow bridle paths winding through the recesses of the mountains; there is hardly a possibility of using wheeled carriages, and the produce of the estates is brought to the place of shipment on the backs of mules. Accompanied by a friend, I accordingly set out on horseback from the town of Plymouth, which is situated at the foot of the mountains on the sea shore. We proceeded by a circuitous and steep route about six miles, gradually ascending the mountain, which consisted entirely of an uniform porphyritic rock, broken every where into fragments and large blocks, and which in many places was so denuded of soil, as to render it a matter of astonishment how vegetation, and particularly that of the cane, should thrive so well. The far greater part of the whole island is made up of this porphyry, which by some systematicks would be considered as referable to the newest floëtz trap formation, and by others would be regarded only as a variety of lava. It is a compact and highly indurated argillaceous rock of a grey colour, replete with large and perfect crystals of white felspar and black hornblende. Rocks of this description generally pass in the West Indies by the vague denomination of fire-stone, from the useful property they possess of resisting the operation of intense heat. A considerable quantity of this stone is accordingly exported from Montserrat to the other islands which do not contain it, being essential in forming the masonry around the copper boilers in sugar works. We continued our ride a considerable distance beyond the estate called "*Galloway's*," (where we procured a guide) till we came to the side of a very deep ravine which extends in a winding direction the whole way from one of the higher mountains to the sea. A rugged horse-path was traced along the brink of the ravine, which we followed amidst the most beautiful and romantic scenery. At the head of this ravine is a small amphitheatre formed by lofty surrounding mountains, and here is situated what is termed "The Sulphur." Though the scene was extremely grand and well worthy of observation, yet I confess I could not help feeling a good deal disappointed, as there was nothing like a crater to be seen, or any thing else that could lead me to suppose the place had any connexion with a volcano. On the north, east and west sides were lofty mountains wooded to the tops, composed apparently of the same kind of porphyry we had noticed all along the way. On the south, the same kind of rock of no great height, quite bare of vegetation, and in a very peculiar state of decomposition. And on the south-eastern side, our path and the outlet into the ravine. The whole area thus included, might be three or four hundred yards in length, and half that distance in breadth. The surface of the ground, not occupied by the ravine, was broken and strewed with fragments and masses of the porphyritic rock, for the most part so exceedingly decomposed as to be friable and to crumble on the smallest pressure. For some time I thought that this substance, which is perfectly white and in some instances exhibits an arrangement like crystals, was a peculiar mineral; but afterwards became convinced, that it was merely the porphyritic rock singularly altered, not by the action of the air or weather, but, as I conjecture, by a strong sulphureous or sulphuric acid vapour which is generated here, and which is probably driven more against one side by the eddy wind up the ravine, the breeze from any other quarter being shut out by the surrounding hills.*

Amidst the loose stones and fragments of decomposed rock are

* This peculiar decomposition of the surrounding rock has been frequently observed in similar situations, and under analogous circumstances, and has I find been accounted for by other persons in the same way: thus Dolomieu says, "La couleur blanche des "pierres de l'interieur de tous les craters inflammés est due a une veritable alteration "de la lave produite par les vapeurs acido-sulfureuses qui les penetrent, et qui se com- "binent avec l'argile qui leur sert de base, y formant l'alun que l'on retire des matières "volcaniques." Voy. aux Isles de Lipari. p. 18.

And he afterwards adds, "cette alteration des laves par les vapeurs acido-sulfureuses, "est une espèce d'analyse que la nature fait elle meme des matières volcaniques. Il y a "des laves sur lesquelles les vapeurs n'ont pas encore eu assez de tems d'agir pour les "dénaturer entièrement, et alors on les voit dans differens ètats de decomposition que "l'on reconnoit par la couleur."

Alum is doubtless formed at this place, as well as elsewhere under similar circumstances: the potash necessary for the composition of this salt, being, as well as the argil, derived from the surrounding rock. See Vauquelin's Memoire. Journ. des Mines, vol. x. p. 441.

many fissures and crevices, whence very strong sulphureous exhalations arise, and which are diffused to a considerable distance; these exhalations are so powerful as to impede respiration, and near any of the fissures are quite intolerable and suffocating. The buttons of my coat, and some silver and keys in my pockets were instantaneously discoloured. An intense degree of heat is at the same time evolved, which, added to the apprehension of the ground crumbling and giving way, renders it difficult and painful to walk near any of these fissures. The water of a rivulet which flows down the sides of the mountain and passes over this place, is made to boil with violence, and becomes loaded with sulphureous impregnations. Other branches of the same rivulet which do not pass immediately near these fissures, remain cool and limpid, and thus you may with one hand touch one rill which is at the boiling point, and with the other hand touch another rill which is of the usual temperature of water in that climate. The exhalations of sulphur do not at all times proceed from the same fissures, but new ones appear to be daily formed, others becoming, as it were, extinct. On the margins of these fissures, and indeed almost over the whole place, are to be seen most beautiful crystallizations of sulphur, in many spots quite as fine and perfect as those from Vesuvius, or indeed as any other specimens I have ever met with. The whole mass of decomposed rock in the vicinity is, in like manner, quite penetrated by sulphur. The specimens which I collected of the crystallized sulphur, as well as of the decomposed and undecomposed porphyry, were left inadvertently on board the packet at Falmouth, which prevents my having the pleasure of exhibiting them to the society. I did not perceive at this place any trace of pyrites, or any other metallic substance, except indeed two or three small fragments of clay iron-stone at a little distance, but did not discover even this substance any where *in situ.* It is very probable that the bed of the glen or ravine might throw some light on the internal structure of the place, but it was too deep, and its banks infinitely too precipitous, for me to venture down to it. I understood that there was a similar exhalation and deposition of sulphur on the side of a mountain not more than a mile distant in a straight line; and a subterranean communication is supposed to exist between the two places.

Almost every island in the western Archipelago, particularly those which have the highest land, has in like manner its "Sulphur," or as the French better express it, its "*Souffrière.*" This is particularly the case with Nevis, St. Kitt's, Guadaloupe, Dominica, Martinico, St. Lucia, and St. Vincent's. Some islands have several such places, analogous I presume to this of Montserrat; but in others, as Guadaloupe, St. Lucia, and St. Vincent's there are decided and well characterized volcanos, which are occasionally active, and throw out ashes, scoriæ and lava with flame. The volcano of St. Vincent's is represented by Dr. Anderson, and others who have visited it, as extremely large and magnificent, and would bear a comparison with some of those of Europe. These circumstances appear to have been entirely overlooked by geologists in their speculations concerning the origin and formation of these islands. It has indeed occurred to most persons, on surveying the regular chain of islands, extending from the southern Cape of Florida to the mouths of the Orinoco, as exhibited on the map, to conclude that it originally formed part of the American Continent, and that the encroachments of the sea have left only the higher parts of the land, as insular points above its present level. But this hypothesis, however simple and apparently satisfactory in itself, will be found to accord very partially with the geological structure of the different islands. Many of them are made up entirely of vast accretions of marine organized substances; and others evidently owe their origin to a volcanic agency, which is either in some degree apparent at the present time, or else may be readily traced by vestiges comparatively recent. There is every reason to believe, however, that some of the islands are really of contemporaneous formation with the adjacent parts of the continent, from which they have been disjoined by the incursions of the sea, or by convulsions of nature, and it is probably in those islands which contain primitive rocks, that we are chiefly to look for a confirmation of this supposition.

VIII. *Observations on the Wrekin, and on the great Coal-field of Shropshire.*

By Arthur Aikin, Esq.

Member of the Geological Society.

AMONG the many interesting features which the mineral formations of the County of Salop present to the geological observer, there is none more worthy of study than that line of hills of which the Wrekin is the most celebrated. It has attracted the notice of several mineralogists, and especially of Dr. Townson;* but even this acute observer appears to have fallen into some important errors on the subject, principally from not having investigated with sufficient accuracy the nature and bearings of the different beds on each side of the elevated central ridge. I shall not therefore, I trust, be considered as occupying unprofitably the time of the Geological Society by the following general sketch of my own observations on the same district.

The red sandstone, which forms the surface of so large a portion of Cheshire and of the northern half of Shropshire, extends but a few miles south of Shrewsbury to the west of the confluence of the Tern and Severn: from this latter point a line drawn N. E. to the town of Newport will form the boundary of the sandstone in this quarter; but from Newport this rock passes nearly due south between Shifnal and Prior's Leigh to the Severn, crosses this river

* Townson's Tracts, p. 158.

three or four miles above Bridgenorth, and accompanies its course to Wire forest, the extreme south-eastern point of the county. The eastern limit of this tract extends into Staffordshire, approaching within a few miles of the county-town, whence it proceeds south to the village of Tettenhall near Wolverhampton, and then passes by Kidderminster to beyond Droitwich.

This rock consists for the most part of rather fine grains of quartz with a few spangles of mica, cemented by clay and oxyd of iron. Its colour is generally brownish-red, and it has but little cohesion; on which account large tracts of loose deep sand are found in many parts of it. Sometimes it occurs nearly of a cream colour, and is then sufficiently hard to form an excellent building stone: it does not effervesce with acids, and, to the best of my knowledge, never contains shells or other organic remains. Rolled stones of quartz, of granite, of greenstone-porphyry, and of other primitive rocks, are found dispersed over its surface and imbedded in the loose sand, but are rarely, if ever, observed at any considerable depth in the solid rock. It rises at an angle of 10° or 12° between S. and S.W. At Alderley Edge in Cheshire, it is mixed with grey oxyd of cobalt, and contains veins of heavy spar with galena and yellow copper ore; and is tinged green by oxyd of copper at Hawkestone, at Pym-hill, and elsewhere in Shropshire. The salt deposit of Northwich, and the salt-springs of Droitwich, of Adderley near Drayton, and of Admaston and Kingley-wich near Wellington are subordinate to this formation. Its southern extremity in Shropshire rests upon highly elevated strata of grauwacke. It is covered in several places by thin strata of sandstone-slate, which passes into slaty marl containing shells: these beds rise in the same direction as the sandstone on which they rest, but with an angle rarely exceeding 6°. The general face of this tract is an undulated country, having usually the southern declivities of the hills considerably steeper than the northern, and sometimes even quite precipitous, where they constitute the boundary of the vallies of the Severn, and the other principal streams that flow through it. None of these hills, in the Shropshire part of the district, exceeds the height of four hundred feet above the level of the Severn at Coalbrook-dale. Another circumstance remarkably characteristic of this kind of sandstone, is the great number of *meres*, or deep pools, which it contains. The outline of all these pools more or less approaches to circular: they receive no streams, and very often do not transmit any, the loss by percolation and evaporation being nearly supplied by the springs that occupy the middle and deepest part of their bottoms; I say nearly, because all that I have examined bear evident marks of gradual diminution: in many, this change has advanced so far as to convert the whole area, with the exception of a deep pit or two near the centre, into a peat-moss, and some of the smaller and shallower ones are not only entirely filled up, but are even converted to the purposes of agriculture. The above characters seem to identify this rock with the *old red sandstone formation* of Werner.

That portion of it which lies between the great coal-fields of Staffordshire on the east, and of Shropshire on the west, is about twelve miles wide. The Staffordshire strata dip rapidly towards it in a western direction, while those of Shropshire decline towards it, at a lower angle, in an eastern direction. Whether they actually pass under the sandstone, or terminate abruptly on coming in contact with it, has not yet been demonstrated; many intelligent miners are of the former opinion: but to me, the latter appears the more probable, from an observation that was made a few years ago in Welbach colliery near Shrewsbury. In this coal-field, as in the two before mentioned, the strata dip towards the sandstone; and there being occasion to put down a drainage pit, its place was fixed upon about one hundred and fifty yards further in the dip of the work than a pit which had already been sunk through the regular coal-strata to the depth of about one hundred yards: when the new pit was begun, the workmen were surprised on finding themselves in the sandstone; they nevertheless persevered till they reached the depth of fifty yards, when the work was abandoned, the entire sinking having been in an uniform bed of red sandstone.

The town of Newport may be considered as marking the apex of an acute angle formed by one line passing to the S.W. through a trap-formation including the hills of Lilleshull, the Wrekin, the Lawley, Caer Caradoc, and Ragleath; and by another line running nearly due south and coinciding with the western edge of the red sandstone. The stratified rocks included within this angle rise to the west or north-west, and of course have their dead level or line of horizontal bearing between N. and S. and N.E. and S.W. being inflected towards the one or the other of these points apparently by their proximity to the sandstone or to the trap. They are also much more closely accumulated on each other, and are generally elevated at a higher angle, as they advance from the south to the north: thus, the same succession of strata, which occupies a line of between four and five miles in the parallel of Caer Caradoc, is contracted within a space of less than three quarters of a mile in the parallel of the Wrekin.

I now proceed to give a brief detail of the several strata and beds, beginning with the most recent.

The *independent coal-formation* is found immediately adjacent to the red sandstone from Wombridge in the parallel of Wellington to Coal-port on the Severn, a length of about six miles; its greatest breadth is about two miles. It rises west a little to the north at an angle of about 6°. It is composed of the usual members, namely, of quartzose sandstone, of indurated clay, of clay-porphyry, of slaty-clay, and of coal, alternating with each other without much regularity, except that each bed of coal is always immediately covered by indurated or slaty-clay and not by sandstone. The series is the most complete in the deep of Madeley colliery, where a pit has been sunk to the depth of seven hundred and twenty-nine feet through all the beds, eighty-six in number, that compose this formation.

The sandstones which make part of the first thirty strata, are fine-grained, considerably micaceous, and often contain thin plates or minute fragments of coal. The thirty-first and thirty-third strata are coarse-grained sandstone entirely penetrated by petroleum; they are, both together, fifteen feet and a half thick, and have a bed of sandy slate-clay about four feet thick interposed between them. These strata are interesting, as furnishing the supply of petroleum that issues from the *tar-spring* at Coalport. By certain geologists this reservoir of petroleum has been supposed to be sublimed from the beds of coal that lie below; an hypothesis not easily reconcilable to present appearances, especially as it omits to explain how the petroleum in the upper of these beds could have passed through the interposed bed of clay so entirely as to leave no trace behind; it is also worthy of remark, that the nearest coal is only six inches thick, and is separated from the above beds by a mass ninety-six feet in thickness, consisting of sandstone and clay strata without any mixture of petroleum. At the depth of four hundred and thirty feet occurs the first bed of very coarse sandstone or grit; its thickness is about fifteen feet. The next bed of sandstone deserving notice occurs at the depth of five hundred and seventy-six feet, is about eighteen feet thick, is fine-grained and very hard, and often mixed with a little petroleum; the name given to it by the colliers is the *big flint*.

The lowest sandstone, called the *little flint*, is the eighty-fifth in number, and is about fifteen feet thick; the lower part of it is very coarse, and full of pebbles of quartz; the upper is of a finer grain, and sometimes is rendered very dense and hard by an intimate mixture of iron ore; it occurs at the depth of seven hundred and five feet. Vegetable impressions are met with in most of the sandstone beds, but I have not heard of their containing any shells.

The clay porphyry occurs only once in the whole series; it forms a bed nine inches thick, at the depth of seventy-three feet from the surface. The basis of this rock is a highly indurated clay of a liver-brown colour, in which are imbedded grains of quartz, of hornblende and of felspar.

The indurated clay is mostly of a bluish-brown colour with a tinge of olive, which by decomposition passes to bluish-grey and ash-grey, and, when containing much iron, to ochre yellow and red, and becomes very tough and plastic. In some beds it is compact, dull and smooth, but somewhat meagre to the touch, and is then usually distinguished by the name of *clod;* in others it is glossy, unctuous, and tending to a slaty texture, and is then called *clunch*. It incloses subordinate beds of clay ironstone in the form of balls more or less compressed, or in flat pieces of considerable magnitude, and two or three inches thick. Besides vegetable impressions, it contains a few shells; small mytili in particular are found in the iron ore, called *crawstone*, which lies immediately above the little flint. One of the most remarkable beds of this clay is called the *pinny* or *penny-measure*. It is the sixty-third in number, lying the next below the big flint, and occurs at the depth of five hundred and eighty feet. Its thickness in Madeley colliery is scarcely seven feet, but at Ketley is full twenty-seven feet; in the latter district it contains subordinate beds of ironstone in flattened nodules, called *pen-*

nystone, and also of a singular substance, here called *curlstone.* This latter is a bluish-grey limestone intimately mixed with clay ironstone, and occurs in distinct concretions of the size of a cubic foot or more, bearing a rude resemblance to the capital of a Corinthian column, each of which is again subdivided into irregular cones, laterally aggregated, the larger of which contain smaller ones included within them. The singularity and uniformity of structure, observable in each concretion, seem to render the animal origin of this substance very probable.

The ironstone is first met with, at the depth of about five hundred feet, in the twenty-eighth bed from the surface, the thickness of which is nearly twenty-seven feet. Being often wanting in the upper part of this bed, it is named when found in this situation *chance iron-stone:* that which is met with in the lower part of the bed is of much more general occurrence throughout the whole extent of the coal-field, and is called *ball-stone.* The other beds of iron ore are five in number, and are distinguished by the following names, viz. *yellow-stone*, *blue-flat*, *white-flat*, *pennystone*, and *crawstone.* These all form subordinate beds in indurated clay, each bed being composed of balls or of broad flat masses.

The slaty-clay, called by the colliers *basses*, is of a bluish-black colour and a slaty texture; it usually contains pyrites and is always either intimately mixed with coal or combined with petroleum; in the former case it passes insensibly into slaty coal, and in the latter into Cannel coal; so that the real beds of coal in some parts are found to degenerate into basses, and on the other hand the basses often contain very tolerable coal.

The beds of coal usually present a mixture of slate coal and pitch coal, rarely of Cannel coal: none of it possesses the quality of caking. Several beds are so penetrated by pyrites that the coal which they yield can only be applied to the burning of lime: these are called *stinking coals*. The first coal forms the ninth bed from the surface, at the depth of one hundred and two feet, and is not more than four inches thick: it is very sulphureous. In the space between this and three hundred and ninety-six feet, lie nine other beds of stinking coal, none of which exceeds the thickness of seven inches except the lowest, which is a little more than a foot and a half thick. The first bed that is worked is a five-foot coal at the depth of four hundred and ninety feet, between which and the big-flint sandstone, already mentioned, are a ten-inch and a yard coal.

But the greatest deposit of coal is in the space (about one hundred feet) between the big and little flints, consisting of nine beds, the aggregate thickness of which is about sixteen feet. Beneath this, and the lowest bed of the whole formation, is a sulphureous eight-inch coal.

The depths and thicknesses mentioned above are such as present themselves in the *meadow pit* in Madeley colliery, which from its offering a greater number of strata than are to be found in any other pit, deserves to be considered as the best authority for the whole coal field, as far as regards the number and order of the beds of which it is composed. But, by consulting the registers of the other collieries, we learn, that some of the strata composing this formation, especially the beds of coal and clay, are by no means so regular, either in their extent or thickness, as is generally represented to be the case with stratiform floetz rocks.

Thus, if we confine our attention only to those beds which lie between the big and little flints, and which constitute by far the most regular part of this coal field, we shall find that the pennystone bed, which in the Madeley pit varies in thickness from six to eight feet, is fifteen feet thick at Lightmoor, about twenty feet at Dawley, sixteen feet at Old-park, and eighteen feet at Ketley. That the *Viger* coal, with its superincumbent clay, occupies a thickness of about twelve feet at Madeley, is diminished to three feet at Lightmoor, and is entirely wanting in all the collieries which lie to the north of the latter. That a bed of clay, usually known by the name of the *upper clunches*, bears a thickness of from fifteen to twenty-six feet in all the above mentioned collieries, except that of Ketley, where it is entirely wanting.

The rock upon which the coal formation rests, is either die-earth or limestone.

The *die-earth*, or dead earth as it is also called, is a name given by the miners to this bed as indicative of the fact that from hence downwards all the coal strata *die* or cease. Its colour is greyish ; and it consists of fine sand, of particles of limestone, and of clay, mixed together in very various proportions ; it is often also micaceous. It has sometimes a strong tendency to a slaty structure and a stratified arrangement, with which also the direction of the spangles of mica that it contains for the most part corresponds. It contains a few bivalves, chiefly of the genus cardium, and the entomolithus paradoxus, or *Dudley fossil*. The thickness of this bed is very various, from a few feet to an hundred yards ; it incloses fragments of limestone, and is interposed between the limestone and the coal-formation without possessing the dip or direction of either one or the other.

In order to obtain a clear idea of the *limestone-formation*, it will be necessary to commence our observations at the south-eastern extremity of the district here described, where we shall find two parallel ranges of limestone running nearly N.E. and S.W. Of these ranges, that which lies the most easterly will first engage our attention. It consists of a line of hills, between five hundred and six hundred feet above the level of the Severn; and about two hundred feet above the second ridge, hereafter to be described. These hills consist of beds of limestone and sandstone rising to the N.W.; hence their south-eastern sides present an uniform slope, while their north-western are nearly precipitous. They are separated from each other by short strait vallies, which run nearly in the direction of their dip and rise; and from their nearly equal heights, their correspondence of stratification, and the strait line along which they are distributed, there can be but little doubt that the vallies, by which they are separated from each other, are of later formation than the hills, which last at some former period constituted an uninterrupted range. This limestone is characterized by the madrepores which it contains, particularly the *catenaria*, or chain coral, by the pentacrinite, by small ammonites, by a few bivalve shells, and especially by the natural joints of the strata being often lined by flesh-coloured tabular heavy-spar. Detached lumps of galena are often found on the surface, and a few small veins of the same mineral have been traced in various parts, but chiefly near the southern extremity of the range; cavities lined with and occasionally full of petroleum occur at the northern extremity, where it comes in contact with the coal-formation. The names of the hills constituting this tract of limestone are, Mochtre Forest on the borders of Herefordshire, Norton Walls, Feifton Forest, Munslow Hill, Mogg Forest, Benthal Edge, and Lincoln Hill. The elevation of the strata, from the Herefordshire border to the northern extemity of Mogg Forest, does not exceed an angle of 9°; but when, after having crossed the upland valley in which Mar brook takes its rise, we arrive at Benthal Edge, it appears that this latter ridge, though evidently a mere continuation of that already described, rises at an angle of 12°. Soon after, the strata change their direction from N.N.E. to east by north, and at the same time acquire an elevation of 36°. Benthal Edge is separated from Lincoln Hill merely by the narrow valley of the Severn, at that place not two hundred yards wide; and the strata of this latter hill have the same direction as Benthal Edge, but their horizontal angle has increased to 45°, and the height of the hill above the level of the Severn is considerably inferior to that of Benthal Edge. Beyond Lincoln hill the strata, as far as they have been explored, preserve the same angle and direction; but their height is not superior to that of the coal-field which they traverse, hence the circumstances of their termination in the neighbourhood of the red sandstone are unknown.

In a geological point of view, the limestone strata above described are remarkably interesting. We see them stretching for several miles, nearly in a strait line, N.E. and S.W. with an elevation not exceeding 9°; and this part may be considered as exhibiting the limestone, with regard to these circumstances, in its original situation. The interval now occupied by the valley of Mar brook points out the direction of a fracture caused by the motion of the whole body of limestone between this brook and the Severn, which has elevated its north-western and proportionally depressed its south-eastern extremity. The narrow valley of the Severn itself points out another nearly parallel fracture, caused by an analogous and probably contemporaneous motion of the strata of Lincoln Hill, by which it is obvious that the present valley of the Severn was formed. With the above unequivocal fact is connected an important object of enquiry, namely, the mode by which the elevation and depression of these beds was effected.

With regard to this question, it may be observed that strata are capable of vertical motion by a force acting either from below upwards, or from above downwards; in the former case, the force must have been applied to the elevated portion, in the latter, to that which is depressed. It does not appear how a great extent of strata can be first raised and afterwards supported in its new position otherwise than by a mass of fluid matter, capable of subsequent consolidation, bursting up from below with a great force; nor on the other hand is it easily conceivable how an extensive depression can take place except by some great cavity under the depressed part giving way. Now, in the present instance, if we examine the elevated extremity of Benthal Edge, we shall find that between the abrupt termination of this, and the low range of limestone called Wenlock Edge, (hereafter to be described) which lies about a mile to the west, the whole intervening space is occupied by shattered fragments of limestone strata and great irregular deposits of die-earth, but without the smallest appearance of basalt, amygdaloid, or those other unstratified rocks which by many geologists are considered as the great instruments by which the heaving up of strata is effected. The non-existence, at least the non-appearance, of these in the present case, countenances the opposite hypothesis of depression; and this appears still more probable from an examination of the coal strata superincumbent on the eastern end of the limestone in the parish of Brosely, which are full of fractures, thus indicating very considerable disturbance in that part.

The western range of Limestone runs precisely parallel to that already described as far as the Severn; its average height rarely exceeds three hundred feet above the level of this river. It forms an unbroken range with a nearly even top, on which account it is known by the name of Wenlock *Edge*. It is very full of tubulites and other coralline remains, but I have never seen in it any of the heavy-spar which characterizes the eastern range. In its line of direction and in its rise and dip it corresponds with the before-mentioned limestone, except that the angle which its strata make with the horizon is very uniformly 8°, undergoing no change in this respect as it approaches the Severn. But when it has crossed this river and crops out beneath and to the west of the coal strata at Little Wenlock, it appears elevated at an angle of about 20°, and forms a continuous line parallel to the Wrekin as far as the Steeraway-hill, the northern extremity of the range, where the strata are suddenly raised to between 30° and 40°.

In tracing the outburst of this deposit of limestone it is impossible not to be struck by the uniformity in the line of direction of the whole ridge, at the same time that the elevation of that portion north of the Severn so greatly exceeds the almost horizontal position of the part which lies to the south of that river. A second circumstance peculiar to the elevated portion is its intimate connexion with a green-stone trap of which no traces are to be found in the other part of the range.

This *greenstone* is perfectly unstratified, and forms two principal deposits; the one constituting the chief mass of the hill on which the town of Little Wenlock is built, the other that of Steeraway-hill.

Of this greenstone there are several varieties. Sometimes it is of a dark bluish-green colour, passing into iron-grey; is massive, glimmering, of a coarse-grained uneven fracture, and breaks into irregular rather blunt-edged fragments; it gives a pale greenish-grey streak, is considerably heavy and difficultly frangible. When immersed in an acid an effervescence is perceived from various parts of its surface: by examination with a lens it appears to be composed of hornblende and felspar, with a little calcareous spar and mica.

In the next variety it is coarser, consisting for the most part of visible grains of white or greenish-white felspar and hornblende, and often exhibits an arrangement in egg-shaped masses, from a foot to a yard in length, each mass being obscurely composed of thick curved concentric laminæ, and pretty uniformly covered externally by a coat, an inch or more in thickness, of hard fibrous calcareous spar. In this variety, where the greenstone is not figurate, it is more or less amygdaloidal, inclosing globules of radiated calcareous spar. Another remarkable variety that it assumes, is where, in addition to the two former component parts, there is a predominating proportion of flesh-coloured felspar giving the rock a sienitic appearance. All these varieties are strongly magnetical, but the figurate is most so.

At Little Wenlock this rock appears for the most part to occupy the space between the coal-formation and the subjacent limestone, and accordingly, at the eastern foot of the hill may be seen the great body of the coal at its usual angle, while the little-flint sandstone (the lowest member of the coal-formation) highly elevated, covers the ascent of the hill, and is found in several detached patches on its summit, but in nearly horizontal strata. The general cultivation of the surface of this hill is a great obstruction to minute research, a difficulty that fortunately does not apply to the other great deposit at Steeraway, where an excellent opportunity of observation is afforded by the limestone quarries at that place. If we begin our research in a little shallow valley, about two hundred yards wide, that lies at the bottom of the eastern side of the Steeraway-hill, we shall first find the flint-coal and the little-flint sandstone cropping out very evenly at an angle of about 6° on the eastern side of the valley. The bottom of the valley itself, as far as can be ascertained, on account of the covering of grass which overspreads its surface, is die-earth. The western side of the valley (the first step of the ascent of Steeraway-hill) presents fragments of a bed of limestone, between which protrude masses of coarse globular greenstone; then occurs a bed of sandstone slate, or flagstone, at an angle of 35°, which is succeeded by a bed of limestone elevated at nearly the same horizontal angle; then come four more beds at an angle of 40°, being an alternation of sandstone and limestone, and the last of these reaches to about two thirds of the ascent of the hill; the remainder, together with the summit, consists of amorphous and sienitic greenstone, covered with fragments of sandstone-slate strata, the inclination of which, as far as can be ascertained, approaches much more to horizontal than that of the preceding. Although for the sake of brevity and clearness I have characterized the above formation as an alternating series of four beds of sandstone and limestone, yet it must be observed that each limestone bed consists of several strata, each about a foot in thickness, composed alternately of compact limestone and of bluish-grey clayey marl filled with very delicate and brittle tubulites, the direction of the tubes being perpendicular to the plane of the strata.

An important geological question now occurs with regard to these beds, which in their composition and in the general line of their direction bear a close resemblance to the limestone of Wenlock Edge, though they differ so greatly in the amount of their horizontal angle; are they or are they not in the position in which they were first deposited? The negative side of this question appears to be supported by the impossibility of a bed of sandstone, and much more of clay marl (or mud as it no doubt was in its original state) being deposited on a plane at an elevation of from 30° to 40°, in such a manner as to constitute an extensive stratum of an uniform thickness, and that hardly exceeding a foot, for a depth of at least one hundred feet. The position also of the tubulites which pierce through the marl is a subsidiary argument of no small weight: these tubes, some of which are very thin and scarcely an eighth of an inch in diameter, with a length of twelve inches, are in a position perpendicular to the plane of the stratum, which, when this latter is at an angle of 40°, causes the coralline tubes to form with the plane of the horizon an angle of 50°; a situation by no means agreeable to the known habit of this class of animals which always affects a vertical position with regard to the horizon.

If then it be conceded that these beds have undergone a vertical motion, what remains is to collect the local probabilities relative to each of the two methods, by which, as already described, mineral beds are elevated or depressed.

The principal argument in favour of motion by depression, is the absence of any unstratified rock between the elevated stratum and that which naturally lies below and in contact with it; to which may be added the fracture and disturbance of those superincumbent beds which lie on the dip of the elevated stratum. These circumstances, however, are directly the opposite of those which take place at the Steeraway-hill; for, in the first place, the coal strata that lie upon the limestone crop out with perfect regularity, and nearly horizontal, along the opposite side of the valley, parallel to the hill and not more than two hundred yards from it, a line which, on the hypothesis of depression, would be the precise situation of the principal disturbance. Secondly, the beds of limestone and sandstone, which a hundred yards south of the Steeraway are found with an elevation of about 24° and resting immediately on a soft and sandy slate clay, are in the Steeraway itself tilted up at an angle of 40°, with a great mass of greenstone interposed between them and the slate clay. Is it not therefore probable that the greenstone has occupied the situation which it now holds, posteriorly to the formation of the stratified rocks between which it is at present found, and that to this intrusion is owing the high elevation of the limestone? But though the above facts should be considered as justifying the hypothesis of the active agency of the greenstone, and consequently its fluidity, I am by no means prepared to affirm that this fluidity was that of igneous fusion; for neither the sandstone, nor the limestone, nor even the crumbling clayey marl appear to me to have undergone the smallest alteration by the contact or close vicinity of the greenstone.

The bed which lies immediately below the limestone and greenstone is (as I have already mentioned) a soft, rather sandy *slate-clay*. Its colour is bluish-brown and greyish white, and some of the strata contain egg-shaped nodules highly impregnated with clay iron, inclosing the impressions of marine remains. It is very shivery and easy of decomposition, passing into a tenacious blue clay. On the south of the Severn, along the bottom of Wenlock-edge, it may very distinctly be seen supporting the limestone, and, like this latter, rising west by north at an angle of about 8°; but on the north of the Severn, and especially in the vicinity of Little Wenlock and Steeraway, its place seems to be taken by the greenstone already described.

This bed rests upon another of considerable thickness composed of a fine-grained soft micaceous stone of a dirty bluish-green colour, passing into greenish-grey and ochre yellow. On inspection by the lens it is manifestly a fine-grained mixture of green hornblende and brownish felspar with numerous spangles of mica, and little or no quartz. It is composed of strata which are alternately massive and slaty, and in the latter the direction of the mica is strictly parallel to that of the bed. That part of the bed which lies to the south of the Severn is elevated at an angle of 37° rising N. N. W. and forms a ridge of considerable height in the parallel of the Lawley and Caer Caradoc, on which are situated the villages of Cardington, Church

Preen and Kenley. The texture of this stone is loose, so as readily to admit the infiltration of water, in consequence of which the hornblende decomposes into a yellowish-brown clay, and then the rock is apt to be confounded with clayey sandstone-slate.

The space between the outburst of this bed and of the quartz-grit, hereafter to be mentioned, is a valley, the bottom of which is occupied by patches of a *sandstone*, varying considerably in its external appearance, presenting no marks of stratification or regular position, and (as I apprehend) not belonging to the series of strata, but quite superficial and composed of the materials of the two beds upon which it is situated, together with small shells, either entire or in fragments, belonging chiefly to the genus cardium. It always contains mica, but for the most part in small scales, and dispersed irregularly through its substance.

The *quartz-grit*, which is the next bed, consists essentially of quartz in rounded grains from the size of a pin's head to that of an egg. In some parts it is so entirely free from admixture as to be well fitted for the finer kinds of porcelain, since it acquires a snowy-white colour by calcination; but more generally it is mixed with angular fragments of the bed which lies beneath it, in a state of greater or less decomposition. Its northern boundary is the Arcal hill, the eastern side and top of which it entirely covers; it then skirts along the eastern side of the Wrekin, overspreading it to about one third of its height with conical hillocks. It is interrupted by the valley of the Severn, but re-appears on the south of this river, constituting the high ridge whereon are situated the parks of Acton-Burnwel, and Frodesley; it then runs parallel to the Lawley, but separated from it by a deep valley; the ridge then rapidly declines in height, and applies itself on the eastern side of Caer Caradoc (as it had before done on the Wrekin) accompanying this hill along its whole length, and then terminating.

This bed is very distinctly stratified; it rises N.W. at an angle of about 55° where it rests on the Wrekin and Caer Caradoc, but in the intermediate space at an angle of about 40°.

Beneath the quartz-grit lies a very extensive bed of *claystone* or *compact felspar* (for it presents the characters of both these minerals in different places, and even occasionally passes into jasper). Sometimes it is very distinctly slaty and stratified, which is particularly the case with the lowest part of the bed, which rests on greenstone and amygdaloid, and occasionally exerts a pretty strong action on the magnetic needle. The craggy eastern side, both of the Wrekin and of Caer Caradoc, consists of the slaty variety of this rock in nearly vertical strata; at the Arcal hill, it appears in the state of compact felspar, covered to a considerable thickness by a mixture of fragments of greenstone and felspar, more or less decomposing into a tenacious clay; it is nearly pure compact felspar at Wrockardine hill, the sides of which are covered by a soft brownish-red very fine-grained sandstone, probably originating from the decomposition of the felspar.

Under the claystone occurs an unstratified *trap-formation* which constitutes the great mass of the Wrekin, the Lawley, Caer Caradoc, Ragleath and Hope Bowdler hills, the various component parts of which will be best understood by arranging them under the general heads of felspar rocks and greenstone rocks.

1. Felspar rocks.

The basis of all these is a claystone or compact felspar, of a colour between flesh and brick-red, and they serve as the immediate support of the superincumbent claystone. None of them affect the magnetic needle.

The variety which is most prevalent on the top of Caer Caradoc is a cellular claystone, the cavities of which vary in size from that of a small almond to a pin's head, and are all of them, especially the larger ones, very much compressed. These cells are lined with minute hexahedral prisms of quartz mixed with a greenish-yellow earthy matter, which is perhaps decomposed actynolite. This rock is penetrated by veins containing quartz, flesh-red jasper, and chalcedony, the latter of which fills all the cells of the adjacent rock.

An analogous variety is found on the top of the Wrekin, in which, however, the compression of the cells has proceeded so far as to bring their sides into actual contact, thus giving the rock a waved and striped appearance.

2. Greenstone rocks.

These for the most part appear to lie under the claystone rocks. Their essential component ingredients are dull-green hornblende and greenish or reddish felspar. They all affect the magnetic needle, some of them in a very remarkable degree. They are more easy of decomposition than the felspar rocks just mentioned, and, in consequence, the respective place of each may be easily distinguished in the hills where they both occur, by the bare craggy surface of the one, and the smooth depressed verdant surface of the other.

When the component parts of the greenstone are distinct, and the felspar has its foliated crystalline structure, the only foreign ingredient which I have observed in the rock, is magnetic pyrites, in small grains. But where the hornblende and felspar are more intimately mixed, the rock usually becomes amygdaloidal, and contains globular concretions of felspar, quartz, calcareous spar, hæmatite, zeolite, and actynolite. Of these amygdaloids there is one of remarkable beauty, (described by Dr. Townson in the tract already referred to), and forming large masses on Caer Caradoc, but which has not yet found a place in the works of systematic mineralogists. It consists of a dull earthy basis, formed by an intimate mixture of dark bluish green hornblende, with flesh-red felspar, inclosing globular concretions of greenish yellow radiated glassy actynolite, a quarter of an inch or more in diameter, smaller concretions of quartz, intimately mixed with actynolite, and therefore nearly in the state of prasium, together with concretions and irregular veins of foliated white calcareous spar.

Of the above described trap-formation, it is not easy to ascertain its geognostic relations on the western side. The portion north of the Severn, which is by far the most extensive, is bounded by the old red sandstone; and the line of their junction is marked by the course of Strine brook from Newport to its confluence with the Tern, and thence by this latter to the point where it falls into the Severn. Along the greater part of this boundary line the two rocks may be observed adjacent, and in some places the sandstone appears to be incumbent on the trap-formation. The little *coalfield* of Dryton, on the Severn side, containing only two beds of thin coal, is certainly bounded on the east by the trap, but on the west seems to be adjacent to the sandstone.

With regard to the portion south of the Severn, it may be remarked, that the western and northern sides of the base of the Lawley, Caer Caradoc, and Ragleath, are overspread with a bed of coarse *sandstone*, consisting of angular fragments of felspar, hornblende, quartz, indurated reddish clay slate, and a little mica. This aggregate has by some been erroneously described as granite, and this mistake has led to the further error of considering the whole of the trap-formation as primitive. There are indeed detached rolled masses of true granite of considerable magnitude, as well as of other primitive rocks, in the near vicinity of the Lawley, but they occur only in a superficial bed of gravel that skirts in this place the southern boundary of the old red sandstone.

Patches of the same *coal-formation* as occurs at Dryton are distributed here and there in the flat ground of Stretton valley; they rest on the aggregate sandstone already mentioned, and rise E.S.E. at a small angle towards the Lawley and Caer Caradoc, in the parallel of which they are situated, but they entirely cease in the more contracted part of the valley, a little further to the south, where the trap of Ragleath hill is evidently incumbent on the *transition* (or, perhaps, newest primitive) *clay slate*, which breaks out to-day in the streets of Church Stretton.

From these facts it appears that the line of elevated ridge-hills from Lilleshall to Ragleath is an unstratified mass of rocks of trap-formation incumbent on highly elevated strata of transition slate: that on the eastern side of this mass there is a great deposit of stratified rocks, consisting of quartz-grit; of a micaceous sandstone nearly allied to greenstone; of a sandy slate-clay; of limestone, slaty marl and sandstone slate in alternating beds; and of the independent coal-formation: all rising up parallel, or nearly so, with the trap at a horizontal angle, the magnitude of which decreases, in proportion to the distance of each bed from the trap, unless where interrupted by casual and local causes. That on the western side of the trap, the mass of deposits is very small, consisting of a sandstone composed of angular fragments, on which rests a thin broken coal-formation. That the old red sandstone bounds the whole of this series of rocks on the east, north, and north-west, but though in contact, appears to be perfectly unconnected with them.

The trap-formation itself does not seem to correspond with any of those described by mineralogical writers, and its essential characters are, its unconformableness with the transition slate on which it rests, the great abundance of claystone, both massive and vesicular, which it contains, and the presence of actynolitic amygdaloid.

IX. *A Chemical Account of an Aluminous Chalybeate Spring in the Isle of Wight.*

By Alexander Marcet, M.D. F.R.S.

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THE accurate analysis of a mineral water, although attended with considerable difficulty and labour, muft be allowed, in a general point of view, to be an object of so little importance, that unless there be some interesting medical question to investigate, or some new analytical methods to point out in the course of the inquiry, it may be questioned whether researches of this kind are worth the time and attention which they require, or deserve to be placed amongst the records of natural science.

Having thought it necessary, in the present essay, to confine myself to the natural and chemical history of the spring in question, without any digression upon its medicinal qualities, and being well aware that chemical details are considered by geologists merely as collateral objects, some apology may be required for the length of this communication. But if the relation which the history of mineral waters bears to geological and mineralogical inquiries, and the peculiarities of composition for which this spring is remarkable, entitle the subject to the attention of this Society, I hope that the general views and investigations which I have occasionally introduced respecting the analysis of mineral waters, and the composition of several salts connected with this inquiry, will be deemed a sufficient excuse for having thus expanded an account from which they were almost inseparable.

It is about two years since my attention was directed to this chalybeate spring by Dr. Saunders, to whom in consequence of his valuable treatise on mineral waters, inquiries of this kind are frequently referred. Having been requested by him, and soon afterwards by the discoverer of the spring, Mr. Waterworth, Surgeon, of Newport, to examine this water, I soon perceived by a few preliminary experiments, that its principal ingredients were sulphat of iron and sulphat of alumine, and that it possessed a degree of strength far more considerable than any mineral water of the same kind that had ever come to my knowledge.

This last circumstance, and the probability that this spring might some day attract public notice from its medicinal properties, induced me to undertake the present analysis, which, after many interruptions, I have at length brought to a conclusion.

§ 1. *Situation and Natural History of the Spring.*

This spring is situated on the south-west coast of the Isle of Wight, about two miles to the westward of Niton,* in one of those romantic spots for which that coast is so remarkable.

In its present state it may be said to be of difficult access, for there is no carriage road, nor even any regular foot-path along the cliff leading to it, and the walk would appear somewhat arduous to those unaccustomed to pedestrian excursions. But it would be practicable, and probably not very expensive, to render this path equally easy and

* On an estate belonging to Michael Hoy, Esq.

agreeable. It was in walking along the shore, a few years ago, that Mr. Waterworth's attention was accidentally directed to this spring, which he traced to its present source, by observing black stains formed by rivulets flowing from that spot.

With regard to the mineralogical history of that district, I have been favoured through the kindness of my friend Dr. Berger, who visited the spot very lately, with so much more accurate an account of it than I should, from my own observation, have been able to offer, that I shall make no apology for transcribing it in his own words.

" The aluminous chalybeate spring," says Dr. Berger, " issues " from the cliff on the S.S.W. coast of the Isle of Wight, below St. " Catherine's Sea Mark, in the parish of Chale. The bearing of the " needles from the spot is N.W. while that of Rockenend, not far " distant, is S.E. by S.

" The elevation of the spot, as far as I could ascertain it by the " barometer, is one hundred and thirty feet above the level of the " sea. Its distance from the shore may be about one hundred and " fifty yards.

" The water is received into a bason formed in the rock for that " purpose, and flows, as I was informed, at the rate of two or three " hogsheads in a day. Its temperature I found to be 51°, that of the " atmosphere being 48°; and it may be worth while to observe that " this temperature corresponds with that of several springs of pure " water which I have met with in the island.

" The lower part of the cliff is rather incumbered with masses of " rock, or portions of soil, which have fallen from the upper strata. " Immediately above these, the spring issues from a bed of loose " quartzose sandstone containing oxyd of iron. This sand, in which " vestiges of vegetable matter are discoverable,* alternates with a pur-

* On being sprinkled on a heated shovel, this sand scintillates as if undergoing a

" plish argillaceous slate of a fine grain, disposed in thin layers " with a few specks of silvery mica interspersed through the " mass. Black stains, or impressions of vegetables, are seen on the " natural joints of this rock. Above this, lies a stratum of several " fathoms in thickness, of a bluish calcareous marl, with specks of " mica, which has an earthy and friable texture, and contains im- " bedded nodules or kidneys of sulphuret of iron. Many of these " nodules have undergone a partial decomposition, to which, no " doubt, the existence of the principal ingredients of the spring is to " be ascribed. The upper strata of the cliff are composed of a cal- " careous free stone, alternating with a coarse shelly limestone, ac- " companied by nodules or layers of *chert* or flint.

" As the same arrangement of rocks here observed prevails in " several other parts of the Isle of Wight, and even along the coast " of Hampshire, it is not improbable that other springs of a similar " nature might be discovered. May not *Alum Bay*, which lies " to the north of the Needles, have derived its name from a circum- " stance of this kind?

" On the road from Shorwell to Chale, the soil consists of a ferru- " ginous sandstone, and chalybeate iridescent waters are to be seen " in several places. To the east of Fresh-water Bay, not far from " the place where the cliffs of chalk begin to make their appear- " ance, there is a rivulet, the taste of which strongly indicates the " presence of iron. At Blackgang Chine, a little to the N.W. of " the aluminous chalybeate, is another ferruginous stream running

partial combustion. When submitted to chemical analysis, it yields a quantity of iron, but no lime, nor alumine, nor any other earthy matter soluble in an acid. Close to the spring, this sand contains some traces of sulphuric acid, but not at a distance from it: it is evident therefore that the sand-rock is not the medium through which the spring is impregnated.

" to the sea. The rock there, is a sort of decomposed iron-stone " under the form of balls. The sound compact iron-stone, having " the appearance of flat pebbles worn by the rolling of the sea, occurs " not unfrequently along the shore."

§ II. *General Qualities and specific Gravity of the Water.*

a. The water issues from the sand rock above described, perfectly transparent, and it continues so for any length of time, provided it be collected immediately, and preserved in perfectly closed vessels; but if allowed to remain in contact with the air, or even if corked up after a temporary exposure to it, reddish flakes are soon deposited, which partly subside, and partly adhere to the inside of the vessel.

b. It has no smell, except that which is common to all chalybeates, and this it possesses but in a very slight degree.

c. Its taste is intensely chalybeate, and, besides a considerable degree of astringency and harshness, it has the peculiar kind of sweetness which sulphat of iron and sulphat of alumine are known to possess.

d. Its specific gravity somewhat varies in different specimens. In three different trials I obtained the following results:

1st specimen	1008,3
2d specimen	1007,2
3d specimen	1006,9
	3022,4
which gives a mean specific gravity of	1007,5

§ III. *Preliminary Experiments on the effects of Reagents.*

A. Paper stained with litmus was distinctly reddened by the water.

B. Paper stained with Brazil-wood was changed to a deep purple.

C. When agitated in contact with the air, or repeatedly poured from one vessel into another, the water became turbid, and on standing deposited reddish flakes.

D. On applying heat to a portion of the water just uncorked, and boiling it *quickly*, till it was reduced to one half or even one third of its original bulk, no precipitation whatever took place; but on continuing the evaporation, a white feathery crystalline substance appeared on the surface of the fluid, and on pushing the process still further, a saline matter of a pale yellowish green colour appeared, which continued to increase till the whole was reduced to a dry yellowish mass. These were the phenomena observed with water recently uncorked; but when, previous to the evaporation, it had been for some time exposed to the air, or when the evaporation was conducted very slowly, an appearance of reddish flakes was the first circumstance observed.

E. The mineral acids produced no obvious change in the water.

F. Oxalic acid produced a slight yellowish tinge; but no immediate precipitation or turbidness.

G. Oxalat of ammonia, in small quantity, likewise produced a yellow colour, without precipitate: but on adding more of this test a white precipitate appeared.

H. Prussiat of potash and infusion of galls produced abundant precipitates, the one blue, and the other black or dark purple; and the colour of these precipitates was much paler when the water had not previously been exposed to the atmosphere.

I. Alkaline solutions produced copious greenish flocculent precipitates, which became darker on standing in the air.

K. Nitrat of silver occasioned a dense, white, but not considerable precipitate.

L. Both muriat and nitrat of barytes occasioned copious white precipitates.

M. A piece of marble being boiled for some time in a few ounces of the water, the marble was found to have undergone no sensible loss of weight by that operation; but its surface had acquired a faint yellowish tinge.

N. A quantity of the water being evaporated to dryness, and a considerable degree of heat applied to the dry residue, a solution of this in water had the same effect of reddening litmus as before.

§ IV. *Inferences arising from those Effects.*

1. From experiment A, connected with experiments C, H, I, M and N, and from the circumstance of taste, and other general properties, it appeared highly probable that the water contained sulphat of iron, and perhaps also sulphat of alumine, without any uncombined acid.*

2. From experiments C and D, it appeared evident that iron and lime were contained in the water, and that their solvent was not carbonic acid.†

* Solutions of sulphat of iron and sulphat of alumine, though made from these salts in their crystallized state, have, like acids, the power of imparting a red colour to litmus.

† The reddish flakes mentioned in C & D, and in § ii, *a*, are uniformly found to be sub-sulphat of iron.

3. The experiments D and E concurred to show that the water did not contain any sensible quantity of carbonats.

4. The experiments F and G afforded additional evidence of the presence of iron, and whilst they shewed the existence of lime in the water, seemed to indicate that the quantity of this earth was not considerable.

5. It appeared probable from experiment K, that the water contained a small quantity of muriatic acid.

6. The change produced in experiment B, on the infusion of Brazil-wood, appeared at first ambiguous; it could not be owing to the prevalence of an alkali or carbonated earth, since the water turned litmus red, and since the presence of carbonated earths had been disproved by other results. But having found by comparative trials, that solutions of sulphat of iron changed paper stained with infusions of Brazil-wood to a black, or at least intensely dark violet colour, and that solutions of alum turned it crimson; and observing that a mixture of these solutions produced a dark purple hue, the appearance in question was easily explained.

7. The result of experiment L indicated the presence of sulphuric acid.

8. Upon the whole, and from a review of the foregoing experiments, the substances which, at this early stage of the analysis, the water appeared most likely to contain, were *sulphat of iron*, *sulphat of alumine*, *sulphat of lime*, and a small quantity of *muriatic salts*. Some sulphat of magnesia, and some alkaline sulphats, might possibly be contained in the water, though their presence could not be satisfactorily ascertained by these preliminary experiments.

§ V. *Gaseous Contents of the Water.*

A quantity of the water measuring ten cubic inches, being boiled briskly over mercury, the gas given out, together with the air contained in the apparatus, was received in a graduated tube; on admitting caustic alkali into the tube, one-tenth of a cubic inch of gas was absorbed. It appears therefore that one hundred cubic inches of the water contain one cubic inch of carbonic acid gas, which is equivalent to about three-tenths of a cubic inch to each pint. The water was uncorked at the moment of being examined, but I had not an opportunity of ascertaining the quantity of gas.

§ VI. *Evaporation of the Water, and Estimation of the Quantity of solid Ingredients.*

1. Sixteen ounces of the water by measure, being evaporated down to a soft mass over a lamp, and afterwards desiccated in a drying apparatus at the heat of 180°,* the solid mass weighed eighty-six grains. During the evaporation the same appearances were observed as have been already related (in § III., D,) and the dry saline mass assumed a pale greenish colour. On standing in the air, it slightly deliquesced, and its colour became somewhat darker. This saline mass, though slowly evaporated, never assumed a distinct crystalline appearance.

* This is the heat I have usually employed for desiccation, because it is that which is obtained by the water-bath which I use, and can scarcely be raised higher by that apparatus. By a heat of 180° however, I generally mean some intermediate point between 170° and 180° for it is imposible to regulate the temperature with perfect accuracy.

2. I have stated before (§ II. d.) that some difference prevailed in the specific gravity of the several specimens of the water which were examined. A similar want of uniformity was observed in regard to the quantity of solid ingredients, as will appear from the following statement:*

	GRAINS.	
The 1st specimen yielded	86.	In the pint of sixteen ounces.
2d	92.	
3d	63.6	
4th	80.4	
5th	82.8	
6th	77.2	
7th	84. †	
8th	78.	
	644	

These eight results therefore give 80,5 grs. dried at 180°, as the average quantity of solid ingredients in each pint of the water.

* In the first of these trials, a whole pint was evaporated; but in the subsequent ones, the quantity of water was diminished to eight, six, and sometimes only four ounces, all of which, for the sake of uniformity, I have reduced in the table to the common standard of the pint.

† This specimen I brought myself from the spring; the others were sent me in sealed bottles from the Isle of Wight.

§ VII. *Of the different Methods of Analysis applicable to the present Inquiry.*

In analysing a mineral water, two modes of proceeding occur from the very first. We may either evaporate the water first, and apply our reagents to the solid residue; or operate at once upon the water itself. The former plan is in general found expedient when the quantity of solid contents of the water is small; but when, as in the present instance, the impregnation is considerable, it may be more convenient to adopt the latter method. But at all events, as the re-dissolution of the solid residue, when the first mode of proceeding is resorted to, generally requires the introduction of an acid, which may modify or complicate the process, it is always desirable that both methods should be tried in succession, in order to obtain comparative results.

We may also, if necessary, precipitate from the same portion of the water the several ingredients which it contains, by applying to it in succession their respective reagents; or if our supply be considerable, we may use a fresh portion of it for each successive operation, a mode of proceeding which is generally preferable. No difficulty being experienced during the present inquiry in regard to the supply of water, a variety of methods was tried, with the details of which I shall not trouble the Society: but in order to convey a general idea of them, and in hopes that a summary review of this kind may afford some assistance to chemical inquirers not yet accustomed to researches of this nature, I shall briefly enumerate the different plans which presented themselves at this period of the analysis, and it will be seen afterwards how these plans were gradually modified.

1*st method.* To precipitate in succession from a known quantity of the water, the *iron* by prussiat of potash—the *lime* by oxalat of ammonia—the *alumine* and *magnesia* by caustic potash, which, by boiling, re-dissolves the alumine and leaves the magnesia untouched.

2d method. To precipitate the *iron* and *earths* by subcarbonat of ammonia. To evaporate the remaining clear solution to dryness, and apply a red heat. To re-dissolve this saline residue, and evaporate the solution slowly, in order to discover any fixed *alkaline sulphat* or *muriat* which may exist in the water. To boil in caustic potash the precipitate containing the iron and earths, in order to separate the *alumine* and *silica.* To dissolve the remaining mass (supposed to contain iron, lime, and magnesia) in nitric acid, evaporate to dryness, and apply a red heat, in order to render the peroxyd of iron thus formed insoluble in acid. To add to the mass minutely pulverized, nitric or acetic acid, as either of these acids will only dissolve the *lime* and *magnesia*, which may be separately obtained by their respective reagents. And lastly, to ascertain the quantity of *oxyd of iron*, supposed to have been left untouched by the acid.

3d method. To precipitate from another portion of water, the iron, lime, alumine and silica, by a solution of neutral carbonat of ammonia, which reagent retains the magnesia in solution. To boil the precipitate in caustic potash, which takes up the *alumine* and *silica.* To re-dissolve in muriatic acid the residue not taken up by potash, which consists of lime and iron—separate the *iron* by pure ammonia, and the *lime* by oxalat of ammonia.* Precipitate the *magnesia* † from the clear solution by an alkaline phosphat.

* It is necessary to precipitate the iron before the lime, whenever any considerable quantity of sulphat or muriat of iron is present. For oxalat of ammonia acts upon solutions of iron, as will be fully explained under the head of sulphat of lime.

† The magnesia might be equally, and perhaps more conveniently separated, by

4th method. To evaporate to dryness a known quantity of the water and to boil the residue in caustic potash, which will dissolve the *alumine* and *silica*, both of which may be precipitated again by muriat of ammonia.* Treat the residue, insoluble in potash and supposed to contain *iron*, *lime* and *magnesia*, in the manner pointed out in the 2d method.

5th method. After having obtained by the preceding methods a knowledge of the proportions of iron and earthy substances, and formed an estimate of the nature and quantities of acids with which they are united, to ascertain in a direct manner the quantities of acids by their respective reagents, with a view to obtain a confirmation of the preceding results.

6th method. To boil a known quantity of the water in succinat of ammonia, till all the *iron* and *alumine* are precipitated—edulcorate, precipitate and separate the alumine from the iron by boiling in caustic potash. From the clear concentrated fluid, to separate the *lime* by oxalat of ammonia, and the *magnesia* by pure ammonia; to evaporate the remaining clear fluid to dryness, and to apply a red heat, in order to burn or volatilize any remaining portions of the tests used in the processes above described. To re-dissolve the residue in order to ascertain by subsequent evaporation the presence and quantity of sulphat and muriat of soda.†

7th method. To boil a known quantity of residue of the water, in alcohol, in order to ascertain what salts it may contain which are soluble in that menstruum.

boiling a known quantity of the solid residue in the neutral carbonate of ammonia, instead of applying this reagent to the water itself.

* The mode in which the silica may be separated from the alumine, will be detailed in a subsequent part of this paper.

† This process is liable to an objection which will be hereafter fully stated, namely, that muriat of soda is decomposed by sulphat of ammonia at a high temperature.

Although I found it expedient, before advancing farther in the examination of the water, and in order to regulate my steps in the progress of the inquiry, thus to trace the various plans which seemed adapted to the purpose, yet I apprehend it would be superfluous to detail here in regular succession all the trials which arose from these different methods. I shall therefore confine myself to such as belong more immediately to my object; and in relating them, shall consider singly and under separate heads, the various ingredients of the water, stating, as I proceed, the proportions in which they were ultimately obtained.

§ VIII. *Sulphat of Iron.*

The presence of iron, in the state of sulphat, having been abundantly proved by the preliminary experiments, the next step was, to ascertain the proportion of this salt in a given quantity of the water. The first reagent which I tried for this purpose, was prussiat of potash; but after many trials which afforded uncertain and discordant results, I convinced myself that this test, however useful for detecting the *presence* of iron, is quite inappropriate when our object is to ascertain the *quantity* of that substance.*

* Prussiat of potash, as a precipitant of iron, is liable to the following objections:—

1st. It is apt, although apparently well prepared and crystallized, to precipitate certain earthy substances, and in particular alumine; this I found distinctly to happen in two experiments in which the mixture was heated.

2dly. If the solutions be used cold, and if the metal be not highly oxydated, some of the Prussian blue unavoidably passes through the filters; or if no filters be used, it subsides but slowly and imperfectly.

3dly. If the solutions be heated, the prussiat of potash is itself decomposed, and yields a quantity of oxyd of iron which vitiates the results.

1. Fifty grains of residue * dried at the temperature of between 170° and 180°, (as described in § VI.) and therefore equal to ten ounces of the water, were boiled in successive solutions of potash, so as to saturate all the acid contained in that residue, and to dissolve the alumine. The remaining solid residue (which had passed first to a dark green, and some hours afterwards to a dark brown or nearly black colour) was dissolved in nitric acid and the solution evaporated to dryness, after which a red heat was applied in order to bring the iron to the state of peroxyd, and thus render it insoluble in the same acid. The mass being now treated with nitric acid, in order to separate the lime and magnesia supposed to be mixed with the oxyd of iron, and the whole being thrown into a filter, the clear solution was found still to contain a good deal of iron. This last solution was, like the former, evaporated to dryness, and to the residue, again heated to redness, acetic,† instead of nitric acid, was this time added, and the solution filtered. The filtered fluid still contained a quantity of iron, which however, from subsequent examination, appeared very inconsiderable. The oxyd of iron left in the filter being roasted with wax and heated to redness, in order to bring it to an uniform state of oxydation, weighed 6,8 grs.‡

* By the word *residue,* thus generally used, is always meant the residue of the water under examination, dried at the temperature of between 170° and 180°. And in comparing a quantity of residue with a corresponding portion of the water, the average proportion of 80,5grs. for each pint (§ VI. 2) is always assumed as the standard of comparison.

† The acetic acid, as well as the nitric, is said to be incapable of dissolving any iron, which has been peroxydated by the process just described. In this instance a few particles of oxyd were taken up by the acid; but it is probable that if, instead of heating the residue to redness only for a few minutes, the oxyd had continued exposed to a red heat for half an hour or more, the whole of it would have become insoluble.

‡ It may be asked in what state of oxydation the iron is after that operation? It has generally been supposed to be reduced to the state of protoxyd in consequence of

2. With a view to repeat and vary the last experiment, another portion of residue, also weighing 50 grs. was thrown into a solution of neutral carbonat of ammonia, the quantity of the latter being more than sufficient to saturate any acid present, and to dissolve the magnesia suspected to exist in that residue. A considerable effervescence took place. The mixture, after this, was gently heated and filtered. The residue left in the filter was of a pale yellowish-brown colour. The clear solution deposited on standing a small quantity of precipitate similar to the residue left in the filter, to which residue this precipitate was added. The contents of the filter were then treated with potash, in the manner before described (§ VIII. 1), in order to separate the alumine, after which the residue (now supposed to contain nothing but carbonat of lime and iron) was treated with dilute muriatic acid, which dissolved it with effervescence. From this solution, the lime was precipitated by oxalat of ammonia, and the remaining liquor, now containing nothing but muriat of iron, was treated with carbonat of ammonia, so as to precipitate the whole of the iron, which, in subsiding, assumed a pale reddish colour. The clear fluid being decanted off, and the pre-

the affinity of the combustible matter for oxygen; but in an experiment which I made some years ago to ascertain that point, (the particulars of which may be seen in my account of the Brighton chalybeate) this process appeared to bring the iron to the state of peroxyd; for 100 parts of iron gave 147,6 parts of oxyd, proportions which are now considered as constituting the red oxyd of iron. And as a confirmation of this, I observe that Dr. Thomson in his valuable paper on the oxyds of iron, published in the twenty-seventh volume of Nicholson's Journal, states (page 379) that some of the red oxyd being mixed with oil and heated to redness till it became black and magnetic, no diminution of weight took place. Indeed I have always obtained by this process, not a black, but a brown oxyd, which in cooling passes to a red-brown colour, somewhat varying in shade, but mostly resembling powdered cinnamon, and being more or less magnetic.

cipitate carefully washed, dried, and ultimately heated to redness with a little wax in a platina crucible, weighed 7,2 grs.

3. It will be observed that between this and the former result there was a difference of 0,4 grs. in the quantity of oxyd of iron contained in 50 grs. of residue. But when it is considered that in the first of these analyses, a small quantity of iron was positively detected in the acetic solution, which, from the best estimate I could make, would have brought the quantity of iron very near that obtained in the second process, it will readily be admitted that the coincidence was such as to authorize me to consider the last result as sufficiently accurate.*

4. If therefore we consider 7,2 grs. of peroxyd of iron, as the quantity of this metal contained in 50 grs. of the residue, which corresponds to 11,59 grs. of the oxyd for 80,5 grs. of residue (that is for each pint of the water, according to the average before established, § VI. 2), we shall be able to infer the quantity of sulphat of iron contained in the water.

5. In order to do this, however, it was necessary to ascertain by a comparative experiment the proportion of oxyd which a known quantity of sulphat of iron yields by a process similar to that which I have just described. For this purpose, 50 grs. of transparent crystallized green sulphat of iron were dissolved in water, and treated with carbonat of ammonia as long as any precipitate appeared.

* In one experiment in which the iron was precipitated from a similar quantity of residue, by prussiat of potash, and the prussiat of iron roasted with wax, the quantity of oxyd obtained amounted to 11 grs. from which I infer either that a portion of the oxyd of iron, always contained in prussiat of potash, must have been precipitated with the Prussian blue, or that the prussiat of iron was not completely decomposed in the process in question, or that some earthy substance was precipitated along with the iron.

This precipitate, after being carefully separated, edulcorated, dried, and ultimately heated to redness with wax in a platina crucible, weighed exactly 14 grs. It appeared in the form of a red-brown magnetic powder.*

6. Since therefore 50 grs. of crystallized green sulphat of iron gave 14 grs. of this oxyd, the 7,2 grs. of oxyd obtained from 50 grs. of residue, would represent 25,7 grs. of green sulphat of iron; and 11,59 grs. of oxyd (which is the quantity contained in an English pint of the water), would represent 41,4 grs. of that salt.

§ IX. *Sulphat of Alumine.*

1. Fifty grains of residue † were boiled in two successive lixivia of caustic potash (as in § VIII. 1), so as to take up all the alumine present; the residue was separated and well washed, and the washings were added to the alkaline solution. The clear liquor had a brownish colour, and on being tried with muriatic acid and prussiat of potash, a blue tinge was produced, which appeared to have arisen from a few particles of oxyd of iron which were suspended

* This result which was obtained in two different trials, with the variation of only 0,1 gr. corresponds exactly with the proportions given by Mr. Kirwan in his treatise on mineral waters (table iv.), in which 28 grs. is the quantity of oxyd stated to exist in 100 grs. of green sulphat. But in order to establish the perfect coincidence of these results, it would be necessary to know the process which Mr. Kirwan followed. The iron in his experiment, is stated to have been obtained in the state of black oxyd.

† These fifty grains had been previously boiled in neutral carbonat of ammonia, in order to separate the magnesia as will be detailed hereafter. The previous intervention of a carbonated alkali renders the subsequent application of caustic potash for the separation of the alumine, more unexceptionable, as a solution of caustic potash might redissolve a small portion of the lime, if it were not previously carbonated.

in the lixivium rather than actually dissolved; for the solution being left at rest for some time, these particles subsided.

2. To the clear alkaline solution, muriat of ammonia was added, till no further precipitate took place; the precipitate was edulcorated and collected in a filter. It was white and gelatinous. Caustic potash being added to the clear fluid, ammonia was disengaged, showing that it contained an excess of muriat of ammonia; and acetic acid being added to another portion of the same liquor, no turbidness appeared, both circumstances showing that all the alumine was precipitated. This precipitate being dissolved in muriatic acid, in order to separate a minute portion of silica, which it contained*, and being again precipitated by succinat of ammonia with excess of ammonia, formed a gelatinous mass, which being edulcorated, dried, and ultimately heated to redness, weighed 2,4 grains.

3. Another portion of residue, weighing thirty grains, being treated in a manner exactly similar to that just described, with this exception, that the redissolution of the alumine in muriatic acid and its subsequent precipitation by succinat of ammonia, were omitted, the gelatinous precipitate, heated to redness, weighed 1, 4 grains †, which afforded as close a coincidence with the former result as may be well expected in processes of this kind.

4. Having never been able to obtain, by the mere evaporation of the water, any appearance of crystals resembling alum, I was

* The particulars of the manner in which the silica is separated, by the intervention of muriatic acid, will be detailed under the head Silica, in another part of this paper.

† The real weight was 1,6 grains, but 0,2 grains were deducted, on account of the quantity of silica known, by other experiments, to have been present, as will be seen under the head *Silica.* It may be proper to mention, that the gelatinous precipitate, during its gradual desiccation, shrunk into small fragments resembling coarsely pulverized glue, an appearance which is well known to characterize alumine.

desirous, for the sake of obtaining further evidence on the subject, to bring the sulphat of alumine to a crystallized state, by artificially supplying what I conceived to be wanting for the completion of that process. For this purpose, having dissolved about thirty grains of residue in distilled water, I added to the filtered solution two or three drops of a solution of carbonat of potash, and evaporated it very slowly; crystals were thus obtained, dispersed in the saline mass, which, though of a size scarcely exceeding that of a pin's head, had a distinct octohedral form, and when separated and chemically examined, had all the properties of alum.

5. With regard to the proportion of sulphat of alumine, contained in the water, it will be seen, that by connecting together the results of the experiments just related (1, 2, 3), eighty grains of residue, or a pint of the water, yield 3,8 grains of alumine heated to redness, which, according to the proportion of twelve parts of ignited alumine, in one hundred parts of crystallized alum†, would be equivalent to 31,6 grains of alum in each pint of the water‡.

§ X. *Sulphat of Lime.*

1. Some of the former experiments (§ III. d and g) had shown, beyond all doubt, the presence of selenite, and indeed, from the general composition of the water, lime could scarcely be supposed to exist in it in any other form of combination.

* These are the proportions stated by Mr. Kirwan, and which I obtained myself on a former occasion (See the Analysis of the Brighton Chalybeate.)

* It is scarcely necessary again to observe, that the sulphat of alumine contained in the water does not appear to exist there in the state of alum; but it is perhaps better to express the quantity of alumine by the quantity of alum which it would form, as the crystallized state of a salt affords a much more precise standard of comparison.

To ascertain the quantity of this substance, a variety of methods was used, the principal results of which I shall cursorily relate.

2. It would have been in vain, in this instance, to have applied, without any previous step, oxalat of ammonia, the usual test of lime, in order to obtain an accurate estimate of the quantity of lime present in the water; for as oxalic acid also acts upon iron, some ambiguity would necessarily have occurred. Indeed that oxalat of ammonia did not, in this case, re-act upon the lime in the manner that it usually does, had been noticed (§ III. f, g) in some of the preliminary experiments*.

* By adding a considerable quantity of oxalat of ammonia, and concentrating the solutions by heat, the whole of the lime appeared to be precipitated, together with a portion of iron; but in order to obtain the oxalat of lime pure, it was necessary to calcine the precipitate so as to drive off the oxalic acid, to redissolve the residue in muriatic acid, and to precipitate the lime again by oxalat of ammonia. The small quantity of iron present did not *then* interfere, and this process, however circuitous, proved tolerably accurate.

I was drawn by this part of the subject into an experimental inquiry respecting the action of oxalat of ammonia on solutions of iron, and the unfitness of that test for the precipitation of lime when iron is present, the principal results of which I shall state summarily.

1. If to a strong solution of sulphat of iron, a small quantity of sulphat of lime be added, and then a little oxalat of ammonia, no precipitate or cloudiness appears; whilst the same quantities of sulphat of lime and oxalat of ammonia added to a bulk of water equal to that of the solution of iron, instantly form a precipitate.

2. If oxalat of ammonia be added to a solution of sulphat of iron, a bright yellow colour is produced, and presently after this a copious white precipitate appears, which, in subsiding, assumes a pale lemon colour. If at the moment the cloud is forming, the vessel be scratched with any pointed instrument, white lines appear, as in the precipitation of magnesia from carbonic acid by phosphoric acid.

3. This precipitate being washed, and gently heated over a lamp, assumes a bright cinnamon colour, and becomes magnetic, in consequence, no doubt, of the carbonization of the oxalic acid, and these changes take place at a heat much inferior to ignition.

3. It was therefore necessary to separate the iron previous to the precipitation of the lime. This was done in one instance by prussiat of potash, and in another by succinat of ammonia. I shall not trouble the society with the detail of these operations. It will be sufficient to state, that the two most unexceptionable experiments indicated the one 8 grains, and the other 8,3 grains of oxalat of lime, dried at 160°, for each pint of the water, making an average of 8,15 grains of oxalat of lime, or 10,17 grains of sulphat of lime dried at 160°; or 7,94 grains of the same salt dried at a red heat*.

§ XI. *Inferences obtained from the application of Alcohol.*

1. Having ascertained (§ III. k), that a small quantity of muriatic acid was present in the water, it became desirable, before proceeding any farther, to discover, by the agency of alcohol, which has the well known property of dissolving the earthy muriats, with what bases this acid was combined. With this view, 20 grains of residue were digested in successive quantities of alcohol of great purity, and the solution filtered. The residue, by this operation, acquired a lighter colour and a more pulverulent appearance. Part

4. If a solution of potash be added to the washed precipitate, previous to the application of heat, a strong smell of ammonia arises, and the oxyd passes to a dark greyish colour, showing that the precipitate is a triple salt of oxalic acid, iron, and ammonia.

* I avail myself, in forming these various estimates, of the proportions given by Dr. Henry, in his valuable 'Analysis of several varieties of Sea Salt' (published in the Philosophical Transactions for 1810, page 114), where he states that 100 grains of ignited sulphat of lime (which he finds to be equal to 128 grs. dried at 160°), give 102,5 grs. of oxalat of lime dried at 160°; so that 100 grs. of oxalat of lime dried at 160°, correspond to 124 grs. of sulphat of lime dried at the same temperature.

of this residue being treated with muriatic acid and oxalat of ammonia, oxalat of lime was precipitated; and another portion being treated with neutral carbonat of ammonia and phosphat of soda, some magnesia was precipitated in the form of triple phosphat, circumstances which confirmed the presence of lime in the form of selenite, and that of magnesia, in the form of sulphat or Epsom salt.

2. The alcoholic solution being evaporated to dryness, a yellowish deliquescent residue was obtained, which, being dried at 160° weighed 0,9 grains. Water being added to this residue, a small portion of it remained undissolved. The filtered watery solution was yellowish, though perfectly transparent, and being examined by the usual reagents, appeared to contain iron, sulphuric acid and muriatic acid, with imponderable vestiges of lime and magnesia, without any trace of alumine.

3. From these circumstances, it was inferred that the only deliquescent salts yielded by the residue, in ascertainable quantities, were sulphat of iron, and muriat of iron, both of which had probably been formed in consequence of some new orders of attraction taking place during the process of evaporation to which the water had been subjected.*

§ XII. *Sulphat of Magnesia.*

1. The presence of magnesia† was ascertained beyond all doubt, in the following manner:

50 grains of residue minutely pulverized, were boiled in a solution of neutral carbonat of ammonia, so as to decompose all the

* Namely, the red sulphat from the hyper-oxygenation of the iron, and the muriat from the decomposition of muriat of soda, as will be explained hereafter.

† The presence of this earth in the form of sulphat had already been proved by the application of alcohol, (§ xi. 1).

sulphat of iron and earthy salts, and dissolve all the magnesia which might be present.* This process was, of course, attended with considerable effervescence, and when this had subsided, the liquor was filtered. The clear solution deposited on standing a brownish sediment, which was separated and proved to be oxyd of iron. The residue left in the filter had passed from a greenish-yellow to a pale brown colour.

2. Phosphat of ammonia being added to the clear solution, a precipitate appeared, having all the characters of the ammoniaco-magnesian phosphat, and in particular, that of forming white stripes on the inside of the vessel when scratched with a pointed instrument. This precipitate dried at a temperature of about 120°, weighed 1,9 grains,† and being made red hot in a platina crucible, was reduced to exactly 1 gr. = 0,385 grains of pure magnesia = 2,26 grains of crystallized sulphat of magnesia in 50 grains of residue, or 3,63 grains in a pint of the water.‡ The magnesian

* It is scarcely necessary again to state here the well known fact, that carbonat of ammonia, when fully saturated with carbonic acid, has the power of dissolving magnesia.

† In a subsequent experiment in which the water itself, instead of the residue, was treated in the same manner with neutral carbonat of ammonia, the quantity of magnesia appeared somewhat greater; but the difference did not amount to more than one-tenth of a grain.

‡ It will be necessary here to state the grounds of this computation, which will afford me an opportunity of relating some general results concerning the proportions in which magnesia and phosphoric acid combine.

By dissolving 11,82 grains of the purest magnesia (perfectly free from carbonic acid and water) in muriatic acid, and precipitating it by a mixture of phosphat of ammonia and neutral carbonat of ammonia, I obtained 65,8 grains of the triple phosphat dried by exposure for near forty-eight hours to a temperature which never exceeded 120°, a degree of heat under which this salt appears to retain the whole of its ammonia. These 65,8 grains of triple salt being exposed for half an hour to a strong red heat in a platina crucible, were reduced to 30,8 grains. The salt appeared then in the form of a friable cake or loose aggregate, a fragment of which, on being urged by the blow-pipe, ran into a phosphat became slightly brownish during the calcination, owing to the presence of a few particles of iron, the quantity of which was too minute to be ascertained.

§ XIII. *Precipitation of the sulphuric and muriatic Acids, with a view to ascertain their Quantity.*

Before drawing any ultimate conclusion respecting the contents of the water and the proportions of its ingredients, I found it necessary to ascertain the quantities of sulphuric and muriatic acids which it contained, in order to enable me to try how far these quantities might coincide with the conclusions obtained by the separation of

white opaque vitreous globule, without any further diminution of weight. In its friable state it was readily dissolved by muriatic acid; in its vitrified form it required heat and trituration. This salt was perfectly tasteless and shewed no attraction for water. With regard to the proportions of acid and base to be inferred from this experiment, it is obvious that if 30,8 grains of phosphat of magnesia contain 11,82 grs. of earth, the remainder, viz. 18,98 grs. represents the proportion of phosphoric acid; which is equivalent to 38,37 grs. of magnesia, in 100 of phosphat. In another experiment conducted in a similar manner, the magnesia amounted to 38,7 grains, so that by taking the mean between these two very nearly similar results, we have the following proportions, viz.

$$\left.\begin{array}{ll}\text{Magnesia} & 38{,}5 \\ \text{Phosphoric acid} & 61{,}5\end{array}\right\}\text{ in 100 grains of ignited phosphat of magnesia.}$$

We may infer therefore that one grain of phosphat of magnesia, the quantity yielded by the twenty grains of residue, indicated 0,385 of pure magnesia; and if, according to the statements of Kirwan and Wenzel (which very nearly agree) one hundred grains of crystallized sulphat of magnesia contain seventeen grains of magnesia, 2,26 grains of that salt will be the quantity corresponding to 0,385 grains of magnesia. And I have the satisfaction of observing that the proportions obtained by Dr. Henry, of one hundred grains of ammoniaco-magnesian phosphat dried at 90°, for one hundred and eleven grains of crystallized sulphat of magnesia, would have led to a very similar result. (See Dr. Henry's 'Analysis of several varieties of Salt,' in Philos. Trans. for 1810, page 113.)

the basis, and also to assist me, as will be seen hereafter, in forming certain inferences with regard to the alkaline salts. For this purpose I made the following experiments.

1. To four ounces of the water was added nitrat of barytes till the whole of the sulphuric acid was precipitated; the sulphat of barytes thus obtained being carefully edulcorated and heated to redness in a platina crucible, weighed 18,5 grains, which correspond to 74 grains of sulphat of barytes from a pint of the water.

2. Four ounces of the water were treated with nitrat of silver as long as any precipitate appeared, and the muriat of silver thus obtained, being well edulcorated, and afterwards brought to a state of incipient fusion by the heat of an Argand lamp, weighed 2,05, which is equivalent to 8,2 grains of luna cornea, or four grains of muriat of soda,* in each pint of the water.†

§ XIV. *Sulphat and Muriat of Soda.*

1. The mode in which I first attempted to ascertain the presence of alkaline salts in the water, was that alluded to in a former part of this paper, which consisted in precipitating the iron and the earths by subcarbonat of ammonia, evaporating the clear solution to dryness, heating the dry mass to redness, with a view to drive off the sulphats and muriats of ammonia, redissolving the residue in water, and eva-

* I have found by direct experiments that one hundred grains of pure muriat of soda heated to redness, and decomposed by nitrat of silver, yield 241,6 grains of luna cornea heated to fusion.

† The same experiment was tried three times upon different specimens of the water, and I here give the average. The smallest quantity of luna cornea obtained was two grains, and the largest 2,5 grains, a difference too great to arise from mere inaccuracy. From this and several other circumstances I have reason to suspect that the water is subject to occasional variations in the proportions, as well as in the aggregate quantity of its solid contents.

porating again very slowly in order to obtain crystals. But the saline mass yielded by this process did not crystallize regularly, and on being examined by reagents, was found to contain only sulphat of soda, with minute quantities of sulphats of alumine and magnesia, which had escaped the action of the carbonat of ammonia.

2. In hopes of obtaining more satisfactory results I had recourse to the following process: five ounces of the water were boiled with a solution of succinat of ammonia till the whole of the iron and alumine were precipitated.* The lime was precipitated by oxalat of ammonia, and the magnesia by ammonia. The solution was then concentrated over a lamp, and gradually evaporated to dryness in a platina crucible. A white pungent smell arose, and on raising the heat to redness, these fumes took fire and burnt with a blue flame, till the whole was fused and reduced to a fixed saline mass mixed with a black coaly matter. Distilled water was poured upon this mass and the solution filtered. This clear solution being now evaporated and dried at a gentle heat, so as to obtain the salts in a crystallized state, the mass weighed 6,3 grains,† which would give 20 grains of alkaline salts in a pint of the water. The centre of this mass exhibited no distinct crystallization, though from its appearance and disposition to effloresce, it evidently contained sulphat of

* This is a long operation, because the iron does not combine with the succinic acid at a low degree of oxygenation, so that the mixture must be long digested with access of air, or repeatedly boiled and allowed to stand in the air for some hours during the intervals, before the process can be completely effected. This operation necessarily requires one or two days, but is remarkably accurate as to the precipitation of both the iron and alumine.

† This was the combined result of two separate experiments tried on three and two ounces of the water, the first of which yield 3,5 grains, and the other 2,8 grains of alkaline salts.

soda; but the circumference was strewed with numerous and perfectly regular crystals of muriat of soda.*

3. This saline mass being dissolved in water the solution had the following properties:

a. It was neither acid nor alkaline.

b. Its most obvious taste was that of muriat of soda.

c. It formed copious precipitates with nitrat of barytes, nitrat of silver, and nitrat of lime.

d. Oxymuriat of platina, oxalat of ammonia, and prussiat of potash, produced no precipitate whatever.

Therefore the only salts contained in this solution were sulphat of soda, and muriat of soda.

4. As to the proportions of those two salts, it would have been easy to ascertain them by precipitating their acids. But it occurred to me that the sulphat of ammonia formed in the solution by the ammoniacal salts which had been introduced for the precipitation of the earths, had probably reacted upon the muriat of soda when

* This result shews the compatibility of muriat of soda with sulphat of iron, the latter being in excess, which has been questioned by some chemists. Being desirous of obtaining a confirmation of this by a direct experiment, I mixed together solutions of two parts of sulphat of iron and one part of muriat of soda. The mixture became yellowish, and on applying heat reddish flakes subsided. On separating these by filtration, and repeating this process two or three times, I nevertheless obtained by evaporation distinct crystals of muriat of soda, partly cubic, partly octohedral, deposited in the centre of a saline yellowish mass, without any appearance of efflorescence or of any thing resembling sulphat of soda. Therefore muriat of soda is compatible with sulphat of iron, although these two salts evidently exert some degree of action on each other, as appeared from the change of colour and the formation of reddish flakes, which I suppose to be sub-sulphat of iron. I may take this opportunity of mentioning that by an analogous experiment on sulphat of iron and muriat of alumine, and by the assistance of alcohol, I satisfied myself that those two salts *could not* exist together.

urged by heat, so as to decompose it partially, and form the sulphat of soda obtained by the process just described; so that muriat of soda might perhaps in fact be the only alkaline salt contained in the water.

5. In order to ascertain this, another portion of the chalybeate having been treated in the way just described with succinat of ammonia, the residue was gradually desiccated, and then heated to redness in a platina crucible, which was at first kept closed, in order to retard the escape of the sulphat of ammonia, and thus promote its action on the muriat of soda. The remaining mass being dissolved and very slowly crystallized, assumed the form of clusters of regular prismatic efflorescent crystals of sulphat of soda, amongst which scarcely any vestige of muriat of soda could be discovered.

6. The decomposition of muriat of soda by the above process being thus well established, it became necessary to determine the proportions of sulphat and muriat of soda by some less direct method; and the expedient which appeared the most appropriate was that of inferring the point in question from a reference to the quantities of acids as estimated in the preceding section. Thus as it was obvious that, whatever the case might be with regard to sulphat of soda, the presence of muriat of soda in the water was unquestionable; and as the whole quantity of muriatic acid discovered in the water (§ XIII. 2), corresponded to a quantity of muriat of soda which fell far short of the sum total of alkaline salts, I naturally inferred that the whole of the muriatic acid was united with soda, and that the water must also contain a quantity of sulphat of soda sufficient to complete the 20 grains of alkaline salts which the experiments just related had shewn to exist in each pint of the water.

7. Since therefore, the whole of the muriat of soda, as was before computed (§ XIII. 2), amounted only to 4 grains in a pint, the quantity of crystallized sulphat of soda contained in each pint of the water will be 16 grains.

§ XV. *Comparison of the quantities of Acid actually obtained from the water by precipitation, with the quantities inferred from the precipitation of the bases.*

1. It appears evident, from all that precedes, that the only acids contained in the water are the sulphuric and muriatic. The whole of the muriatic acid having been shewn to exist in the form of muriat of soda, nothing further remains to be said on this head. But it will be curious to examine how far the total amount of sulphuric acid, obtained from a portion of the water, would coincide with that which might be inferred from the quantities of bases with which it was combined. This inquiry will give rise to the statement of certain results respecting the proportions of acid and base in some of the salts concerned, and the precipitates obtained from their decomposition, which, from their general import in chemical analysis, appear to deserve some attention.

2. It was ascertained by a direct experiment (§ XIII. 1), that the whole of the sulphuric acid contained in a pint of the water, formed, when precipitated by a barytic salt, a quantity of sulphat of barytes, which, after being ignited, weighed 74 grains.

I shall now recapitulate the several sulphats discovered in the water, and from the quantities of each, compute the quantities of barytic sulphat which would result from their decomposition.

Sulphats contained in a pint of the Water.

	Sulph. of baryt. ignited.
Sulphat of iron (§ VIII. 9) 41,4 grs. crystallized	= 31,8 grs.*
Sulphat of alumine (§ IX. 5) 3,8 grs. ignited alumine	= 17,7 ditto †
Sulphat of lime (§ X. 4) 10,17 grs. dried at 160°	= 13,9 ditto †
Sulphat of magnesia (§ XII. 2) 3,63 grs. crystallized	= 4,0 ditto ‖
Sulphat of soda (§ XIV. 7) 16,0 grs. crystallized	= 11,6 ditto §
Total amount of the sulphat of barytes	79,0 grs.

* These proportions were deduced from the following experiment: 50 grains of crystallized green sulphat of iron were dissolved in water, and nitrat of barytes was added as long as any precipitate took place. The sulphat of barytes after being carefully edulcorated and heated to redness in a platina crucible, weighed 38,5 grs. Therefore 50 : 38,5 :: 41,4 : 31.

† It may be recollected that 3,8 grs. of ignited alumine, would, according to the proportion before stated (§ IX. 5,) correspond to 31,6 of crystallized alum. I found by a direct experiment that 100 grs. of regular octohedral crystals of alum formed by gradual deposition from a saturated solution of common alum, being dissolved in water and precipitated by muriat of barytes, produced 88,2 grs. of ignited sulphat of barytes; so that the 31,6 grs. of alum would correspond to 27,8 grs. of the barytic sulphat. This, however, could not be an accurate estimate of the real quantity of sulphuric acid, since the sulphat of alumine does not exist in the water in the state of alum.

With a view to learn the proportions of acid and base in *pure* sulphat of alumine, I made the following attempt. A quantity of alumine (which had been prepared by precipitation from alum, redissolution in muriatic acid, and second precipitation by carbonat of ammonia, and appeared to contain no impurity except a vestige of muriatic acid), was dissolved in sulphuric acid, and the solution evaporated to siccity. When reduced to the consistence of a thick syrup, and allowed to cool, the saline mass congealed into a hard whitish deliquescent cake, capable of being pulverized. This was redissolved and re-evaporated four successive times, and the last time was made red-hot, in rder to expel the excess of sulphuric acid which always appeared to prevail. By this last operation a portion of the salt was decomposed and rendered insoluble in water, in spite of which the remainder still exhibited signs of acidity. The clear solution of this mass being divided into two equal portions, one of which was precipitated by succinat of ammonia, and the other by nitrat of barytes, yielded 4,5 grs. of ignited alumine,

3. It appears therefore that the aggregate of the analytical results would indicate 79 grs. of ignited sulphat of barytes, instead of the 74 grs. obtained by a single direct operation. This difference I apprehend to be in a great degree owing to my estimate of the proportion of acid in sulphat of alumine being over-rated, from the circumstance of not having been able to obtain a neutral sulphat of alumine in the experiment just related from which that estimate was deduced.

§ XVI. *Silica.*

I. During the various solutions of the residue in acid, I had repeatedly observed that, besides the selenite, (the solution of which

for 21 grs. of ignited sulphat of barytes. From which it may be inferred, that the 3,8 grs. of ignited alumine found in a pint of the water, were combined with a quantity of acid equal to 17,7 grs. of ignited sulphat of barytes. But it is assumed in this computation that the artificial sulphat of alumine subjected to analysis, was in the same state of combination as that which exists in the water, a supposition which may not be strictly accurate.

‡ The quantity of sulphat of barytes produced by the precipitation of a given quantity of sulphat of lime, was ascertained in the following manner: some pulverized crystals of native selenite, apparently perfectly pure, were dissolved in water and afterwards slowly precipitated by evaporation. The object of this previous operation was to obtain the sulphat of lime in a state more fit for subsequent re-dissolution. Fifteen grains of this selenitic residue were dissolved in water, slightly acidulated by muriatic acid, in order to supersede the necessity of using a large quantity of water; and the solution, after being neutralized by pure ammonia, was precipitated by muriat of barytes. The sulphat of barytes thus obtained, weighed, after careful edulcoration and ignition in a platina crucible, 26,75 grs. which is equivalent to 175,6 grs of barytes for 100 grs. of ignited sulphat of lime.

|| According to Dr. Henry 100 grs. of crystallized sulphat of magnesia give 111 grs. of ignited sulphat of barytes. See Philos. Trans. 1810, p. 114.

§ These proportions were deduced from the following experiment: 40 grs. of crystallized sulphat of soda, being dissolved in water and precipitated by nitrat of barytes, the sulphat of barytes, well edulcorated and ignited, weighed 29,1 grs.

was attended with some difficulty, and required a considerable quantity of water) there always remained a small proportion of earthy matter, which resisted all solvents, caustic potash excepted. This insoluble matter, I had thought from some of the first trials, amounted to about 1 gr. in 100 of the residue; but from some subsequent experiments in which the silica was separated by caustic potash, there appeared to be reason to suppose that this estimate was rather over-rated. I shall relate the process, to which, after various trials, I gave the preference.

2. 50 grains of residue being boiled with very dilute muriatic acid, a white flocculent substance remained undissolved, upon which neither acid nor water could make any impression. This substance being separated and boiled in a solution of caustic potash, readily redissolved with the exception of a few particles of highly oxydated iron which subsided. Muriat of ammonia * being added to the clear alkaline solution in sufficient quantity to saturate the whole of the potash with muriatic acid, the white flocculent substance reappeared, which, after being well washed and heated to redness, weighed between 0,3 and 0,4 gr. This substance when heated with alkali ran into a vitreous globule, and muriatic acid being poured upon this, the alkali was dissolved, and the earthy matter remained untouched. It was therefore silica, the quantity of which may be estimated at 0,7 gr. in a pint of water.†

* This precipitant, which was, I believe, first proposed by Mr. Chenevix, is much more appropriate than acids, because if an excess of acid be incautiously added, the precipitate is re-dissolved; whilst with muriat of ammonia, an excess of the test is attended with no inconvenience.

† The presence of silica was also shewn, and its quantity attempted to be ascertained by the following process. A portion of residue was boiled in caustic potash: this dissolved not only the silica, but also the alumine; both these earths were precipitated from the alkaline solutions by muriat of ammonia, and separated; muriatic acid being

§ XVII. *Conclusion.*

On reviewing and connecting together all the foregoing results, it appears that each pint, or sixteen-ounce measure of the aluminous chalybeate, contains the following ingredients:

Of carbonic acid gas three-tenths of a cubic inch.	GRAINS
Sulphat of iron, in the state of crystallized green sulphat .	41,4
Sulphat of alumine, a quantity which if brought to the state of crystallized alum, would amount to	31,6
Sulphat of lime, dried at 160°	10,1
Sulphat of magnesia, or Epsom salt, crystallized . . .	3,6
Sulphat of soda, or Glauber salt, crystallized	16,0
Muriat of soda, or common salt, crystallized	4,0
Silica	0,7
	107,4

I am not acquainted with any chalybeate or aluminous spring, in the chemical history of mineral waters, which can be compared, in regard to strength, with that just described. The Hartfell water, and that of the Horley-green spaw near Halifax, both of which appear to be analogous to this in their chemical composition, and were considered as the strongest impregnations of the kind, are stated by Dr.

now added, both the silica and alumine were re-dissolved (for silica, just precipitated from its solution, and not desiccated, is soluble in acid); and this solution being evaporated to dryness in a water-bath, by which means the silica parts with its acid and becomes insoluble, the muriat of alumine was washed off by distilled water, and the silica remained undissolved. This method, though affording a very useful means of discrimination, must obviously be liable to inaccuracy as to proportions, when very minute portions of silica are to be separated from considerable quantities of alumine. This however was the process to which I trusted on a previous occasion (IX. 2), to free the alumine from the silica which was mixed with it.

Garnett to contain, the one only about 14 grs. and the other 40 grs. of saline matter in each pint.

No doubt therefore can be entertained that the water which is the subject of this essay, will be found to possess in a very eminent degree the medical properties which are known to belong to the saline substances it contains. Indeed there appears to be in that spring rather a redundance than a deficiency of power, and it is probable that in many instances it will be found expedient to drink the water in a diluted state; whilst in others, when it may be desirable to take in a small compass large doses of these saline substances, it will be preferred in its native undiminished strength.

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X. *A Sketch of the Geology of some parts of Hampshire and Dorsetshire.*

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ALTHOUGH the chalk hills form the most striking feature of Dorsetshire, Hampshire, and the Isle of Wight, they do not occupy the whole of the surface of those counties. Several other strata or mineral beds there occur, the general arrangement of which it is the purpose of this communication briefly to illustrate.

The chalk hills which appear on the south eastern-coast of the Isle of Wight traverse the interior of that district in a line nearly due west to the Needles; they are interrupted by the sea, and by the alluvial deposits on the eastern side of Studland Bay; but re-appear at Corfe Castle, and on the coast at Lulworth, from which last place they may be observed passing towards Weymouth, still preserving their original direction, having left to the south of them nearly the whole of the Isle of Purbeck.

The breadth of this range of chalk is not very considerable, for the entire coast from Christchurch Bay to Poole lies to the North of it.

The dip of the strata varies from N.E. to S.E. but the point of the compass, towards which they all tend, is the east.*

* In the S.S.W. coast of the Isle of Wight, below St. Catherine's Sea-mark, the dip of the strata is E.N.E. In the southern coast called the *Under Cliff*, the dip is N. by

The outline of these hills, is characterized by gradual and successive swellings and depressions of the ground; they also offer natural scoops or semi-circular excavations on their acclivities. Though covered with a short grass, they may be called *naked*, being entirely destitute of timber.

They rise to a greater absolute elevation than the other beds by which they are accompanied; so that even at a distance, we may safely conclude the highest bare hills to be chalk.

This rock is harder than most of those with which it is associated, and in consequence wherever it appears on the coast, the sea-water is in such places, more transparent, and generally of a greater depth, on account of the cliffs being cut off more abruptly.

The cliffs of chalk assume often the shape of recesses or semicircular bays, the outline of which is well defined: such is Freshwater Bay, Lulworth Cove, the Bay of Weymouth, &c.

In the Isle of Wight, the chalk hills, as far as I could ascertain form a belt across the middle of the island, the greatest breadth of which may be five or six miles. As this belt proceeds westward, it contracts gradually to a point of land deeply indented on the north by Alum Bay, and on the south by Freshwater Bay. On that projecting tongue of land called *High Down* stands the signal post, the light house further on to the west, and the Needles lower down. I found by the barometer the elevation of the signal house to be 430 feet above the level of the sea; that of the light house 379; and of the furthest and most western part of the cliffs, above the Needles, 189 feet.

N.E.—in Freshwater Bay N. by N.E.—towards the Needles at High Down, N.E.—in Hampshire, near Alresford, S.S.E.—at Kimeridge Bay, and generally along the coast of the Isle of Purbeck, E.N.E.—in the Isle of Portland, E. by S.E.

The chalk hills in the Isle of Purbeck lie in the prolongation of a line westward from the Needles: they pass through Corfe Castle, and establish a separation between two troughs, or basins. The one on the north has a gentle slope towards Poole Harbour, the other on the south is more horizontal, extending towards the sea, on the coast of which it presents a range of rather abrupt cliffs. The soil of the latter is very fertile, while that of the former is completely barren, and covered all over with heath.

These hills pass under particular names, such as Nine Barrow Downs, which I found by the barometer to be 625 feet above the level of the sea; Challer Hill, 390; Norden Hill, 369; and East and West Creach. Between Challer and Norden Hills, stands on the top of an hillock, the fine ruin of Corfe Castle, the height of which is 207 feet. These hills consist of what is called *hard* chalk, perhaps from the greater quantity of sand which it contains.*

Over the chalk lie several beds or strata of a later formation, the relative age of which I shall not now presume to determine, as their alternation with each other appears to be several times repeated.

I. *Flint Gravel in loose Sand, or Loam.*

This is the formation which prevails chiefly on quitting London, in travelling to the south-west. On the road to Southampton by Bagshot, Farnham, &c. I have traced it as far as to New Alresford;

* It would be interesting to trace the characters of this rock more distinctly, and especially to ascertain whether it inclosed fossils which are not to be found in the common and *soft* variety. Chaux *écrivante* of the French.

at this latter place the chalk is first to be found *in situ*, at the distance of fifty-seven miles from the metropolis. We lose the chalk in the neighbourhood of Otterborne, five or six miles to the S. S. W. from Winchester, where we enter again into a loam mixed with flint gravel. In the Isle of Wight, the same flint gravel in loam occurs near Marsh Green in Brixton Bay, not far from the chalk hills called Brixton and Mottiston Downs.

The heath, which extends from Christchurch town to Poole, a distance of eight miles, has for its bottom the same flint gravel either in sand or in loam. It forms also the upper part of the cliffs in Christchurch Bay by Milford, Hordel, &c.

The flint pebbles found in this formation are rounded and much smaller than those which are imbedded in the chalk; they have no coat, but on the contrary, a sort of semi-transparence approaching that of amber. They have in all probability been worn by the sea.

II. *Quartzose loose Sand.*

It is always strongly impregnated with oxyd of iron; it presents sometimes all the varieties of colour imaginable, white, ochre-yellow, brownish-red, pink, green and black, but in all these instances the iron seems to be in a state of peroxide, as none of the rocks which the sand forms, act at all on the magnet, though the considerable quantity of this metal which they contain is readily shewn by the application of chemical solvents.

This sandy formation is to be met with in the Isle of Wight on the southern boundary of the chalk from Shorwell to Chale, but especially in Alum Bay, where it makes high, precipitous and very grotesque cliffs, remarkable both for their variety of colour and the multiplicity of short pyramids implanted one upon the other.

This loose sand is also the matter which fills up for the most part the inclined semi-trough, which from the shallow inner harbour of Poole extends to the northern acclivities of the chalk hills by Corfe Castle. It is there of a whitish-grey colour, covered with heath reduced in some places to the state of turf. To this formation of sand belong the following mineral substances:

(a) *Coarse hard ferruginous sandstone*, passing to a conglomerate, composed of rolled quartzose pebbles of different sizes, united by a ferruginous cement which does not effervesce with acids. This rock strikes fire, and has at first the appearance of slag, being rough, hollowed out, and covered externally with a crust of an earthy brown colour, arising from the oxidation of the iron. It has no action whatsoever on the magnet. It occurs in the form of flat scattered masses at the depth of a few feet from the surface of the sandy soil; the upper strata of loose sand being sometimes washed away, these pieces project, making a sort of cornices, and protecting the inferior strata of sand. I suspect this conglomerate to be of a very late origin, and indeed, daily forming by a process somewhat like that of *cementation*, viz. the percolation of water strongly impregnated with iron coming from the upper strata, and thus agglutinating the loose sand.

This rock is to be seen plentifully on the road from Shorwell to Chale in the Isle of Wight, and in the sandy trough of Poole.

(b) *Potters' clay.*

It alternates with the loose sand in the trough of Poole, where it is found in beds of various thickness at different depths. It does not effervesce with acids, and from a cursory chemical examination which Dr. Marcet had the kindness to make at my request, we traced in it the existence of alumine, of lime, of magnesia, of oxyd of iron, and of silica. It feels greasy and smooth, its colour varies from ash-grey to blue, its fracture is a little shining and uneven. It contains sometimes cylindrical blue nodules (called *pins* by the workmen) of a more close texture, in which there is probably a greater proportion of oxyd of iron. This clay is sent to Staffordshire, where it is mixed with ground flints, and employed in the finer kinds of pottery. I found the specific gravity of one of the purest specimens from *Threshers's* clay-pit, 1. 723. Mr. Kirwan states potters' clay to be from 1,8 to 2.*

I have been informed by very competent persons that the beds of clay in the trough of Poole do not affect any particular direction.

The situation of the potters' clay in this present instance, is perfectly agreeable to Werner's opinion.†

(c) *Coaly bituminous matter.*

Remains of vegetables, some of which still retain their texture and shew that they belonged to the tribe of aquatic plants, are to be found in a white quartzose sand impregnated however with oxyd of iron, in the cliffs of the south-western coast of the Isle of Wight: at the east of Freshwater bay, some scaly carbonated wood with iron pyrites, is also to be found in the sand.

An earthy brown-coal extremely friable, and which crumbles to pieces when put into water, underlies the potters' clay in the sandy trough of Poole, where it forms a seam of some thickness. It burns with a weak flame emitting a particular and rather fragrant smell of bitumen, somewhat analogous to that of the *Bovey coal.* They differ however in point of specific gravity, this being 1,153, while Bovey

* Elements of Mineralogy, vol. i. p. 130.

† Brochant, Traité de Minéralogie, tome i. p. 325.

coal varies from 1,4 to 1,558.* There are frequently *pins* of clay passing through this earthy brown-coal.

I have seen at West Lulworth, another brown-coal passing into pitch coal, in a black loose quartzose sandstone, in which it makes a very thin layer or seam. It hardly burns with a flame, but chars like wood, emitting an empyreumatic or subacid smell. The spec. grav. of the specimen I tried, was 1,340. This last species of combustible matter, as well as the former, is used by the poor people as fuel, and they may be both referred, I think, to the *spurious coal* of Mr. Kirwan; the range of the specific gravity which he gives, is that of 1,500 to 1,600†

III. *Marl.*

This rock occupies a pretty large extent along the coast: I have observed the four following varieties.

(a) Marl of an earthy semi-indurated texture, which assumes spontaneously polyhedral forms, and contains nodules or kidneys of sulphuret of iron, some of which have undergone a partial decomposition. It has no lustre, the fracture is coarse, the colour of a bluish-grey; it contains numerous specks of mica, it does not effervesce with acids, though the presence of lime is readily shewn by chemical tests; it is composed also of alumina and of a good deal of oxyd of iron; it adheres slightly to the tongue, and is friable when immersed in water, it soon falls into a powder which is rather rough and dry, it decrepitates on the first impression of the fire, becomes hard, and when heated to redness, turns greyish-yellow. It forms a bed of several fathoms in thickness on the south-western coast of the

* Kirwan's Mineralogy, vol. ii. p. 61.

† Ditto vol. ii. p. 57.

Isle of Wight, where it lies between a stratum of loose quartzose sand, and one of calcareous freestone with chert, above the source of an alum chalybeate spring. It is found also to the north-east of Alum bay, where it alternates with sand; at High Cliff in Christchurch bay, where it constitutes most part of the cliff, and is covered only by the flint-gravel; and between Encombe and St. Aldham's Head in the Isle of Purbeck.

(b) Marl of a bluish-grey colour, intermixed with iron-pyrites. It has a degree of lustre, its texture is slaty, it feels smooth and greasy, does not contain mica, and is not acted upon by acids; it falls in water into a very fine powder, but not so readily as the former variety: when heated it becomes harder, of a yellowish colour, and its structure appears more evidently foliated. I have observed it in the bed of a rivulet which runs to the sea near Compton-field, on the west-south-western coast of the Isle of Wight, not far from Brixton bay. The flint gravel lies over it.

(c) Marl of a greyish-white colour, harder than the two former varieties, effervescing with acids, and adhering more strongly to the tongue. In water it does not fall into powder; the fracture is earthy; no specks of mica are visible in it; when heated to redness it does not decrepitate, but becomes harder, and of a reddish-brown colour. The surface is often covered with compressed nodules of sulphuret of iron; it alternates with the preceding kind.

(d) Marl of a bluish-grey colour effervescing with acids; its fracture is dull and earthy; it contains a great many shells and a few specks of mica. In water it does not fall into powder; it hardly adheres to the tongue; when heated, it decrepitates slightly, and the texture becomes more evidently slaty; by a red heat it acquires a white-reddish tinge, and gives out a bituminous smell analogous to that of the *Kimeridge* coal, or to express myself more correctly, with the slate-clay, or shale (*Schiefer-thon* of Werner) with which it alternates.

IV. *Calcareous Sandstone.*

This is coarse-grained, loosely aggregated, of a yellowish-white colour, with small brown grains of siliceous sand, and some specks of mica; it effervesces briskly with acids; it is disposed in strata of several yards in thickness which alternate with coarse shelly limestone and thin layers of chert; it enters into the composition of the cliffs of the south-western and southern coast of the Isle of Wight. As it is easily acted upon by external agents, it is often hollowed out, leaving the interposed strata of coarse shelly limestone, and the layers of chert, like shelves or overhanging cornices projecting from the cliffs, till, the sandstone giving way to a great extent, the upper strata fall down, and take in settling all degrees of inclination. This is the only way to account for those large and numerous blocks which have encumbered the *under cliff* in the Isle of Wight. I have observed in many instances the passage of the sandstone to *chert*,* and of this latter to a beautiful transparent calcedony.

* Though the words *flint* and *chert* are pretty often used indiscriminately, I do not by any means consider them as synonymous: *chert*, I believe, is a kind of *hornstone*, the fracture of which is between scaly and flat conchoidal: it has a somewhat drier aspect, and is more generally of a greyish colour, or variegated white and brown: such are some of the characters clearly made out by Mr. Kirwan. Elements of Miner. vol. i. p. 303. There is besides, I think, a geological character, viz. that chert is not generally to be found in distinct globular masses as flint is, but rather in continuous layers, separating thicker strata of rocks.

V. *Coarse Shelly Limestone (Calcaire grossier).*†

This kind of rock I am rather anxious to introduce here, because it seems to constitute a formation by itself, which, I believe, was first pointed out by M. Brongniart, who has given us some very valuable information on the subject. This variety of limestone was thought to be very scarce in England, but I am now disposed to believe, that upon a further examination, it will be found to occupy a great extent of country, and will, by many persons perhaps, be considered as a continuation of the same strata or beds which exist on the opposite coast of France. I have observed it in the southern part of the Isle of Wight called the *under cliff*, in several places of the Isle of Purbeck, in the Isle of Portland, and, from some specimens which I have seen at the Geological Society's apartments, I have but very little doubt, that it exists also in the counties of Surry, Sussex, Oxford, Rutland, and Somerset. In France, it forms the bottom or basis of several extensive plains; such as that of the neighbourhood of Paris, and that of Caen in Normandy.

I have seen it alternating with a calcareous sandstone, with the *oolithe*, (oviform limestone of Kirwan), and with marl: passages of it may be traced on one hand to the calcareous sandstone, and on the other to the oviform limestone. At the quarry of *Tilly Wym* by Seacombe Cliff, to the east of St. Aldham's Head, and at *Chapman's Pool* near Encombe, as also in the Isle of Portland, it includes patches of a compact limestone of a greyish, or dark blue colour, which becomes harder as it passes gradually into a state of complete flint or

† *Chaux carbonatée grossière ; pierre à bâtir ; pierre de taille* when in large blocks, and *moëllon*, when it is in smaller masses. Brongniart, Traité de Minéralogie, tom. 1. p. 204.

chert. Although these patches of compact blue limestone effervesce with acids, they are however hard enough to strike fire with steel. I have seen at the apartments of the Geological Society a series of specimens from the County of Rutland (Nos. 890 to 896), so very much like those of Purbeck and Portland, that they might be taken one for the other. But generally speaking, the texture of the coarse shelly limestone is uneven and rough; it contains a great many shells, which, according to M. Brongniart, belong mostly to the tribe of the *littoral* shells. Sand also occurs either filling up the cavities of the shells, or dispersed through the substance of the limestone. It is generally calcareous, and of a dirty-yellow colour; sometimes it is siliceous, and then appears under the form of very small brown grains. In the coarse shelly limestone of Swanage, the colour is yellowish grey, and the texture somewhat resembles that of a *pisolite:* (var. of the oviform limestone of Kirwan). In the quarry of *Tilly Wym* and in that of *Wind Spit,* a little westward of the former, it is mostly composed of shells of oysters, which have lost their outside coat. In the Portland stone, judging from the quarry which lies on the north-east of the island, the greatest part of the remains included within it, are casts of a species of *Trigonia* of Lamarck (Hippocephaloides of Plott) as I am informed by Mr. Parkinson; a genus of which Mr. Péron has found a living species in the Southern Seas. This stone is rather rough, on account of the many cavities left by the casts of the shells, and which cause the air contained within, to oppose a resistance to the hammer, in the manner of the porous lavas: some of those cavities are however lined with crystallized calcareous spar.

The specific gravity of the different specimens of this limestone, I have found to be as follows:

From the *Under Cliff* in the Isle of Wight . .	2,666
From Steeple Ashton, Oxford	2,624
Wind Spit quarry	2,592
Swanage	2,563
Portland N.E. quarry	2,563
Tilly Wym quarry, passing to a calc. sandst. . .	2,466
Mean spec. grav.	2,579

The ratio between the extreme points, is as 92 : 100; a range much less than is stated by M. Brongniart from Rondelet's experiments, viz. of 24 : 17.*

The specific gravity of the compact hard bluish limestone found in patches in the coarse shelly limestone, I have ascertained to be as follows:

From *Tilly Wym* quarry	2,501
From Portland	2,511
Mean . . .	2,506

Lastly, the specific gravity of a dark-blue flint or chert, from Portland, connected with the bluish compact limestone, and passing gradually into it, is 2,545.

In the quarry of *Tilly Wym*, the flint or chert is mostly under the form of detached masses or nodules; while in the *under cliff* in the Isle of Wight, and in the Isle of Portland, it forms continuous layers; in the latter place, their direction is that of the strata, viz. nearly from north to south, their dip being east by south.

* Traité élémentaire de Minéral. tome i. p. 208.

With respect to the existence of *chert* or *flint* in the coarse shelly limestone, M. Brongniart is not very consistent with himself: "Il "paroit que les silex si abondans dans la variété suivante (la craie), "and qui se voyent aussi dans la précédente (l'oolithe), ne se "trouvent presque jamais, ou peut être même jamais dans la chaux "carbonatée de cette formation."*

While on the contrary, speaking of the *silex pyromaques*, he says, "Les silex pyromaques blonds se trouvent aussi en couches minces "continues, ou presque continues, entre les bancs de chaux car-"bonatée grossière, & au milieu d'un sable grossier."†

* Traité élémentaire de Minéral. tome i. p. 206.

† Traité élémentaire de Minéral. tome i. p. 315.

Since the publication of his "Traité de Minéralogie," M. Brongniart, with the able assistance of M. Cuvier, has given the following more pointed characters—"Les pierres "siliceuses du *terrain d'eau douce* sont tant t un silex pyromaque pur et transparent; "tantôt un silex à cassure résineuse, transparent ou opaque; tantôt un silex opaque à "cassure terne, largement conchoide et semblable à celle du jaspe; tantôt c'est un silex "carié, opaque, à cassure terne et droite qui a tous les caractères de la meulière propre-"ment dite, mais qui est géneralement plus compacte que la meulière sans coquille; "tantôt enfin c'est un vrai grès à grains plus ou moins fins, disposés en rognons ou en "couches minces."

"Les caractères de ces pierres siliceuses ne diffèrent donc pas de ceux qu'on leur "connoit; leur origine n'est décelée que par celle du terrain au milieu duquel il se trou-"vent, ou par les coquilles qu'ils renferment."

"Mémoire sur des terrains qui paroissent avoir été formés sous l'eau douce;" p. 3, Paris, Juillet, 1810.

"By the term *terrain d'eau douce*, Messrs. Cuvier and Brongniart understand those mineral beds which, according to their theory, were deposited by fresh-water lakes (inclosing the vegetables and animals that inhabited their banks or waters), at the same period that marbles and schists were formed by depositions from the sea. Is the *calcaire grossier*, then, anterior to or coeval with the "terrains d'eau douce?"

VI. *Oviform Limestone (Oolithe).*

I have observed two beds or strata of this rock: one is in the quarry of *Wind Spit* in the Isle of Purbeck. This quarry is open in two places. To the east, where the rock has been excavated on a very large scale, there is nothing but the coarse shelly limestone before mentioned, which as it extends to the western quarry, passes into oviform limestone. The grain of the rock quarried at this latter place, is more close, the colour uniformly white, the texture less coherent; it still however retains some fragments of shells, but they are small and broken. I found the specific gravity of one specimen 2,539.

The quarry to the north-west of the Isle of Portland, which is the most extensive, is composed almost entirely of the oviform limestone, containing but very few shells; the texture of the work is granular, the nodules very small, and united by a calcareous cement. It crumbles to pieces much more readily than the coarse shelly limestone which lies on the opposite coast of the island. The specific gravity of one specimen I found 2,464; thus giving for the mean specific gravity of the two specimens here mentioned 2,5015.

" Les oolithes," says M. Brongniart, " se trouvent en bancs ou " en masses considerables au pied des collines ou des montagnes, " dans le passage des terrains de cristallisation, aux terrains de sédi- " ment : elles sont rares dans la chaux carbonatée compacte : on ne les " a jamais vues dans la craie proprement dite ; il paroit qu'elles sont " particulières à la chaux carbonatée grossière."*

* Traité élement. de Minéral. tome i. p. 203.

VII. *Kimeridge Coal.*

Of the bay where this coal is found, I have seen but the eastern part, about a mile to the east of Little Kimeridge, where the cliffs are cut down rather abruptly. These are composed of a slate-clay (Kirw.) of a greyish yellow colour, finely slaty, containing both animal and vegetable impressions. The leaves of which the rock is composed, become much more evident, after it has undergone some decay, or, when sound, after it has been exposed to the fire. It divides spontaneously into large tabular masses. The fracture of the rock is earthy, with many small specks and nodules of indurated clay. The outside of the rock is covered with a thin layer of calcareous spar. The specific gravity of the specimen I tried, was 2,052. The mass effervesces with acids, but the nodules of indurated clay do not.

This rock passes gradually to a bituminous shale. The first transition is to a slate-clay of a lighter or darker colour, the joints of which are covered with iron pyrites. It burns with a yellowish flame, giving out a sulphurous smell, and becomes afterwards of a light grey colour. The second transition is to a bituminous shale called *Stony-coal*, the spec. grav. of which is 1,319. Its colour is dark-brown without any lustre: it effervesces slightly with acids, contains no iron pyrites and burns readily with a yellowish rather smoky and heavy flame. The smell is bituminous but not sulphurous. The top and bottom of the Kimeridge coal consist of the slate-clay first described. At little Kimeridge on the shore, I saw several large blocks of a very hard, compact brown limestone, having a conchoidal fracture, and displaying a few specks of indurated clay: it had an external covering of a grey earthy colour, owing no doubt to the oxydation of the iron, though the rock itself does not act in any sensible manner on the magnet. This limestone has a superficial resemblance to iron-stone and to some basaltic rocks; passages however might be traced to the slate-clay just mentioned, with which perhaps it alternates. I found its spec. grav. 2,641. It was not *in situ*, but comes very probably only from a little distance.*

On taking a general view of the district here described, we shall find that of the two islands which it comprehends, one, the Isle of Wight, has its greatest dimension from east to west, while the other, the Isle of Portland, extends longitudinally from north to south, or nearly so: that in the Isle of Wight, the shelving of the land, independently of the particular slopes of the hills, is from south to north, as is clearly shewn by the rise of the Medina river, and by the elevation of Niton, one of the most southern villages, situated on the back of St. Catherine's-hill.† In the Isle of Portland, on the contrary, we have an uninterrupted plain, with a gradual and uniform slope from north to south, of nearly four hundred feet in a distance of five miles. No river, that I am aware of, waters the Isle of Portland, but the inhabitants are plentifully supplied with fresh water, by two very fine and abundant springs.‡

In the Isle of Wight, the tract of land to the north of the ridge

* The Kimeridge coal is used as fuel by the poor people in the neighbourhood, and the ashes spread over the meadows, are considered as a good manure.

† It may not be amiss perhaps to observe, that in the Isle of Wight, and along the coast of Hampshire, the rivulets which empty themselves into the sea, go by the name of *chine*, which is synonymous with *gully*, and the beds of those streams or brooks widen very much at their approach towards the sea.

‡ One of them, called *Fortune's well*, is situated a little above the village of Chesil, on the way to the signal-house. The other spring is in the south of the isle, at the village of Southwell, a name derived no doubt from the spring.

of chalk, from Newport to Cowes, is but little elevated, being indeed almost flat: in Portland, the abruptness of the cliffs on all sides is rather considerable, and as far as I have been able to judge, pretty nearly the same, somewhat less perhaps to the south.

St. Aldham's Head, the most projecting part of the *peninsula* of Purbeck, lies exactly on the same parallel as the southern part of the Isle of Wight, and both belong to the same formation, as does also the Isle of Portland, which projects still further to the south.

In following that part of the coast step by step, the attention is strongly drawn towards the considerable wearing away of the land and of the solid strata which is daily taking place. Between Rockenend and Blackgang Chine on the S.S.W. coast of the Isle of Wight, a land slip happened in 1799, the fragments of which cover a space of near half a mile in diameter.

As we walk along the cliffs, we see every where the surface of the soil rent by deep fissures; but a circumstance particularly remarkable is, that in this district, the decay seems to begin with the upper strata, which are gradually removed in succession. At Freshwatergate and at the *Needles*, those standing pyramids of chalk present us with a striking illustration of this supposed mode of decay. At the furthest extremity of High Down below the light house, there is a gap now interrupting in its upper part the continuity of that projecting tongue of chalk. Without attempting to estimate within how many years such a portion of the solid strata will be completely broken asunder, and make a *Needle* by itself, no one will deny that it is one step towards such an event. Conformably with this and other similar appearances, in attempting to account for the separation of the Isle of Wight from the opposite coast of Hampshire, I should be more disposed to ascribe it to the continued action of causes, the effects of which we may ascertain and even almost calculate every day, than to a sudden subsiding of the strata at a period of time far beyond the reach of all historical monuments.

If the chalk hills constitute ridges separated by low troughs or vales which have been filled up by alluvial depositions, may not the bottom of one of these vales have once existed in the space now occupied by the Southampton channel; and thus the separation of the Isle of Wight have taken place in consequence of an encroachment of the sea on a portion of little elevated land, the loose materials of which besides, could have presented but a feeble barrier to the repeated assaults of the sea?*

May not that narrow arm of the sea, which from Cowes-harbour extends four miles inland to Newport, and which is improperly called *Medina river*, be owing to a cause of that kind; as also that other still deeper arm of the sea which from Yarmouth runs to Freshwater-gate, and makes almost a complete island of that portion of the land which lies westward?

The shape of this channel, and its slanting declivity on both sides, affords also a further presumption of the truth of this hypothesis.

That I have not gone beyond the warrant of the facts in admitting such a disposition, as has been described, of chalk-hills with vales between them, may, I think, be clearly demonstrated from actual observations.

In Kent and Sussex are two ranges of chalk hills, the north and south downs, with an alluvial vale between them. In Hampshire, near Alresford, where the chalk begins to crop out, we pass over a ridge of this rock in a transverse direction to its length; till near

* "The ebb, at low water, between the coast of Hampshire and the Isle of Wight, "runs so strong that it shoots into Poole harbour, (which lies in the line of its course) "so that when it is low water at Hurst-castle, it is high water here." Maton's Obs. on the West. Count. vol. i. p. 28.

Otterborne, on the southern slope of that same ridge, we lose the chalk, because, the country lowering, we enter into an alluvial basin in which lies Southampton, and which probably extends as far as to Carisbrook a little beyond Newport, in the Isle of Wight. There we meet with the belt of chalk hills before mentioned, and again on the southern slope we enter at Shorwell, a sandy basin, till we come to the southern coast of the isle which is chiefly composed of calcareous sandstone, chert, and coarse shelly limestone

We shall find that the same arrangement prevails about Corfe Castle, and there indeed we may fairly say that the shallow inner harbour of Poole lies in the bottom of the trough of sand which rests on the acclivities of Corfe Castle chalk-hills. Were the sea to force itself a passage somewhere between Lulworth and Wareham, (situated at the head of Poole harbour) would not then the Isle of Purbeck improperly called so now, become a true island? and would not then its formation be owing to a cause exactly like that which I have ventured to suppose, has formed the present Isle of Wight?

I shall close these observations by saying, that if we take a comprehensive view of the southern counties of England, from the east of Kent to the Land's End, we may safely assert, that there are very few countries which, within such limits, can boast of so varied and regular a succession of rocks, from those which are reckoned by most geologists to be of the latest formation, to those which belong to the oldest.

Elevation of some places in the Isle of Wight, and the County of Dorset.

	By the Barometer, Height above the level of the sea.	From the trigonometrical Survey.
HAMPSHIRE.		
Isle of Wight.	FEET.	
Niton, S.S.W.	275	
St. Catherine's Sea-mark, or Signal-house	750	
Alum Chalybeate Spring, below St. Catherine's, S.S.W. Coast	130	
Shanklin-hill, S.S.E. the chalk begins to crop out at Steep-hill	769	
Bembridge Down, E.S.E.		. . 400 from Sir H. Englefield. Vide vol. vi. of the Linn. Trans.
Motteston or Mottiston Downs W.S.W.		. . 698
High Down, Signal-house	430	
High Down, Light-house	379	
The furthest and most western part of High Down above the Needles	189	
DORSETSHIRE.		
Isle of Purbeck.		
A hillock on Poole heath, half a mile W. by S. of the town of Poole; and S.W. by S. of Branksea Castle	102	
Nine Barrow Down W. of Studland	625	. . . 642, reckoning the level of the sea from low-water mark.—Vide Maton's Obs. on the West. Count. vol. i. p. 18.
Corfe-castle (village) Ship-inn	105	
The hill on which Corfe-castle stands	207	
Challer hill, E. of Corfe-castle hummock	390	
Norden hill, W. of Corfe-castle hummock	369	
St. Adhelm's, St. Alban's or St. Aldham's head	344	
Swyer hill (top) W.N.W. of Encombe	669	
Isle of Portland.		
Signal-house, a little to the N.N.E. of the village of Chesil	458	
Southwell (village) S.S.W. of the island	99	
Southern Light-house	64	

XI. *Notice respecting the Geological Structure of the Vicinity of Dublin; with an Account of some rare Minerals found in Ireland.*

By William Fitton, M.D.

Communicated by L. Horner, Esq. Sec. to the Geological Society.

THE following observations are to be ascribed principally to the late Rev. Walter Stephens. I present them to the Geological Society in their present imperfect form, with the hope that they may attract the attention of mineralogists to the country in the vicinity of Dublin; for they are sufficient to shew that very interesting information may be expected from a correct examination of that district; which from its situation is easy of access, and presents many advantages to the observer. I shall subjoin to a brief statement respecting the geological structure of that country, an account of some minerals of not very common occurrence, recently found in Ireland.

The city of Dublin is placed in a flat limestone country, at the distance of about five miles to the northward of a range of mountains, which form the verge of a mountainous district, extending from thence for more than thirty miles to the southward. Through this tract there passes in a south-western direction from the shore on the south side of Dublin bay, a broad body of granite, bounded on its eastern and western sides by incumbent rocks of great variety; the structure and relations of which, as well as of the granitic mass, are in many places very distinctly exhibited.

Within this mountainous district, distinguished by the interesting and beautiful scenery which it presents, are found the copper mines of *Cronebane* and *Ballymurtagh*;* and the lead mines of Glenmalur; the veins of lead ore at *Dalkey*, and that near the *Scalp* also belong to it. The stream works commonly called the *Gold mine*, at the mountain *Croghan Kinshela* are on the southern range of this district and of the County of Wicklow; and gold has been found within it, at another mountain also named *Croghan*, about seven miles to the northward of that place.†

The occurrence of *tinstone* at the "Gold-mine," where it has been obtained in fragments,‡ is a fact which deserves attention; for from the great extent of primitive country in the Wicklow mountains, the probability of finding veins of tinstone there, appears considerable. *Porcelain* earth in purity equal to the "China clay" of Cornwall, has been found in the lands of *Kilranelagh*, on the south-western side of this county; and granite in a state of decomposition is found so extensively in other parts of it, that this valuable production may very probably be obtained there in considerable quantity.

The country around the village of *Bray*, at the distance of ten miles from Dublin, presents within a small space an instructive series of rocks; and the appearances observable at *Killiney*, first noticed I believe by Dr. Blake of Dublin, particularly deserve attention. Schis-

* An account of the metalliferous waters of these mines was published in the Philosophical Transactions so far back as the year 1752, vols. xlvii. and xlviii.

† Gold is said to have been found also in the *King's River*, near the village of Holywood, in the County of Wicklow.

‡ Report by Messrs. Mills and Weaver. Trans. Dublin Society.

tose beds are to be seen at that place to a considerable extent reposing upon granite; and the line of junction, which begins here at the sea-side, may be traced by the eye for some miles across the country. The regularity of this junction is remarkable on the top of *Rochestown* hill, adjoining that of *Killiney;* where ledges of granite, against the foot of which the incumbent rocks incline, present in several places, a rectilinear course for many fathoms together. On the shore at the base of *Killiney-hill*, the granite is traversed by numerous veins, many of which themselves consist of granite; and in some instances, two granite veins, differing from each other and from the mass, in fineness of grain and in proportion of their ingredients, are seen to intersect; one vein often deranging the continuity of the other's direction. The substance of these veins is perfectly continuous with that of the mass through which they run, and the surface of the fracture passes through both without interruption.

The conical masses of the *Sugar-loaf* mountains, with the summits of *Brayhead*, and *Shankhill*, resembling them in structure, are composed of quartz; and it may be remarked, that the conical form appears to be in some measure characteristic of mountains composed of that substance; for Mr. Jameson informs me, that he has seen in Lusatia detached conical summits composed of it; and that the well-known *Paps* of Jura, and the conical summits in the mountains separating Caithness from Sutherland, are of the same material; as also is, according to Dr. Berger, the mountain *Durnhill*, near the town of Portsoy.*

The actual contact of granite with incumbent rocks, has been ob-

* Humboldt states, that in South America, quartz constitutes, exclusively, a mass of more than nine thousand five hundred feet in thickness, which he considers as of a "formation" peculiar to the Andes. He has not mentioned the form of the summits. Tableau Phys. p. 128.

served at the following places in the counties of Dublin and Wicklow. On the western side of the granite, in a streamlet joining the *Dodder*, west of the glen above *Ballinascorney;* at *Golden-hill*, near the granite quarries; and at *Kilranelagh:* on the eastern side, at *Killiney*, at the southern extremity of the *Scalp;* at *Jonelagee*, near *Aghavanagh* to the eastward; and at the south-western side of *Croghan Kinshela*. On the shore of Dublin bay, between *Booterstown* and *Blackrock*, a mass of compact limestone is visible within a few fathoms of the granite, but in the interval the rock is concealed.

Near *Ballinascorney*, on the western verge of the granitic mountains nearest to Dublin, rocks of the trap family occur; and from thence to the south-westward, along the borders of the counties of Wicklow and Kildare, various intermediate rocks between the granitic tract above mentioned, and the limestone of the flat country to the westward will be found. At *Arklow-rock*, on the south-eastern extremity of the county of Wicklow, columnar rocks of the trap family have been observed by Dr. Wollaston and the Rev. Dr. Brinkley.

The quarries in the more immediate neighbourhood of the city, afford many varieties of calcareous productions. The *Calp* of Mr. Kirwan, a variety of limestone, of which an excellent description and analysis have been published by Mr. Knox,* is the prevailing rock. *Brown-spar* (Jameson) is found in veins at the quarries near *Dolphinsbarn;* and beds of *magnesian* limestone were observed by Mr. Stephens in the bed of the river Dodder, at *Miltown*, and at *Classons-bridge*, above that place. The petrifactions, which abound in many parts of this limestone country, the *Calp*, and the beds of magnesian

* Transactions of the Roy. Irish Acad. vol. viii. p. 207.

limestone afford some of the features which may assist in deciding on the "*formation*" of Werner, to which it is to be referred; a point of considerable interest, from the great extent which the limestone occupies in the Counties of Dublin, Kildare, and Carlow.

In the peninsula of *Howth*, which forms the northern side of Dublin bay, *grey ore of manganese* with *brown iron-stone*, and *brown iron-ore* (Museum of Dublin College, Nos. 1067-8, 887.) have been obtained in considerable quantity: and a variety of the *earthy black cobalt ore* of Werner has been found by Mr. Stephens and Dr. Stokes on the southern side of the hill, forming a crust of a rich blue colour lining the fissures of a rock of slate clay nearly approaching to whetslate, (Mus. I. C. D. No. 267): Mr. Tennant has in this substance ascertained the presence of the oxides of cobalt and of manganese; and the discovery of it is important, as it indicates the probability of the existence of other more valuable ores of cobalt in that neighbourhood. *Lugnaquilla*, which is supposed to be the highest of the Wicklow mountains, is situated to the south-westward of the centre of the mountainous district. I have found it, by the barometer, to be 2455.1 feet above the house of Mr. Greene at Kilranelagh, which is itself considerably elevated above the sea. *Cadeen*, a hill detached from the body of the mountains, and forming a striking object from the adjacent flat country, is 1558.9 feet; *Baltinglass-hill*, 681.8 feet; *Eadestown*, 749.4 feet; *Brussels-town*, 740.1 feet; *Kilranelagh-hill*, 705.5 feet above the same place.*

Of the mountains nearest to Dublin, one of the highest, *Garry-*

* The first three heights above mentioned, are each the mean of three observations, the rest are from single observations, with two excellent barometers. Mr. Greene's house is (by a single observation) 95.08 feet above the level of the cross roads at the bridge of *Tuckmill*, a little village on the river Slaney; the elevation of which above the sea will be very well supplied when the line of the grand canal shall be extended in this direction, as is now intended.

castle, is 1531.7 feet above the level of the road at Ballinteer; and the *Three Rock mountain* is 1247.9 feet above the same place, the elevation of which is considerable. The highest point of *Howth* is 567 feet above high-water mark.

Account of Minerals, &c.

I. *Vesuvian.—(Idocrase*, Haüy). This substance was observed by Mr. Stephens in specimens found by me at Kilranelagh, where it occurs in irregular crystalline masses, in a rock composed of common garnet of a reddish-brown colour, of quartz for the most part greenish, apparently from the admixture of a lamellar fossil of that colour, and a small quantity of felspar. The crystalline form of the garnet is here often very distinct, but in the specimens hitherto found, that of the Vesuvian is not well exhibited, although some indistinct prisms are to be observed. In general, its particles assume a scapiform aggregation, sometimes approaching to stellular, a form which I have not observed in specimens of this substance from other places; but its fusibility, lustre, colour, and other characters leave no doubt as to its nature.

The blocks of this compound at Kilranelagh were not in their natural place, but their size, their great weight and angular form, render it probable that they were not far removed from it. Garnet rock is described as occurring in beds in primitive mountains, and the country at Kilranelagh is of that description.

It is remarkable, that a compound much resembling that which I have described, occurs also in the County of Donegal, from whence specimens now in the cabinet of the Dublin Society, and that of Dublin College (No. 30.), were obtained. The garnet and vesuvian in these specimens, are scarcely to be distinguished from those of

Kilranelagh; and, as at that place, are accompanied by quartz, often of a similar greenish colour; with the addition however of bluish grey granular limestone, and a fibrous substance, not improbably *tremolite*, mixed with carbonate of lime. I have not seen any felspar in the specimens from Donegal.*

2. *Grenatite.* (*Staurotide*, Haüy). This was detected by Mr. Stephens in crystals in a micaceous compound of which I found a specimen at the *Glenmalur* lead mines in the County of Wicklow; the crystals are small, but their colour, form, and characteristic crossing are very distinct, and they are infusible before the blowpipe.

3. *Beryl.* (Var. of *Emerald*, Haüy). The *precious beryl* has been found by Mr. Stephens and myself imbedded in granite, near *Lough Bray* in the County of Wicklow. (Museum of Dublin College, No. 39.) Mr. Weaver has discovered it in blocks of granite, near Cronebane in the same county; and I have found in the Dublin mountains above *Dundrum*, specimens probably belonging to the same species.

4. *Andalusite.* (*Feldspath apyre*, Haüy). This has been found by Mr. Stephens and myself, in very distinct specimens, on the north-east side of *Douce* mountain in the County of Wicklow, apparently imbedded in the mica slate of which that mountain is composed, and accompanied by quartz, mica, and a remarkable crystallized substance hereafter to be mentioned. It differs from the Andalusite of Spain and of Scotland, chiefly by inferior hardness; for although some pieces scratch window-glass, others yield easily to the knife: but the Count de Bournon has observed an equal variation in the hardness of specimens of this substance found by him at Forez;* and I have found that of the Scottish stone to vary very much.

* Since this paper was written, I have found that this compound from Donegal has been described by Mr. Sowerby. British Mineralogy, August, 1810. p. 133.

This fossil seems to have been first taken notice of under the name of *Wurflicher* (cubic) *Feldspath* by Karsten, who took his description from specimens in the Leskean cabinet now in Dublin † (No. 907 *b*, &c.); and from a comparison of these with the specimens from Douce, the identity of Karsten's fossil, with Andalusite is ascertained. I have not found however, that his claim to the first detection of it has been mentioned by subsequent writers: although his opinion with respect to its affinity to felspar, accords with that which Haüy is disposed to adopt. *Tableau comparatif*, &c. p. 217.

To this species is also to be referred a mineral which occurs in great abundance at Killiney in the County of Dublin, first observed there by Dr. Blake, and for some time considered as belonging to a non-descript species. It is most remarkable on the shore at the southern extremity of the cliff under the obelisk hill, where it appears thickly on the surface of beds of mica slate; and it seems to abound also imbedded in the substance of that rock, although less distinctly visible until it has been exposed to decomposition, being less affected by exposure than the rock in which it is contained.

The *Andalusite*, when thus brought to view, appears generally in slender prismatic crystalline pieces rounded at the angles, seldom sharp, promiscuously aggregated, sometimes in a stellular form, and of a greyish-black colour, remarkably contrasted with the lustre and light colour of the micaceous substance in which they appear. But in fresher pieces, the form, colour, cleavage, and other characters of this mineral are distinct; and I have observed an approach to the peculiar appearances which it presents at this place, in some Spanish specimens, where the crystalline shoots had assumed a scapiform arrangement.

* Journal de Physique, xxxiv. p. 453. 1789.

† Bergman's Journal, vol. ii. p. 809. ann. 1788.

5. The Andalusite of Douce mountain is accompanied, as has been mentioned, by a crystallized mineral, the characters of which have much affinity to those of *indurated talc ;* and which is placed under that denomination in the collection of Dublin College (Nos. 405, 6, 7) ; and a specimen of the same kind, stated to be from *Glendalagh* in the County of Wicklow, was found in the same collection (No. 404.)

The crystals are rhomboidal prisms, of which the length is in some instances more than twice the breadth, but no acumination is observable. They are easily cut by the knife, faintly translucent, their colour yellowish-grey. Small fragments before the blowpipe appear to swell a little from the separation of the folia on the first application of the heat; they become white, and give with some difficulty a solid white enamel. The specimens to which I have access at present do not enable me to give any detail of the remaining characters.

The connection of this substance with the Andalusite of Douce is remarkable ; the latter often forming the nucleus of crystals externally of four sides, sometimes filling nearly the whole of the interior, but in other specimens, forming little more than an axis, with rounded edges, and of irregular form, from which the folia of the investing talc-like substance appear to radiate.

The occurrence of indurated talc in crystals has hitherto been very rare : it is not mentioned by Jameson ; and Brochant, though he quotes from Emmerling the rhomboidal prism as one of its forms, expresses doubt as to the correctness of the statement ; I therefore do not give that name to the crystals found at Douce, without some uncertainty.

6. *Hollowspar*, Jameson. (*Macle*, Haüy). Very distinct specimens of this mineral have been found by Mr. Davy at *Aghavanagh*

in the County of Wicklow; and I have observed it at *Baltinglass* hill, within a few miles of that place. I may mention here, that from the appearances of many specimens found in the neighbourhood of Killiney, Mr. Stephens was inclined to suppose that a connection existed between this singular species and *Andalusite*.

7. *Pitchstone.* This substance is found in a vein traversing granite, in the vicinity of Newry in the County of Down. I am indebted to Mr. Jameson of Edinburgh, for much of the following description of its external characters, as it appears there.

Its colour is intermediate between mountain and leek green. It is massive. Fracture small and not very perfect conchoidal.

Internal lustre, resino-vitreous and shining. It exhibits lamellar distinct concretions; the plates are from one-fourth to one-tenth of an inch in thickness, and are further divisible into pieces of the rhomboidal form of various angles.

The surface of the concretions is smooth, and strongly glistening. Slightly translucent on the edges. It scratches window-glass, but is easily scratched by quartz. Easily broken. Specific gravity, 2,29. Before the blowpipe without addition it yields a greyish-white frothy enamel.

It is in some places porphyritic, containing imbedded, minute crystals of feldspar and of quartz.

A letter from a very intelligent observer, who has examined this substance in its native place, states the following particulars respecting its position.

" The vein is first observable in the Townland of Newry, at the
" bottom of a bank of granite, about half a mile from the northern
" end of the town, on the right of the road leading to Down-
" Patrick. It crosses the road, and runs due westward, ending on

" the side of the great road from Newry to Belfast. Its length, so " far as hitherto observed, is half a mile.

" The rock, which is covered with mould to the depth of about " a foot, consists of a grey granite. The vein is about two feet and " a half, or two and a quarter in width; at the places of contact both " the granite and pitchstone are disintegrated, the latter being almost " as soft as clay, but becoming gradually harder, as it approaches the " center of the vein. The structure of the vein is foliated, the " folia being perpendicular to the horizon, and also to the walls; " and besides these, there are seams, that run longitudinally, parallel " to the horizon, and nearly perpendicular to the folia."

Although this substance presents some peculiarity, in being divisible into rhomboidal fragments, it approaches in this respect to the *pitchstone* of Arran (in lamellar concretions) which holds as it were a middle place between it, and that possessing the more usual characters.

Mr. Jameson has described a vein of pitchstone " running in granite," observed by himself in Arran;* and he states that " lamellar distinct concretions have been hitherto observed in the " pitchstone of that island only."†

8. The *granular sulphate of barytes*, hitherto very rare, has been found, as the Rev. Mr. Hincks of Cork informs me, by Dr. Wood of that city, on the sea shore, near *Clonakilty*, from whence a specimen in the Museum of Dublin College, (No. 653) has probably been obtained: it is accompanied by iron pyrites.

9. *Wavellite.* This remarkable mineral has recently been found in the county of Cork, at *Springhill* near *Tracton-abbey*, about ten miles south-eastward from the city. The Rev. Mr. Hincks of the

* Min. of Scottish Isles, 4to. vol. I. p. 81. † Jameson's Mineralogy, vol. I. p. 261.

Cork Institution, from whom the specimens that I have seen were obtained, informs me, that it was found at a small distance from the surface, near the base of a hill composed of a flinty slate, and that he has seen it adhering to a piece of rock of that description. But it has occurred principally detached in the form of globular nodules, irregularly grouped together, and of various sizes, the longest about an inch in diameter, externally coated with a yellowish brown earthy crust, and within composed of radiating crystalline spiculæ, the characters of which agree very nearly with those of the wavellite from Devonshire, described by Mr. Davy; indeed some of the specimens from the county of Cork, are scarcely to be distinguished from some of those obtained at that place.

The most distinct specimen that I have seen was a nodule about three-fourths of an inch in diameter, in part affected by decomposition and containing some small spongy cavities. On its external surface indistinct dihedral terminations of the crystalline shoots are discernible; and internally, where it is not decomposed, its lustre is higher and more glossy than is common in the Devonshire fossil. The specific gravity of that part of it, which was very pure and nearly transparent, was 2.34.

The nodules are in some instances decomposed throughout, the spiculæ having lost their lustre, acquire a dull grey or brownish colour, and become much softer than when unchanged; and Mr. Hincks has seen some of them altogether in the state of clay, apparently from the effect of decomposition.

It would appear that the fluoric acid, of which Mr. Davy has ascertained the presence in the wavellite from Devonshire, exists also in that from Cork; for glass is corroded by heating upon it, in a drop of sulphuric acid, a fragment of the mineral from either of those places.

XII. *On the Mineralogy of the Malvern Hills.*

By Leonard Horner, Esq.

Secretary of the Geological Society.

§ 1. THE Malvern hills are situated in the south-western part of Worcestershire: the boundary which divides the counties of Worcester and Hereford, passes along their western side.

§ 2. They consist of an uninterrupted chain of about nine miles in length, extending nearly in a straight line from north to south; their greatest breadth from east to west not exceeding two miles. The several parts of the chain all present rounded summits, and from one extremity to the other they are nearly covered with a luxuriant vegetation.

§ 3. When viewed from a little distance on the eastern side, we see that there is a gradual rise from south to north, and that there are three hills which form the principal features, as they stand considerably above the general outline. The highest of these is in the centre, and is known by the name of the Herefordshire Beacon; but the greater elevation of this hill above the other two is not very apparent on this side, as it falls back to the eastward, and rather stands out from the general direction of the range.* The two other

* On the top of this hill are the remains of a camp, with a treble ditch. "Some have "imagined it Roman, because of the prætorium, or centre part, and the name of the

prominent hills are situated nearly close together at the northern extremity; of these, that which is farthest south is called the Worcestershire Beacon, and is the highest of the two; the name of the other is the North-hill.

§ 4. On the eastern side, the hills rise at a considerable angle, from a level plain that stretches to the banks of the river Severn, a distance of between three and four miles. On the western side, the ascent is more gradual, and the country for several miles to the westward is formed of a succession of small hillocks which are covered to their tops with coppice wood: the longitudinal bearing of these, is in general parallel to that of the range. There is a very extensive and beautiful view from the top of the Malvern hills, and the different appearances of the two sides present a very remarkable contrast: on the one hand, the widely extended plain of Worcestershire stretching for many miles to the eastward, the continued level of which is only here and there interrupted by small wooded eminences rising in detached spots; on the other hand, a constant succession of rising ground, which is terminated by the distant Welsh mountains.

§ 5. The eastern side does not present the same continued slope that extends on the western, from the summit to the base, but is very much broken by narrow vallies or water courses that run at right angles to the direction of the range. Besides these, there are some vallies of more considerable extent: two of them are at the northern extremity, the one separating the Worcestershire Beacon from the North-hill, the other dividing this last from what is

"parish, in which the greater part of it is situated, Collwall, that is *Collis Vallum.* The "whole circumference of it is two thousand nine hundred and seventy yards, the length "one thousand one hundred yards. The whole camp contains forty-four statute acres." Nash's History of Worcestershire.

termed the End-hill. Where the Herefordshire Beacon falls back to the westward, occurs a wide, and in some places thickly wooded, valley, in the bottom of which is situated the retired village of Little Malvern. All these vallies run from west to east, and gradually widen as they descend. There are none parallel to the direction of the chain.

§ 6. In Nash's History of Worcestershire, the highest point of the Malvern Hills is said to be 1313 feet above the level of the Severn at Hanley. In the table lately published of the altitudes taken in the course of the Ordnance Survey in different parts of England, the height of the Malvern Hills above the level of the sea is stated at 1444 feet. I am informed by Lieut. Col. Mudge that the particular hill to which this measurement refers, is that situated in the centre of the range, the Herefordshire Beacon. I had not an opportunity of ascertaining the height of this hill above the adjacent plain; I obtained however that of the Worcestershire Beacon and of the North-hill. The instrument I made use of was Sir Henry Englefield's portable barometer, and the following are the results of my observations. My lowest station was at the north-eastern extremity of the common, called the Links, from which point there is almost a dead level to the banks of the Severn.

	FEET
The Worcestershire Beacon (by the mean of three observations)	1238
The North-hill (by the mean of two observations) . .	1151
The road before the door of the Crown-hotel, in Great Malvern (by the mean of three observations) . . .	273

As the right bank of the Severn, at the termination of the plain from which these measurements are calculated, is between sixty and seventy feet in perpendicular height, this added to the above elevation of the Worcestershire Beacon, very nearly corresponds with the statement in Nash's History of Worcestershire.

§ 7. The whole range from one end to the other is, as I have already mentioned, almost entirely covered with vegetation. It is only in a few places that the rock projects above the surface; this is more particularly the case at the northern extremity, and there, principally on the eastern side; the western slope hardly offers in any part of it any thing more than a very fine close turf: even the rocks that do appear are in general thickly coated with lichens, and decomposed at the surface; so that it is difficult without a very close examination, to obtain an accurate knowledge of the mineral structure of these hills. There are however several quarries worked in different places and at different heights, and besides the opportunities which these afford to the mineralogist, there are two carriage roads that cross the hill, in the making of which, the rock has been in many places laid bare. The most northern of these, rises gradually along the side to within thirty or forty feet of the summit, where a cut has been made through the hill from east to west, thus exhibiting a transverse section of the rocks: this chasm is known by the name of the Wych. The other, is the turnpike-road from Worcester to Ledbury; it crosses the hill immediately above Little Malvern, passing along the side of the Herefordshire Beacon, and in the making of this road the rock has been in different places cut down to the depth of twenty or thirty feet.

§ 8. Besides the obstacles to accurate observation, that I have already mentioned, there is another difficulty which it requires some patience to overcome. The greatest proportion of the rocks are in that state which the quarriers term rotten; which means, that when a block of the stone is struck with the hammer, it breaks into a number of small irregular fragments, frequently not exceeding the size of a walnut, the surfaces of which are generally covered with oxide of iron, probably arising from a partial decomposition. This is the case, not merely near the surface, but in some degree even where the rock has been quarried to a considerable depth. This peculiarity renders it very difficult to obtain such a fracture as shews the real nature of the rock, and makes it almost impossible to procure good cabinet specimens.

§ 9. When I first began to examine the rocks of which these hills are composed, I was particularly struck with the great variety that presented itself, for almost every specimen which I detached within a very limited space, offered a new character. A closer examination, however, shewed that there is a greater uniformity than I at first suspected, and that the diversity of appearance depends on the different proportions in which the same materials are united together. Felspar, hornblende, quartz, and mica, forming different compound rocks, and varying as much in the size as in the proportions of the ingredients, constitute the greater part of the range. There are very few rocks in which the size of the component parts is so minute as to give the internal structure a homogeneous appearance.

§ 10. If every "compound granular aggregated rock, composed of felspar, quartz, and mica," is to be considered as granite, a very great part of the Malvern hills is composed of it; but among the various compounds of that nature, found in this place, there are very few which present the same appearance as the granite of Alpine countries; they have not the decided crystalline structure, which these granites usually exhibit; nor are the several parts so closely intermixed. The felspar is generally red, and predominates considerably in the mass; sometimes the quartz and sometimes the mica is wanting, but more frequently the latter. I shall, however, for the sake of brevity in the following descriptions, distinguish all those rocks, in the composition of which these three ingredients are found, however disproportionate they may be to each other, by the general name of granite. I feel the more warranted in doing so, from what Mr. Jameson has said in the definition he gives of granite. "The parts," he says, "vary in quantity, so that sometimes one, sometimes the other, and frequently two of them, predominate. Felspar is generally the predominating, as mica is the least considerable ingredient of the rock. In some varieties the quartz is wanting; in others the mica; and these have received particular names. Such distinctions, however, are useless." But I considered it necessary to give this previous explanation of the peculiarity of their structure, as the mere term granite would convey to most mineralogists, an erroneous idea of the true nature of the rocks I now allude to. I ſhall also, for the sake of brevity, occasionally distinguish those rocks in which hornblende forms a predominating ingredient by the general name of sienitic rocks. It would be an endless task to give separate names to the various compounds met with in the Malvern hills, although they certainly have different external appearances; and were I to attempt to do so, I should perhaps be making distinctions, which their origin does not warrant, as all the varieties comprehended in the same class have probably been produced under similar circumstances. But in the present state of geological science, and more especially when the great imperfection of the nomenclature of rocks is considered, it would be well if geologists made a practice of describing the simple minerals of which a rock is composed, wherever they can be distinguished, instead of giving specific names without any explanation of the nature of the

* Jameson's Geognosy, p. 102.

compounds to which their terms are applied, and particularly those in which theory is involved. They would thus be following a more precise and more philosophical method, the accuracy of their observations would be more firmly relied on in the present day, and there would be a greater probability of their proving valuable in a more advanced state of the science. Those who have had an opportunity of seeing the various rocks to which the names grauwacke and greenstone are applied, will perhaps agree with me in the opinion I have thus ventured to advance.

§ 11. Before proceeding to a detailed account of the several rocks met with in the Malvern hills, I shall point out the general structure of the great masses. The central part of the range, and nearly the whole of the eastern side consist of the different compounds of felspar, hornblende, quartz, and mica, I have already alluded to. These are irregularly heaped together in large masses, and in no part could I discover them disposed in any way that could be considered as continued stratification. In some instances, the materials of the rock are so arranged as to give it a fissile appearance, and in these cases, the slaty structure is either vertical or very highly inclined. But the masses themselves I never found to be of any great extent, and they are frequently inclined to different points of the compass within a very short space. Except in regard to the granite, I did not discover any uniformity in the occurrence of any one compound in particular situations, but all seem confusedly heaped together. The granite is sometimes found in the highest parts of the hills, but chiefly prevails in the lower parts, particularly towards the northern extremity, either in large masses, or what is very frequent, forming veins which traverse the other rocks. These veins or shoots are for the most part narrow, and, as far as I had an opportunity of ascertaining, they generally become more so, the higher they ascend.

§ 12. The stratified rocks which occupy the country to the westward, rise in some places to a considerable height on the side of the range; the highest point where I found them, was on the Herefordshire beacon, at about one third of the elevation of that hill. The particular arrangement of these stratified rocks I shall relate in a subsequent part of this paper.

§ 13. I have deposited in the collection of the Society, a series of specimens illustrative of the mineralogy of the district I am now describing. Among these, there are several which may at first sight appear to be duplicates. but they all possess shades of difference; and in a collection of the mineral productions of any particular district, it is material that every variety should be contained, for by these gradations the connection between rocks of very dissimilar appearances is frequently made out. The specimens of the unstratified rocks are chiefly from the northern part of the range where the rock is most exposed.

Of the unstratified Rocks.

§ 14. Although some of the rocks I shall describe under this head have a slaty structure, and as such, were probably formed by successive deposition; yet as they are of comparatively rare occurrence, and when found, are only in irregular masses without any continued stratification, I shall employ this term to distinguish the rocks that compose the central part of the range, from the stratified rocks, which, as I have already said, occasionally rise to a considerable height upon the western side of it.

§ 15. The most northern point where the unstratified rocks are seen above the surface, is about a quarter of a mile in a direct line from the road which winds round the End-Hill. The rock found in this place is of a dark green colour, of a loose texture, and is composed principally of steatite, with a little felspar and quartz. It is traversed by a slender vein of granite, but as there is a very inconsiderable mass of the rock exposed, I had not an opportunity of tracing the vein but for a very short way.

§ 16. A great part of the End-Hill is composed of granite, particularly on the west side, where it contains veins of quartz in several places. It occurs near the bottom of the hill on the south-east side, and is also found in very large masses on the opposite side of the valley which separates the End-Hill from the North-Hill. In this valley I found a loose black, composed of white felspar, grey quartz, and greenish-black mica, with a little hornblende. In one part of the specimen that I detached from the mass, these materials become more minute, and assume somewhat of a slaty structure. Where this is the case, the mica is more abundant.

§ 17. In the same part of the End-hill, but at a higher elevation than the granite, there is a rock which prevails very much throughout the whole range. It is of a purplish-brown colour, with a fine close-grained texture and an uneven fracture. It is composed of hornblende, felspar, and a little quartz; sometimes contains a small quantity of magnetic pyrites, and slender veins of compact epidote; in the fissures of it, crystallized sulphate of barytes and minute rhomboidal crystals of ferriferous carbonate of lime are also occasionally met with: this rock would probably be arranged with the greenstones in the classification of Werner. On the west side of the End-hill, and in some part of the eastern side, a rock is met with, the characters of which correspond very nearly with those of sienite; it is composed of hornblende and felspar, with a few spangles of mica.

§ 18. On the northern side of the End-hill, a rock occurs which differs very essentially from those that I found in any other part of the range. It is composed of nearly an equal mixture of hornblende and epidote in small grains, with a few specks of mica. It is of a yellowish-green colour, of a close texture, with rather an uneven fracture, and is crossed in all directions by slender veins of compact epidote. In some instances, the surfaces of the irregular fragments into which it breaks, are covered with minute crystals of magnesian carbonate of lime, and with slightly magnetic oxide of iron: the rock itself does not act upon the magnet. It occurs in very large masses, but neither in the disposition of these, nor in the internal arrangement of its parts, does it exhibit any signs of stratification. Within a very limited space, it assumes different aspects; the difference seeming chiefly to depend on the greater or less abundance of the epidote, and also on different states of decomposition.

§ 19. The epidote is found on the End-hill, under various appearances; in some of these, the crystalline forms peculiar to this substance may be seen, but I did not meet with any complete well-defined crystals: it is most commonly found in a compact and granular state, forming small veins of a yellowish-green colour, which sometimes pass through the granite, and sometimes through the sienitic rocks. It is not confined to the End-hill, but I found it in greater abundance there than in any other part of the range, particularly on the northern side of the valley, which separates that hill from the North-hill, and among the loose fragments that are scattered over that valley. It is very often found in veins mixed with quartz and with felspar, but the only place where I found it forming the constituent part of a rock was at the northern face of the End-hill. In some instances, the epidote would scarcely perhaps be recognized, especially where it is much mixed with felspar or quartz; but if a series of specimens be examined, from that in which it is very abundant, and exhibits the distinctive characters of the simple mineral, to that in which it is with difficulty perceptible, very little doubt will remain of its existence in the latter.

§ 20. This mineral is not of very common occurrence in its simple state, and is probably less so as a constituent part of a rock; for it is not noticed as such in the Wernerian system, nor am I aware of its being mentioned in any mineralogical work, except in a very few instances. Brongniart, in treating of epidote says, "This "mineral seems to belong exclusively to primitive countries, but it "does not usually enter into the structure of rocks. It is found "crystallized in the fissures of these rocks, or in the cavities of veins, "and even penetrates the substances composing the veins in all direc-"tions; it is thus that it traverses carbonate of lime, quartz, &c."* He does not however name any place where it is found to enter into the structure of a rock. Saussure met with it not far distant from Mont Blanc: "On the road," says he, "from Modane to Villa-"rodin, in descending the hill above this village, I found in the high "road and in the walls of the houses, stones of a very beautiful "green, sometimes mixed with white. The green parts, some of "which are yellowish-green, having a sparkling lustre, granular and "hard, are of the same nature as the green schorl of Dauphiny. "This schorl I name Delphinite,† to distinguish it from some other "green schorls of a very different nature. These yellowish parts are "therefore granular delphinite. The parts of a leek-green, which are "included in this stone, and which have a schistose or lamellar struc-"ture, are hornblende. The white parts are crystalline and granular

* Brongniart, Traité Elémentaire de Minéralogie, tom. i. p. 412.

† This substance has obtained a great variety of names. It is called Glassy Actynolite by Kirwan, Thallite by La Metherie, Akanticone by Dandrada, Pistazite by Werner, and Epidote by Hauy.

"felspar.*" From this description, the epidote may be considered as forming a constituent part of the mass, and it accords with some of the varieties I found on the Malvern-hills. But as the rock which Saussure met with was in detached pieces, we cannot determine whether they were not portions of a vein.

§ 21. Since my attention has been directed to the subject, I have ascertained that epidote occurs in Cumberland, and in the Islands of Iona and Rona, two of the Hebrides, in a state similar to some of the varieties I found on the Malvern-hills. In examining some specimens from those places in the collection of Mr. Greenough, I found the following.

1. *From Cumberland.*

a. Crystallized epidote shooting through quartz, from Wallow Crag near Keswick, very similar to what is found in the valley of Chamouni. It is more distinctly crystallized than any I saw at Malvern. The specimens are evidently portions of a vein.

b. Epidote in a compact state, mixed with reddish felspar, forming a vein in a schistose rock from the same place.

2. *From Iona.*

Compact epidote disseminated in small veins, through a rock consisting of red felspar and quartz.

* Saussure, Voyages dans les Alpes, § 1225.

3. *From Rona.*

a. Compact epidote of a bright yellowish-green colour, forming slender veins which traverse a rock principally composed of flesh-red felspar and a little grey quartz. It is very similar to that from Iona, except that this contains less quartz.

b. A rock composed of hornblende and reddish felspar, together with epidote, both as a constituent part and in veins passing through the rock.

These two specimens, and particularly the first, are nearly identical with some of the varieties from Malvern.

c. Compact epidote in small threads passing through vitreous quartz.

Dr. Wollaston, who had the goodness to compare, at my request, the above specimens from the Western Islands, with those I brought from Malvern, has since found the epidote in similar circumstances, in the Islands of Guernsey and Jersey; and he has been so kind as give me some of the specimens he collected. They are as follow:

a. A granular rock, composed of yellowish-green compact epidote and hornblende, in small grains. It is nearly the same as that which I found on the northern face of the End-hill; the only difference is, that this specimen from Guernsey contains a greater proportion of epidote.

b. This so exactly resembles the specimen *a* from Rona, that they might be considered as portions of the same mass.

c. Granite consisting of reddish felspar, white quartz and a little greenish-black mica, including a mass of epidote crystallized in slender divergent prisms. This specimen is from Jersey.

§ 22. On the summit of the ridge which connects the End-hill with the North-hill, there is a rock almost wholly made up of hornblende, with a few spangles of mica and a little felspar. Near this, I found granite, which may perhaps be a vein, as the mass is very narrow, and the hornblende rock occurs on both sides of it; but the turf forms so close a covering, and leaves so very little of the rock exposed, that the relation between the hornblende rock and the granite cannot be determined.

§ 23. The western side of this ridge is principally composed of a rock of a reddish-brown colour, in which the chief ingredients are quartz and felspar, together with mica and a little epidote: in some of the fissures of it there are minute crystals of quartz and of felspar. On this side of the ridge I also found granite, containing subordinate portions of hornblende; in some parts of the same mass, the hornblende becomes the prevailing ingredient, and the mica is wholly wanting; thus passing into sienite. It is of very small extent, and the micaceous rock just mentioned occurs on both sides of it.

§ 24. On the summit of the North-hill, a very small portion of the rock is laid bare, and it is so much decomposed, that a gentle blow of the hammer makes it break down into very small fragments. I succeeded however in obtaining a fracture that shewed the composition of the stone, which is a mixture of hornblende and reddish felspar in very small grains, similar to that noticed § 17 as occurring on the south-east side of the End-hill, and as prevailing very generally throughout the range.

§ 25. A considerable part of the north-eastern side of this hill, is composed of granite. This I have already stated to be identical with that on the opposite side of the valley in the lower part of the End-hill, § 16. This is the only place in the whole range, where I found the arrangement of the rock-masses exhibiting any signs of stratification; but the indications of it are so very indistinct, that I hardly think the rock can be considered as stratified. If it is so, the strata are very highly inclined, and dip to the east. In the spaces that intervene between large masses of the granite, there is a rock composed of hornblende and mica, with somewhat of a slaty structure and a loose friable texture. It is intersected by veins, which are sometimes very slender, and in that case they consist of red felspar; but when the same vein becomes wider, it is found to contain the usual component parts of granite. These veins are disseminated irregularly through the mass, the line of separation is very distinct, and there is no mutual penetration of the two rocks.

§ 26. On the south-east side of the North-hill, and at the entrance of the valley above Great Malvern, which separates that hill from the Worcestershire Beacon, there is an aggregate rock consisting of small angular and rounded fragments of quartz and felspar, cemented by a ferruginous earthy base; the whole in a decomposing state. It occurs in the lower part of the hill, and is probably produced from the disintegration of a granite, the mica of which has been chiefly decomposed and has afforded the cement. Above this aggregate rock, the hill consists almost entirely of granite, in which the materials are in some places so disposed as to give the rock somewhat the appearance of gneiss. It is fresher than most of the rocks in these hills, that is to say, it is less disposed to break into irregular fragments with decomposed surfaces. It sometimes contains veins of epidote, and in one instance I found in it a slender vein of calcareous spar. Subordinate portions of a mixture of hornblende and felspar occasionally occur in it, and sometimes the hornblende, felspar, quartz and mica are combined in equal proportions, forming a uniform mass. In this part of the hill, I also met with a fine-grained rock, consisting of quartz, felspar, mica and granular epidote, traversed by a narrow vein of granite.

§ 27. The upper part of the Worcestershire Beacon is composed of granite, and the rocks which rise above the surface, about a quarter of a mile to the south, are of the same nature. On the eastern side, the greenstone I have described, § 17, forms the prevailing rock. I found in this place, another compound of hornblende and felspar, which has perhaps more distinctly the appearance of a greenstone than the other. The constituent parts are larger grained, and the felspar is white: magnetic pyrites are disseminated through the mass.

§ 28. About the middle of the hill on this side, I found a rock of a brownish olive colour, of a close texture, with an uneven fracture, and, as far as the fineness of the grain enables me to determine, composed of hornblende and felspar, but chiefly the former; there are also some detached portions of calcareous spar imbedded in it. It is attracted by the magnet. When broken, it appears full of angular fragments; and I in consequence considered it of secondary formation, but when the fracture is made across the fragments, they are found to be composed of the same materials as the base in which they appear imbedded, nor can they be distinguished from it; I am therefore of opinion, that the fragmented appearance arises from a disposition in the rock to split into small irregular pieces with decomposed surfaces, a peculiarity I have already noticed as being common to most of the unstratified rocks of the Malvern hills.

§ 29. In a lower part of the hill, and close by the high road, there is a very loosely aggregated red and white quartzose sandstone, accompanied with patches of reddish-brown clay, containing fragments of a granitic rock, and of the sandstone itself. The situation of this sandstone is remarkable; it occurs at a considerable height above the plain, it offers no signs of stratification, and is of very small extent, lying as it were in a hollow of the other rocks. It is very similar to what is found in the plain below, except that the latter contains some calcareous particles which this does not. It is evidently produced from the disintegration of other rocks, probably those of the chain, and has every appearance of being of very late formation.

§ 30. On the north-east side of the Worcestershire Beacon, and in the road leading from Great Malvern to St. Ann's Well, I found a rock of a loose coarse-grained texture, with an earthy fracture, composed of mica and hornblende in a state of decomposition, mixed with red felspar. It has a slaty structure, which in some places is more distinct than in others from there being a greater proportion of mica, and its disposition is, within a short space, sometimes vertical, sometimes inclined at a considerable angle, and dipping to different points of the compass; having the appearance of large masses irregularly heaped together. This rock is traversed by a vein of sulphate of barytes about four inches in thickness, and which occasionally includes detached portions of the rock through which it passes. The particular spot where I saw this rock, was where an excavation had been made in the hill round a house newly built, and as the rock was cut down to a considerable depth, a good section of it was exposed to view.

§ 31. The western side of the Worcestershire Beacon is covered with turf, so that whatever rocks occur there, are completely concealed.

§ 32. Between the Worcestershire Beacon and the chasm called the Wych, the rocks, on the eastern side, are similar to those I have already mentioned, except in one instance on the top of the hill, where a rock is found composed of greenish-brown mica, intermixed with hornblende. Although mica is the chief ingredient, this rock has not the slaty structure which most micaceous rocks have, but the laminæ which are pretty large, are irregularly grouped together, and cross each other in all directions. It is an insulated mass of very small extent. In this place, a hundred years ago, a shaft was sunk in the hope of finding metal, but from the following account in Nash's History of Worcestershire, the attempt does not appear to have been attended with much success. "In the year 1711, "one Williams of Bristol sunk a mine about a mile from the town (Great Malvern), on the top of the hill as you go to the Holy Well. He at first worked by a level, about eighty yards, then sunk a perpendicular shaft, near 220 feet deep: he built several furnaces, but never extracted any considerable metal; though he asserted that both tin and copper were to be found. He persevered in his trials for ten years, and then gave up the project." It is very probable, that the metallic lustre of the micaceous rock was the cause of the speculation; and to this day, the country people call the scales of mica, which are washed down by the streams in this part of the hill, gold dust. They are, however, so far aware of the difference, that they save themselves the trouble of collecting it. There is now no appearance of the level, and the shaft is almost completely filled up; a large heap of loose stones however lies upon the side of the hill, immediately below the mouth of the shaft, which is probably the rubbish of the mine, although it is so long since it was worked; for there are no rocks above from which they could have fallen down. Among these, I found the following varieties:

a. Composed chiefly of hornblende, mica, and felspar. In some places the mica is crystallized.

b. The same rock as the preceding, but containing a larger proportion of flesh-red felspar. A small quantity of copper and iron pyrites is disseminated through the mass.

c. A friable rock, composed of greenish black mica and green decomposing felspar.

§ 33. In the road which leads up to the Wych, the rocks are laid bare in several places. That which is the most prevalent, is the fine grained greenstone I have mentioned, as forming so great a part of the northern end of these hills, §§17.24. There are besides, several other compounds of hornblende, felspar, quartz, and mica, united in various proportions, which are very similar to those I have already spoken of, and which it is now unnecessary to describe in a more detailed manner. These are traversed in many places by veins or shoots of granite: in one of these, the constituent parts are of a larger size than usual, and the mica is regularly crystallized; but it is decomposed near the surface. In one place, there is a vein of white opake quartz intermixed with silvery mica. All these rocks are so confusedly heaped together, and in so shivery a ſtate, that it requires some attention before their real nature, and their relative situations can be well understood.

§ 34. At the Wych, where the rocks have been cut through, as mentioned in § 7. granite is the prevailing rock; in this, red felspar predominates, and the mica, which is also in some places very abundant, is of a dark green colour. Slender veins of calcareous spar are occasionally met with in this granite. There is a considerable quantity of another rock, which seems to fill up the spaces that intervene between the masses of granite. It is chiefly argillaceous, of a dark olive-green colour, with an imperfect slaty structure, and when broken across, shews an earthy fracture: the flat thin masses into which it splits have smooth and shining surfaces, as if polished by friction; it occasionally contains veins of calcareous spar. In some places it is found decomposed, and in that state it becomes very friable. I did not meet with this argillaceous rock in any part of the range that lies to the north of the Wych. I found here some small portions of a granite partially decomposed, and the surfaces of the fragments into which it breaks are covered with dendritical delineations of manganese. The same kind of granite also occurs in a quarry by the side of the road near Little Malvern.

§ 35. Between the Wych and that part of the hill where the road from Worcester to Ledbury crosses it, a distance of about three miles, the rock is seldom seen above the surface of the ground on either side. I examined most of the places where it does appear, but did not find any thing different from what I had met with in the northern part of the range.

§ 36. The road now mentioned, rises along the side of the valley above Little Malvern, and winds round the northern face of the Herefordshire beacon. In making it, the rock has been cut down considerably on one side. I found a greater uniformity in the rocks of this part of the range, than in those which compose the northern half; there is less granite, and hornblende also occurs more rarely. The most prevalent rock is one of a pale flesh colour, of a fine grain, and chiefly composed of compact felspar: it is very full of fissures, so that it easily breaks into small irregular fragments, the surfaces of which are covered with yellow oxide of iron, and on some of these there are minute dendritical delineations of manganese. They are also occasionally covered with small rhomboidal crystals of spathose iron of a golden yellow colour, with a metallic lustre. Calcareous spar, sometimes in distinct crystals, is likewise occasionally met with in it. This rock forms the greater part of the hill to the north of the road, as well as that part of the Herefordshire Beacon through which the road has been cut: but what this last hill is chiefly composed of, I am unable to say, as it is nearly covered with vegetation on all sides.

§ 37. A short way to the south of the Herefordshire Beacon, there is a mass projecting above the surface, which consists of a fine grained conglomerate, of a dark brown colour, composed of felspar, steatite, and calcareous spar, united by a ferro-argillaceous base, and containing some minute specks of a greenish yellow substance, in diverging fibres, which is probably actynolite. The rock is attracted by the magnet.

§ 38. In a lane at the foot of the Herefordshire Beacon, on the western side, I found a vein of red hematite, passing through a rock consisting of red felspar and quartz, partially decomposed.

§ 39. The next height to the south of the Herefordshire Beacon is Swinnit-hill.* The upper part of this hill is composed of a granite, that is more distinctly characterized as such, than the greater part of those found in the Malvern Hills: still, however, it is very different from an Alpine granite, the mica is in minute specks, and there is also a very small proportion of it. In the lower part of the eastern side of the hill, the rock has been excavated to a considerable depth at Castle Morton quarry; it consists chiefly of hornblende, with a little reddish white felspar and quartz, and in some places it contains pyrites. Among a heap of large blocks, that had been recently got out of the quarry, I observed this rock penetrated in many places by veins consisting of flesh red felspar and grey quartz: when the vein was narrow, these were the only ingredients; but where it became wider, silvery mica also formed a component part of it, and in some places it was accompanied with steatite. I was prevented from examining the spot from whence these blocks were taken, in consequence of a heavy rain having, a few days before, washed down so much earth from the upper part of the hill, as to fill up the place where the quarriers had been at work.

§ 40. About a quarter of a mile further south, I found a schistose

* I write the name of this hill, as it is pronounced by the country people. I have not seen it in any map, nor in the county history.

rock composed of hornblende and mica, intermixed with a small quantity of felspar, quartz, and pyrites. It occurs in large masses irregularly heaped together, and the relative position of the schistose structure in the different masses preserves no uniformity. It is traversed by granite veins, varying from one to six inches in thickness, branching in different directions, and diminishing in thickness as they ascend. This schistose rock is very similar to one that occurs by the side of the road leading up to the Wych, where it is also traversed by granite veins.

§ 41. A deep but narrow valley separates Swinnit Hill from the Holly-Bush Hill. In this valley, and in the lower part of the latter hill, I found the following rocks:

a. Different varieties of gneiss, imperfectly characterized. It seems to bear the same relation to true gneiss, that the granite of these hills has been described to bear to Alpine granite.

b. A fine grained sandstone, consisting principally of quartz, with a few particles of felspar and mica: in some places it includes large rounded fragments of quartz and felspar, having the appearance of a breccia.

c. Granular quartz, mixed with small white specks of decomposed felspar.*

* The same rock as this occurs in strata, by the side of the road between Bromesgrove and Birmingham, and many of the pebbles of the gravel, that covers so great an extent of country in that part of England, are composed of it.

Mr. Playfair, in his Illustrations of the Huttonian Theory, §§ 336, 337, speaking of this gravel, says, that it might in part have been produced from the detritus of these strata near Bromesgrove. About two years ago, when in that part of the country, I examined a great variety of the pebbles in a gravel pit, about a mile to the north of Birmingham, and I afterwards examined the strata near Bromesgrove. On comparing the specimens from both, I found a perfect identity between several of the pebbles and the stratified quartzose rock. Between these strata and the gravel pit, there is an extent of about ten miles of nearly level country.

These several rocks are all found within a very limited space; but it was impossible to form any conclusion as to their relation to each other, in regard to position, for they are only seen in separate masses projecting above the surface. The gneiss seems, however, to be the prevailing rock on the northern side, as well as in the upper part of the Holly-Bush Hill, and in the latter place, the slaty structure of the rock is perpendicular to the plane of the horizon.

§ 42. On the south side of the Holly-Bush Hill, there is a rock of a dark brown colour, composed of compact felspar, hornblende, quartz, and steatite, with a few detached crystals of felspar imbedded in it, producing a kind of porphyritic structure: this appearance becomes more distinct, when the rock is a little decomposed. It has an earthy texture, with somewhat of an uneven fracture, and is attracted by the magnet. In a small quarry, about a quarter of a mile to the westward, I found the same rock in various stages of decomposition. Where it is most decomposed, it becomes a friable mass of an ochre yellow colour.

§ 43. The last place, where I found the rock exposed at the south end of the range, was about half a mile beyond the Holly-Bush Hill; it was called the Ragstone Hill by some quarriers whom I found at work. The rock that occurs here is different from any other I met with in these hills. It is of an olive green colour, and, as far as the closeness of its texture enables me to say, is composed of felspar and mica, united by a ferruginous clay, forming nearly a homogeneous mass, and occasionally traversed by veins of calcareous spar. It occurs massive, without any signs of stratification.

§ 44. Before concluding this enumeration of the unstratified rocks, I may notice a breccia, of which I found a loose block in a lane near the Holly-Bush Hill on the western side, but which I could not discover any where *in situ.* It is composed of rounded fragments of quartz and felspar, united by an argillo-calcareous cement, and the whole crossed by veins of calcareous spar which sometimes cut through the imbedded pebbles. It is very different from the breccia noticed § 41. *b*, as occurring in the lower part of the north side of the Holly-Bush Hill; for in that, the fragments are united by a quartzose base.

§ 45. In the account which I have now laid before the Society of the unstratified rocks of the Malvern Hills, I have chiefly dwelt upon those found in the northern parts. It is there that the rocks are most exposed, and as I resided at Great Malvern, I had an opportunity of examining that end of the range with more leisure and attention than I could bestow on the more distant hills to the south.

Of the Stratified Rocks on the Western Side of the Malvern Hills.

§ 46. In describing these, I shall observe the same plan I have adopted in regard to the unstratified rocks, by beginning at the northern end of the range, and proceeding towards the south.

§ 47. The first stratified rock that is exposed in turning round the End-hill from Great Malvern, is a coarse-grained sandstone of a purplish-brown colour, composed of rounded and angular fragments of quartz and felspar, but chiefly of the former, few of them exceeding the size of a pea. This rock is loosely aggregated, particularly in those parts where the fragments are largest, as the ferro-argillaceous cement is in very small quantity, and even appears to be itself composed of minute grains. It occurs in strata seldom exceeding a foot in thickness, in a vertical position, and bearing N. and S.; a good section of them is exhibited in the side of the road. This sandstone is not however the nearest stratified rock to the Malvern range, for the road at this place makes a turn towards the hill, and on the left hand side of it, after proceeding a short way to the south, there appear several thin strata also bearing N. and S. and nearly vertical; the slight inclination they have from that position is towards the west. They consist of an alternation of a very compact argillo-quartzose sandstone, and containing a few impressions of terebratulites; of another rock similar to this, but much mixed with calcareous particles; and of a limestone, which contains a great number of the shells I have juft named.

§ 48. Proceeding farther south, the road inclines towards the west, and is cut through a compact quartzose sandstone, similar to that mentioned in the preceding section, and containing impressions of madreporites and of terebratulites. It is here however mixed with a considerable quantity of mica, has a slaty structure, and breaks into rhomboidal fragments; giving it very much the appearance of a grauwacke slate. It occurs in thin strata, the bearing of which continues parallel to the direction of the range; but they dip *east* at an angle of about 60°. The road very soon turns to the westward, at a right angle to its former direction, and as it is still cut through the rocks, exhibits a transverse section of them; and in the space of about a quarter of a mile, they display some very remarkable changes in their mode of stratification. The inclination of the compact sandstone diminishes for some way as it recedes from the hill, but it again begins gradually to increase: to this rock succeed thin strata of an argillaceous limestone coated with a slaty clay, the inclination of which becomes more and more considerable. Thin strata of an argillaceous rock now appear, which very soon acquire a vertical position; they continue so for a short way, and then begin to dip towards the *west*, with a gradually diminishing angle of inclination. By the fall of the hill, the road very soon comes upon level ground, so that the rocks are no longer cut through. This level ground continues for a short distance, when a limestone ridge suddenly rises up, dipping west at an angle of about 40°. In the sketch No. 1, I have represented the appearance which these strata would exhibit, if a vertical section of them was made in a line at right angles to the direction of the Malvern Hills.

§ 49. It is worthy of remark, that although the coarse sandstone, found at the foot of the End-Hill in vertical strata, lies to the westward of the compact sandstone, as mentioned in § 47; it is not found in the section of the rocks I have now described; nor did I see it in any other part of this side of the range, except in the neighbourhood of Castleditch, at the distance of seven or eight miles to the south.

§ 50. The same argillaceous rock that occurs in this place is met with very frequently on the western side of the range. It is seen under different appearances; sometimes it is of a friable texture, resembling fullers' earth; in other places it contains a great deal of mica, and has a slaty structure; when in this last state, many impressions of shells, principally terebratulites are found in it; it also occasionally contains some calcareous particles, forming a kind of marle. When it is in the earthy state, and with the slaty structure less distinct, it very generally includes lenticular-shaped masses and balls of an argillaceous limestone, containing a few terebratulites, the shell of which is sometimes partly preserved and retains its pearly lustre. In one of these masses I met with a specimen of the orthoceratites. This argillaceous rock is found not only on the eastern side of the limestone hills, but also lies upon the limestone, and in conformable stratification with it.

§ 51. The limestone does not form a continued ridge; but for several miles along this side of the range rises up in different places, forming low hills, the longitudinal bearing of which is in general parallel to the direction of the Malvern Hills. The dip of the strata is in general towards the west, but this is subject to much more variation than the bearing. It is in general of a bluish-grey colour, but is sometimes of a pale brown, especially in the strata nearest the surface. It contains a great many organic remains, particularly terebratulites, and occasionally vertebræ of the encrinite, so common in some of the limestones of Derbyshire: these organic bodies are most distinct in the upper strata. It is traversed in many places by veins of calcareous spar. The strata are thin, and present uneven waved surfaces; they are separated from each other by an argillaceous slaty coating, that becomes more compact the nearer it is to the limestone, to which it adheres so closely in some places, as to seem to be incorporated with it. This limestone is very similar to that found in the neighbourhood of Dudley, both in the mode of its stratification and in the nature of the rock itself.

§ 52. From the point where the road turns to the westward as mentioned in § 48, the ground for a considerable way to the south is covered with trees. There are very extensive plantations of the ash and the alder, all along this side of the Malvern Hills; the former being employed in making the hoops for the cider casks, and the other for hop poles. In the road which leads along the side of the hill from the Wych to Pearly Quarry, I found the argillaceous rock in a very loose friable state; the stratification of it however can be easily perceived. The strata are vertical, bearing N. and S. and they rise to about one third of the height of the hill. Between this place and Pearly Quarry, which is a short way to the westward, the rock is not exposed.

§ 53. At Pearly Quarry, the limestone strata are found; their bearing is N. and S. and they dip W. at an angle of about 40°. At the point where these strata crop out, they are very much broken, and irregular in their position ; in one place I observed the ends of the strata turned completely up into a vertical position, as is represented in the sketch No. 2. This appearance is however only of partial occurrence, for in returning a few days afterwards to the same place, the quarriers had removed that part of the rock, and at the cropping out of the strata then exposed, although they were irregular, they were not in a vertical position. In Chamberlain's quarry, to the north of Pearly Quarry, I also observed the limestone strata becoming more inclined and as it were bent up, towards the point where they crop out at the surface.

§ 54. In the limestone of Pearly Quarry, I obtained a specimen of the vertebra of an encrinite, and which, as I am informed by Mr. Parkinson, is one of a very rare species : the only other specimen of it which he has seen is in the British Museum.

§ 55. To the westward of Pearly Quarry the argillaceous rock is found in conformable stratification with the limestone. It has somewhat of a slaty structure, and includes balls of argillaceous limestone. A road that is cut through this rock exhibits a section of it at right angles to the bearing of the strata : it is of very considerable thickness, as the section is about a quarter of a mile in extent, and the same rock continues the whole way. On this there lies a fine quartzose sandstone in thin strata, dipping W. at an angle of 42°, and bearing N. and S. The quartzose sand is united by a calcareo-argillaceous cement with a few spangles of mica disseminated through the mass. In those places where the mica is most abundant, it acquires a slaty structure, and the slates may sometimes be obtained as thin as coarse paper. The colour of the rock, which is derived from a considerable admixture of oxide of iron, is in general yellowish-brown : it contains in many places dendritical delineations of manganese, and occasionally a small quantity of spathose iron.

§ 56. In the road which leads from the Wych to Colwall-green, and immediately at the foot of the range, the argillaceous rock occurs in strata bearing N. and S. but dipping *east* at an angle of 60°. It is mixed with calcareous particles, includes, as usual, balls of limestone, and abounds very much in petrifactions. I obtained specimens of the following varieties.*

a. A small madreporite, the stars of which are bounded by circles. In the cells of this there is a small quantity of red sulphate of barytes.

b. Different species of the porpital madreporite.

c. A turbinated madreporite, with a longitudinal section of a ramose madreporite.

d. A ramose madreporite, with terebratulites.

e. A coralloid, neither the form or structure of which can be defined.

I am informed that the chain coral is also to be met with in this place, but I did not find any specimen of it.

§ 57. About two hundred yards beyond this argillaceous rock, the limestone appears dipping towards the west, but as there is very little of it exposed, I could not make any exact observations as to its position. A short way to the westward is Stony-way quarry, where the limestone strata are seen in a very different position from what I found them in any other part; for in place of their direction being parallel to that of the range, as is generally the case with all the stratified rocks, particularly towards the north, it is at right angles to it: their bearing is E. and W. and they dip N. 35°.

§ 58. Near Eventon, there are very large quarries of limestone,

* I am indebted to Mr. Parkinson for this description of the organic remains.

which exhibits some remarkable changes in its stratification. The strata rise to a considerable height on the side of the hill, bearing N. and S. and dipping W. 60°. As they ascend, the ends of the strata become more inclined, and at the place where they crop out, they are nearly vertical; exhibiting the same appearance as the limestone strata of Pearly quarry, represented in sketch No. 2. About a hundred yards to the westward of this place, another quarry is worked in which the strata have the same bearing as in the quarry above, but they dip E. 60°, so that if a transverse section were made of the limestone in both quarries, the strata would be seen to meet like the sides of the letter V.

§ 59. A long ridge, called Old Castle Bank, extends from the Herefordshire Beacon, with a gradual slope towards the west. This ridge is almost entirely composed of the argillaceous rock, containing balls of limestone, in strata bearing S.W. and N.E. and dipping N.W. 18°. On the side of the Herefordshire Beacon, and on the left of the road from Worcester to Ledbury which passes along the top of this ridge, there are thin strata of limestone alternating with the argillaceous rock: but the strata in this place have a direction from N. to S. and they dip E. 60°. This is the highest point where I found the stratified rocks rising upon the Malvern range, and it is about one third of the elevation of the Herefordshire Beacon.

§ 60. To the south of Old Castle Bank, in a wood belonging to Lord Somers, there is a limestone quarry immediately at the foot of the Herefordshire Beacon, where the strata occur in a vertical position, with a direction from N. to S.

§ 61. In the extensive limestone quarry on the right hand side of the road to Ledbury, and near that town, the bearing of the strata is in one part N. and S. with a dip to the E. of 18°. Within a very short distance, both positions are completely changed, the bearing becoming E. and W. and the dip N. at an angle of 20°: at the point where the change begins to take place, the strata are very much twisted and broken. The limestone contains large veins of calcareous spar, which in some places has red sulphate of barytes disseminated through it. I also observed that mineral in the interior of the shells that are found in the limestone. In the quarry on the opposite side of the road, there is also great irregularity in the position of the limestone strata: in some places their bearing is N.E. and S.W. with a dip to the N.W. of 40°; in others, their bearing is N. and S. and their dip E. In this quarry I found a specimen of a madreporite, resembling in form the lithostrotion of Lhwyd, but much smaller in size. This is the same fossil that is represented in plate V. fig. 3 and 6 of the second volume of Parkinson's Organic Remains.

§ 62. In the road from Ledbury to Longdon, by the Holly-Bush Hill, the argillaceous slaty rock, which is the most prevalent, varies considerably in its direction and dip. In the place where I first observed it, after leaving the limestone hills above Ledbury, its bearing was N. and S. with a dip of 65° to the E. rising up to these hills; as it recedes from them, the angle of inclination gradually diminishes. At Low Hurst, the bearing is from N.E. to S.W. with a dip of 50° N.W. Near Castleditch, the seat of Lord Somers, I found the same coarse sandstone that occurs in vertical strata at the foot of the End Hill, as mentioned in § 47; the bearing of the strata in this place is N.E. and S.W. with a dip of 30° N.W. Proceeding eastward, towards the Malvern range, the argillaceous rock again occurs upon the rise of the Holly-Bush Hill, in thin strata bearing N. and S. and dipping W. at an angle of 70°.

§ 63. It appears from the preceding account, that the direction of the stratified rocks is, with a few exceptions, parellel to that of the range; but that there is a great irregularity in the dip, even within a very limited space, § 58; that the strata nearest the unstratified rocks are in general vertical, §§ 47, 52, 60; or inclined at a considerable angle with a western dip, § 58; but that in some places they dip in an opposite direction, that is, towards the hill, § 56; and they are found in that position, at the highest point to which they rise upon the side of the range, § 59. I did not, in any situation, discover the actual contact of the stratified and unstratified rocks.

Of the Rocks on the Eastern side of the Malvern Hills.

§ 64. From the bottom of the hills to the banks of the river Severn, there is a wide extended plain, the uniform level of which is only interrupted in a few places by low wooded eminences.

§ 65. At the foot of the hills, immediately below the surface soil, there is a coarse gravel, consisting chiefly of angular fragments, which I found to be the same as the unstratified rocks of the range. These are mixed with a small quantity of red clay, that seems to be produced from the decomposition of the rock, many of the fragments being quite friable.

§ 66. The ground is quite unbroken in the whole extent of the plain, except where an occasional rising has been cut through for the sake of preserving the level of the road; and as the rock is not adapted to economical purposes, there is no quarry where it is exposed. But at the termination of that part of the plain which is opposite to the Worcestershire Beacon, the right bank of the Severn is nearly 70 feet in perpendicular height, so that a good section of the rock is exhibited in that place. It is a red argillaceous sandstone, with occasional beds or long patches of a white quartzose sandstone: it does not offer any signs of stratification, except that these white sandstone beds are in a horizontal position, and are parallel to each other. It is the same red sandstone that prevails over the greater part of Worcestershire.

Of the Mineral Waters of the Malvern Hills.

§ 67. There is no river, and scarcely a brook of any consequence, that takes its rise in these hills, but throughout the whole extent there are several small springs, some of which are found to be mineralized. Malvern Wells have been long celebrated as a watering place, and still continue to be very much resorted to.

§ 68. The mineral waters of this place were first examined by Dr. Wall of Oxford, who published an account of them in 1756, and they have since that time been analyzed by Dr. Wilson of Worcester, whose treatise appeared in 1805. There are three different springs that have been examined; the Holy Well which is the most celebrated, situated at Malvern Wells; St. Ann's Well, and the Chalybeate in the neighbourhood of Great Malvern. I shall state the results obtained by Dr. Wilson, as his experiments were made at a more advanced period of chemical science; but he has only yet published the analyses of the Holy Well, and of St. Ann's Well.

§ 69. *The Holy Well water* afforded no other gaseous contents than atmospheric air. A gallon of it yielded 14,6109 grains of solid ingredients, which were found to consist of:

Carbonate of soda . .	5,33
Carbonate of lime . .	1,6
Carbonate of magnesia .	0,9199
Carbonate of iron . .	0,625
Sulphate of soda . .	2,896
Muriate of soda . . .	1,553
Residuum	1,687
	14,6109

§ 70. *St. Ann's Well water* afforded no other gaseous contents than atmospheric air. Its solid ingredients are precisely of the same nature as those of the Holy Well, but in much less quantity. A gallon of the water yielded 7,395 grs. which consisted of:

Carbonate of soda	3,55
Carbonate of lime	0,352
Carbonate of magnesia	0,26
Carbonate of iron	0,328
Sulphate of soda	1,48
Muriate of soda	0,955
Residuum	0,47
	7,395

§ 71. The chalybeate spring, according to the analysis of Dr. Wall, contains about 6 grains of solid ingredients in a gallon.

§ 72. I was informed by Mr. Wallett, Surgeon at Great Malvern, that a spring on the western side of the Herefordshire Beacon, known by the name of Walm's Well, has been long used, by the country people in the neighbourhood, as an outward application in cutaneous diseases. The water flows in a pretty copious stream, and at the place where it issues from the hill, is collected by an embankment, so as to form a large bath. Through the kind assistance of Dr. Marcet, I have made the following examination of this water, with the view of ascertaining merely the nature of its contents, without any regard to proportions, as the quantity I brought away was much too small for that purpose.

§ 73. The water, as it issues from the hill, is perfectly transparent, and remains so after exposure to the air. It produced no change on tincture of red cabbage.

Its specific gravity is 1000,10.

Six cubic inches of the water were boiled for some minutes, and the gaseous contents were received over mercury. On the admission of caustic potash, no absorption took place. The transparency of the water remained undisturbed.

The following tests produced no change. Litmus paper, violet paper, turmeric paper, lime water, muriate or nitrate of barytes, tincture of galls, and prussiate of potash, even after the addition of a little muriatic acid.

Caustic potash, oxalate of ammonia, and nitrate of silver, all occasioned a turbidity. On the addition of barytic water, there is also a cloudiness, even after the water of the spring had been boiled; although neither muriate nor nitrate of barytes produced any effect. Super-carbonate of ammonia with phosphate of soda occasioned at first no change; but after standing for some time, the rod left white streaks wherever it was drawn along the sides of the glass vessel.

Eight ounces of the water slowly evaporated to dryness, yielded 0.75 gr. of solid ingredients. On adding cold distilled water to this, only a small part was re-dissolved. To the solution the following tests were applied:

a. Violet paper, slightly changed to green.

b. Oxalate of ammonia, no change.

c. Muriate of barytes, a cloudiness.

d. Nitrate of silver, a dense precipitate.

e. Super carbonate of ammonia with phosphate of ammonia, a slight cloud, and the rod produced white streaks on the sides of the vessel.

f. Nitrate of lime, a considerable precipitate.

g. There was no change produced by tincture of galls, or by prussiate of potash, even after the addition of muriatic acid.

To the residuum insoluble in water there were added:

h. A few drops of dilute muriatic acid, which dissolved the whole with a brisk effervescence.

i. Oxalate of ammonia, a copious precipitate.

k. The solution from which the lime was thrown down, by the last experiment, was filtered, and the same test applied as in exp. *e.* which produced a similar effect, but in a very slight degree.

The water of Walm's Well therefore contains about 12 grains of solid ingredients in a gallon, which appear to consist of:

1. *Carbonate of lime* as the principal ingredient; by exp. *h. i.*

2. *Carbonate of magnesia* in minute quantity, by exp. *a. k.* and by the effect of the barytic water in the preliminary experiments. From the change produced on the violet paper, in exp. *a*, and from the action of the barytic water, which last test occasions a precipitate with carbonate of soda, I suspected that there might be a small quantity of that alkali existing in the water of the spring; but by comparative trials I found that, on applying these tests to a solution of carbonate of magnesia in water, exactly the same effects were produced.

3. *Muriate of soda, or magnesia*, by exp. *d, e;* probably the latter; for in one experiment, the entire solid ingredients were, by accident, dried at a heat that must have decomposed the muriate of magnesia, that earth being found in the insoluble residuum in greater quantity than when the evaporation had been carried on with a gentle heat, and there was only a trace of it discovered in the part soluble in water.

4. *Sulphate of soda, or magnesia*, by exp. *c, e, f;* probably the former; as the proportion of sulphuric acid indicated is more considerable than that of magnesia, and that earth seems to be combined with muriatic acid.

IN the account which I have now laid before the Society, of the physical structure of this interesting range of hills, I have, I fear, executed the task I have undertaken in a very imperfect manner; but I have endeavoured to avoid all theoretical speculations, and have confined myself as much as possible to a description of the facts as they present themselves. Before concluding however, I shall take the liberty of offering a few remarks on the phenomena I have described, and of examining by what theory they may, in my opinion, be most satisfactorily accounted for.

With the exception of the small bed of red sandstone on the eastern side of the Worcestershire Beacon § 29, all the unstratified rocks seem to belong to the primitive class of the Wernerian system, and in general, accord very much with the account given by Mr. Jameson in his Geognosy of the third or newest granite formation. The structure of the granite is very irregular, it is generally of a red colour, and it is found in veins that probably shoot from a great body of rock: it is frequently traversed by veins of quartz, and is not stratified. The rocks in which hornblende exists correspond with some of the varieties of primitive trap, and of sienite, as described in the same work.

The stratified rocks on the western side, are probably of very early formation, as the organic remains that are found in them are such as only occur in the oldest of the secondary rocks. The characters of the limestone quite agree with those of the transition limestone of Werner; and although the argillaceous rock does not exactly correspond with any of the transition rocks enumerated by Mr. Jameson; yet as the same organic remains are found in it, as in the limestone, and as it occurs in some places on both sides of the limestone-strata, in conformable stratification, it is very probable that both belong to the same class. The argillaceous rock may perhaps be a grauwacke-slate, as that name has so very wide a range; but it is in general much less indurated than any rock I have yet seen, to which that denomination has been applied.

Whether I am correct or not in the application I have made of the Wernerian names to the individual rocks of the Malvern district, if we consider their geological arrangement, we shall find that they exhibit appearances very inconsistent with the Wernerian system of Geognosy.

The most remarkable feature of this district is the very great contrast between the two sides of the range. On the eastern side, a level plain, extending for many miles; on the western, a constant succession of hills. Now if the unstratified rocks in the centre are to be considered as the oldest, and if the stratified rocks have been deposited upon them, how does it happen that they are only found on one side, that not a vestige of the strata that occur on the western side is to be met with on the eastern, and *vice versa*, that the red sandstone of the eastern side is not to be found on the western; at least for three or four miles all along the range, beyond which my observations did not extend. Besides, if the stratified rocks were deposited on the unstratified central rocks, we should expect to find their bearing always parallel to the direction of the range, and their dip uniformly towards the west, corresponding with the slope of the hill, supposing, what is maintained in the Wernerian system, the possibility of a stratified rock being deposited in any other than a horizontal or nearly horizontal position. We should also expect, in so short an extent as that of the Malvern range, that the same kind of stratified rock would always be found next to the unstratified. But I have shewn that neither of these things occur. It is true that the direction of the strata is in general parallel to that of the range; but there are some remarkable exceptions to it, as in the limestone of Stony-way Quarry, where the direction of the strata is from E. to W. exactly at right angles to that of the range: again, the strata nearest the range are in general quite vertical, and even in some places dip towards it, that is, eastward at an angle of 60°; and so far from the same stratified rock always occurring next the unstratified, it is in some places sandstone; in others, the argillaceous rock; and in others, limestone.

The unstratified central rocks are so much concealed, that any inferences with respect to them are liable to more uncertainty than those we are enabled to draw from the frequent exposure of the stratified rocks on the western side. But wherever they can be seen to any extent, they exhibit a great degree of irregularity, the different kinds of rock being found in large masses confusedly heaped together. The granite chiefly occurs in the lower part of the hill, and the veins of it, which penetrate the other rocks, become more slender as they ascend, in all those places where they can be distinctly traced.

Such remarkable variations in the direction and dip of the stratified rocks, can only be accounted for, on the supposition of some violent force, that has elevated them from the horizontal position in which they must have been originally deposited, and thrown them into the different situations in which they are now found; and the Huttonian Theory offers, in my opinion, a more satisfactory explanation of these phenomena, than any other with which we are yet acquainted. The situation of the granite, and the veins of it that penetrate the other rocks, in almost every part of the range, perfectly accord with the supposition of its being of later origin, and of its having been thrown up from beneath them: it is also probable that the elevation of the granite has produced the great disturbance in the strata, which I have described. The direction of the force seems to have been from West to East, and its action appears to have ceased where the unstratified rocks broke through, and appeared above the surface; and as these have been thrown up in a line between N. and S. the bearing of the elevated strata ought in general to be parallel to that line, and this has been shewn to be the case: the force would be greatest at the point where the unstratified rocks burst forth, and accordingly we find the strata there generally vertical, and in those places where they dip towards the range, they seem to have been raised, not only into a vertical position, but even thrown back and in some degree inverted.

The elevation of the strata in different places, forming the low hills which occur on the western side of the range, and in which the strata exhibit such remarkable changes in their position as at Stony-way quarry, Eventon quarry, and the quarries near Ledbury, seems to point out very distinctly, that the force has acted unequally, and has had an occasional increase in different places, sufficient to throw up the strata, but not so great as to raise the unstratified rocks above the surface. The bending up of the ends of the strata into a vertical position, where they crop out, as is represented in sketch No. 2, clearly shews that they have been acted upon by some violent force.

With regard to the red sandstone of the plain on the eastern side of the Malvern Hills, it is very evident that it has been produced from the disintegration of other rocks; but it is not I think equally clear that it owes its origin to the detritus of the unstratified rocks of this range. For if that were the case, it would probably be found on the western side as well as on the eastern, but not a vestige of it is to be seen there; and instead of a level plain beginning immediately at the foot of the hills, there would be a gradual slope towards the east. It appears to me more likely that this red sandstone existed previous to the elevation of the range, and that it covers stratified rocks similar to those found on the western side:

but the granite which raised these strata from their horizontal position having burst forth, the force ceased, and the red sandstone remained undisturbed. The disappearance of it on the western side may be accounted for, from its being of a very loose friable texture, and if it was much broken during its elevation, it would be easily disintegrated, and gradually washed away. Perhaps it may be found covering these strata, further to the westward than my observations extended, and where the disturbance was not so great. It covers a great extent of country in Shropshire, considerably to the westward of the line of the Malvern Hills.

As I have related the facts I observed, independently of any theory, if they are at all valuable in the geological history of this country, their value will remain undiminished, whether the speculations I have entered into are just or fallacious. If the geologist strictly guards himself against the influence of theory in his observations of nature, and faithfully records what he has seen, there is no danger of his checking the progress of science, however much he may indulge in the speculative views of his subject.

XIII. *Notice accompanying a Section of Heligoland, drawn up from the Communications of Lieutenants Dickinson and Mac Culloch, of the Royal Engineers.*

By John MacCulloch, M.D. F.L.S.
Member of the Geological Society.

I HAVE not been able to obtain any accurate account of the changes which this island has undergone; but it is said to be in a state of rapid destruction from the encroachments of the sea. It is currently reported among the inhabitants that it has been reduced within the last century from eleven miles in length to its present dimensions of one mile.

It seems to consist of strata of an indurated clay, alternating with beds of grey limestone. These form an angle of 30° with the horizon, and dip to the N. E.

The clay is of a strong red colour, containing much oxide of iron, and with it so much carbonate of lime as to effervesce considerably with acids. The limestone is in some parts formed of various marine remains, in others it is uniformly granular. Through both these there are dispersed in various places deposits of copper ore in small quantities. These consist of carbonate of copper, diffused through the earthy matters; and of crystallized masses of the same substance; and, more rarely, there are found lumps of red oxide mixed with particles of grey ore and native copper. The beach is covered with various siliceous pebbles, containing grains of the same substances imbedded in them, together with porphyries and hornstones of various colours.

Belemnites, and other fossil remains, both calcareous and flinty, are also found on the shore; and the clay strata often contain considerable quantities of pyrites, together with carbonized and pyritaceous wood.

XIV. *Observations on some of the Strata in the Neighbourhood of London, and on the Fossil Remains contained in them.*

By James Parkinson, Esq.

Member of the Geological Society.

THE study of fossil organized remains has hitherto been directed too exclusively to the consideration of the specimens themselves; and hence has been considered rather as an appendix to botany and zoology, than as (what it really is) a very important branch of geological inquiry.

From a comparison of fossil remains with those living or extant beings to which they bear the closest analogy, great resemblances and striking differences are at the same time perceivable. In some instances the generic characters materially differ, but in most they very closely correspond; whilst the specific characters are very rarely found to agree, except when the fossil appears to have existed at, comparatively, a late period. Of man, who constitutes a genus by himself, not a single decided remain has been found in a fossil state.

Chemical analysis has been called in to the aid of the naturalist, in order to account for the perfect state of preservation observable in remains organized with the most exquisite delicacy, and which there is every reason for supposing to have been readily decomposable in their recent state. From this investigation we learn the manner in which these memorials of the old world, so interesting and so frail have been preserved. Some have been impregnated with calcareous matter, others with siliceous, and others with iron or copper pyrites.

But these facts, however important and interesting, cannot, when considered by themselves, add much to our knowledge respecting the formation and structure of the earth. To derive any information of consequence from them, on these subjects, it is necessary that their examination should be connected with that of the several strata, in which they are found.*

Already have these examinations, thus carried on, taught us the following highly instructive facts. That exactly similar fossils are found in distant parts of the same stratum, not only where it traverses this island, but where it appears again on the opposite coast: that, in strata of considerable comparative depth, fossils are found, which are not discovered in any of the superincumbent beds: that some fossils, which abound in the lower are found in diminishing numbers through several of the superincumbent, and are entirely wanting in

* This mode of conducting our inquiries was long since recommended by Mr. W. Smith, who first noticed that *certain fossils are peculiar to, and are only found lodged in, particular strata;* and who first ascertained the constancy in *the order of superposition,* and *the continuity of the strata of this island.* It will appear from the following quotation, that these observations have lately also occurred to Messrs. Cuvier and Brongniart whilst examining into the nature of the strata of the neighbourhood of Paris. " Cette constance dans l'ordre de superposition des couches les plus minces, et " sur une étendue de 12 myriamètres au moins, est, selon nous, un des faits les plus " remarquables que nous ayons constatés dans la suite de nos recherches. Il doit en " résulter pour les arts et pour la géologie des conséquences d'autant plus intéres- " santes, qu'elles sont plus sûres.

" Le moyen que nous avons employé pour reconnoitre au milieu d'un si grand nombre " de lits calcaires, un lit dejà observé dans un canton très-éloign , est pris de la nature " des fossiles renfermés dans chaque couche, ces fossiles sont toujours généralement " les mêmes dans les couches correspondantes, et présentent des différences d'espèces " assez notables d'un système des couches à un autre système. C'est un signe de recon- " noissance qui jusqu'à présent ne nous a pas trompés." Annales du Muséum d'histoire naturelle, tome XI. p. 307.

the uppermost strata: that some fossils, occurring in considerable numbers in one stratum, become very rare in the adjacent portion of the next superincumbent stratum, and afterwards are lost: that fossils of one particular genus, which exist abundantly in the lower strata, and occur in several of the superincumbent ones, are not found in the three highest strata; whilst one species of that genus, but which has not been found in a fossil state, exists in our present seas: and lastly, that most of the remains which are abundant in the superior strata, are not at all found in the lower. These general facts lead us to hope, that geology may derive considerable assistance, from an examination of fossils, made in connexion with that of the strata to which they belong.

The following is an attempt to investigate on this plan some of the upper strata in the vicinity of the metropolis with their contained fossils; and, although by no means complete, it will, it is hoped, induce others, who possess superior abilities and opportunities, not only to re-examine more correctly these strata, but to extend their researches to the subjacent strata.

The whole of this island displays evident marks of its stratification having, since its completion, suffered considerable disturbance, from some prodigious and mysterious power. By this power all the known strata, to the greatest depths that have been explored, have been more or less broken and displaced; and in some parts have been so lifted, that some of the lowest of these have been raised to the surface; whilst portions of others, to a very considerable depth and extent, have been entirely carried away.* From these circum-

* See several essays on this subject in the Philosophical Magazine, by Mr. Farey, and the Report on Derbyshire. vol. I. p. 105.

Also a Letter on the alterations which have taken place in the structure of rocks, on the surface of the basaltic country in the counties of Derry and Antrim, by William Richardson, D.D. Phil. Trans. 1808.

stances great difficulties and confusion frequently arise in examining the superior strata; the counties however immediately surrounding the metropolis, as well as that on which it stands, having suffered least disturbance, are those in which an investigation of these strata may be carried on with the smallest chance of mistake.

Real alluvial fossils, washed out of lifted or original superior strata by strong currents, and which in other parts are very abundant, are rarely seen in the counties adjacent to the metropolis. This remark is rendered necessary, since those widely extended beds of sand and gravel, with sandy clay, sometimes intermixed and sometimes interposed, and which have been generally hitherto considered as alluvial beds, are here assumed to be the last or newest strata of this island, slowly deposited by a pre-existent ocean; with the strata, therefore, of this formation, these remarks commence.

Beds of Sand and Gravel. The sands of this formation vary in colour from white, which is most rare, through different shades of yellow up to orange-red: the colour proceeding partly from a ferruginous stain on the surface of the particles of sand, and partly from the intermixture of yellow oxide of iron. Particles of those sands, which are disposed in distinct seams or beds, when examined by the microscope, are found to be transparent, most of them angular, but some a little rounded, with all their surfaces smooth, having no appearance of fracture, and resembling, in every respect, an uniform crystalline deposition. Those sands on the contrary, which blended with broken and unbroken pebbles form gravel, appear, when thus examined, to be mostly opaque, to be variously coloured, and to be marked with conchoidal depressions and eminences, the result of fracture.

The pebbles of this formation appear to be of four kinds,

1st. Various pieces of jasper, gritstone, white semi-transparent quartz, and other rocks. These have acquired, in general, smooth surfaces and roundish forms, evidently from attrition, and exhibit no traces of organization, except when, as is very rarely the case, the substance of the pebble is jasperised wood. The white quartz pebbles, like quartz crystals, on being rubbed together, emit a strong white lambent light, with a red fiery streak on the line of collision, and an odour which much resembles that of the electric aura.

2d. Oval or roundish, and rather flat siliceous pebbles, generally surrounded by a crust or coat differing in colour and degree of transparency from the internal substance, which also varies in different specimens, in these respects, as well as in the disposition of the parts of which the substance is composed. In some this is spotted, or clouded, in very beautiful forms; in others it is marked by concentric striæ, as if the result of the successive application of distinct laminæ: the prevailing colours in most of these pebbles being different shades of yellow. In several the traces of marine remains are observable: these are, in some the casts of *anomiæ*, and the impressions of the spines and plates of *echini;* and in others, which generally possess a degree of transparency, the remains of *alcyonia.* The impressions, though frequently on the surface of the pebble, seldom, if ever, appear to be in the least rubbed down; thus seeming to prove decidedly, that these pebbles have not been rounded by rolling; but that they owe their figures to the circumstances under which they were originally formed: it is apprehended therefore, that these pebbles have each been produced by a distinct chemical formation, which, it may be safely concluded from the remains of marine animals so frequently found in them, took place at the bottom of the sea, while these animals were yet living.

The formation of these fossils at the bottom of a former sea, and perhaps, on the identical spots in which they are now frequently found, is more plainly evinced by pebbles agreeing in some peculiar characters, being found together in particular spots. Thus those in the County of Essex, ten miles northward of London, contain a much greater proportion of argil and iron, than those met with in many other places; hence their colours are darker, and the delineations which their sections display are very strong and decided, sometimes closely agreeing with those seen in the Egyptian pebbles.* Passing on into Hertfordshire, pebbles of a very different character are found: their crust is nearly black, and their section displays delicate tints of blue, red, and yellow, disposed on a dead-white ground in very beautiful forms. In another part of the same county, occurs the pebble of the pudding-stone, which also presents peculiar characters of colour, &c.

3d. Large tuberous, or rather ramose, irregularly formed flints, somewhat resembling in figure the flints which are found in chalk, materially differing however from them, not only in the colour of their external coat which is of various shades of brown; but also in that of their substance, which is seldom black, but exhibits shades of yellow or brown, in which red likewise is sometimes perceptible. The traces of organic structure, particularly of the *alcyonium* occasionally seen in these stones, determine them also to have been formed at the bottom of the sea.

4th. Pebbles, owing their form to an investment and impregnation with silex, of various marine animals of unknown genera, but bearing a close affinity to the *alcyonia*. These stones display, in general, not only the external form, but the internal structure also of these animals. The congregation of many pebbles of this genus, and

* The gravel pebbles of Epping Forest are of this description; and on most of the grounds leading down from the forest to the hamlet of Sewardstone and to the town of Waltham, white, opaque, and partly decomposed pebbles are frequently seen, in which the argil and iron have been removed, and the silex only has remained.

indeed of the same species, in particular tracts, warrants the conclusion, that these animal substances were thus changed, whilst inhabiting that bottom of a former ocean, which now forms the stratum the contents of which are here sketched. Pebbles of this description are most frequently found in the gravel pits of Hackney, Islington, &c.

Among the traces of organization discoverable in this stratum are casts of *echini*, which are frequently found among the gravel, and which have generally been supposed to have been washed out of the chalk. But these casts have their origin plainly stamped on them. Their substance is covered with iron; they are almost always of a rude and distorted form, and I apprehend that they are never found with any part of the crust of the animal converted into spar, adherent to them, as is commonly the case with the casts of echini found in chalk.

A sufficient proof, that these several strata of gravel, sand, &c. have been deposited by a former ocean, is to be found in a circumstance which does not appear to have been hitherto sufficiently adverted to. This circumstance is the existence of fossil shells belonging to, and accompanying the superior part of these strata in particular spots: their absence in other parts being, perhaps, attributable to the removal of the upper beds.

These fossil shells are still found disposed over a very considerable extent. Their nearest situation to the metropolis is at Walton Nase, a point of land about sixteen miles S. E. of Colchester. Here a cliff rises more than fifty feet above high water mark and the adjacent marshes. It is formed of about two feet of vegetable mould, twenty or thirty feet of shells, mixed with sand and gravel, and from ten to fifteen feet of blue clay. The bed of shells is here exposed for about three hundred paces in length, and about a hundred feet in breadth.

Immediately beyond the Nase the shore suddenly recedes and forms a kind of estuary, terminated towards the east by the projecting cliff of Harwich, which is capped in a similar manner with beds of these shells. The height of this cliff is from forty to fifty feet, about twenty-two feet of the lower part of which is the upper part of the blue clay stratum; "above which," as Mr. Dale observes, "to within two feet of the surface, are divers strata of sand "and gravel mixed with fragments of shells, and small pebbles; and "it is in some of these last mentioned strata that the fossil shells are "imbedded. These fossils lie promiscuously together, bivalve and "turbinate, neither do the strata in which they lie observe any order, "being sometimes higher and sometimes lower in the cliff; with "strata of sand, gravel, and fragments of shells between. Nor do "the shells always lie separate or distinct in the strata, but are "sometimes found in lumps or masses, something friable, cemented "together with sand and fragments, of a ferruginous or rusty colour, "of which all these strata are."*

The coast of Essex is here separated from that of Suffolk by the river Stour, by which the continuity of this stratum is necessarily interrupted. It however occurs again on the opposite side of the river, and through Suffolk and great part of Norfolk the same bed of shells is found on digging; thus appearing to extend over a tract of at least forty miles in length.

These shells are in general found in the same confused mixture, as is described by Mr. Dale; but they are also sometimes so disposed, that patches of particular genera and species appear to be now occupying the very spots where they had lived. This seems particu-

* Appendix by Samuel Dale to the History and Antiquities of Harwich and Dovercourt by Silas Taylor, 1732.

larly the case with the small *pectens*, the *mactræ*, and the *left-turned whelk.*

From the excellent state of preservation in which many of these shells have been found, it has been thought that they could hardly be regarded as fossil. Many acknowledged fossil shells however have undergone much less changes than those of this stratum ; the original coloured markings are entirely discharged, and the external surfaces are deeply penetrated with a strong ferruginous stain ; the inner surfaces also are considerably changed, their resplendence being superseded, to a considerable depth, by a dead whiteness, the consequence of the decomposition of this part of the shell.

Like the fossils of most other strata this assemblage of shells manifests a peculiar distinctive character. A few shells only, which may be placed among those which are supposed to be lost, or among those which are the inhabitants of distant seas, are here discoverable; the greater number appearing not to differ specifically, as far as their altered state will allow of determining, from the recent shells of the neighbouring sea.

Among those, of which no recent analogue is known, appears to be the *terebratula*, figured in Dale's History and Antiquities of Harwich, &c. tab. XI. fig. 9. p. 294, and described, Phil. Trans. No. 291, p. 1578. Mr. Dale describes this shell as *Concha longa fossilis fasciata*, and remarks that he has not observed " either in " Aldrovandus, Rondeletius, Belonius, Gesner, Johnson, Lister, or " Bonanus, any shell that resembles this our fossil, unless it is one of " those figured by Lachmund, p. 43, No. 6 and 7, the inward part " resembling our fossil." The shells figured by Lachmund are undoubtedly *terebratulæ*, but they manifest no particular agreement with this fossil.

This shell appears to be figured by Lister, *Histor. Conchyl. tab.*

211, *fig.* 45, and is assumed by Gmelin, as *Anomia spondylodes.* The other shells, fig. 46, of the same plate, referred to by Gmelin as *Anomia psittacea*, appear to be mutilated specimens of the same shell. This opinion is corroborated, by the tint given by the accurate artists, to the whole of the shells contained in this plate, agreeing with the dark colour of the Essex fossil; and by the circumstance of their being generally found in the mutilated state in which they are here figured by Lister. Besides, neither of Lister's specimens at all agrees with the pellucid shell, with a triangular foramen, of *Anomia psittacea*, but they all agree with the oval antiquated shell, with an obtuse canaliculated beak, of *Anomia spondylodes.*

In consequence of this agreement, it seems proper to consider this fossil shell as forming the species, *Anomia spondylodes.* But as the channelled beak is not natural to it, but is the consequence of injury; and as this part, in its natural state, is pierced with a large round foramen, a correspondent change should be made in the description, and it may be placed under the more appropriate genus of terebratula, as, *Terebratula spondylodes*, with an oval antiquated shell, the beak pierced by a large round foramen.

This shell is, in general, about an inch and a half long, thick, nearly oval, roughly striated transversely, and has its large foramen defined by a distinct border. It appears to differ from every known recent or fossil *terebratula.*

Another of the probably lost shells of this stratum is the fossil *oyster*, figured Organic Remains, &c. vol. III. pl. XIV. fig. 3, and which is there conjectured to be the same oyster as that which is described by Lamarck as *Ostrea deformis.*

The *volute*, Organic Remains, vol. III. pl. V. fig. 13. is another shell belonging to this stratum, of which it is believed that no recent analogue has been yet found. This ovate and rather fusiform shell appears to have been smooth; and at its full size about four inches in length: the columella has four folds, and the shell is formed by about six spiral turns, the last of which makes two thirds of the shell, dilating at about its centre, and contracting nearly equally upwards and downwards. The specimens yet seen give no opportunity of judging of the lip, or of the termination of the spire.

The Essex *reversed whelk*, as it has been termed, *murex contrarius* Linn. *Hist. Conch.* of Lister, *tab.* 950, *fig.* 44. *b. c.* which is here very abundant, does not appear to be known in any other stratum of the island. The fossil shell, with the whirls in the ordinary direction, is sometimes found in this stratum.*

It has been said that the recent analogues of both these shells are found in the adjoining sea. A recent shell is indeed found which very nearly agrees with the ordinarily turned shell in its general characters: but there appears no authority for supposing that the analogue of the left-turned variety has been discovered there.

Among those recent shells, the resemblance of which to the fossil ones of this stratum is such as appears to render a comparison by an experienced conchologist necessary, may be enumerated:

Patella ungarica, *Patella militaris*, *Patella sinensis*, (*Calyptræa*, Lam.) *Patella fissura*, (*Emarginula*, Lam.) one or two species of *Patellæ*, with a perforation in the apex, (*Fissurella*, Lam.) *Nerita glaucina*, *Nerita canrena*, (*Natica*, Lam.) *Turbo terebra*, (*Turritella*, Lam.) *Murex corneus*, *Murex erinaceus*, *Strombus pes pelicani*, *Cypræa pediculus*, with no sulcus along the back, *Pholas crispatus*, in fragments, *Solen ensis*, and *Solen siliqua*, in fragments, *Cardium edule*, *Cardium aculeatum?* bearing the size and form of this shell,

* It is erroneously stated, Organic Remains, vol. III. p. 66, that this shell has not been yet mentioned, as found in this stratum; since it is so particularised by Dale.

but having from thirty-four to thirty-six ribs, with no depressed line down their middle, nor vestiges of spines; *Mactra solida*, *Venus exoleta*, *Venus scotica?* *Venericardia senilis*, Lam. *Arca glycemeris*, *Arca nucleus*.

Besides these remains of marine animals, the fossil hollow tubercles, having lost the spines, of the *thornback* are here found; also fragments of the *fossil palate*, (*Scopula littoralis* of Lhwydd) and fossil remains of *sponge* and *alcyonia*, particularly a very fair specimen of the *reticulated alcyonium*. Org. Rem. vol. II. pl. IX. fig. 9.

In this bed, among the gravel and the shells, are frequently found fragments of *fossil bone*, which possess some striking peculiarities. They are seldom more than half an inch in thickness, two inches in width, and twelve in length; always having this flat form, and generally marked with small dents or depressions. Their colour, which is brown, light or dark, and sometimes inclining to a greenish tint, is evidently derived from an impregnation with iron. From this impregnation they have also received a great increase of weight and solidity; from having been rolled they have acquired a considerable polish; and on being struck by any hard body they give a shrill ringing sound. These fragments, washed out of the stratum in which they had been imbedded, are found on the beach at Walton, but occur in much greater quantity at Harwich.

Of the flat rounded pieces described above, no conjecture can be formed as to the particular bone or particular animal to which they belonged. But within these few years an Essex gentleman found, on the beach at Harwich, a tooth which was supposed to have belonged to the *mammoth*. This fossil was kindly obtained at my request, for the purpose of being exhibited to the members of the Geological Society, by my late friend Dr. Menish; and certainly it appeared to be part of a tooth of that animal. It had been broken and rounded by rolling, but its characters were still capable of being ascertained. It possessed, in the softer parts, the colour and appearance of the Essex mineralised bones so distinctly, as to leave not a doubt of its having been imbedded in this stratum; whilst in the enamel it manifested decided characters of the tooth of some species of the mammoth, or *mastodon* of Cuvier.

The actual limit of this stratum has not been ascertained; it is however known to extend through Essex, Middlesex, part of Kent, and Surry, and through Hertfordshire, Buckinghamshire, and indeed much further both to the northward and westward. In many parts its continuity has been interrupted, apparently by partial abruptions of it, together even with a portion of the stratum on which it rests. The shells of this stratum have hitherto been discovered only in the parts already noticed.

BLUE CLAY STRATUM. This, the next subjacent bed, is formed of a ferruginous clay exceeding two hundred feet in thickness. Its colour for a few feet in the upper part is a yellowish-brown, but through the whole of its remaining depth is of a dark bluish grey, verging on black. It is not only characterised by these circumstances, but by the numerous *septaria* which are dispersed through it, and by the peculiar fossils which it contains.

The difference of colour observed between its superior and inferior part, and which has generally been supposed to be owing to a difference in the degree of oxidation of the iron present in it, appears to be the result of a difference in the quantity of it, occasioned by the washing away of this metal in the upper part by the water which percolates through it, and which runs off laterally by the numerous drains made near the surface. The dark red colour of tiles made from the blue clay, the reddish-yellow colour of the *place* bricks made of the yellowish-brown clay, and the bright yellow hue of the *washed malms*, those bricks which are formed of the yellow clay which has been exposed to repeated washings, are thus accounted for.

The septaria lie horizontally, and are disposed at unequal distances from each other in seemingly regular layers; and, as has been just observed of the stratum itself, they become of a paler colour, and it may be added suffer decomposition, when placed so high in the stratum as to be exposed to the action of percolating water. They frequently include portions of wood pierced by the *Teredines*, *Nautili*, and other shells; and it is a fact that may be worthy of being attended to, whilst inquiring into their formation, that the septa of calcareous spar frequently intersect the substances enclosed in the septaria.

This stratum is to be found not only wherever the preceding deposition extends, but in other parts also where that has been removed. The cliffs of this clay, at Shepey, extend about six miles in length; the more elevated parts, which are about ninety feet in height, being about four miles in length, and declining gradually as they terminate towards the east and west.

The fossils of this stratum have been already carefully particularised. A catalogue of those found at Shepey was added by Mr. Jacobs to his *Plantæ Favershamienses;* and an account of several of the fossil fruits found at Shepey was published by Dr. Parsons in the fiftieth volume of the Philosophical Transactions. The fossils of Hampshire have been scientifically described by Dr. Solander, in the *Fossilia Hantonensia* of Mr. Brander, where the fossils themselves are very exactly figured.

It was not supposed, even after the publication of these accounts, that the fossils of Shepey and those of Hampshire were of the same stratum. Among the Hampshire fossils no mention is made of *crabs*, *lobsters*, *tortoises*, *nautili*, nor of the heads or bodies of *fishes* so abundant at Shepey; whilst the *Murex pyrus*, *Murex longævus*, *Strombus amplus*, &c. of the Hampshire cliff had never, perhaps, been enumerated among the Shepey fossils.

The identity of the stratum at Shepey and in Hampshire has, within a few years, been decided by digging into this same stratum at Kew, where several of the fossils, which had hitherto been supposed peculiar to Shepey, were found in the same pit with those which had been considered as peculiar to Hampshire.

In the present year, on cutting through a mound of this stratum which forms Highgate-hill, this identity has been still farther manifested by the discovery of great numbers of those fossils mingled together which had been generally distinguished into Hampshire and Shepey fossils; as *crabs*, *nautili*, &c. like those of Shepey, together with several shells which had been generally regarded as peculiar to Hampshire, and in particular that uncommon alated shell, *Strombus amplus*, Solander. (*Rostellaria macroptera*, Lamarck.)

In examining this stratum, the curious fact that certain organic remains are peculiar to particular depositions, is first observed. Very few indeed of the fossil shells of the gravel strata are to be found in the bed of blue clay. In the gravel strata, by far the greater number of the shells bear a close agreement with those which now exist in not very distant seas; but in this clay stratum, "very few of the "shells are known to be natives of our own, or indeed any of the "European shores, but the far greater part of them, upon a comparison with the recent, are wholly unknown to us."*

But although this clay stratum contains fossils of a much older date than those of the gravel stratum, it possesses other marks which agree with its position in shewing that it is of comparatively modern

* Fossilia Hantoniensia, p. 5.

formation. It includes none of the remains of any of the lost fossils, such as the *Cornu ammonis*, *Encrinites*, &c. Mr. Jacobs indeed speaks of one imperfect specimen of *Belemnites* and of *Astroitæ* having been found, but at the same time as being very uncommon; Mr. Brander however does not appear to have met with any of these older fossils; nor have any of them been discovered either at Kew or at Highgate. Hence it seems reasonable to conclude, that the single imperfect belemnite and the few astroitæ were not inhabitants of the sea at the period when this stratum was deposited, but were washed out of some of the more ancient strata, and lodged by accident in the bed where they were found.*

The quantity of fruit or ligneous seed vessels and berries, which has been found in this stratum at Shepey, is prodigious. Mr. Francis Crow, of Feversham, has procured from this fertile spot a very large collection, and by carefully comparing each individual specimen by their internal as well as their external appearance, he has been enabled to select seven hundred specimens, none of which are duplicates, and very few agree with any known seed vessels. These vegetable remains have also been found on the opposite Essex shore, but in very small numbers. They have also been met with in that part of the stratum which has been examined at Kew. At Highgate and at Shepey a resinous matter, highly inflammable, of a darkish brown colour, and yielding, on friction, a peculiar odour, has also been found. This substance has been conjectured to exist in an

* It appears to be necessary to guard against two sources of error whilst appropriating fossils to their respective strata: one is the circumstance here alluded to, where the fossils of a preexistent stratum have been washed out by the waters while depositing a more recent stratum: the other is where, at the line of junction of two strata, the animals of the one are found within the borders of the other stratum; a circumstance by no means difficult to be conceived or explained.

unaltered state, and this indeed seems to be the fact from its resinous fracture; but it must be observed, on the other hand, that pieces of it occur which are penetrated by iron pyrites.

This stratum is also rendered exceedingly interesting by its surface appearing to have been the residence of land animals, not a single vestige of which seems to have been found in any of the numerous subjacent strata of the British series. Mr. Jacobs relates that the remains of an *elephant* were found at Shepey. The remains of the *elephant*, *stag*, and *hippopotamus* have also been dug up at Kew. At Walton in Essex, not only the remains of the *elephant*, *stag*, and *hippopotamus* have been discovered, but also remains of the *rhinoceros*, and of the *Irish fossil elk.* Org. Rem. vol. iii. p. 366.

It has been generally supposed that these remains were contained within the stratum of blue clay; but the circumstances, under which they are found, seem rather to warrant the conclusion, that they were deposited on the surface of those low spots where abruptions of the superior part of this stratum had taken place. Thus the remains of the elephant mentioned by Mr. Jacobs were not in the cliff, but in a low situation at a distance from it; so also the remains of land animals in Essex occur a little below the surface, in a line with the marshes, which are a very few feet above high water mark. By a communication of the late Mr. William Trimmer of Kew, it appeared that he found, under the sandy gravel, a bed of earth, highly calcareous, from one foot to nine feet in thickness; beneath this a bed of gravel a few feet thick, containing water, and then the main stratum of blue clay. At the bottom of the sandy gravel, he observed that the bones of the *hippopotamus*, *deer*, and *elephant* were met with; but not in those parts of the field to which the calcareous bed did not extend. Here also a considerable number of small and apparently fresh-water shells, and, at the bottom, snail-shells were found.

Does it not seem that the first appearance, or creation, of land-animals was on the dry land of this stratum, and that they were overwhelmed in these spots, by that sea which deposited the present superincumbent strata of gravel?

STRATA INTERPOSED BETWEEN THE CLAY AND THE CHALK.

It is almost impossible to speak with precision of the subjacent strata, which are situated between the clay and the chalk, since very considerable variations occur as to their thickness, and indeed as to the form in which their constituent parts are disposed; and since there exist but few sections, at least in the neighbourhood of the metropolis, which present a view of the strata composing this formation. They are included in the following account by Mr. Farey: "A sand stratum, of very variable thickness, next succeeds, and lays "immediately upon the chalk, in most instances, as between Green-"wich and Woolwich, on the banks of the Thames; which has "often been called the *Blackheath sand*: it frequently has a bed of "cherty sandstone in it, called the grey-weathers."*

On the upper part of a mound at New Charlton some traces of the lowest part of the blue clay appear, covered by not more than a foot of vegetable earth. This layer of clay does not seem to exceed two feet in thickness, which, indeed, it possesses only on the top of some of those mounds, which occur so frequently as to render the surface in this district very irregular. In this clay, oysters of different forms are found: some approaching to the recent species, and others longer and somewhat vaulted; but they are in general so tender as to render it very difficult to obtain a tolerable specimen. With these also occur numerous *Cerithia*, *Turritellæ* and *Cythereæ*, Lam. all of which are in a similar state with the oysters, and appear

* Report on Derbyshire, &c. vol. I. p. 111.

to be shells strictly belonging to the subjacent stratum, but which, having lain uppermost, became involved in the first or lowest deposition of the blue clay.

Immediately beneath the clay there is found a line of about three or four inches of the preceding shells imbedded in a mass of calcareous matter, the result of their disintegration. Beneath this are numerous alternating layers of shells, marl, and pebbles, for about twelve or fifteen feet. The shells are those which have been already mentioned ; but are very rarely to be met with whole, and when entire are so brittle as to be extricated with much difficulty. In some of these layers scarcely any thing but the mere fragments of shells are to be found, and in others a calcareous powder only is left.

The pebbles are almost all of a roundish oval form, many of them being striped, but differing from those of the superior gravel stratum, in being seldom broken, in there being few large ramose masses, and in their not bearing any marks or traces of organization. Many of these pebbles are passing into a state of decomposition, whence they have in some degree the appearance of having been subjected to the action of fire: small fragments of shells are every where dispersed amongst them.

Beneath the pebbles is a stratum of light fawn-coloured sand of about ten feet in depth, and immediately under this is the stratum of white sand, which is about five and thirty feet deep, and is here seen resting immediately on the chalk.

At Plumstead, about a mile distant in a south-eastern direction, there is a pit, in which the shells, about two years ago, were to be obtained in a much better state of preservation than at New Charlton ; but this seam of shells, as the pit has been dug further in, has by degrees become so narrow as to be now nearly lost. In this pit, not only the shells already mentioned were found, but many tolerably perfect specimens of *Calyptræa trochiformis*, Lam. *Trochus apertus*, Brander. *Arcæ glycemeres*, *Arcæ Naticæ*, and many minute shells in good preservation. All these shells appear to have entirely lost their animal matter, and not having become imbued with any connecting impregnation, they are extremely brittle. On examination with a lens it also appears that in most of the specimens nothing of their original surface remains, it having been every where indented with impressions of the surrounding minute sand, made whilst the shells were in a softened state. This circumstance is particularly evinced in the *Cyclades*, in which a particular character in the hinge was thus concealed; in a mass of these shells from the Isle of Wight, it appears that the lateral teeth are crenulated, somewhat similar to those of the *Mactra solida* in the gravel stratum; but in the *Cyclades* of Plumstead, this was not discoverable from the injuries which their surface had sustained from the sand.

The fossils of this stratum evidently agree with those found by Lamarck and M. De France, above the chalk at Grignon, Courtagnon, &c. and they have been just shewn, incidentally, to exist in the Isle of Wight. In an eastern and southern direction from London this stratum with its fossils is frequently discovered.

On the heath near Crayford, about four miles eastward of Charlton, long vaulted oysters are found similar to those already mentioned. About two miles further in the parish of Stone, is *Cockle-shell-bank*, so called, as Mr. Thorpe, the author of *Custumale Roffense*, says, p. 254 of that work, " from the great number of small shells there " observable." These are the *Cyclades* already spoken of, and which Mr. John Latham, author of *The general Synopsis of Birds*, thought bore some resemblance to *Tellina Cornea*, Linn. *Histor. Conchyl.* of Lister, tab. 159. fig. 14. Mr. Latham here also met with a species of *Cerithium*, and another of *Turritella*. Fragments of these shells are also frequently turned up with the plough in that neighbourhood. They have likewise been found at Dartford, at Bexley, and at Bromley, to the southward.

Mr. Thorpe also relates that in the parish of Stone, there was a large mass of stone, of some hundreds weight, full of shells, which was brought from a field, and used as a bridge or stepway over a drain in the farm-yard. (*Custumale Roffense*, p. 255.)

In several spots in the neighbourhood of Bromley, stone is found near the surface, formed of oyster-shells, still adhering to the pebbles to which they were attached, and which are similar to those which have been just described, as occurring at Plumstead and at Charlton: the whole being formed by a calcareous cement into a coarse shelly limestone containing numerous pebbles. The only quarry of this stone which has been yet worked is in the grounds of Claude Scott, Esq. The opening hitherto made is but small; it is however sufficient to shew that the stratum here worked has suffered some degree of displacement, as it dips with an angle of about forty-five degrees.

At Feversham, over the chalk, Mr. Francis Crow has discovered a bed of dark brown sand, slightly agglutinated by a siliceous cement, and intermixed with a small portion of clay. In this stratum, which has been hitherto but little explored, he has found in a siliceous state, specimens of *Strombus pes pelicani* and a species of *Cucullæa*, nearly resembling those which are met with in the Black-down whetstone pits.

Patches of plastic clay are frequently found over the chalk: some of these are yellow, and employed for the common sorts of pottery; but others are white, or greyish white, and are used for finer purposes. The coarser clay is very frequently met with, nor are the finer kinds of very rare occurrence. In the Isle of Wight two species of plastic white clay are worked for the purpose of making tobacco-pipes.

A similar clay, which is used for making gallipots, is dug from the banks of the Medway. A fine, light ash-coloured, nearly white clay, which is employed in pottery-works, is also dug at Cheam near Epsom in Surry.

The UPPER OF FLINTY CHALK, which is the next older stratum, is extremely thick, forming stupendous cliffs upwards of six hundred and fifty feet high, on the south-eastern coasts of the island. It extends nearly through almost all that part of the island which lies south of a line supposed to be drawn from Dorchester in the County of Dorset to Flamborough-head in Yorkshire.

In this stratum there is a great quantity of flint, chiefly in irregularly formed nodules, disposed in layers, which preserve a parallelism with each other and with continuous seams of flint, sometimes not exceeding half an inch in thickness. The chalk contains a fine sand, which may be separated by washing.*

The fossils of this stratum are for the most part peculiar to it; very few of them being found in any other. They also appear to agree very closely with those species found in the chalk of France, by Messrs. De France, Cuvier and Brongniart. The number of fossils noticed by these gentlemen amounts to fifty; but they have as yet only particularised a part of them. These are here compared with what appear to be the correspondent fossils in the English part of this stratum; and some others are also pointed out, which these gentlemen have not yet mentioned as being found in the neighbourhood of Paris.

In the French stratum there occur,

Two *Lituolites*. No species of this genus is noticed as having

* The chalk in the neighbourhood of Paris contains according to M. Bouillon La Grange, Magnesia 0,11, and Silex 0,19.

been seen in our English chalk. But research has not been made with the necessary precision.

Three *Vermiculites*. The fossil figured Org. Rem. vol. III. pl. VII. fig. 11, was considered as a vermiculite, until by removal of the chalk and opening different specimens it was found to be a chambered and an adherent shell. Should these gentlemen not have perceived these circumstances in the specimens they met with, they would certainly regard this fossil as a vermiculite. It must also be observed that from the different forms in which the spiral part is disposed, its division into two or three species might be authorised.

Belemnites. These, according to M. De France, are different from those which accompany the *ammonites* of the compact limestone. The *belemnites* of our chalk are smaller than those of the limestone, besides which they are different in form, being narrower and more elongated. But M. De France may also have confounded with them the spines of the *echinus*, which so closely resemble the *belemnite:* if that gentleman should not have met with perfect specimens, he might not be able to remark the difference between these two fossils. The characters which he has noticed are however sufficient to lead to the belief of a correspondence between the French and English fossils.

Fragments of a thick shell of a fibrous structure. The doubts expressed respecting the nature of this shell, and the observations made with regard to it, offer another strong point of agreement between the shells of the two strata. The shell here alluded to is most probably that represented Org. Rem. vol. III. pl. V. fig. 3 ; the structure of which agrees exactly with that mentioned as found in the French stratum of chalk. That shell is however described as being of a tubular form ; it is therefore right to observe, that fossil *pinnæ* do sometimes possess this peculiar structure.

A *Muscle.* No instance appears in which any shell of this genus has been found in our chalk.

Two *Oysters.* The Kentish chalk-pits yield at least three species of this genus. One of them bearing very much the form and appearance of *Ostrea edulis*, but being only about a fourth of its size; one smaller, the serrated edge of which places it in the family of *Cristæ galli;* and the third still smaller, not half an inch in length, crenulated on each side of the hinge.

A species of *Pecten.* There are two or three small species of *pecten* in the English chalk; besides a shell, with long slender spines, which may be safely classed with the pecten.

A *Crania (Anomia Craniolaris*, Linn. *Crania personata*, Lam.) This fossil is not known in the English chalk; nor indeed could it be easily ascertained, unless the inferior valve happened to be well displayed.

Three *Terebratulæ. T. sulcata* and a terebratula agreeing with *Anomia terebratula* Linn. are frequently found in our chalk; and sometimes another species, hardly half an inch in length, with remarkably acute and well defined ribs.

A *Spirorbis.* Traces of these shells are frequently found on the surface of the *echinitæ.*

Ananchitæ, (Echinus ovatus.) The crustaceous covering of which, it is remarked by M. Cuvier and Brongniart, remains calcareous, and has assumed a sparry texture, whilst the middle alone is changed into silex. No actual change has however taken place, as far as respects the flinty part of the fossil, the flint having merely filled up the hollow of the sparry crustaceous covering. This fossil is frequently found in the English chalk.

Porpitæ. These also occur in the English chalk.

Five or six different fossil bodies called by the French oryctologists, *Polypiers*, one appearing to belong to the genus *Caryophyllæa.* Several of these bodies, from the English chalk, have been figured in the Org. Rem. vol. II. Pl. XIII. fig. 70 to 79.

Another is supposed to belong to the genus *Millepora*. This is generally brown, and is in the state of oxydized iron, as resulting from the decomposition of pyrites. These fossils exist in the Wiltshire soft chalk.

Lastly, *Shark's teeth*. These also occur frequently in the English stratum.

Messrs. Cuvier and Brongniart state, that there are many more fossils in the chalk stratum of France than those which have been just referred to. This is also the case with the fossils of the English chalk; since the following may be enumerated as occurring in this stratum. *Rugous palates*, and, though rarely, the *scales* and *vertebræ of fishes*. Three or four species of *stellæ marinæ*. A *long saccular bivalve*, with an uncommonly thin shell, of which so little has been hitherto saved, as not to give a chance of gaining a knowledge of its general form, or the structure of its hinge. *A bivalve*, which approaches to a circular form, but is so thin as to afford but little hope of discovering its genus. *A bivalve, nearly circular, the margin turning upwards so as to give it a patella or disk form, with numerous long processes passing from the margin and external surface, and fixing it to other bodies. A small pecten with sharp angulated ribs*, not exceeding a quarter of an inch in length. *A bivalve*, not an eighth of an inch in length, finely striated longitudinally, bearing a bright polish, and seemingly possessing its original light brown colour. *Plates of the tortoise echinite*, and several remains apparently of other species of this genus.

When to these are added the remains of various *echini*, such as *conulites*, *cassidites*, and *spatangites*, and the different *spines* of *echini* which are found in this stratum; and when it is also considered that the present account is drawn up almost entirely from the productions of chalk cliffs of not more than two miles in length, it will not be difficult to conceive, that the number of these fossils is not less in the English than in the French chalk.

The state, in which these fossils are found, plainly evinces that the matrix in which they are imbedded was formed by a gradual deposition, which entombed these animals whilst living in their native beds. The fine and delicate spinous projections of the shells are unbroken, and the spines are still found adhering to the crustaceous coverings of the *echini;* neither of which circumstances could have occurred had these bodies been suddenly and rudely overwhelmed by these investing depositions, or had they been brought hither from distant spots.

It may be said that the specimens possessing the characters here alluded to are rare. With respect to the spinous shells, however, they certainly occur often, although it is almost impossible to extricate them unbroken from their surrounding chalk; and the rarity of the specimens of *echinites* with their attached spines, depends in a great measure on the mode in which these specimens are obtained. The specimens seen in cabinets are seldom found by the naturalist himself, but are preserved by the work people who break the chalk, when any uncommon appearances catch their eye. But it frequently happens that these marks are not seen until the piece is broken by their tool, and with it, perhaps, the entire animal.

The perfect state of the surfaces of the chalk fossils proves also that this deposition proceeded from the surrounding fluid, and that it was not derived from the immediate action of any chemical agent, on the shells and other calcareous coverings of the animals living at the bottom of the sea. In the fossil animal bodies found in chalk, not the least diminution of the sharpness of their ridges or points is observable, nor is the least dulness of the delicate lines and embossments of the crusts, or of the spines of the *echini*, to be detected.

That the deposition of chalk and of flint was sometimes alternate, and even, as it is expressed by Messrs. Cuvier and Brongniart, *periodical*, appears from the seams or strata of flinty nodules, and particularly from the widely extended flat or tabular flinty depositions interposed between the chalk.

But that the chalk was permeated by the silex at some distance of time after the deposition of the former, seems also to be proved by the state of the fossils of this stratum. There does not appear to be a single instance in which the animal remains are impregnated with silex. On the contrary, the substance of all these fossils has become calcareous spar, and their cavities have been filled with flint; thus plainly evincing that sufficient time must have elapsed for the crystallization of the calcareous spar, previously to the infiltration of the flint.

It may not be improper to remark, that in no instance does the flint, although in contact with the calcareous spar, appear to have become mixed with it. The reverse of this is the case with the chalk, since this latter may be seen in almost every degree of union with the flint; from being blended with its substance, to being merely united with its surface, and forming the white coat of the flint. It has been, without doubt, from certain appearances resulting from this union, that M. Carrosi and others have been led to believe in the change of lime to flint.

There can be hardly any hesitation in agreeing with Mr. Jameson, that the most probable explanation of the formation of imbedded flint is that which was first proposed by Werner, " that during the " deposition of chalk, air was evolved, which in endeavouring to " escape, formed irregular cavities, that were afterwards filled up, by "infiltration, with flint."* The decomposition of the softer parts of the animals, which were thus entombed, may be considered as a very probable source of a part of those gaseous matters which formed these cavities: and the connection of the animal remains with these nodules of flint is easily explained by supposing the shells, crusts of the *echini*, &c. to have projected into these cavities, or to have been adherent to their sides, at the period at which this infiltration took place.

That the separation and deposition of the matter forming these siliceous nodules have been the work of crystallization, is rendered evident by the cavities left either in these nodules, or in the fossils, being generally lined with quartz crystals.

Whilst endeavouring thus to explain the formation of these flinty nodules, and the filling up of the cavities of the fossils with flint, a difficulty arises from observing these bodies, insulated as it were in their bed of chalk: it not being easy to conceive, how so copious an infiltration should have taken place into these cavities, whilst the surrounding chalk should only have received a slight intermixture of siliceous grains.

Something analogous is however observable in the formation of the calcareous stalactite; since in those caverns in which these concretions have been forming for a very long period, the infiltration by which they are formed is found to continue to the present day; proving that the interstices of the superincumbent stone, have not yet been filled by the concreting of the earthy particles held in solution in the percolating fluid, by the crystallization of which these bodies have been formed, and are now augmenting.

The Oberstein nodules of agate appear to have been formed under somewhat similar circumstances; since it is in general evident from their external surfaces, that they also have had very little adherence to

* System of Mineralogy by Prof. Jameson, vol. I, p. 172.

their matrices, which would hardly have been the case had these been highly impregnated with silex.

The HARD CHALK lies immediately beneath the soft chalk. In this stratum there are no flint nodules. " Its beds," according to Mr. " Farey, " increase in hardness, until near the bottom where a " whitish freestone is dug, at Totternhoe in Bedfordshire, and at " numerous other places; that brought from Ryegate and other quar-" ries, of this stratum, south of London, is used as a fire-stone."*

It has been generally supposed that these two strata of chalk are of one formation: but not only the absence of the flints, but the characters of their fossils prove them to be of distinct formations. No fossils indeed are marked by more decidedly peculiar characters than those of this stratum; since hardly a single fossil has been found in it, which has been met with in the soft chalk, or any other stratum.

It is in this chalk that the genus *Ammonites*, is first met with, or, in other words, it appears that the water which formed this stratum was that in which this genus last existed, no traces of it having been seen in the soft chalk or in the other superior strata. The chief, and perhaps the only circular species of this genus which has been found in this stratum, is of a large size, with nodular projections on its sides, towards the back, which is generally flat. This fossil appears to be of a different species from any of those that are found in the subjacent strata.

It is very remarkable that in this stratum, the last in which the genus *ammonites* is met with, so remarkable a deviation from the original form of the genus should occur, as almost to claim its being considered as the characteristic of another genus. In the fossil here referred to, which possesses all the other characters of *ammonites*, the spiral coil is disposed in a form rather approaching to that of the oval than the circle.†

* Report on Derbyshire, &c. p. 112. † Organic Remains, Vol. III. Pl. IX. fig. 6.

In another fossil of this stratum, a still more extraordinary deviation exists. This fossil possesses the concamerations and the foliaceous sutures of the cornu ammonis; but instead of being spirally coiled, it has its ends turned towards each other, somewhat in the form of a canoe. This peculiar form has led to the placing of this fossil under a separate genus, which has been named *Scaphites*.*

Of the extent of this stratum no correct account has been given; but there is sufficient reason for believing that it accompanies the other chalk in its range through this island. It also appears that its peculiar fossils exist in it at very considerable distances. Thus the *oval ammonite*, which is found in the Sussex hills, likewise occurs in the hard chalk of Wiltshire; and the *scaphites*, another inhabitant of the Sussex hills, has also been discovered in Dorsetshire.

ON comparing the preceding sketch with the Essay on the Mineralogical Geography of the Neighbourhood of Paris, by Messrs. Cuvier and Brongniart, some important variations will be perceived between the strata found above the chalk in this island and in France. In France, the strata above the chalk differ both in number and quality from those which have been hitherto observed in a similar situation in England. In France too, several strata of sand and sandstones exist above the strata of the gravel formation, which in this island appear to be highest.

The first of these differences appears to result chiefly from the existence of numerous beds or patches, the formation of which must have depended on certain local circumstances, such as the existence of fresh or salt water lakes, at the period of the drying up of a former ocean; the different chemical combinations which might thence have taken place, &c. But the occurrence of such

* Organic Remains, Vol. III. Pl. X. fig. 10 and 11.

variations can hardly be considered as interrupting the continuity of the stratification.

Indeed when it is considered, that in France much more frequent opportunities are afforded of examining the stratification immediately above the chalk than in England, it will not be regarded as improbable, that several of these beds or patches may exist here, the discovery of which would render the accordance of the two series of strata much more close.

Even from the examinations which have been already made, the identity of the French and English chalk is established. The British strata above the chalk are also found to contain patches of plastic clay, of most of the varieties mentioned in the French strata, as well as patches of coarse limestone, with its accompanying sand and its peculiar fossil shells, such as are found to exist in the corresponding French strata.

The other difference, the existence, in France, of beds of sand and of sandstone above those of gravel, which are the highest strata of this island, is very remarkable. May it not be attributable to the abruption, from this island, of the superior strata or beds of this formation, by that catastrophe, instances of the astonishing force of which have been already noticed ?

XV. *Memoir on Bardiglione or Sulphate of Lime, containing a Sketch of a Theory of the true Nature of Plaster, as well as of its Properties; in order to determine the differences that exist between it and Bardiglione.*

By The Count de Bournon, F.R.S. &c.

Foreign Secretary of the Geological Society.

[Translated from the original French Manuscript.]

THIS substance is a combination of lime and sulphuric acid, in the proportion, according to Vauquelin, of 0,40 lime and 0,60 sulphuric acid. It has obtained various names: being called *Chaux Sulfatée Anhydre* by Haüy, *Chaux Sulfatine* by Brongniart, *Anhydrite* and *Würfelspath* by Werner, *Muriacite* by Poda and Klaproth, *Pierre de Vulpino* by Fleuriau de Bellevue, and *Marmo bardiglio di Bergamo* by the Italian statuaries. The name sulphate of lime has hitherto been applied to gypsum; but as it is now well known that the simple combination of lime and sulphuric acid produces bardiglione, while water is essential to the composition of the former, that expression is inapplicable, and might be supplied by that of Hydro-sulphate of lime.

Essential specific Characters.

A. *Crystallographical.*

Primitive Crystal. A rectangular tetrahedral prism with square bases, which, from every indication, do not belong to the cube, but the height of which it has hitherto been impossible to determine, fig. 1.

Integrant Molecule. The tetrahedral prism very distinctly exhibits natural joints, parallel to the diagonals of its bases; the integrant molecule is therefore a right trihedral prism, having for its terminal face a right angled isosceles triangle, fig. 2: the height of the integrant molecule as well as that of the primitive crystal, which is composed of four of these molecules, fig. 3,* is yet undetermined.

Fracture. Even and shining in the direction of the cleavage; but having commonly more lustre, and often a pearly aspect, on those sides of the prism on which the cleavage is most easily obtained. In every other direction it is uneven and granular; but this latter fracture is rarely observed, from the facility with which the fracture takes place in the direction of the natural joints.

B. *Physical.*

Specific Gravity. In very pure and transparent crystals from the salt-works of Hall in the Tyrol, I found it to be 29,57, which agrees perfectly with that stated by the Abbé Haüy.

Hardness. It scratches carbonate of lime with great facility; but is scratched, though with some difficulty, by fluate of lime.

Refraction. Double in a high degree according to the Abbé

* As my conclusions with respect to the primitive crystal and integrant molecule of bardiglione do not agree with what the Abbé Haüy has said concerning them in his *Tableau Comparatif*, &c. I have inserted, after the details relating to the several varieties of this substance, the reasons that have compelled me to dissent from the opinion of that celebrated mineralogist, for whom I have the greatest esteem, and from whom I never differ but with extreme regret.

Haüy. I have however been able to perceive only a simple refraction in this substance.

C. *Chemical.*

Action of Acids. None, when the bardiglione is pure.

Action of Heat. A moderate degree of heat renders such of its varieties as are indeterminate of a dull white colour; but has no such effect on those that are crystallized; yet when the crystalline variety of the salt-works of Bex, enclosed in a mass of compact bardiglione mixed with gypsum and sea-salt, is exposed to heat, it gives both to its crystal and to their fragments a whitish tint, frequently accompanied with a pearly lustre.

When the heat of the blowpipe is applied to the thin edges of this substance, it appeared to me to act in the same manner as it does on gypsum: the bardiglione passing, without any ebullition, into a very friable white enamel. The resistance of this substance to fusion, when tried on large pieces, added to the friability of the enamel, is no doubt the reason why several mineralogists have said it was infusible by the blowpipe; but if its action be applied, as I have mentioned, to the thin edges, their blistered appearance instantly demonstrates its fusibility.

Analysis. In the first analysis of bardiglione, Klaproth found 15 parts of sea-salt, 27 of gypsum, and 58 of sand; but the specimen analysed by him must certainly have been very impure. Vauquelin, after having freed it from the sea-salt, which is foreign to its composition, found it to consist of 40 parts of lime and 60 of sulphuric acid.

Accidental Characters.

Colour. Bardiglione is most frequently colourless; but it is sometimes of a pale violet-red; such is the crystalline variety of Hall, as well as that of Sweden, and that of the lead mine of Pesai near Mont Blanc. It is of a deep grey at the salt-works of Bex, and of a bluish tint at Vulpino, which has occasioned some mineralogists to confound it with the bluish variety of sulphate of strontian.

Electricity. The transparent violet-coloured bardiglione of Hall is pretty strongly electrical by friction. That of the salt-works of Bex is likewise electrical, but in a less degree. I could not find this property in any of the other varieties of this substance: even in that of Hall the intensity of the electricity varies considerably; for in some pieces it is very weak, and is excited with difficulty.

Phosphorescence. This character, like the preceding, varies very considerably. Some of its varieties, as that of the salt-works of Hall, give a slight and bluish phosphorescent light. In others, as that of Sweden, which I have already noticed in the 77th number of the *Journal des Mines*, and which I have said is mixed with actinote, yellow copper, and magnetic iron ore *(fer oxidulé)*, the phosphorescent light is of a yellow colour inclining to orange. In some of the varieties of this substance, which come from Vulpino, this light is of a very deep orange yellow, and with the brightness of a burning coal. Several other varieties, among which is that belonging to the salt-rock of Arbonne near Mont Blanc, as well as that of a deep grey with a somewhat reddish tint of the salt-works of Bex, are totally destitute of this character.

Table of Bardiglione and its Varieties.

Species.	Variety.	Division.	Sub-division.
Bardiglione. Sulphate of lime.	Of determinate crystalline forms.	Primitive crystal.	The crystals mixed with sea-salt.
		Its modifications & varieties.	Würfelspath (Werner).
	Of indeterminate crystalline forms.	Approaching a determinate form.	
		Fibrous	With divergent fibres.
		Globular.	
	Lamellar . .	With large laminæ . .	Lying in the same direction.
			Very thin, and placed one upon another, so as to form separate and distinct aggregations.
		With small laminæ . .	Appearing, when examined by the lens, in the form of small distinct crystals.
			Intersecting each other in different directions.
	Granular . .		
	Stalactiform .	Contorted, *(pierre de tripe)*.	
	Compact.	Intermixed with small crystalline masses of the same substance.	
		Mixed with sea-salt *(muriacite)*.	
		Mixed with quartz *(pierre de vulpino)*.	
		Including small globules of the same substance.	
	Epigène of Haüy.		

Bardiglione of a determinate Figure.

The crystalline state is that in which this substance most commonly occurs; but its forms are seldom determinate. The finest crystals, and the greatest variety, have been found in the mine of rock-salt at Hall in the Tyrol; which is also the place where it has been most commonly observed of a determinate crystalline figure. The crystals occur there in groups, either colourless, or of a pale red slightly inclining to violet. They are commonly pretty large, frequently flattened, and often of very little thickness. They intersect each other in different directions, and very often several are joined together so as to have the appearance of a single crystal: but in these cases their lines of separation are readily perceivable; and, as they adhere together but slightly, they are easily separated. Sea-salt is frequently found disseminated through these crystals; and in this case, the same salt very often also shews itself externally in small distinct masses, which are easily known by their inferior lustre and hardness. When the Abbé Poda first noticed these substances, it was the variety of Hall that came under his observation. The sea-salt, of which there are frequently considerable masses in it, led him to consider it as a mixture of this salt with gypsum. Its rectangular figure also contributed to this error, which made him give it the name of *Muriacite*.

In 1802, when Mr. Chenevix analysed this variety of bardiglione from Hall, at my request, the person employed in pulverizing it found some small needles of antimony included in the interior of one of the crystals, most of them adhering to small groups of crystals of quartz; and to prevent all dispute about it, he preserved a fragment of the crystal, to which one of these needles still adhered. This fact, which I mentioned at the time in the brief account I gave of this substance in the *Journal des Mines*, No. 77, is very singular, when we consider the local circumstances of the bardiglione in which it occurred.

There is another variety of this substance in determinate crystals, often of considerable bulk, and imbedded in a mass of compact bardiglione of a reddish-brown colour, penetrated with gypsum and sea-salt. In this mass different cavities are perceivable, in which the gypsum, likewise coloured red, is in small crystals; and some of these also include sea-salt, perfectly pure, and of a red colour. The crystals of bardiglione which are scattered through this mass, while they remain adhering to it, appear themselves reddish, on account of their transparency; but, when they are detached, their colour is a deep grey. This variety comes from the salt-works of Bex, and is that which I have already mentioned as having its colour destroyed by heat.

Bardiglione of indeterminate Crystallization.

1. *Approaching to a determinate form.* Among the crystals of this substance there are several in very thin rectangular laminæ, which grow thinner by imperceptible degrees towards the two narrow sides of the prism, and this thinning, which varies considerably, is subject to no law.

At other times, as the edges of the primitive tetrahedral prism, according to the observations hitherto made, may be subjected to six different retrogradations with regard to the placing of the crystalline laminæ, the crystals having undergone these six retrogradations in succession, without the crystallization having perceptibly rested at any of them, the faces have assumed a curvilinear figure throughout a more or less considerable portion of their extent. This variety, as well as the preceding, is frequently observed among the crystals of bardiglione from Hall.

2. *Fibrous.* I have a small specimen of bardiglione from Hall, in which the crystals, which are very thin, extremely brittle, and nearly colourless, intersect each other in very different directions. In one of the parts of the specimen, this substance exhibits itself in divergent fasciculi, the fibres of which are of unequal lengths, and have a glistening lustre, which gives them an appearance that has considerable resemblance to that of the satiny coralliform arragonite. M. Mohs, in his catalogue of the splendid mineralogical collection of M. Von der Null of Vienna, mentions another variety of fibrous bardiglione, which he says came from Ischel in Upper Austria, and is of a colour intermediate between brick-red and blood-red.

3. *Globular.* To this variety I believe should be referred the globules of different sizes, from that of a poppy seed to that of a large pea, or still larger, which are met with in a rock of compact bardiglione mixed with sea-salt, known by the name of the Salt Rock of Arbonne, and situated at a very considerable height, being a very little distance from the region of perpetual snow near St. Maurice, in the vicinity of Mont Blanc. These globules are distinguishable from the compact bardiglione in which they are included, not only by their figure, but by their brown colour, that of the mass being grey, or reddish. Their substance is mixed in like manner with sea-salt. They are much more fusible before the blowpipe.

Lamellar Bardiglione.

1. *With large laminæ, lying in the same direction.* Such is the tex-

ture of one of the varieties of this substance, of which I have never seen but two specimens; one in the collection of the late Mr. Greville, the other in my own. The bardiglione of these two fragments is of a light violet colour: it is intermixed with a great deal of actinote of a pale green colour, and of asbestos; as well as with a great number of small particles of yellow copper ore, of pyrites, and of magnetic iron ore, *(fer oxydulé)* which makes them act strongly on the magnetic needle. I have said, in No. 77 of the *Journal des Mines*, that I presumed, from the nature of the substances accompanying it, that this bardiglione came from Sweden or Norway. The specimen I have, was given to me about two years ago, with a positive assurance that it came from Sweden; but I could not gain any more particular information respecting the place.

M. Mohs, in the same catalogue, mentions two specimens of bardiglione of a similar texture, and of a smalt blue colour, one from Carinthia, the other from Swabia. This variety appears also in the violet bardiglione from the lead-mine of Pesai near Mont Blanc.

2. *With large laminæ, very thin, and placed one upon another, so as to form separate and distinct aggregations.* This variety, which is of a very beautiful white slightly inclining to blue, comes from Vulpino, a few leagues from Bergamo in Italy. Its laminæ are very thin, and placed one upon another, so as to form little separate aggregations, crossing each other in different directions, and giving the whole mass sometimes a lamellar, sometimes a fibrous appearance, according as the eye is directed toward the flat sides of the laminæ, or their edges. This variety, which belongs to one of those of the stone known by the name of *Marmo Bardiglio di Bergamo*, takes a very fine polish, and has often a little admixture of quartz.

3. *With small laminæ, in an uniform direction.* This variety differs from that with large laminæ, only in regard to their size. I have a

specimen of it that exhibits an interesting fact. Its surface shews the union of an immense number of small rectangular prisms, all, or nearly all, having their planes in a parallel direction; but a very great number of them are very distinct in all the extent of their square surface. This texture appears to have been occasioned by a very slight alteration. The matrix of this bardiglione is an indeterminate massive quartz, to which there adheres a fragment of foliated micaceous rock, mingled with galena and some iron pyrites. It came from the lead-mine of Pesai, near Mont Blanc.

4. *With small laminæ intersecting each other in different directions.* The bardiglione of Vulpino frequently presents us with this variety, which sometimes has a very deep bluish colour, and is frequently mixed with a few particles of quartz. We are indebted to M. Fleuriau de Bellevue for a knowledge of the different varieties of the bardiglione at Vulpino. It was he who found that this substance, which takes a very fine polish, and is employed by the statuaries of Bergamo and Milan for making slabs, chimney-pieces, &c. differed essentially both from carbonate of lime and gypsum. The first analysis of this substance having shewn it to contain sulphate of lime and quartz, the latter in the proportion of 0.8, it was called *quartziferous sulphate of lime;* till a second analysis by Vauquelin ascertained its real nature. The interposition of quartz, and the interruption of contiguity occasioned by this interposition, diminishes its specific gravity, which was found to be 28.78 by the Abbé Haüy, who some time after discovered that it belonged to the bardiglione. The quartz interposed in this substance may sometimes be perceived by a good lens.

Sometimes too this variety of bardiglione, and more particularly the following, in the granular state, includes particles of carbonate of lime, but always in very small quantity.

I have seen specimens of bardiglione, in small bluish laminæ, including pretty considerable masses of sulphur; but I was unable to learn whence they were obtained.

Granular Bardiglione.

This variety has considerable resemblance in its texture and external aspect to the granular magnesian carbonate of lime; but in its lustre it approaches nearest to the lamellar variety of that substance.

Stalactiform Bardiglione.

This variety presents itself in a mamillary, and frequently contorted form, resembling the convolutions of the intestines, whence it was called *Pierre de Tripe*, by which name alone it was known for some time. Its texture is compact, approaching more or less to lamellar.

This variety of bardiglione appears hitherto to have come exclusively from the salt-mines of Wieliczka, though it is also said to have been met with in those near Bochnia, in Poland. It was at first very improperly considered as a sulphate of barytes, which very probably may have been the cause of a variety of the latter substance, which sometimes approaches to a stalactical figure, having been confounded with it; hence it has been said by some mineralogists to have been found also in Saxony, and in Derbyshire, from which places I have never seen any thing that could be referred to it.

According to Klaproth this substance is mixed with a small proportion of sea-salt; his analysis gives 42 parts of lime, 56.5 of sulphuric acid, and 0.25 of sea-salt, leaving a loss of 1.25.

Compact Bardiglione.

This variety is less compact in its texture than compact carbonate of lime, or compact feldspar: its substance, at least in all the specimens which I have hitherto had an opportunity of observing, being more or less mixed with small particles of lamellar bardiglione. Hence its fracture is very rough and irregular; but we can always distinguish in it those little prominent and somewhat detached splinters, which are characteristic of minerals having a compact structure. This variety has generally a slight semitransparency at its edges.

1. *Mixed with quartz.* This variety of the compact bardiglione occurs with the lamellar variety at Vulpino; the quartz which it contains is sometimes visible with a good lens.

2. *Mixed with sea-salt.* The salt-rock of Arbonne belongs to this variety. Hitherto this rock has been considered as a *gypsum* mixed with sea-salt; but all the specimens I have yet seen, and which have been sent to me by my friend Gillet de Laumont, belong no doubt to the species bardiglione. This variety includes also in its substance very brilliant small laminæ of bardiglione, and its fracture is more irregular than that of the pure compact variety.

The salt-rock of Arbonne presents two varieties of this substance; one of a dirty grey, and the other a little reddish. The latter of these varieties is somewhat closer and finer grained than the other, and it is also less loaded with sea-salt. Very small dodecahedral crystals with pentagonal faces of iron pyrites, are disseminated through its substance. Small globules of compact bardiglione, very easily separable from the substance inclosing them, are likewise included in it. These little globules are destitute of the brilliant laminæ observable in the surrounding mass, are of a brown colour, and appeared to me larger and more numerous in the grey compact variety, than in the reddish. I observed similar globules in one of the varieties of bardiglione, consisting of small blue laminæ, from Vulpino.

When pieces of the rock of Arbonne have been boiled a certain time in water, to free them from the sea-salt they contain, they become porous, but very irregularly so; and thus shew, that the sea-salt is distributed unequally, and chiefly in small masses.

Bardiglione Epigène of Haüy.

M. l'Abbé Haüy, in his *Tableau Comparatif*, gives the name of epigène, agreeably to its Greek etymology, to every transition of one mineral to another.

The mention which he makes of this variety of bardiglione, from which alone I am acquainted with it, is in consequence of a specimen presented to him by M. Cordier, in which one part of the substance is in the state of lamellar bardiglione, while the other is in that of compact gypsum. To the gypsum of this specimen M. Haüy gives the name of *bardiglione epigène*, because, in his opinion, its formation has taken place from an action exerted on the lamellar bardiglione itself, subsequent to its production; which action, from what he says p. 141, was effected by the introduction of water into its interior: *whence*, he adds, *the substance of the bardiglione has lost part of its hardness, and its texture has become looser.* He further states, that according to an observation communicated to him by M. Hassenfratz, there are at Pesai, whence this specimen came, galleries carried through the bardiglione, the outward part of which, being penetrated by moisture, has experienced a considerable enlargement.

Such a transition of one substance into another essentially different, not by decomposition and the consequent loss of one of the component parts of the substance; not by another kind of decomposition, in which the loss of one of the component parts of the substance is spontaneously replaced by another, thus giving rise to a new compound; but by the introduction of a new principle, by the combination of new constituent molecules with those of which the integrant molecules of a substance are previously composed; would be so highly interesting, and lead to consequences so new, so remote from every thing presented to us in the mineral kingdom, and at the same time so important to the science of geology, that it requires to be examined with the most scrupulous attention. Accordingly I shall reserve the further consideration of this subject for the observations which will conclude this memoir.

Observations on the Primitive Crystal, and Integrant Molecule of Bardiglione.

In my enumeration of the specific characters of bardiglione, I have said that its form was a rectangular tetrahedral prism with a square base, fig. 1; in which the absence of additional faces, either at the edges or angles of the terminal faces, had not hitherto permitted me to determine the height. I added, that this prism was divisible in a direction parallel to its two diagonals, as pointed out in fig. 4, which shows at the same time, that each of the primitive rectangular tetrahedral prisms is composed of four right trihedral prisms, the bases of which are right angled isosceles triangles, fig. 3. The height of these trihedral prisms remains equally unascertained, and they constitute the integrant molecule of this substance, fig. 2.

When I thus determined the primitive crystal and integrant molecule of bardiglione, the *Tableau Comparatif des Résultats de la Crystallographie et de l'Analyse Chimique* of M. l'Abbé Haüy had not appeared. This work informs me, that its learned author had also determined the form of the primitive crystal, as well as of its integrant molecule: and at the same time I perceive, with infinite regret, that, as he was not more fortunate than myself with respect to the height of these two molecules, the other dimensions he assigned them differ from those to which I had been led by my study of this substance. According to this distinguished mineralogist, the base of the rectangular tetrahedral prism is not a square, but a rectangle, the sides of which are to each other as 16 to 13.4 (fig. 5); the prism is divisible in a direction parallel to its diagonals by planes, the intersection of which forms angles of 100° 6′ and 79° 54′ (fig. 6). Thus it would be divisible into rectangular rhomboidal prisms, the bases of which would be rhombs of 100° 6′ and 79° 54′. But these prisms, it appears to me, cannot in any way be considered as the integrant molecules of the tetrahedral prism with rectangular bases, considered as the primitive one; for this prism being also divisible in a direction parallel to each of its sides, as shown at fig. 7, this second division would separate each of the prisms with rhomboidal bases of 100° 6′ and 79° 54′ into four rectangular trihedral prisms, of which two opposite ones would have for their base an isosceles triangle of 100° 6′, and the other two an isosceles triangle also of 79° 54′, fig. 5. Thus these molecules would be of two different forms, and consequently could no more be considered as the integrant molecules of the substance, than those with rhomboidal bases of 100° 6′ and 79° 54′.

On the other hand, this substance presents a very particular and interesting fact, likely to mislead, with respect to the primitive crystal, and which probably deceived the Abbé Haüy. On looking at the crystals of this substance, through their terminal faces opposite to the light, lines are observed in the interior of several, perfectly distinct, and in the direction of the two diagonals of these terminal faces. The intersection of these lines, instead of taking place perpendicularly, so as to be at right angles, and thus forming squares, as in figs. 3 and 4, appears to be made obliquely, fig. 5, so as to form rhombs, as shown at fig. 6. If, in order to find the measure of the angles of these rhombs, different angles be placed on them till their sides apparently coincide, an angle of 100°, or nearly so, appears to agree very well with the obtuse angles, so that the rhombs have apparently 100° and 80° for the measures of their angles. But then if a natural, or an artificial fracture, the latter of which is very difficult, be made according to the natural diagonal joints of the primitive crystal of this substance, the plane produced should make with the adjacent planes of the prism on one side an angle of 140° 3′, and on the other an angle of 129° 57′; which never is the case, for these two angles are always very exactly 135°, being what the same section must produce on the supposition of the sides of the terminal faces being equal. Yet if we compare the direction of this face, with the lines traced in the interior of the crystal, according to the natural joints, it appears to be perfectly parallel with that of these lines.

Such are the reasons which determined me to consider the base of its primitive rectangular tetrahedral prism as a square: yet, as I have observed above, there is in this substance, on account of the difference between the appearance of the angles formed by the meeting of the interior lines, indicating the natural joints; and the correspondent ones formed by the planes parallel to these joints, something very peculiar, which would seem owing to some illusion dependent on refraction, for which I cannot account.

The only crystals of this substance in which I have found perfectly determinate forms, except the primitive prisms and its fragments, have occurred to me in the bardiglione from Hall, in specimens that included groups of these crystals. Most of them, though having secondary faces, are so united together, commonly in a direction parallel to their planes, that, till they were broken, and their planes thus exposed, they appeared absolutely to compose but one crystal, as is also the case in the laumonite. Owing to this their additional faces are most frequently destitute of that lustre, which commonly belongs to the crystals, and are even in general striated. The fractures made in the direction of the diagonals, which are difficult to obtain, are likewise usually striated, thus exposing to view the edges of the laminæ placed on the planes of the prism, especially on those which have a pearly lustre.

I have represented at fig. 23, that which was already given at fig. 14, but of which, in the crystal that has furnished me with the variety I possess, as well as all those I have inserted in the plate annexed to this work, one part alone is in a state of perfect preservation. I placed this crystal so, that I could show the natural interior joints, as they are perceived in looking through its terminal faces. The lines that indicate these joints are very conspicuous in it. The two planes 1 and 3 are equally devoid of all lustre and striated, and both of them appear parallel to the interior joints. That marked 1, which I consider as belonging to a fracture, and which might have been produced by a retrogradation by a single row along the edges of the prism with square bases, makes with the faces of the primitive crystal adjacent to it an angle of 135°. That marked 3 appears to answer to *r* fig. 24. pl. II. of the Abbé Haüy's *Tableau Comparatif;* but instead of making with the primitive planes an angle of 129° 56′, as mentioned by that celebrated author, that which it does form has constantly appeared to me to be at least one degree smaller. I conceive it to be the product of the retrogradation by five rows in breadth and four laminæ in height on the edges of the prism with square bases. The angle it forms with the primitive planes would consequently be 128° 40'. I place this crystal here anew, under the aspect proper to it, because it appeared to me better adapted than any other, to set in its true light the opinion of the Abbé Haüy, as well as my own; and may more easily enable the reader to decide between the two. Whichever may be adopted, the crystals represented will remain the same; the calculation alone will require to be rectified, as I have myself done in the second table of the modifications of the primitive crystal, annexed to this memoir.

General Observations on Bardiglione.

From what has been said, in the preceding description of the varieties of bardiglione, of the different circumstances in which they present themselves, and of their localities, this substance appears not to be confined to secondary strata, but also to occur in some veins in primitive rocks. Such is the bardiglione that has been said to be found in the vein of lead-ore at Pesai near Mont Blanc, as well as that accompanied with actinote from Sweden. But hitherto it has been met with much more frequently in the newer rock formations, particularly those that include large deposits of sea-salt. Of this kind is the bardiglione which is found in the salt-works of Bex, in the salt-mines at Hall, in those of Wieliczka, and in the salt-rock of Arbonne: as well as that of Carinthia, Upper Austria, and Swabia. Are these the only places in which this substance accompanies rock-salt? and in the great repositories of this mineral, at Voltiera in Navarre, Almengranilla in la Mancha, and elsewhere in Spain, at Northwich in Cheshire, in the salt-works of Altamonte in Calabria, &c. may not much of the accompanying gypsum, as it has been hitherto considered, be rather in the state of bardiglione? It appears besides, that under certain circumstances bardiglione forms particular deposits, such as that at Vulpino, at a little distance from Bergamo in Italy, which has long been employed by the statuaries of that city, and of Milan: but we are still in want of information respecting its exact position, as well as the nature of the accompanying rocks.

This substance must still be considered a new object of observation for the geologist. I am strongly persuaded, that it will be to him what the magnesian carbonate of lime has proved, since Mr. Tennant turned his attention towards it, and shewed, that it exists in deposits of considerable extent, where its presence had not been before suspected.

I have postponed to this part of my paper the grounds of my opinion as to the essential difference between bardiglione and gypsum, the detail of which will oblige me to take a view of the calcination of gypsum, and of the different phenomena it exhibits.

By calcination, gypsum is known to undergo no other alteration than the loss of the water that formed part of its substance. The residue of this process, properly called plaster, contains nothing but lime and sulphuric acid in the same proportions as in bardiglione. These two substances might therefore be ranked together, but we shall presently see that there is a wide difference between them. In this state of calcination, when we would make use of it, we mix it with water, by tempering and beating them together. A certain quantity of the water is absorbed, and after the evaporation of the superabundant part of this liquid, which is promoted in some degree by the caloric evolved in the operation, the mixture acquires solidity;

still however retaining a slighter cohesion between its particles than existed between those of the gypsum previous to its calcination, and without receiving any degree of transparency. In the transition of Plaster to this state of solidity, the gypsum has hitherto been said to resume its water of crystallization; but what is this water of crystallization? what idea ought this expression to convey to the mind?

If, in order to settle my opinion on the subject, I consult those who have written on chemistry, or on mineralogy, the majority conceive, that this water is that which a large quantity of salts and earthy substances retain when they crystallize; and that this water is necessary, in these cases, to the crystallization of the substances, but constitutes no part of their essence. But how can the water, absorbed by the plaster, which is evidently very different from water of crystallization, be necessary to the process? What part does the water in crystallized gypsum act in the crystallization of it? a satisfactory answer to these two questions, is, I conceive, requisite in all the cases in which they occur.

Some of these authors think, that, in several instances, the water enters into their composition as an essential ingredient; and upon this subject I refer to a passage in the first volume of the Mineralogy of M. Brongniart, page 96; as also to a very judicious doubt expressed by the Abbé Haüy, in his Mineralogy, vol. IV. p. 351. I confess, that I had long ago adopted this opinion. But is all the water, that may be included in these mineral substances, to be so considered? Certainly not. In many of them the water is foreign to their substance, and has entered merely in consequence of the attraction (to which I have given the name of attraction by approximation) more or less powerful, exerted upon it by their integrant molecules; in this case it is only imbibed and interposed between them, but does not affect, in any degree, the essence of the substance containing it; this is water of crystallization in the true sense of that term. But it happens not unfrequently that water enters as an essential part or principle into the formation of their integrant molecule, in which case it is not water of crystallization but water of composition, and ought so to be denominated. It is obvious, that the one does not necessarily exclude the other, for they are totally unconnected with each other. It is obvious too, that we cannot consider the water, which a substance may contain, as making one of its component principles, unless there be solid reasons for such a conclusion. For instance, in the case in question, the combination of lime with sulphuric acid gives rise to rectangular tetrahedral prismatic molecules with square or rectangular bases; while water, uniting with the same principles, combined in the same proportion, gives rise to molecules in right tetrahedral prisms, with rhomboidal bases, having angles of 113° 4′ and 66° 56′; it is very evident, that this water, by its union, has totally changed the form of the integrant molecule, which it could only do by combining with it. This fact will be rendered still more evident by what follows.

Calcined gypsum then, from what has been shewn, must have lost its water of composition. This loss must be owing to the molecules of water having a much greater affinity for caloric in motion, or heat, than it has for the other component molecules of gypsum.

If the gypsum had lost in calcination only its water of crystallization, or, what comes to the same thing, that which was regularly interposed between its molecules, there would remain a simple combination of lime and sulphuric acid, in the proportion of 32 parts of lime and 46 of acid in every 78 parts, or 40 of lime and 60 of acid in 100: a combination precisely the same with that which constitutes bardiglione. Plaster, which is the result of the calcination of gypsum, would then be bardiglione, which is far from being true. The distinctive property of gypsum, when changed to the state of plaster, is rapidly to absorb water, and, by that absorption, to acquire consistency, and even a certain degree of hardness. Bardiglione, neither before nor after calcination, has any action whatever on water; and if reduced to powder before it is mixed with it, its particles still retain their state of division.

It is certain, therefore, that bardiglione and plaster, though composed of the same principles, lime and sulphuric acid, and in the same proportions, are two substances of different natures. And as this difference cannot arise from the nature of the principles entering into combination, or from the manner in which they are proportioned to each other, it must necessarily arise from the mode of arrangement of the constituent molecules which form the integrant molecules. Directing our view to this point, we shall see that gypsum, in its transition to the state of plaster, having been deprived only of its water of composition, without the combination of sulphuric acid with the lime having been destroyed, each of the integrant molecules, which compose the mass of plaster, should be considered as a right trihedral prism, having scalene triangles for its base, perfectly similar to the integrant molecules of gypsum, and exactly the half of its primitive crystal; but having void spaces, within the solid, similar in shape to the molecule or molecules of water removed, the figure of which is yet unknown to us. Thus the component particles of lime and sulphuric acid are not in immediate contact in the integrant molecules of plaster, except in parts of their surface; while in bardiglione, on the contrary, these same component molecules are in that state of approximation which is adapted to their complete solidity.

Hence we can readily explain the cause why plaster, when in contact with water, absorbs this liquid, and acquires solidity; while bardiglione, in similar circumstances, undergoes no change. From what has been said of the effect of calcination on the integrant molecules of gypsum, it appears that the moment when plaster is brought into contact with water, the molecules of the fluid are attracted into the vacuities of similar shape with themselves by the compound attraction of the bare surfaces of the constituent molecules of lime and sulphuric acid, and are fixed there anew. The plaster then returns in reality to the state of gypsum; and this change takes place more perfectly, when the same water that has completed anew the imperfect integrant molecules of gypsum, affords by its temporary superabundance a vehicle, by the intervention of which, the new formed molecules are enabled to approach each other afresh, and crystallize. The gypsum however neither recovers the form, the hardness, nor the transparency which previously belonged to it: the crystallization just mentioned cannot be otherwise than greatly confused, on account of the considerable motion that must exist at the moment in which the process takes place, on the one hand, from the absorption of the water in the transition of the integrant molecules from the state of plaster to that of gypsum; and on the other, from the evaporation of that liquid, which is occasioned by the disengagement of caloric, expelled by the return of the molecules of water of which it had occupied the place, added to that set free by the water of combination, at the moment of its passage from the liquid to the solid state. The superabundance of the water, beyond what is necessary for the regeneration of the molecules of the gypsum, is indicated by the volume of that absorbed by the plaster. It is well known, that the volume of this is at least equal to that of the plaster, which is itself of more considerable bulk than the gypsum from which it was produced. It is known too, that the moment the water is absorbed by the plaster, there is always a disengagement of heat, though much less than that produced in the absorption of the same liquid by quicklime.

As the integrant molecules of gypsum, in their regeneration from plaster, can only crystallize, as has been said, in a very irregular and confused manner, the space occupied by the whole mass, after this reproduction, must be in proportion to this irregularity. Accordingly it is found that plaster acquires a very evident increase of bulk, a circumstance that is often very detrimental in the purposes for which it is employed; and this increase is greater, in proportion to the purity of the gypsum from which it was made. The swelling allows part of the water, superfluous to the regeneration of the gypsum, to remain interposed in the plaster, till the caloric of the ambient air has in its turn absorbed it, during the process of drying. In this state, the plaster must be considered as perforated with little vacuities interspersed throughout its substance: and in consequence of this texture, when it afterward comes again into contact with water, or even with air loaded with humidity, these vacuities exert a capillary attraction, and imbibe the water afresh; and plaster of this sort can be used only in places that are dry, and sheltered from all accidental dampness.

Gypsum mixed with carbonate of lime affords a better plaster than such as contains none; that is to say, it acquires in time greater solidity and hardness, because, while by calcination it loses only its water of composition, the carbonate of lime loses its carbonic acid, and passes to the state of quicklime, which, in course of time regaining its carbonic acid, returns to its former state by a process of real crystallization. This reproduction of the carbonate of lime, occasioning it to occupy a more considerable space, compresses the particles of the plaster, which it has been shewn had a very loose texture; and this joined to the hardness of the carbonate of lime itself, must impart to the plaster that additional solidity, which, in such cases, it obtains by age.

When, on the contrary, the gypsum includes either quartz, sand, or clay, as these substances undergo no change by calcination, they produce an additional want of contiguity between the molecules regenerated from the plaster; and in so far diminish their mutual cohesion, and consequently the compactness of the mass.

I have deferred to this part of my memoir some further observations respecting the bardiglione, placed among the varieties of this substance under the name of *Epigène*, on the authority of the Abbé Haüy, who has established that variety from a specimen in his collection, one part of which is in the state of lamellar bardiglione, while the other is in that of compact gypsum; and, from the sense in which he uses the word *Epigène*, he considers the part of the specimen, which is in the state of compact gypsum, as having been originally lamellar bardiglione similar to the other part; and as having undergone this change *in consequence of the intervention of water, which has introduced itself into the interior of the substance*, and which, in his opinion, has rendered its texture more loose, and diminished its hardness.

From this explanation of the transition of lamellar bardiglione to compact gypsum by the mere absorption of water, it would seem as if this learned mineralogist supposed gypsum to differ from bardiglione only by the interposition of a certain quantity of water; or, if the expression "*introduced into its interior*," implies the combination of this fluid, it would necessarily follow, that bardiglione, like plaster, must pass to the state of gypsum on the addition of water, which we have seen is by no means the case. As to the opinion of the transition of bardiglione into gypsum by the mere interposition of water in its substance, the difference of figure between the integrant molecules of these substances is alone sufficient to prevent our assenting to it; and it certainly cannot be that of the Abbé Haüy. But does a real transition take place in this case, according to the sense in which he uses the term *Epigène?*

As an example of what he means to express by this word, he quotes the transition of sulphuret of iron, or pyrites, to the state of hepatic iron, which is a reddish-brown oxide of that metal, more or less compact in some parts, and frequently cellular in others. He quotes also the transition of phosphate of lead in hexahedral prisms to sulphuret of lead, or galena.

In the first of these examples we can easily understand the nature of the operation which takes place, and which consists in the actual decomposition of the pyrites by the loss of the sulphur that was combined with the iron: a decomposition probably produced by the slow oxygenation of the pyrites, by which the sulphur is changed into sulphuric acid, and is disengaged, leaving the iron in the state of a brown oxide.

The second of these examples, which offers more difficulty, may however also be conceived, though without our being able clearly to trace what was the primary or direct cause of the change. It appears, with respect to this transition, that the decomposition, while it deprived the phosphate of lead of the phosphoric acid, probably by the intervention of sulphuric acid, occasioned at the same time the deoxydation of the lead as well as of the sulphuric acid, which then combined in the state of sulphur with the lead, and produced galena, which is so moulded into the space occupied by the phosphate of lead, that it has completely retained its external form.

In these two natural operations, so interesting and at the same time so remarkable, the change which occasions the decomposition and transformation of the substance begins at the surface, without in the least affecting its figure or dimensions. It then proceeds gradually, till the decomposition and regeneration are complete. Specimens of pyrites are found, in which only the surface to a very slight depth is in the state of hepatic iron, as well as prisms of phosphate of lead, which are precisely in the same circumstances. We find also crystals of these two substances, in which, though the centre has participated in the same decomposition and regeneration, particles of greater or less bulk, that are nowise altered, remain interspersed here and there in the regenerated substance. In phosphate of lead, which has passed into the state of galena, we frequently observe one or more laminæ, of different degrees of thickness, parallel to the planes that form the exterior surface of the hexahedral prism, which have still retained their primitive form.* In the interior of these prisms the galena is in a state of confused crystallization with small laminæ, frequently lying in different directions, so that the fracture, which is irregular and granular, and has no resemblance to what we should expect in sulphate of lead or phosphate of lead, exhibits nothing but shining laminæ of galena without any determinate direction. Frequently too we observe that in the two transitions of which I have been speaking, when they are completed, there are several small cavities, in which the decomposed substance has not been replaced.

In the two examples quoted, though a perfectly exact explanation of the means employed by nature is very difficult, yet we can con-

* In such prisms of phosphate of lead as have passed entirely into the state of galena, we also very frequently observe concentric hexagonal laminæ, the sides of which are parallel to the faces of the prism, and which sometimes even leave intervals between them. This observation alone would lead me to doubt, whether this substance actually has for its primitive crystal a pyramidal dodecahedron with triangular faces, as has been supposed. If to this we add the indications of natural joints parallel to the bases of the hexahedral prism of phosphate of lead, which I have often observed, I am strongly inclined to believe, that this prism is itself the form of the primitive crystal.

ceive the process; and finding on an examination of the native products, all the proofs necessary to substantiate it, we accede to the demonstration. But in the transition of bardiglione, now in question, there is no decomposition indicated, no loss of any principle, no replacing of one principle by another; it is simply the fortuitous introduction of a new principle, which, as far as it appears, has but an extremely weak affinity for the molecule of the substance, which however it must divide into its constituent molecules, since it has to form with them integrant molecules of a different figure belonging to a new compound. Of this we can form no idea; and as nature, when consulted respecting the facts, offers no foundation, on which we can in reality establish the existence of such a transition, we cannot adopt it. If this transition were admitted, it would put an end to all constancy in the nature of mineral substances. The moment they were in contact with any principle whatever, whether this principle could pass as easily as water, or through its intervention be received into their substance, changes would take place, and the large assemblages of matter would be in a continual state of transformation.

In the mountains of La Grande Chartreuse I have observed a calcareous stone including cylindrical nodules, three or four inches or more in length, one half of which was in the state of brownish-red oxide of iron, while the other was compact black oxide of manganese; and I have seen specimens of this stone, containing a great number of such nodules crossing them from one side to the other. I have a cylindrical *Entrochus* about eight lines in diameter, and which, before I had occasion to break it, was two inches and a half long; the exact half of it, supposing it to be cut in the direction of its axis throughout its whole length, is a grey lamellar carbonate of lime, while the other half is a deep violet granular fluate of lime: this *Entrochus* came from Derbyshire. Those fine specimens from Dumbarton are well known, in which analcime and prehnite are so conjoined, that it is generally impossible to say where one terminates and the other commences; but it would be endless to adduce all the examples of this kind, with which I am acquainted, and in which assuredly no transition can be suspected. Why should not the specimen of bardiglione, mentioned by the Abbé Haüy, be classed with these?

Remarks respecting the term Bardiglione.

I have applied to this substance the above denomination, which recalls that already appropriated to one of its varieties by the Italians, and which of itself has no other signification; conformably to my opinion, that every species, to whatever branch of natural history it belongs, should have a peculiar name allotted to it; a name that, from its nature, ought to be invariable, like the species it is intended to designate; while explanatory phrases, which are a natural exhibition of the state of the science at the time they are formed, must necessarily follow its course, and change with it. It is true the name of *Anhydrite* has already been given to this substance: but the intention of this name is to express the absence of water in its composition; and as on this account it may agree with a very great number of other mineral substances, which are in the same situation, it becomes therefore a general term, and not a proper name. This will always be the case, while authors endeavour to give mineral substances a significant name; it being sometimes taken from a quality supposed to be perceived for the first time, but soon after shewing itself to be too general to designate one substance in particular; and being at other times founded on a quality merely peculiar to the individual, or accidental and of which a great number of the individuals that compose the species are afterwards found to be destitute.

Thus for instance M. Cordier, in a paper in which he has described with great perspicuity and accuracy a substance of a violet-blue colour, which is met with either at Cape de Gat in Spain, among volcanic products, or near Nijar, also in Spain, in a granitic rock, gives this substance the name of *Dichroïte*, a word of Greek etymology implying *double colour*, because its crystals present a very deep blue when viewed in a direction parallel to their axis, while they appear of a brownish-yellow, when viewed in a direction perpendicular to this axis. But mica exhibits precisely the same phenomenon of refraction. I have a variety from Somma in very fine short hexahedral prisms, which, if viewed perpendicularly to their axis, are of a green, more or less deep in proportion to their thickness; but when viewed parallel to that axis, through their sides, are of a very deep reddish-orange yellow. A specimen in my collection, likewise from Somma, and perhaps unique for the beauty of the very bright, slightly greenish-yellow topazes it includes, contains small crystals of mica, in incomplete acute hexahedral pyramids, very transparent, and having the lustre of the hardest stones; these have a slightly yellowish-red colour, refracted through the sides of the prisms, in consequence of which they are pretty constantly mistaken for very fine garnets. I have also some specimens of that quartz, which comes from Macedonia, and is known by the name of Leuco-sapphire, polished *en cabochon*, which, seen in one direction, are of a light bluish-grey, or nearly colourless, while in a direction perpendicular to the former, they have the fine blue of the deepest coloured sapphire. Dr. Wollaston, to whom mineralogy is daily under important obligations, has observed tourmalines likewise possessing the same property. If a person, who has never seen the *Dichroïte*, should seek for it, resting on the single circumstance of the double colour, indicated by its name, without regarding the peculiar tints, he might very easily be led into a mistake, as either of the substances which I have just mentioned would exhibit this character.

The name of *Yolite*, which had been given to bardiglione by M. Tondi, beside having the same defect of being derived from a variable character, that of colour, had also the inconvenience of recalling to the mind other substances, the names of which bore a considerable resemblance to it. All these inconveniences, it appears to me, would be avoided, by choosing for mineral substances a proper name without any peculiar signification in itself, and which should have no other object but that of preventing one mineral from being confounded with another.

TABLE OF THE MODIFICATIONS OF THE PRIMITIVE CRYSTAL OF BARDIGLIONE.

Primitive Crystal. A rectangular tetrahedral prism, the terminal faces of which are squares, and the height of which is yet unknown.

Number of the modifications.	Figure of the crystal.	Angles of incidence between the new planes, and the sides of the primitive crystal.		Angles of incidence of the new planes with each other above those of the prism on which the cleavage is least easy.	Nature of the retrogradations.	
		On those on which the cleavage is most easy.	On the others.		On the sides of the prism, on which the cleavage is most easy.	On the others, considered as auxiliary.
Retrogradations along the longitudinal edges of the primitive crystal.						
1st.	Primitive crystal, with planes of substitution on its edges.	. . 135°	. . 135°	. . 90°	Retrogradation by a single row.	Retrogradation by a single row.
2d.		. . 108°, 27′ . .	. . 161°, 33′ . .	. . 143°, 6′ . . .	Retrogradation by 1 row in breadth, and 3 laminæ in height.	Retrogradation by 3 rows in breadth.
3d.		. . 116°, 34′ . .	. . 153°, 26′ . .	. . 126°, 52′ . .	Retrogradation by 1 row in breadth, and 2 laminæ in height.	Retrogradation by 2 rows in breadth.
4th.		. . 128°, 40′ . .	. . 141°, 20′ . .	. . 102°, 40′ . .	Retrogradation by 4 rows in breadth, and 5 laminæ in height.	Retrogradation by 5 rows in breadth, and 4 laminæ in height.
5th.		. . 141°, 20′ . .	. . 128°, 40′ . .	. . 77°, 20′ . .	Retrogradation by 5 rows in breadth, and 4 laminæ in height.	Retrogradation by 4 rows in breadth, and 5 laminæ in height.
6th.		. . 161°, 33′ . .	. . 108°, 27′ . .	. . 36°, 54′ . .	Retrogradation by 3 rows in breadth.	Retrogradation by 1 row in breadth, and 3 laminæ in height.

Note. As all these modifications, except the first, undergo no retrogradation at the edges of the prism, but on one side, I have noticed this retrogradation only with regard to that side on which the cleavage is expressed, pointing out at the same time the auxiliary retrogradation on the other side.

This table, together with the plate, displays the singularity I have just mentioned; which is, that all the crystals of this substance undergo no decrement except on one of the two planes that form each edge of the prism. The fourth and fifth modifications may be considered as forming but one; and the same may be said of the second and sixth: but to render the details respecting the crystallization of this substance more methodical, I have considered each of the retrogradations with respect to those sides of the prism on which the cleavage is easiest. In this view, each of these modifications is perfectly distinct from the other; and while one takes place on these faces, the auxiliary retrogradation is produced on the adjacent faces, which are those on which the cleavage is least easy.

TABLE OF THE MODIFICATIONS OF THE PRIMITIVE CRYSTAL OF BARDIGLIONE,

According to the determination of it by the Abbé Haüy.

Primitive Crystal. A rectangular tetrahedral prism, the terminal faces of which are rectangles, the sides of which are in the ratio of 16 to 13.4, and the height of which is unknown.

Number of the modifications.	Figure of the crystal.	Angles of incidence between the new planes, and the sides of the primitive crystal. On those on which the cleavage is most easy.	Angles of incidence between the new planes, and the sides of the primitive crystal. On the others.	Angle of incidence of the new planes with each other above those of the prism on which the cleavage is least easy.	Nature of the retrogradations. On the sides of the prism, on which the cleavage is most easy.	Nature of the retrogradations. On the others, considered as auxiliary.
Retrogradations along the edges of the primitive crystal.						
1st.	Primitive crystal, with planes of substitution on its edges.	. . 135°, 8′. .	. . 134°, 52′. .	. . 89°, 16′. .	Retrogradation by 5 rows in breadth, and 6 laminæ in height.	Retrogradation by 6 rows in breadth, and 5 laminæ in height.
2d.		. . 108°, 50′. .	. . 161°, 10′. .	. . 142°, 20′. .	Retrogradation by 2 rows in breadth, and 7 laminæ in height.	Retrogradation by 7 rows in breadth, and 2 laminæ in height.
3d.		. . 115°, 32′. .	. . 154°, 28′. .	. . 125°, 36′. .	Retrogradation by 2 rows in breadth, and 5 laminæ in height.	Retrogradation by 5 rows in breadth, and 2 laminæ in height.
4th.		. . 128°, 31′. .	. . 141°, 29′. .	. . 102°, 58′. .	Retrogradation by 2 rows in breadth, and 3 laminæ in height.	Retrogradation by 3 rows in breadth, and 2 laminæ in height.
5th.		. . 140°, 4′. .	. . 129°, 56′. .	. . 79°, 52′. .	Retrogradation by a single row.	Retrogradation by a single row.
6th.		. . 161°, 29′. .	. . 108°, 31′. .	. . 37°, 2′. .	Retrogradation by 5 rows in breadth, and 2 laminæ in height.	Retrogradation by 2 rows in breadth, and 5 laminæ in height.

As the determination of the primitive crystal of bardiglione offers some difficulties, with respect to which I have felt myself obliged to differ from the Abbé Haüy, whose decisions are of great weight in this science; and as it is very possible that I may be mistaken, I have given above, the calculations of the same modifications as in the preceding table, but on the supposition that the bases of the primitive prism of this substance are rectangular, but not squares. From this table we perceive, that the angle of 129° 56′, arising from the retrogradation by a single row, belongs to the incidence of the plane produced on the narrowest sides of the prism; while that of 128° 31′, which is next to it in the preceding table, belongs, on the contrary, to that of the incidence on the broadest side. We also see that the plane of substitution that makes an angle of 135° with the two adjacent sides of the prism, and which would be the product of a retrogradation by a single row, on the supposition of the bases being a square, may likewise exist, or at least with a very trifling difference, on the supposition of the Abbé Haüy. The fracture alone, and particularly that which the crystals themselves exhibit (for I could never obtain one sufficiently regular by cleavage), as well as its striking parallelism with the interior indications of natural joints, and the angle of 135° constantly formed by these fractures, appear to me most in favour of my opinion.

I ought however to add, that the peculiarity exhibited by the crystals of this substance, of undergoing a retrogradation only on one side of the edges of the primitive prism, would seem to support the view taken of it by the Abbé Haüy; though much less so than if a retrogradation took place on each side, and the retrogradations were of a different kind. On the whole, I think there is a majority of circumstances in favour of the opinion which I have formed, but on this point the crystallographical reader will decide.

XVI. *Notice respecting Native Concrete Boracic Acid.*

By Smithson Tennant, Esq. F.R.S. &c.

Communicated by L. Horner, Esq. Sec. of the Geological Society.

THE Boracic Acid is not found like the greater number of substances in almost every country, but as far as our present knowledge extends, appears confined to a few particular places. On this account, as well as the great utility of borax in various arts, the discovery of its existence in any new situation may deserve to be recorded.

Some months ago Mr. Horner was so obliging as to shew me a collection of volcanic productions from the Lipari Islands, presented to the Geological Society by Dr. Saunders. They consisted chiefly of sulphur, and of saline sublimations on the lava, but among these more common substances there were several pieces of a scaly shining appearance, resembling boracic acid. The largest of these had been cut of a rectangular shape, and was about 7 or 8 inches in length, and 5 or 6 in breadth, as if it had been taken from a considerable mass. On one side of most of the pieces was a crust of sulphur, and the scaly part itself was yellower than pure boracic acid. To ascertain if the scaly part was coloured by sulphur, I exposed it to heat in a glass tube, and after the usual quantity of water had come over there sublimed from it about a tenth of its weight of sulphur, and the remainder was pure boracic acid.

Mr. Horner afterwards informed me, that the late Dr. Menish of Chelmsford had presented to the Geological Society a specimen which he had received, with some other volcanic productions, from Sicily, but which had been collected in the Lipari Islands; the box containing them being marked "*Produzioni Volcaniche Raccolte* "*nelle Isole Eolie da Gius. Lazzari—Lipari.*" He found it to consist of boracic acid, and it perfectly resembled that I have just described, having the same yellow colour from an admixture of sulphur, and a similar crust of this substance adhering to one side.

Any future traveller visiting those countries would do well to examine them with a view to this particular object. The boracic acid may be a more extensive volcanic product than has hitherto been imagined; for in the account given of its discovery some years ago by Messrs. Hoëfer and Mascagni, near *Monte Rotondo*, to the west of Sienna, we can have no doubt of its volcanic origin in those places, from the substances which are there described to accompany it.

XVII. *Sketch of the Geology of Madeira.*

By the Hon. Henry Grey Bennett,

In a Letter addressed to G. B. Greenough, Esq. F.R.S.
President of the Geological Society,

And communicated by him to the Society.

THE following notes were taken during a short stay I made last summer in the Island of Madeira. As there appears to be but little known of the structure, or of the phenomena which the strata in that island exhibit, the following observations may not perhaps be wholly unacceptable. They may be considered as furnishing directions to others, where to look for some of the most interesting objects; and may afford to future travellers a small portion of the information, which my guide Dr. Shuter so liberally communicated to me. That gentleman having long resided in the island, had repeatedly traversed it, and was thereby able to point out to me some of the circumstances which were most worthy of examination, particularly the nature of the various strata that are exposed to view in the deep and abrupt vallies which intersect the island in all directions. These vallies are no less picturesque to the eye of the common traveller than they are deserving of the attention of the geologist. They are in general narrow and deep, the summits of the hills that form their boundaries are broken into peaks, rugged and bare, while their sides are covered with the cedar and other trees peculiar to southern latitudes, and with a profuse variety of shrubs and plants, among which the *Erica Arborea* is the most beautiful, and in the greatest quantity.

The Island of Madeira (though I believe it never has been surveyed) is said to be about 50 miles in length, and in its broadest part about 20, but the average breadth does not exceed 15 miles.

It consists of a succession of lofty hills rising rapidly from the sea, particularly on the eastern and northern extremities. The summits of many of these ranges present the appearance of what has been called a Table Land, yet occasionally the forms are conical, and surmounted by a peak, which in some instances I found to be of columnar basalt. Deep ravines or vallies descend from the hills or *serras* to the sea, and in the hollow of most of them flows a small river, which in general is rapid and shallow. The soil of the island is clay on the surface, and large masses of it as hard as brick are found underneath. Though there are not at present any existing volcanoes in the island, yet the remains of two craters are to be seen, one on the eastern, the other on the western side, the largest being about a Portuguese league, or four English miles in circumference. Every thing around wears marks of having suffered the action of fire, yet I was unable to discover any deposit of sulphur, and was told that none had hitherto been found in the island.

The varieties of strata, which I shall term generally lava, are not numerous. I myself saw but four, and I was informed there were no more to be met with. Three of them were invariably alternating in the same order. The first or lowest lava is of a compact species, containing few, if any, extraneous substances, is of a blue colour, and of a remarkably fine grain. Upon that, the second, which is a red earthy friable lava, rests; sometimes separated by beds of clay mixed with pumice, and layers of black ash and pumice. This red lava contains minute pieces of olivine; sometimes it assumes a prismatic form, and in one place was of a moderate degree of hardness: the principal springs of water in the island issue from this stratum. On the top is the third, a greyish lava, generally compact, though at times near the surface very cellular, and containing much olivine. This lava takes principally the prismatic form of basalt. I have seen it in the most perfect prisms from 30 to 40 feet or more in height, the surface being covered with scoria, ash, and pumice. These masses of lava contain more or less, of what I consider to be olivine, occasionally carbonate of lime and zeolite, which last assumes either a crystallized or globular form, or is diffused in a thin coating between the different layers.

The fourth species of lava is of a coarse grain, is used for the making of walls, and the commonest and poorest houses are built of it, the blue and grey lavas being used for the copings, &c. It works easier than the two other kinds above-mentioned, is more friable and soft, and its colour is a mixture of brown and red. I observed it in a stratum by itself, and it did not seem to have any connection with the other three kinds.

These are the principal stratified lavas that the island affords, but in the beds of the rivers, particularly in that which flows in the valley of the *Corral*, several varieties occur in isolated masses, containing olivine and zeolite in greater or less quantity, and exhibing detached portions of strata, similar to those that are found in the *Fossa Grande* on the side of Vesuvius.

In the deep and singular valley called the *Corral*, which I had an opportunity of examing for several miles, the red and grey lava alternated five or six times. The tops of some of its barrier hills are formed of columnar basalt; here and there rising to a peak, or broken into what might be termed a crystallised ridge, or tapering to a point like the granite needles in the *Mer de Glace*. The columnar strata are found here in all directions. They dip usually to the sea, but occasionally are dislocated in the most abrupt manner. Dykes of lava, rising perpendicularly to the horizon, intersect the strata at right angles. I saw one 200 or 300 feet in height, which cut through several of the alternations of the red and grey lava. This valley of the *Corral* well merits the most attentive examination; yet the journey there is one of some labour, and the walk down the river that flows in its bottom so difficult and toilsome, as almost to deter every one from the undertaking. We left the town of Funchal soon after day break, and did not return till between eight and nine at night, having been, during the whole of that period, in a state of incessant exertion on horseback or on foot. The bed of the valley itself cannot be descended on mules or on horseback. The walk is eight or nine miles in length, and you are compelled to clamber over rocks, as there is not even a track, or wade, in the bed of the river, which is rapid, and full of large and pointed stones. Some of the highest hills of the island border on this valley. Several of them rise from the bed of the river in a perpendicular height of 1000 or 1500 feet, judging only by the eye, and are what the French term *taillé à pic*. Others are broken into a succession of steep descents, and are covered with forests of wood and a profusion of plants. Down many there fall small cataracts of water, and some are hollowed into deep recesses, whence issue from the lava numerous little streams that contribute to swell the principal river in the valley.

As you arrive on the brink of the *Corral*, after a ride of about 10 miles from Funchal, you find yourself suddenly on the edge of a precipice, near to which a sort of traversing stair-case is cut, with a track winding to the bottom. On the right is a wall of lava nearly perpendicular from 400 to 500 feet in depth, composed of the two species of the red and grey, alternating five or six times, and assuming in its dislocation the form of a bow, both the lavas following in a regular bend the shape of the curve.

On the left of the stairs by which you are to descend, innumerable small columns of the grey lava project from the side; they dip N.W. and their form in general is quadrangular; but I found several of them in prisms of three, five, and six sides. They are remarkably small, and, as they lie in this bed, appear almost all to break off from each other at five or six inches in length, and I never found them exceed this size. They seem to form a dyke that cuts through the horizontal beds of lava.

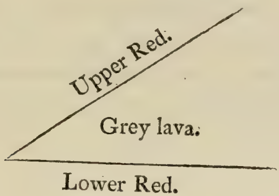
At the edge of the descent there is a projection or range of basaltic columns, rising like a wall, tapering to the top, and separating into large quadrangular prisms. We found no black ashes in the valley of the *Corral*, though towards the bottom there are considerable strata of pumice, great masses of scoriæ, and cellular lava, and lava in a state of semi-vitrification; the whole presenting evident marks of an eruption, anterior to that which had formed these various strata of lava, which are visible from the summit of the hill to the bed of the river.

The dip of the strata is in general towards the sea. Basaltic columns shoot from the side of the ordinary strata, which are intersected by various dykes; and one of these in particular swept across both sides of the valley. There are here also rocks of about 100 feet in height, composed of a species of breccia. We examined one near the church, at the extremity of the winding stair-case, forming the descent into the valley, which was composed of large and small pieces of lava, some of them of many yards in length and depth, the angles being rounded, and the whole agglutinated together by a hard black earthy substance, that resisted all the force we could use to break off a piece of it. There are other rocks where the red lava forms the base, and these are soft.

On our road from Funchal to the *Corral* we saw a stratum of large nodules or balls of lava, composed of concentric layers similar to the coat of an onion, and lying one above another; the stratum exposed was 30 or 40 feet in depth, and appeared to go down to the bottom of the hill.

We also examined the coast to the westward of the town of Funchal. From the beach before the town to Illhoo Castle, and beyond it to the land called the *Punta de la Cruz*, the general character of the coast is as follows: the red stone is the apparent base upon which rests a bed of grey prismatic lava, the stratum being sometimes from 40 to 100 feet in depth. At times this grey lava rests upon a deep bed of ashes and pumice, agglutinated together like the *Peperino* and *Puzzolano* in the vicinity of Naples. The scoria at the surface is remarkably thick, and all the upper parts of the lava appear to be cellular. The general dip of the lava on the coast near Funchal is to the north, but near the fort of Illhoo, it forms with a mass of pumice that is intersected with slight veins of carbonate of lime and zeolite, a rapid angle or curve of declination to the east. To the westward of the fort, the lava is not found for a little distance, and there is nothing but deep beds of pumice and the agglutinated mass abovementioned. These beds of pumice are of various thickness, the deepest appearing to be about 4 feet, and alternating with that stratum which I have called *Peperino*. In different cavities of the pumice bed, there are large deposits of black ashes. Towards the extremity of the strata the red stone appears on the surface in a more solid state, and lies in prismatic masses, the prisms being small, and not exceeding a few inches in diameter. Their substance is brittle and crumbles with ease. This stratum of red lava is of a short continuance. Passing a small brook, it dips rapidly to the westward, and in its place, the grey lava is found in a confused though sometimes prismatic form, and rises from the beach while the red lava still runs along the surface to the height of near 100 feet, the top being covered with a thick scoria.

There is also in the vicinity of Funchal, to the eastward of the town, a fall of water, which, independent of the romantic beauty of the situation, merits being visited on account of the exposure of the two strata of lava in their relative position. The hills are composed wholly of lava, sometimes of a confused, sometimes of a prismatic formation, the red and grey lavas being visible on both sides of the valley. Near the head of it, a short distance from the cascade, the red stratum is at the bottom, and about 60 feet higher it re-appears, and again, about 200 feet higher, alternating with the grey lava. The upper red lava dips rapidly to the south, and the strata are disposed in the following manner.



The rock, down which the cascade falls, is also intersected with a red stratum of about 3 feet wide, that traverses it, and dips to the westward, and is broken off by a broad dyke of grey lava. It appears about 30 feet higher, and dips again to the westward. The substance of the red rock in this place is hard, and it breaks into a columnar form, being by far the most compact of the red strata I met with in the island. I saw this red lava also in the Island of Teneriffe, to the eastward of Santa Cruz, as well as in the neighbourhood of Orotava.

I have thus endeavoured to give you a slight sketch of that which appeared to me most deserving of attention in the Island of Madeira. The short stay I was able to make there prevented a more accurate survey of the island; yet I saw enough to induce me to recommend a careful examination of the strata to those who may have more time than I had to spare, and more knowledge to estimate the value of that which was to be seen. To my mind, the most interesting geological facts are, 1st. The intersection of the lava by dykes at right angles with the strata. 2dly, The rapid dips the strata make, particularly the overlaying of that of the *Brasen Head*, to the eastward of Funchal, where the blue, grey, and red lavas are rolled up in one mass, and lie in a position as if they had all slipped together from an upper stratum. 3dly, The columnar form of the lava itself reposing on, and being covered by, beds of scoriæ, ashes, and pumice, which affords a strong argument for the volcanic origin of the columns themselves; and 4thly, The veins of carbonate of lime and zeolite, which are not found here in solitary pieces as in the vicinity of Ætna and Vesuvius, but are *amid* the lavas and *in* the strata of pumice and tufa, and are diffused on the lava itself, and occasionally crystallized in its cavities.

XVIII. *Notice respecting the Decomposition of Sulphate of Iron by Animal Matter.*

By W. H. Pepys, Esq. F.R.S.

Treasurer of the Geological Society.

AS the following circumstance, that took place in my laboratory, appears to throw considerable light on the mode whereby organic remains become penetrated by pyrites, it may not perhaps be foreign to the objects of the Geological Society, and as such, I have taken the liberty of offering it to their attention.

I was engaged a few years ago in a course of experiments on hydrogen gas, which was procured in the usual method, by the solution of iron turnings in diluted sulphuric acid. The sulphate of iron hence resulting, to the amount of some quarts, was poured into a large earthen pitcher, and remained undisturbed, and unnoticed for about a twelvemonth. At the end of this time, the vessel being wanted, I was about to throw away the liquor, when my attention was excited by an oily appearance on its surface, together with a yellowish powder, and a quantity of small hairs.

The powder, on examination, proved to be sulphur; and on pouring off carefully the supernatant liquor, there was discovered at the bottom of the vessel a sediment consisting of the bones of several mice, of small grains of pyrites, of sulphur, of crystallized green sulphate of iron, and of black muddy oxyd of iron.

These appearances may with much probability be attributed to the mutual action of the animal matter and the sulphate of iron, by which a portion of the metallic salt seems to have been entirely deoxygenated.

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	A Section of a Salt Mine at Northwich in Cheshire.	Henry Holland, Esq. Hon. Memb. G. Soc.
	A Model Illustrative of Stratification.	Wm. Atkinson, Esq. Memb. G. Soc.
June 2.	An engraved Plan of the Tunnel under the Thames.	G. B. Greenough, Esq. Pres. G. Soc.
	Geological Maps of the Counties of Devon and Cornwall.	M. L. A. Necker, Hon. Memb. G. Soc.
	Sections of the Island of Heligoland.	J. Mac Culloch, M. D. Memb. G. Soc.
Nov. 1.	Sections of Pentewan, Carron, and Tregony Stream-Works.	Wm. Rashleigh, Esq. Hon. Memb. G. Soc.
	A Section of a Clay-pit near Swanage, Dorsetshire.	Wm. Babington, M. D. Vice Pres. G. Soc.
	A Model of a portion of the Lowran Mountain near Loch Ken in the County of Kirkcudbright, illustrative of the formation of Mineral Veins, &c.	Sir James Hall, Bart.
	A Section of Mill-Field Collieries, near Bilston, Staffordshire.	Mr. Sowerby, Memb. G. S.
	Rocque's Map of England and Wales.	G. B. Greenough, Esq. Pres. G. Soc.
	Cary's County Maps of England.	Wilson Lowry, Esq. Memb. G. Soc.
	Ainslie's large Map of Scotland, with the Coal District laid down, as ascertained by the several workings mentioned in the Statistical Reports.	Leonard Horner, Esq. Sec. G. Soc.
	Taylor's Map of Ireland.	Wm. Babington, M. D. Vice Pres. G. Soc.
1810. *Jan.* 5.	A Plan illustrative of the Situation of a Gold-mine in a Calcarêous Rock in the neighbourhood of Rio de Janeiro.	Mr. John Mawe.

1810.	DONATIONS.	DONORS.
Jan 5.	A Section of a Coal-pit at Ashby Wolds, Leicestershire.	Mr. Farey.
	Views of Scure-Eigg in the Island of Eigg, of the Island of Staffa, and of the Parallel Roads of Glenroy.	James Skene, Esq. Hon. Memb. G. Soc.
Feb. 2.	An engraved Section of the Bath Easton Colliery.	Thomas Mead, Esq. Hon. Memb. G. Soc.
	A Drawing of a Fossil Madrepore found in Milford Lane near Bath.	....
May 4.	A Section of the Sandstone Strata in the new cut for the river Avon at Bristol.	G. Cumberland, Esq. Hon. Memb. G. Soc.
	A Section of the Strata of the Main-Coal-Field in the County of Clackmanan.	Robert Bald, Esq. Hon. Memb. G. Soc.
	A Profile of the County of Clackmanan from the summit of the Wood-hill of Alva, Ochil Hills, southward to the Forth. Also a Section of the Strata and great Slips.	....
June 1.	A Section of the Grampian Hills accompanying Lieut. Col. Imrie's Paper, from the Transactions of the Royal Society of Edinburgh, with additions.	Lieut. Col. Imrie, Hon. Memb. G. Soc.
	A Section of the Strata met with in digging a well at Twyford near Acton, Middlesex.	W. Atkinson, Esq. Memb. G. Soc.
	Two Drawings executed at Naples, representing the Eruption of Vesuvius in 1794.	W. Babington, M. D. Vice Pres. G. Soc.
Nov. 2.	A Drawing of the Limestone Cliffs at Lydstop, near Fenby.	J. Mac Culloch, M. D. Memb. G. Soc.
	A Copy of a Section of the Strata between London and Brighton, by Mr. Farey.	G. B. Greenough, Esq. Pres. G. Soc.
	A Copy of a Section, by Mr. Farey, of the principal Strata in England, between the Coast of Lincolnshire, and Ashover in Derbyshire.	....
	A Copy of a Section, by Mr. Farey, of the Strata between Wigley in Derbyshire, and the borders of Nottinghamshire.	....
	A Copy of a Section of the Country between Hamburgh and Switzerland.	....
	A Perspective Plan, and Section of a Coal-work near Wednesbury, Staffordshire.	....
	A Section of Bradley Mine near Bilston, Staffordshire.	....
	A coloured Print of the Gold Mines, County of Wicklow.	W. H. Pepys, Esq. Treas. G. Soc.
	A Copy of the Charts and Plans referred to in Mr. Telford's Report and Survey on the Communication between England and Ireland by Scotland. Laid before the Committee of the House of Commons.	Sir Abr. Hume, Bart. Vice Pres. G. Soc.
	A Chart of the English Channel.	G. B. Greenough, Esq. Pres. G. Soc.
1811.		
Jan. 18.	Models of the two remarkable Topazes fonnd in Aberdeenshire, and of some other Crystals.	Wm. Fitton, M. D.

1811.	DONATIONS.	DONORS.
Feb. 15.	A Manuscript Map of the Mine District in Flintshire.	G. B. Greenough, Esq. Pres. G. Soc.
Mar. 15.	Dobree's Maps of the Channel Islands, in three sheets.	A. Jaffray, Esq. Memb. G. Soc.
April 5.	Part the First of the General Survey of England and Wales, containing the whole of Essex, &c. Done by the Surveyors of His Majesty's Ordnance under the direction of Lieut. Col. Mudge, of the Royal Artillery, F. R. S.	Lieut. Col. Mudge, Hon. Memb. G. Soc.
	Part the Second of the General Survey of England and Wales, containing the whole of Devon, &c. &c.	....
June 7.	Three Maps of the Neapolitan Territory, of the Town of Naples, and of the Neapolitan Coast.	G. B. Greenough, Esq. Pres. G. Soc.
	A Map of Kent, by Faden, on a reduced scale, from the Ordnance Survey of that County.	....

III. *Donations to the Cabinet of Minerals.*

1808.		
Feb. 5.	Specimens of the Strata referred to in the Section of St. Anthon's Colliery, Newcastle upon Tyne.	Rt. Hon. Sir. J. Banks, Bart. K. B. &c.
May 6.	A collection of rock specimens formed at Freyberg, and illustrative of the Wernerian System of arrangement.	J. H. Vivian, Esq. Hon. Memb. G. Soc.
	Specimens from the Coal-mine at Coley-hill near Newcastle upon Tyne.	N. Winch, Esq. Hon. Memb. G. Soc.
	A specimen of Native Concrete Boracic Acid, from the Lipari Islands.	The late W. Menish, M.P. Hon. Memb. G. Soc.
	Rock-specimens from Scotland.	G. B. Greenough, Esq. Pres. G. Soc.
	Specimens from the Tunnel at Rotherhithe, and from the neighbourhood of Greenwich.	Leonard Horner, Esq. Sec. G. Soc.
	Specimens from the sinking of a well at Lord Spencer's, Wimbledon.	Rt. Hon. Sir J. Banks, Bart. K.B. &c.
June 2.	A Collection of specimens of the Hartz Rocks, by Lasius.	Wm. Babington, M.D. Vice-Pres. G. Soc.
	Geological Specimens from Otaheite, &c.	....
	Specimens of the Strata found in sinking a Coal-mine in the neighbourhood of Newcastle under line.	Alex. Jaffray, Esq. Memb. G. Soc.
	Specimens of Kimeridge Coal, &c.	Mr. Sowerby, Memb. G. Soc.
Nov. 4.	Specimens of Swedish rocks from the neighbourhood of Gottenburg, &c.	James Franck, M.D. Memb. G. Soc.
	Specimens from Wiltshire, Somersetshire, &c.	Thos. Meade, Esq. Hon. Memb. G. Soc.
	Specimens from Cornwall, Sussex, &c.	G. B. Greenough, Esq. Pres. G. Soc.

Date	DONATIONS.	DONORS.
1808. Nov. 4.	Specimens from Kent and Surry.	Leonard Horner, Esq. Sec. G. Soc.
	Specimens from Sussex.	Mr. Herbert, Hon. Memb. G. Soc.
	Specimens from Ireland, Scotland and Wales.	G. B. Greenough, Esq. Pres. G. Soc.
		Wm. Babington, M.D. Vice-Pres. G. Soc.
	Specimens from the neighbourhood of Dudley.	Mr. Ryan.
Dec. 2.	A Specimen of Fossil Wood from Bedfordshire.	Rt. Hon. Sir Jos. Banks, Bart. K.B. &c.
	A Collection of Specimens from Leicestershire, Derbyshire, Westmoreland, Cumberland, and Scotland.	J. F. Berger, M.D. Hon. Memb. G. Soc.
	Specimens from Ireland.	H. Edgeworth, M.D. Memb. G. Soc.
	Specimens from Ireland.	Mr. Ryan.
1809. Jan. 6.	Specimens of the Whin-dyke and contiguous Strata at Walker Colliery, Newcastle upon Tyne.	The Rev. Wm. Turner, Hon. Memb. G. Soc.
March 3.	A Fossil Elephant's Tusk, Tooth and Bone, found in a gravel pit near Bath.	Jos. Wilkinson, Esq. Hon. Memb. G. Soc.
April 7.	A Collection of Fossil Shells from the coast of Sussex.	Rt. Hon. Sir Jos. Banks, Bart. K.B. &c.
	A Specimen of Native Sulphur from Sicily.	Wm. Babington, M.D. Vice-Pres. G. Soc.
May 5.	Specimens of the Strata from a Rock-salt Mine at Northwich, Cheshire.	Henry Holland, Esq. Hon. Memb. G. Soc.
	Specimens of the Rock-salt from Northwich, in illustration of Mr. Holland's account of that district.	James Laird, M.D. Sec. G. Soc.
	Specimens of the rocks at Malta.	Capt. Beaufort, R. N. Hon. Memb. G. Soc.
June 2.	Specimens of the Strata in the Island of Heligoland.	John Mac Culloch, M.D. Memb. G. Soc.
Nov. 3.	A collection of Specimens from the counties of Devon and Cornwall.	M. L. A. Necker, Hon. Memb. G. Soc.
	Specimens from the Stream-Works of Pentewan, &c. Cornwall.	Wm. Rashleigh, Esq. Hon. Memb. G. Soc.
	Specimens from a Clay-pit near Swanage, Dorsetshire.	Wm. Babington, M.D. Vice-Pres. G. Soc.
	Specimens of Wood, and other remains from the new cut for the river Avon at Bristol.	Rob. Lovell, M.D. Hon. Memb. G. Soc.
	Specimens of Granite and of other rocks from the coast of New-York.	Wm. Babington, M.D. Vice-Pres. G. Soc.
	Specimens of Copper ore and of Lead ore from Ross Island in the Lake of Killarney.	. . . .
	Specimens from Scotland, and from the counties of Cornwall and Kent.	Mr. Rich. Phillips, Memb. G. Soc.
	Specimens from Staffa, &c.	Wm. Macmichael, M.D. Memb. G. Soc.

1809.	DONATIONS.	DONORS.
Nov. 3.	Specimens from the Malvern Hills.	Alex. Jaffray, Esq. Memb. G. Soc.
	A large mass of Marble from Tirce, one of the Hebrides.	Mr. Sowerby, Memb. G. Soc.
	Specimens of Limestone from the quarries of Crich, Derbyshire.	The Rev. John Wood.
	Specimens of various Fossil Remains from Wiltshire and Somersetshire.	Thos. Meade, Esq. Hon. Memb. G. Soc.
Dec. 1.	A Specimen of the Fossil Alcyonium found at Farringdon, Berkshire.	Mr. Sowerby, Memb. G. Soc.
	Specimens from Northamptonshire, &c.	G. B. Greenough, Esq. Pres. G. Soc.
1810.		
Jan. 5.	Specimens from the vicinity of Bristol, &c.	Mr. Herbert, Hon. Memb. G. Soc.
Jan. 5.	A Specimen of Worm-Eaten Wood petrified, found in the Sand under the Fuller's Earth, near Woburn, Bedfordshire.	Mr. Farey.
	Specimens of Granite, *Gossan*, &c. from Cornwall, in illustration of Mr. Phillips's Account of the Arseniated Iron, and Red Oxyd of Copper.	Mr. William Phillips, Mem. G. Soc.
	A Collection of Rock Specimens from the vicinity of Rio de Janeiro.	Mr. John Mawe.
	A Collection of Volcanic Products from the Lipari Islands, containing Specimens of crystallized Sulphur and of Native Boracic Acid.	William Saunders, M.D. Memb. G. Soc.
Feb. 2.	Specimens from the Isle of Shepey, &c.	Mr. Herbert, Hon. Memb. G. Soc.
	Ashes collected on the deck of a Ship 70 miles from Ætna during the eruption of that mountain in March, 1809.	William Williams, Esq. Memb. G. Soc.
April 6.	A Series of Specimens from the Counties of Cornwall and Devon.	J. F. Berger, M.D. Hon. Memb. G. Soc.
	A Specimen of Natrolite in its Matrix from Hoen Twiel, near the Lake of Constance.	M. Lainé, Hon. Memb. G. Soc.
May 4.	A Series of Specimens from Clackmananshire, illustrative of the Stratification of the Coal-district of that County.	Mr. Rob. Bald, Hon. Mem. G. Soc.
	Specimens of the Sandstone Strata in the New Cut for the River Avon at Bristol.	G. Cumberland, Esq. Hon. Memb. G. Soc.
June 1.	Specimens of Fossil Shells from the Coast of Sussex.	Mr. W. Holloway, Jun.
	Specimens of the Rocks of the Island of Guernsey.	J. F. Berger, M.D. Hon. Memb. G. Soc.
	A Series of Specimens illustrative of Lieut. Col. Imrie's Section of the Grampion Hills.	Lieut. Col. Imrie, Hon. Memb. G. Soc.
	A large slab of Marble from Devonshire.	W. H. Pepys, Esq. Treas. G. Soc.
	A Series of Specimens obtained in sinking a well at Twyford, near Acton, Middlesex.	W. Atkinson, Esq. Memb. G. Soc.
	Specimens from the Island of Shepey.	M. Lainé, Hon. Memb. G. Soc.

1810.	DONATIONS.	DONORS.
Nov. 2.	Specimens from the neighbourhood of Oxford, &c.	G. B. Greenough, Esq. Pres. G. Soc.
16.	Specimens from the Isle of Portland.	Wilson Lowry, Esq. Memb. G. Soc.
	Specimens from Wiltshire and other parts of England.	Thos. Meade, Esq. Hon. Memb. G. Soc.
	Specimens from Rio de Janeiro.	....
	Specimens from the district of Minas Geraes, Brazil, &c.	Mr. John Mawe.
	A Mass of Puddingstone from Hertfordshire.	Sir Abr. Hume, Bart. Vice-Pres. G. Soc.
Dec. 7.	A Series of Specimens from Somersetshire, Wiltshire, &c.	Thos. Meade, Esq. Hon. Memb. G. Soc.
21.	Specimens of Alum Slate in different stages of decomposition from the Campsie Hills in Stirlingshire.	Francis Horner, Esq. Memb. G. Soc.
	Fossil Bones found at Walton, Essex.	Mr. Herbert, Hon. Memb. G. Soc.
1811.		
Jan. 18.	A Series of Geological Specimens from the shores of the Baltic.	J. F. Berger, M.D. Hon. Memb. G. Soc.
	Specimens from a Shaft sunk in Tividale Colliery near Dudley.	James Keir, Esq. Hon. Memb. G. Soc.
Feb. 1.	Specimens of the Allanite and of the Sodalite from Greenland.	Thos. Allan, Esq. Hon. Memb. G. Soc.
	A Collection of Specimens from Somersetshire.	Thos Meade, Esq. Hon. Memb. G. Soc.
	Specimens of Amygdaloid containing Agates, from the coast of Ayrshire.	Robt. Ferguson, Esq. Vice-Pres. G. Soc.
15.	Specimens from the neighbourhood of Liverpool.	Rich. Bright, Jun. Esq. Memb. G. Soc.
March 1.	A Series of specimens from Shropshire, in illustration of Mr. Aikin's account of the great Coal-field of that County.	Arthur Aikin, Esq. Memb. G. Soc.
15.	A Series of Specimens illustrative of the Mineralogy of the Malvern Hills.	Leonard Horner, Esq. Sec. G. Soc.
	Specimens of Fossil Teredines from the Isle of Shepey.	H. Warburton, Esq. Memb. G. Sec.
	A Specimen of Fossil Teredo found in the Archway at Highgate.	David Ricardo, Esq. Memb. G. Soc.
April 5.	Specimens of Actinolite and some other Minerals from Scotland.	Robt. Ferguson, Esq. Vice-Pres. G. Soc.
	A Series of Specimens from the Isle of Wight.	J. F. Berger, M.D. Hon. Memb. G. Soc.
	Specimens from various parts of England and Wales.	G. B. Greenough, Esq. Pres. G. Soc.
19.	A Series of Specimens from the Isle of Purbeck and the Isle of Portland.	J. F. Berger, M.D. Memb. G. Soc.
	Specimens from Mowcop, Staffordshire, &c.	Alex. Jaffray, Esq. Memb. G. Soc.
	Specimens from the Souffrière in the Island of Nevis.	Arthur Aikin, Esq. Memb. G. Soc.

1811.	DONATIONS.	DONORS.
May 3.	A Series of Specimens from Iceland, collected in a Tour through that Country.	Richd. Bright, Jun. Esq. Memb. G. Soc.
	Specimens from High-Cliff in Hampshire.	William Young, Esq. Memb. G. Soc.
	Specimens of Coal-Blende and of Black Chalk from the County of Tipperary.	Alex. Jaffray, Esq. Memb. G. Soc.
June 7.	Specimens from the neighbourhood of Harrogate.	Thos. Allan, Esq. Hon. Memb. G. Soc.
21.	Specimens of different Strata in Madeira, illustrative of the Sketch of the Geology of that island.	The Hon. H. G. Bennett
	Specimens of Rocks in North America, collected by Mr. William Maclure, illustrative of his Map and Observations on the Geology of the United States.	William Babington, M.D. Vice-Pres. G. Soc.
21.	Specimens of the varieties of Sulphate of Strontian found in the neighbourhood of Bristol, and of Limsetone from St. Vincent's Cliffs, &c.	James Laird, M.D. Sec. G. Soc.

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TO THE FIRST VOLUME

OF THE

TRANSACTIONS OF THE GEOLOGICAL SOCIETY.

END OF THE FIRST VOLUME.

ERRATA.

Page 17, Line 8, *for* pry *read* dry.
...... 17, ... Bridges ..... Ridges.
243, ... 2 ... (§ VIII. 9.) ... (§ VIII. 6.)
...... 4, ... (§ X. 4.) .... (X. 3.)
.... † .... ‡
.... 5 of the note, *for* 31 *read* 31,8.
244, ... 6 of note ‡ *after* the word residue, *add* dried at a red heat.
.... 10 of same note, *for* of barytes, *read* of sulphat of barytes.
289, ... 12, *for* black *read* block.

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