Palæoniscus, &c. among the other classes, the *facies* of which is equally antique.

M. Marcou does not, however, rely altogether upon the argument just noticed for the support of his views; he advances another, which I believe to be equally erroneous. Apparently under the impression that the Permian strata should be referred to the Trias on account of their lithological and mineralogical relationship, he maintains, after depreciating the importance of palæontological evidence, that the *ensemble* of the purely geological characters of a group of strata is of the chief consequence, and suffices alone to determine the age and relative position of the group in any part of the world. Now, as M. Marcou has specialized the Carboniferous and Cretaceous systems as being highly illustrative of the truth of this, I would ask, how we could have determined the age of the Cretaceous rocks of the United States if we had not been assisted by palæontology?—and who could have told us the age of the Virginian Coal-field, which is described by Sir C. Lyell as being composed of “grits, sandstones, and shales exactly resembling those of older or primary date in America and Europe, and even rivaling the latter in the thickness of its coal-seams,” if we could not have availed ourselves of palæontological tests? And if we refer to the investigations of Dr. Geinitz on the Coal-measures of Saxony, we find that by palæontological evidence he has been able to separate a Permian deposit from those truly Carboniferous, and also to show good reasons for supposing the lowermost coal-strata of the same country to be of Devonian age. Other instances are to be found in formations of all periods. In arguing for the superior importance of palæontological evidence, I do not, as I have before stated, deny the value of other evidence (indeed, it is highly requisite that all characters should be consulted in settling the age of strata), but I argue against coming back to the old doctrine of the universality of deposition of one kind of sediment during certain periods; for the study of organic remains has proved its unsoundness.

2. *On the ROCKS, ORES, and other MINERALS on the Property of the MARQUESS OF BREADALBANE in the HIGHLANDS of SCOTLAND.* By C. H. GUSTAV THOST, Esq.

[Communicated by Prof. James Nicol, F.G.S.]

[Abridged.]

Mica-schists, &c.—On the property of the Marquess of Breadalbane (measuring in a curve nearly 100 miles from east to west, through Perthshire and Argyllshire) mica-schist predominates. The high mountains (Ben More, Ben Lawers, and others) forming the nucleus of the Grampians consist of the same rock, which throughout the property exhibits its many varieties of mineral character, and includes tale-schists, chloritic schist, and hornblende-rocks, often to a great extent. In juxtaposition to the mica-schist, in the northern

and north-western part of the district, gneiss and granite appear. Among the more useful subordinate rocks is a calcareous variety of the mica-schist (limestone), in beds and in lenticular masses, containing as much as 90 per cent. of carbonate of lime. Another stratified rock found in close connexion with the mica-schist is clay-slate, lying on the north side of Ben Lawers, and at a great elevation. The difficulty of access is the only cause why it is only rarely used as roofing-slate. These subordinate strata participate in most cases in the general bearing of the mica-schist, which is nearly east and west; while the dip of the mica-schist, though in general low, appears as often exceptional as conformed to rule. While in special cases the underlie surrounds the several axes of elevation, sloping from them on all sides, both the strike and dip are not unfrequently altered by the appearance of eruptive rocks and other disturbing masses, as, for instance, by intersecting veins and ridges of quartz. The latter mineral in general seems to have played a considerable part in metamorphosing and silicifying the adjacent mica-schist, having in many instances made its appearance after the formation of the mica-schist. Although those disturbing causes have exercised a great influence upon the original beds of the rock, as may often and very clearly be observed, they nevertheless leave sufficient traces of the strata having had originally a horizontal position.

Tomnadashan Mines.—Among the igneous rocks, porphyries and greenstones deserve particular notice, on account of their frequency throughout the district. As a special case, probably illustrating all the others, the rocks near the middle of the south side of Loch Tay, opposite Ben Lawers, at the Tomnadashan Mines, invite close inspection; for in that place mining-operations have extensively aided observation. All the facts there obtained support the supposition, that, after the mica-schist had been broken through by the greenstone, a powerful vein of porphyry was erupted; for the greenstone, while remaining unchanged in position and character on the east and west sides of the porphyry-vein, has near its middle part not only been deranged by mechanical force, but has also been often altered by chemical agency into a substance exhibiting the mixed characters of greenstone and porphyry, with transitions from one to the other. It is not difficult to arrive at a probable estimate of the period when the mineral ingredients—silver-ore, copper-pyrites, grey copper-ore, iron-pyrites, and molybdenite—have made their appearance, if the porphyry be considered as the matrix; for, while the porphyry-vein, although about half a mile wide, and extending about three miles towards the south, is nowhere destitute of one or other of the above-named minerals (particularly iron-pyrites), the greenstone, when in its original condition, nowhere contains a trace of those substances. The only question remaining would be, whether those ores belong to a later formation than the porphyry itself, or whether they are contemporaneous deposits. The general dissemination of these minerals through the porphyry appears to prove the latter view. Closer inspection shows that the greenstone exercised a particular influence upon the deposition and accumulation of the minerals named, which

not seldom, and in marked richness, surround fragments of the greenstone. This probably arose from the fluid mass cooling sooner in these places, so that the metallic minerals suspended in the porphyry adhered to and fastened themselves in greater abundance on and near the cooler surfaces of the broken greenstone; whilst the main stream of the porphyry, loaded with the same minerals, continued its way, and both rock and mineral particles had to harden together. During this process the particles of ore easily penetrated the smallest crevices of the greenstone, where they soon cooled down and solidified, as can be observed on innumerable specimens, and in many varieties.

Not only has the greenstone partaken, partly at least, of a change as regards its absolute situation and its chemical composition, but parts also of the mica-schist, though to a less extent and less frequently.

If mica-schist came in contact with the porphyry, the formation of slickensides or surfaces of friction took place. In the mines of Tomnadashan several such divisions, which have received the general name of "clay-veins," may be seen, forming very regular courses both in perpendicular and horizontal directions. They are of some importance to the miner, because they are leaders through the hardness of the rock to be opened, and they are receptacles of the more valuable minerals, in the same way as the greenstone.

Besides the above-mentioned metallic ores, carbonate of lime, in scalenohedron-macles and in other crystallographic combinations, as well as dolomite, quartz, and sometimes sulphate of baryta, have been found near the richer deposits of ore, especially where the grey copper-ore predominates.

Molybdenite is met with as an accessory mineral everywhere. In all other respects the valuable minerals are deposited apparently in a casual arrangement.

Relation of the Valleys to the lines of fracture.—The same rocks, greenstone and porphyry, appear in many other localities of the valley of Loch Tay; and there is little doubt that to these igneous masses the formation of the now water-covered valley itself is attributable. The same conclusion may be drawn in reference to Loch Awe, Loch Tulla, and Loch Etive, in the western and north-western part of the district, where, however, granites and granitic porphyries have produced the same results that the greenstones and porphyries have effected at Loch Tay. It is thus probable also that very many valleys have received their forms from similar agencies. It is a remarkable fact, that the highest points of the Highlands, like Ben Lawers, Ben More, Ben Nevis, Ben Lomond, Ben Conachan, and many others of less height, have at their feet the deepest valleys, which have become lakes.

Ardtallanaig.—At Ardtallanaig, only a mile distant from the above-mentioned mines, similar geological features reappear; and the mica-schist has been repeatedly intersected by igneous rocks, thereby rending asunder a vein or veins, and intermixing the fragments from different masses, so that the constituent members have

been thrown into perfect confusion. Hence the veins throughout have a fragmentary character; and the portions remaining give proof that they originally contained, besides quartz, several kinds of the common spars (particularly heavy-spar), together with a considerable admixture of galena, blende, and copper, and iron-pyrites. Moreover they either frequently contain porphyry and greenstone, or these rocks have intruded as disturbers of the veins. Mining-operations in such broken strata are very precarious.

Correbuichill.—In a southern direction, ascending from the Tomnadashan Mines, and at a distance of about three miles, the mica-schist at Correbuichill is overlain by a horizontal calcareous stratum. In this rock two systems of veins have been discovered, chiefly by means of surface-trenches. The one system, consisting of three veins which run nearly east and west, is of small importance, on account of their barrenness. But the other is the more interesting system. In a straight line of about 200 yards, eighteen such veins have been met with; and it is more than probable that a far greater number remain undiscovered under the shallow turf. These veins have almost a mathematical parallelism, and run as nearly as possible due north and south, in nearly a vertical position. Their width varies from 4 inches to 3 feet. The contents are chiefly quartz, with galena very rich in silver. The veins vary as to this valuable metal, between 85 and 600 ounces per ton of lead-ore. The elevation of the hill may be about 2000 feet above the level of the sea, and 1600 feet above that of Loch Tay. The veins mostly crop out in fine gossan; and in such cases the produce of ore has been favourable for a certain distance downwards. As far as the field has been opened by mining, experience shows that the valuable lead-ore quickly and considerably diminishes in sinking, so that in about 100 feet below the outcrop the veins only consist of compact white quartz. It has not been ascertained what is the condition of the veins at the depth where the limestone rests upon the mica-schist. In the upper parts of the veins the galena not unfrequently envelopes the crystals of quartz completely, thereby indicating that the galena and quartz are not contemporaneous members. Copper-pyrites is rare, and still more so are blende and iron-pyrites; hence the lead-ore is of a very pure and rich character. In one part of the hill a large deposit of dolomite, in the form of a vein, has been met with, accompanying one of the veins. Twice in the course of mining operations (which some years since were suspended) the interesting and casual discovery of native gold was made when the ore was being crushed under the hammer. The veins have been repeatedly dislocated, both in the horizontal and in the vertical projections. In consequence of this, the veins sometimes approach quite close to each other, and it becomes difficult to discover in the network of veins the identity of each individual vein. The dislocations have been effected by the sliding and uplifting of the strata, which, in the absence of other apparent causes, and as the veins and strata have both been dislocated together, may be ascribed to the disturbances at Tomnadashan, in the neighbourhood. Though mining-operations in such elevated

localities become very inconvenient, this mineral field abounds with interesting matter.

Taymouth.—The most eastern hills on Loch Tay, in the neighbourhood of Taymouth, literally swarm with veins containing copper-pyrites, iron-pyrites, and galena, either singly or together; and the lead-ore has always a tolerable admixture of silver. A common characteristic of all the veins is, that they are almost exclusively quartzose.

Iron-ore of Glenqueich.—Six miles south of Taymouth, at Glenqueich, a large deposit of decomposed iron-ore has been found. The whole arrangement of the slope of the hill shows that the mica-schist has been impregnated with numberless crystals of iron-pyrites, which by paragenesis became transformed, along with the still quite distinct strata of the original rock, into a homogeneous mass, having the nearest resemblance to hæmatite.

Corycharmaig: Serpentine, &c.—Four miles west from the upper end of Loch Tay, at Corycharmaig, the mica-schist contains serpentine, passing in some parts into syenite. As is almost always the case where serpentine appears, it contains chromate of iron. The distant situation of this ore-deposit, which covers about half a square mile, the uncertain prices given for the ore, and the expensive land-carriage have prevented the exploration of that otherwise valuable mineral-field.

In the same vicinity the mica in the mica-schist is more often than usual replaced by graphite, of which beds of tolerable dimensions have been discovered. Furthermore, in the same neighbourhood rutile has been found, enveloped in quartz, and in the shape of thin plates or of fine long needles.

Further west from the serpentine, several veins of a quartz structure have been found; but they are all of small importance for mining-purposes, being only of value as enabling us to observe the great number of fissures existing in almost every place where the rock allows of inspection.

Loch Earn Head.—At Loch Earn Head several galena-veins, of inferior importance, have been discovered in a stratum of calcareous schist. Their outcrop is overlain by gossan, in which particles of native gold appear to have been found. Certain it is that arsenical pyrites, which was at one time met with as an accessory mineral, contained six ounces of gold per ton. As it has been observed above that proofs of the presence of igneous rock accompany a loch, so here also, though few and scattered fragments only have been found.

Glen Fallich.—At the head of Glen Fallich, near Crianlarich, a galena-vein, of about 3 feet in width, and striking from N.N.E. to S.S.W., has been discovered. The vein is in all respects of the same structure as the other veins, to be described presently.

Tyndrum.—The two veins intersecting the mica-schist at Tyndrum, at the head of Glen Dochart, are of importance. The first of these veins runs through a stratum of granular quartz; and the other lies close to the junction of this quartzose mica-schist and the true mica-schist. While the former follows a north-north-eastern and

south-south-western direction, the *latter* approaches nearer to a north-east and south-west line. In consequence, both veins should unite into one,—as has actually been observed, though without increase of the ores. Furthermore, while the *first vein* dips in its higher parts towards the north-west, but soon changes to the opposite direction at a very acute angle, and later with the constant angle of 68° , the *second vein* steadily and regularly dips to the south-west at an angle of 75° . In consequence of their respective dips, both veins meet below. Therefore, and on account of their respective bearing and dip, their junction is effected in a gently sloping line ascending from north-east to south-west. Underneath this line the lead-ore evidently is on the decrease; and the mines therefore are only explored in the higher parts.

In reference to the geological age of both veins, the first is the older, and the second the later formation. The first vein above the line of junction is intersected and slightly dislocated by two cross-courses, which terminate distinctly at the most regular westerly wall of the second vein. Underneath the line of junction, both veins, being closely linked together, are traversed and considerably dislocated by the third cross-course. By means of these facts, five geological periods became discernible, viz.:—

- a. The formation of the first vein.
- b. Its intersection by the first cross-course.
- c. Its intersection by the second cross-course.
- d. The formation of the second vein; and
- e. The intersection of the united veins by the third cross-course.

It is self-evident that such powerful and repeated changes, extending over only about 600 square yards, or about 1-500th of a square mile, lead to the conclusion of powerful agencies having been at work, thereby seriously affecting the surrounding rock-formation. And such evidence, if transferred, by way of analogy, to the many unexplored square miles, offers sufficient material for geological calculations, particularly relative to the formation of valleys of elevation, and the peculiar features of the Highlands in general.

Besides the above-mentioned cross-courses, there exists at Tyndrum a cross lead-ore vein, combining the first vein with the second one, from east to west. The respective widths of these three veins are from 2 to $3\frac{1}{2}$ feet, from 4 to 18 feet, and from $1\frac{1}{2}$ to $2\frac{1}{2}$ feet. The first vein contains solid galena; the second one has fine-grained lead-ore and silicate of lead; the third vein contains both varieties. The first vein is the most mineralized, containing mainly solid quartz, several of the common spars, copper-pyrites, and blende, seldom cobalt-ore, titanite iron-ore, and iron-pyrites. The second vein contains many fragments of soft mica-schist, intermixed with frangible quartz, copper-pyrites, and blende. The third vein participates in the nature of both the others.

The vein first named is characterized by its extent; for it may be traced through valleys and over hills for a distance of more than eight miles.

The mines of Tyndrum have, with intervals, been worked at

different times; and records tell that they have been extensively worked for more than a hundred years. As an evidence thereof, it may be mentioned that a sinking on the main vein had been cut out, measuring 350 feet in length and 72 feet in depth, thus forming an underground lake which was tapped only some months ago, whereby the richer part of the ore-field became accessible.

About half a mile from those veins a powerful quartz-vein, of nearly the same bearings, attracts attention. It stands out like a parapet, running for a great distance over declivities and eminences; and it has produced great changes in the adjacent strata. It may be observed that its influence has towards the east been very suddenly and distinctly stopped at the fissure of the second vein; but it is more difficult to define that influence in the western direction, where the alteration of the rock appears to die gradually away. The stratum at this place consists chiefly of granular quartz, intermixed with much felspar, and with minute scales of mica, together with small specks of iron-pyrites. The strata on the east and west walls of the quartz-vein have been altered from a horizontal position to considerable though variable inclinations with various contortions. Its width is often more than 4 feet, in which case the quartz is quite compact and pure. When the vein is smaller, a tendency towards crystallization begins, and at the same time traces of lead-ore appear. Not only at the very top of the hill, where the quartz-vein intersects the rock, but also at its foot in the valley of Glenlochy, hollows filled with water have been formed, almost as if to verify beyond doubt the theory of elevation and sinking. The former lake is situated at an elevation of about 1500 feet, and the latter, Lochnabuie, at about 800 feet above the sea-level. This quartz-vein, though here and there not outcropping, is traceable for about ten miles.

Southern Slope of Glenlochy.—At the opposite (the southern) slope of the valley of Glenlochy many more such quartz-veins, of similar structure and producing similar appearances, intersect the east-and-westerly course of the mountain-ridge. Among them, one is distinguished by being loaded with more minerals than the rest; so that it forms almost a middle member between the two perfect lead-ore veins and the barren quartz-veins.

Igneous Rocks at Tyndrum.—In the neighbourhood of the district under consideration only a few traces of intersecting rocks have been found. These traces relate to syenite and greenstone. Close to the bridge of the village near Tyndrum a trap-vein intersects the mica-schist; its width is 40 feet. It may be mentioned that iron-pyrites is of the most frequent occurrence in all parts of the district.

Conclusion.—The foregoing remarks on this mountainous country afford proofs that a great variety of minerals, mostly as regular formations, may be found,—and that, too, in nearly all parts which have been or could be examined. By far the most discoveries have been made by the Marquess of Breadalbane, who, by his attachment to geological researches and to the exploration of useful minerals, became the discoverer of the silver- and copper-mines at Loch Tay.

It is remarkable that the Highlands of Scotland, taken as a whole, have afforded so few opportunities for mining operations. Is it that the rocks, having been so often disturbed, have not allowed the quiet settling down of larger mineral deposits? or have the mineral deposits been broken up and scattered about by those more or less evident eruptions? If such be the main causes, then a fair comparison may be drawn between these highlands and others on the Continent,—namely, Switzerland, where, as here, a great variety of minerals is found, but seldom in such abundance as to invite mining-undertakings.

Finally, in this communication I have studiously avoided any reference to the details published about eighteen years ago by the Highland Society. What I have here stated confirms in their essential parts former observations. The additional facts brought to light since that time, and some alterations in the conclusions arrived at, help us partly to generalize, and partly to illustrate in detail the views formerly published.

MARCH 28, 1860.

The Duke of Marlborough, and W. P. Jervis, Esq., Northwick Terrace, Maida Hill, were elected Fellows.

The following communications were read:—

1. *Notes about SPITZBERGEN in 1859.*

By JAMES LAMONT, Esq., F.G.S.

[With APPENDIX.]

HAVING passed upwards of two months last summer (1859) on the coast of Spitzbergen, and amongst the great fields of floating ice in the surrounding seas, I beg to offer the few following observations.

I left Leith on the 6th of June; reached Hammerfest on the 23rd, left Hammerfest on the 26th, and arrived at Spitzbergen on the 2nd of July.

We found a large quantity of heavy drift-ice off the south-eastern end of Spitzbergen and amongst the “Thousand Islands.” At the mouth of Stour Fiord (“Wybe Jan’s Water” of the charts) we met two small sealing-vessels, the masters of which told us that the north coast was unapproachable this summer, on account of the ice being jammed against the north-western corner of the island, about Hakluyt’s Headland; and we therefore proceeded to coast around the edges of the ice towards the east side of the country.

On the 8th, during a dense fog, we passed the last of the Thousand Islands, and lay-to off the S.E. corner of Edge’s Land. The coast from here to Ryke Yse Islands is frightfully barren and desolate, and the mountains are quite destitute of vegetation; these mountains are limestone, and descend abruptly into the sea without the