XXXIX.—*The Ejected Blocks of Monte Somma.* By H. J. JOHNSTON-LAVIS, M.D., F.G.S., &c.; Professor of Vulcanology, University of Naples. *Foreign Corresponding Fellow.*

PART I.—STRATIFIED LIMESTONES.

THE ejected blocks of Vesuvius, or, more properly speaking, Monte Somma, have been renowned for over a century as affording a large number of mineral species. So attractive were they that they are included in the catalogues of the productions of this volcano by Galiani in 1772, "*Galiani Catalogo delle materie appartenenti al Vesuvio*," Lond., 1772, and by Sir William Hamilton, "*Campi Phlegrae*," and Gioieni in 1789, "*Gioieni. Saggio di litologia Vesuviana*," Napoli, 1789.

Hamilton, besides giving figures of some of them in his book, made a rather extensive collection, now exhibited in the British Museum. Many species of minerals were first described from this source, whilst those blocks and their contents have occupied the attention of Thomson, Monticelli, Covelli, and Tenore. Professor A. Scacchi may be said to have devoted his life to the study of their mineral contents, together with that of others produced during the modern eruptive action of this volcano. Scacchi, in a catalogue published not long since,¹ gives fifty-two as the number of mineral species (not varieties) occurring in the ejected blocks of Monte Somma.

It is, therefore, evident that a careful examination of these rock masses would be quite justifiable for the sake of studying the conditions under which so large a number of minerals occur, and of the relation they bear to each other. But beyond this, they have a much higher claim on our attention from a geological or vulcanological point of view. In the first place, no other volcano is yet known to possess, in so great abundance, so large a variety of ejected blocks; secondly, they constitute a collection of different rock-masses associated together, such as occurs in no other known locality of an equal area.

Numerous papers treating of the minerals derived from this source we owe to the investigations of Vom Rath, and, lastly, a recent memoir by Herr Bruno Mierisch, "*Die Auswurfsblöcke des Monte Somma*," *Tschermak's Mineralog. und Petrograph.*

¹ "*Atti. R. Ist. d'Incoraggiamento di Napoli*," 1888, 4a Ser., Vol. I., pp. 57, Pl. 4.—"*Jahrb. f. Mineral.*" B. II., 2a H., Stuttgart, 1888, pp. 123-141.

Mittheillungen," pp. 113-189, Vienna, 1886, is an important addition to our knowledge of the microscopic structure of these interesting minerals. I was unacquainted with this memoir when the present paper was written about six years since, and consequently a revision was necessary which pressure of other work has retarded. Mierisch's and my own investigations, in so far as they cover the same ground, lead to very similar conclusions; but that gentleman has devoted himself in a very skilful manner to the elucidation of crystal structure, whilst my own researches have been along the line of rock structure. In other words, his researches are mineralogical, whilst mine are geological. Over and above that, his investigations were entirely limited to the drusy limestones and their contents, whilst my present paper refers to the stratified limestones and their immediate derivatives. Lastly, Herr Mierisch's observations were upon only eighty specimens, and he had apparently not studied them in the field, a not unimportant condition when we remember that those specimens met with in museums are always chosen for the beauty of their enclosures of free crystals, regardless of the matrix and the associations together of different rock types in the same block.

Having been brought constantly amongst these blocks, whilst constructing the large geological map of Vesuvius and Monte Somma, I have been able to collect nearly seven hundred specimens, and to study in much detail their mode of occurrence, associations, size, and other characters. From these facts, it would impress any one with the very large number of rocks represented, many of which are so far undescribed. The most important fact of all is the graduation from a perfectly unaltered limestone containing recognisable fossils, through various stages of change, to a considerable number of true metamorphic rocks that, in their turn, shade into many both known and unknown kinds of igneous rocks, which more and more approach the different modifications of the normal cooled magma proper to this volcano.

If a geologist attempts to study the relationship of a volcanic neck or duct to the surrounding rocks, even in such districts as Schemnitz or the Tyrol, he meets with two almost insurmountable difficulties—the first is that such a study can only take place at one horizon, so that he knows nothing lower than what is shown in the deepest gorge bottom, or nothing above what is displayed on the highest hill top. In the next place, by the time a volcanic neck has become exposed by denudation, all the rocks have undergone such marked changes as foliation, serpentinisation, schillerisation, hydration, weathering, &c., that the former structure has become so masked by the secondary

metamorphoses and alterations that deductions cannot safely be drawn from such material.

With ejected blocks from a still active volcano it is quite otherwise. These blocks are specimens torn off from the sides of the volcanic neck and canal at various depths, so that the geologist is able to study the rocks in a vertical instead of a horizontal extension; and beyond this, he is able to compare the lavas and scoria, gases, &c., produced at the surface with the specimens of the magma cooled at various depths and pressures during the suspended activity of the volcano.

But above all, he is able to carry on his investigations on rocks in which hardly any of the secondary alteration and metamorphism has occurred; and where this does occur to a slight extent he may learn lessons which were impossible if no graduated series was at hand.

Under such circumstances, I have very reluctantly undertaken a most difficult task, and it is therefore hoped that many defects may be overlooked and gaps filled up by more able hands than mine.

In the present communication the stratified limestones and their derivatives have been taken up on account of the lithological character of bedding serving as a guide and key to what occurs in the more massive varieties.

Classification of the Varieties of Ejected Blocks.—Amongst the rocks, perhaps the most remarkable, at first sight, are masses of plastic clays which show only from one to five millimetres of slight baking on their surface, and containing many fossil shells. These shells, as well as those enclosed in the next group, are nearly all of living species, although thoroughly mineralised. The clays pass into calcareous mudstones, often concretionary in structure, which may or may not be fossiliferous. True sandstone is rarely to be met with, and when it occurs, is not fossiliferous and of doubtful age, but is probably late tertiary, as are all the above-mentioned rocks. Amongst the specimens of my collection is one small piece of yellow quartzose grit looking very much like the Eocene "Macigno," but such material is very rarely to be met with here, whereas at Monte Vultura it is very common amongst the ejected blocks of that volcano. So far, I have not come across anything that indicates these later rocks having undergone metamorphism, which may be attributed to the fact that the magma could not reach so near the surface without opening a way to the atmosphere. Much rarer, but equally unaltered, we have a series of true limestone and dolomitic rocks containing much bituminous substance disseminated through them, which in many cases is collected more or less in different bands, so that the specimens

often show a very fine stratified structure indicated by different shades of greyish brown to black, and often exhibiting miniature faulting. In other cases, the stratified nature of the rock is not apparent, and the structure may even be rather coarsely crystalline; but nearly always the stratification planes are marked by the presence of hydrocarbonaceous substances in greater or less proportions, except where broken by numerous white veins and eyes of pure calcite. There are also to be met with two principal varieties of calcareous conglomerate of small limestone pebbles. In one case these are imbedded in a calcareous matrix of moderately compact character, and are probably of the same age as the breccias that cover the stratified and crystalline limestones of the neighbourhood, whilst in the other the matrix is a soft, white, pulverulent (in fact, flour like) substance quite similar to what is formed at the present time in the neighbouring bay a few metres below sea-level. This rock I take to be very modern, perhaps more so than the clays, whilst the stratified crystalline, and probably compact conglomerate, are of cretaceous and post-pliocene age, respectively resembling in the most minute details of structure, &c., the appennine limestone of the district which constitutes the peninsula of Sorrento and dips beneath Vesuvius. Besides these, there are some specimens rarely met with of breccias and conglomerates of somewhat doubtful composition, which will be examined on a latter occasion.

One acquainted with the ejected blocks of Monte Somma cannot but be struck with the few metamorphosed examples of the tertiary rocks, whilst the limestones of cretaceous or earlier age afford an almost unlimited series of mineral aggregates. The physical changes in them have converted them into graphitic and into saccharoidal marbles, then oxides and aluminates have separated, and silicates have been introduced, so that many kinds of metamorphic rocks and minerals have resulted. They shade on the one hand into a series of ultra-basic and basic rocks, and these again to syenites with zircon, nepheline, and a peculiar rock with leucite may be met with, which in some cases forms a continuous series with certain porphyritic trachytes and pumices. On the other hand, the ultra-basic rocks graduate through a coarse series of crystalline masses that seem to bear the same relationship to the leucite-lavas as a gabbro does to a dolorite or basalt. Then we have a most interesting series of altered breccias, partly composed of limestone fragments and partly of igneous rocks, which have undergone re-metamorphism, so that the limestone fragments may have been simply melted into beads lining their original cavity, or may have become liquid and cooled, forming a minute solid

lake, half filling the hollows, and in some cases with the crystals of wollastonite formed and floating on the surface, projecting as dead leaves from a frozen pond. Where the action has progressed still farther, the limestone has disappeared and olivine takes its place, or the original cavity may be lined with pyroxene, mica, or wollastonite, and more rarely garnet, sapolite, nepheline, mizzonite, or idocrase. This metamorphism of this mixed breccia may have been accompanied by pressure, so that after becoming plastic, the limestone, as well as the igneous fragments, have been pressed out in long streaks.

Various tufas, grey compact trachyte, trachyte breccia, and other odd rocks are also to be met with. These I take to be the remnants of older volcanic deposits from other neighbouring vents which formed the most superficial layers of the Vesuvian subvolcanic platform. Besides these are a series of altered lavas, scorias, lapilli, &c., that often form the nucleus of volcanic bombs in eruptions where the cone is rent open. These are undoubtedly derived from the sides of that rent, in the vicinity of the chimney, crumbling away when no longer supported by the liquid column of lava. Professor Scacchi, who studied (*Contribuzioni Mineralogiche per Servire alla Storia Vesuviana del Mese di Aprile 1872*; *Atti della R. Accad. d. Sc. Fis. e Mat. d. Napoli*, Part I., Vol. V., Part II., Vol. VI.; *Notizie Preliminari di alcune Specie Mineralogiche rinvenute nel Vesuvio dopo l'incendio di Aprile 1872*; *Renicont. d. R. Accad. d. Sc. Fis. e Mat. di Napoli*, Oct. 1872; First Appendix to above in the *Rendiconto* of Dec. 1874, and Second Appendix in same of May 1875) the minerals of these of the eruption of 1872, supposed that they came from greater depths, but one who sees them in the field, and not simply in the hands of collectors, will soon be convinced to the contrary.

Mode of occurrence.—In my former paper on Vesuvius (*Geology of Vesuvius and Monte Somma*, Q.J.G.S., Vol. XL., p. 35) I adopted a classification of the ejectamenta, and more fully developed that classification in a paper specially devoted to the subject (*On the fragmentary ejectamenta of Volcanoes*, *Proceed. Geol. Assoc.*, Vol. IX.). Reference is made to it here because it affords us a means of grouping ejected blocks. *Essential* ejectamenta are those products that issue in an incandescent condition, being the source of energy by which the other two groups are ejected. The *accessory* ejectamenta are those portions of cooled volcanic rocks composing the sides of the crater that are torn off, or, after crumbling in, are shot out by the *essential* ejectamenta. This group would also include old rocks of the volcano that had undergone more or less metamorphism by their proximity to the chimney. Thus, the

bomb-contents of the 1872 lava would come under this head. In all probability most of the calcareo-igneous breccias belong to this group, being old ejectamenta crumbling down and falling into the apex of the tranquil crater, where, after being again covered by the re-growth of a cone, and being exposed to heat and pressure, they have been re-ejected by an explosive eruption. Possibly also, some of the gabbro-analogues may also come under this head, having cooled low down in the volcano and being torn off and ejected during a later explosion. Lastly, we have the *accidental* ejectamenta, called so, since their composition depends upon the chance of what rocks form the sub-volcanic platform. They are only ejected when the apex of the crater cavity formed by an explosive eruption extends below the platform of the volcano into the underlying rock, portions of which are torn off and shot out.

The distribution in time of the ejected blocks of Monte Somma and Vesuvius are extremely interesting. Thus *Phase II.*, or the long period, during which a cone some 7000 feet high was being built up by the chronic activity of the volcano, or by the ejection of lavas, scoria, dust, and other *essential* products, we do not meet associated with these any of the (with one or two rare exceptions) ejected blocks, for the very obvious reason that the lavas, &c., issued quietly from the top or sides of the cone, and only such as the 1872 type of bomb-contents could have been produced. During *Phase III.*, the summit of the great cone commenced to be truncated, and a crater excavated. Now, in the pumices of this first explosive phase, we meet with large numbers of accessory ejectamenta torn from the mass of the great cone, but in addition, large fragments of fossiliferous mudstones and clays are rather common, showing that the crater apex had reached down into the tertiary deposits beneath the volcano. We encounter a few bits of grey and white limestone, and sometimes a bit of *silicate*-charged limestone, but these are very rare and never larger than a nut, so that probably they were brought up by the violent purging of the volcanic duct. The next phase of the volcano, probably in direct sequence to the last, was a return to chronic activity, during which lava streams issued from rents in the side of the mountain, and no doubt the crater of explosion became more or less filled up by a new cone of eruption. This was followed by a comparatively long period of inactivity, after which occurred one of the most violent explosive eruptions of which there is evidence of having shaken the flanks of the ancient Somma.

It constitutes the PERIOD I., *Phase VI.*, and is represented by a mantle of fragmentary materials varying from one to five metres in thickness, covering the neighbouring district. These materials

consist of the pumice or *essential* mixed with the *accessory* and *accidental* ejectamenta. This admixture takes place in different proportions at different horizons. In the lowest part, or the first ejected, almost all the bed is a mixture of pumice and leucitic lava fragments, indicating that the latter were derived from the sides of the crater cavity, being excavated within the mass of the cone. At a little higher level fossiliferous mudstones and clays, with the limestone conglomerate with white matrix, indicating that the apex of the crater cavity was extending down through the tertiary rocks forming the most superficial part of the platform. Soon fragments of altered limestone become very common, so that in some localities they form a large part of the ejectamenta, and a few bits of metamorphosed or silicated limestone may be met with. To quote the words in my former paper (*op. cit.* p. 67): "None of these erratics are absent from any part but they predominate at certain horizons." It is evident, therefore, that as the eruption progressed, the crater apex was gradually lowered into the limestone subjacent to the tertiary clays and mudstones, but only reached that part that had been baked, stopping short of the still lower more highly metamorphosed materials.

PERIOD II., *Phase VI.*, was a small pumice eruption, apparently too weak to eject any *accessory*, and still less any *accidental*, ejectamenta. This was followed by PERIOD III., which seems to have chiefly been occupied in enlarging the upper part of the crater without extending it in depth, as *accessory* ejectamenta are common, whilst the *accidental* are almost absent. The pumice is very vitreous and spongy, and probably there was much expansion and escape of gas high up in the vent, so that only the crumbling edges of the crater were ejected.

In PERIOD IV., *Phase VI.*, the lower part of the pumice-bed is again rich only in pieces of old lava, whilst the upper part is crowded with the metamorphic limestones and their derivatives in every stage of metamorphism, and in many localities the upper part of the pumice-bed is almost entirely composed of these rocks, which constitutes, with their rich mineral contents, the great store for collectors of them. This, it will be seen, teaches us that during the first part of the eruption, leucitic rock fragments from the sides and choked bottom of the crater were ejected, and that later the apex of this cavity was carried down into the highly-metamorphosed limestones and possibly (?) subjacent rocks.

On a former occasion I estimated the depth of the apex of the crater of this eruption at about 890 metres below sea-level (*op. cit.* p. 38), so that we may suppose this thickness of rock, aided by the weight of the mountain above, sufficient super-

incumbent pressure, combined with igneous matter in fusion, to have produced these various metamorphic products.

The Plinian eruption, PERIOD I., *Phase VII.*, tells much the same tale, on a smaller scale, as the last. The deposits of the feeble explosive eruptions that followed it are rich in ejected blocks, but many show signs of being metamorphosed twice over, and many are the calcareo-igneous breccias which it would seem might be due to earlier materials that crumbled into the crater neck and subsequently were re-cooked.

In a considerable number of volcanoes that I have examined, analogous facts were evident; but beyond this the *ejected blocks of a volcano* bear a definite *chemical and mineralogical relationship to its essential ejectamenta and the rocks subjacent to it*, which principle we shall see fully borne out by Monte Somma and Vesuvius.

The stratified limestones have been chosen for the first part of this paper, because their original lithological structure serves as guide and landmark as we proceed from a normal limestone to its extreme modifications. This group exhibits the different changes rather on a miniature scale, but such is of great advantage before proceeding to large rock masses often tons in weight, with in many cases almost a uniform structure. Some chemical investigations have been already undertaken, but it is preferable to consider them more fully when we study the massive limestones and their derivatives.

PART I.

Stratified limestones and their altered and metamorphosed derivatives.—The peninsula of Sorrento, which faces Vesuvius on the south, is composed of a great mass of magnesian limestones at least 4700 feet in thickness. The age of the entire mass is somewhat uncertain, but the upper portion is no doubt of Upper Cretaceous age, which, without any apparent uncomformability, is continuous with the whole of the underlying limestones which are referable to jurassic age.

These limestones are often finely banded, as indicated by differences of colour along the stratification planes. Fossils no doubt abounded, but, by intense mineralisation, are now represented by little else than patches or geodes of white calcite, which stand out rather markedly on the more or less grey, brown, or blackish matrix due to a very general distribution of bituminous matter. Perhaps specimens from hardly any other region of limestone of the same size has been so much analysed. In the following table are included twenty-seven analyses by L. Ricciardi and five by Abich :—

Generally speaking, the purer limestones are mostly amorphous or crypto-crystalline, whilst the dolomitic ones are distinctly crystallised only in a very few examples, and this is quite a different structure from that which is developed by metamorphic action as exhibited in the ejected blocks.

A large number of specimens show traces of iron, but where estimated even together with alumina it never reaches 1 per cent. Unfortunately, in many of the analyses, the residues insoluble in nitric acid were not estimated, although in two cases they varied from 6 to 8 per cent. This residue, besides the above compounds, no doubt was in part made up of silica. In Abich's analysis, silica and bituminous matter are grouped together, so that it is probable that silica rarely exceeds 2 or 3 per cent., whereas in the greater number of limestones it is absent. The bituminous matter, although having a marked effect in colouring the rocks, yet usually exists only in quantities too small for estimation, except in the greyish black, shaley limestone from Vietri sul Mare, where it exceeds $3\frac{1}{2}$ per cent. The black dolomite from Minori, analysed by Abich, was no doubt as rich in it, but it was not determined separately from the silica. It will be seen also that the greater number of these limestones contain traces of chlorides, and have often sulphates, but in such small quantities that they may be practically disregarded.

The causes of the dolomitisation of these limestones that dip under Vesuvius do not concern our present inquiry, though it may be remarked by the way that the structure coincident with the presence of a large proportion of magnesia in the rock is not such as would indicate any relationship with neighbouring active volcanic agencies. There is, in fact, the clearest evidence that the cretaceous rocks had already taken on nearly their present configuration before the deposition of Eocenes and Pliocenes, which are precedent to the volcanic outburst of the Campania.

These rocks we have been considering are therefore the materials out of which such an extraordinary series of silicate compounds have been developed beneath Vesuvius. That there do not exist the materials in these limestones, out of which peridotites, pyroxenes, micas, and other complex silicates could be elaborated, is self-evident. It is clear that the silica, alumina, iron, fluorine, &c., must have been introduced from without; therefore we have every reason to believe that these substances were derived from the neighbouring igneous magma. By what methods they are introduced is difficult to determine. It could hardly be by osmosis of fluids, because had the limestone been softened sufficiently to allow such to take place, it would not

have retained all the minute details of its stratification structure. Scacchi has demonstrated that many silicates, such as pyroxene, amphibole, leucite, biotite, nepheline (microsomite), garnet, &c., have been deposited by sublimation. Of course, here is not meant the actual mechanical sublimation of the mineral species, but rather the deposition of a particular species by the reaction of one or more vapours on each other, or on some solid. We find the closed vesicular cavities of old lavas filled by these minerals. It is consequently not difficult to conceive that such vapours as would be required can find their ways between the calcite grains, undergoing decomposition with the formation of the different metamorphic minerals. What these vapours were it is difficult to guess at; but from the great abundance of HCl, SO₂, and HF, it is very probable that these in combination with the required elements did the work, taking an important part, the first and last.

Description of Ejected Blocks.

(205).¹ Coarse granular dark buff limestone, affording a bituminous odour. It is spotted by small geodes of white calcite, and streaked by fissures lined by the same, so that combined with its granular structure the fracture of the rock is very irregular. Faint traces of bedding are present, and an extremely thin light coloured crust exists, which is evidently the effect of weathering by percolating water. Under the microscope (No. 205, Plate xv.) this is a most beautiful rock, being nothing more than one vast aggregate of foramenifera, forming a compact limestone which has been crushed and again re-cemented by infiltration of calcite, forming a micro-breccia. The crystals of the white veins show with the polariscope the beautiful lattice pattern of some calcites. The bitumen is collected in certain cracks and fissures.

(24). This is dark buffish-grey earthy-looking splintery limestone, with a strong bituminous odour when scraped. It is traversed by very fine veins of calcite. Microscopically, it is seen to consist of minute crystalline grains with a very uniform size. The hydrocarbon seems to be scattered between the grains and along the fissures. In the midst of these are many minute oval bodies of clearer calcite that are probably highly mineralised foramenifera. The grains are about one-hundredth of a millimetre in diameter. There is no sign of original crust.

(25). Is a greyish, buff, compact limestone of very fine granular structure very distinctly stratified, the different bedding planes being indicated by variation in colour. Scraped it

¹ These numbers refer to those of the catalogue of my collection, and are employed for convenience in referring to a particular specimen.

gives out a strong bituminous odour. The darker bands are composed of more minute crystals than the lighter ones, as if the presence of bituminous substance had impeded their growth. There is a layer of from 2 to 6 millimetres of the surface that has been bleached probably by heat during the ejection. Under the microscope the rock is seen to be a fine grained limestone, the average size of the crystals being rarely more than the thirtieth or fortieth of a millimetre. Stratification on a minute scale also exists. The bituminous matter of a very dark brown to black colour is distributed between the grains, but principally in minute druses the size of a few grains, or it forms bands parallel with the stratification. In a few places are minute druses and veins filled by larger and whiter calcite, and in some the centre of the druse contains the hydrocarbon. The white crust differs in no way from the rest, except containing less bitumen, so that it seems that the heat was only just sufficient to volatilise or burn it off without attacking the limestone, unless the attacked part has been lost by solution or abrasion. The grains, both new and old, polarise in brilliant colours, but are very patchy.

(39). Is a markedly stratified limestone, finely crystalline in structure, the grains glistening almost like a saccharoidal marble. It breaks easily across the fine bedding planes, but some more marked bands are sources of splitting. Most of the bandings are indicated by varying shades from light brown to yellow, with a few white and grey, so that the whole seen from a distance appears of a light rusty colour. The crust, half a centimetre, in thickness, differs only that the brown tints change to grey, as if the limestone had been removed or reduced. Under the microscope, the grains are well defined with an average size of from a thirtieth to a tenth of a millimetre, and are somewhat gritty in structure, being choked by fine dark dust and polarise in patchy colours. A very large number of small exceedingly fine grained patches, apparently of calcite, seem to be the remnants of some organisms. Under a high power, no further knowledge can be gained of these bodies. Besides these there are also patches of coarser calcite grains. The colour of the rock is seen to be due to a very large number of decomposing crystals of pyrite surrounded by a cloud of limonite. The crystals vary up to a twentieth of a millimetre in size, and appear to occur as pentagonal dodecahedra. The banding depends on the more or less abundance of these different components. There is no evidence of any bituminous substance.

(52). Very similar to last specimen, composed of white, bluish-grey, and rusty brown groups of strata. The whiter bands are more crystalline at one end of the specimen, and pass into coloured ones at the opposite end. The surface is simply contused.

(38). Resembles the last to a certain extent. It is a little more crystalline and whiter, with dark rich ferruginous laminae, so that it splits almost entirely along the bedding planes. It is also slightly faulted.

(48). Much like 52, but colour is a grey, tending towards a greenish tint. The rock is much faulted, traversed by calcite fissures, and contains some small geodes of the same mineral. It seems to have suffered much crushing whilst still plastic, as small faults so die out, and some strata are crushed up or drawn out.

Remarks.—In the first three examples we have as many types of bituminous limestones, such as form a very large part of the Castellamare (cretaceous) rocks, and so unaltered that foraminifera, in one at least, are beautifully preserved, and neither by the naked eye nor by the microscope can any differences be seen, except in 25, in which the hydrocarbonaceous matter seems to be blacker or carbonised, as if a faint baking had taken place. From this group we proceed to a series of graphitic limestones, and their derivatives to be described. The remainder of the specimens seem to consist, for the most part, of ferruginous limestones, with traces of organised structure. They appear to have undergone a very faint alteration, in that they tend to a saccharoidal structure, and some of their calcite grains contain minute impurities, which are probably small peridot and brucite crystals from hydration of original periclase. In one, at least, we have pyrites which might have been introduced by the percolation of water containing sulphuretted hydrogen. This second group, therefore, seem to show a very faint change tending towards metamorphism, which we shall see increases, so that these latter slightly ferruginous rocks, which were probably never bituminous, give rise to derivatives quite different from the last.

(202). Carbonaceous limestone, with very strongly marked bedding, which beds vary in colour from almost black to light grey. The more carbonaceous bands are much finer grained, whilst the lighter ones are almost saccharoidal in structure. When scratched no bituminous odour is emitted. No crust apparent. As the specimen is one of the darkest in colour amongst this type of limestone, I estimated the amount of carbon contained in it. It afforded 0.608 per cent., or a little more than a half per cent. This carbonaceous matter is structureless, and exhibits all the characters of graphite. (27.7150 grams of limestone were dissolved in dilute hydrochloric acid, evaporated to dryness, re-treated with dilute HCl, and filtered. The black residue, after prolonged drying at 200° C., weighed 0.7500 grams, which on being calcined at a white heat lost

0.1685, which was counted as carbon. The siliceous residue, which was therefore considerable, being equal to more than 2 per cent., gave a strong reaction of iron with borax bead, and was therefore probably some silicate of that base.) The specimen chosen for analysis was an average of all the bands, of which the dark ones predominate, and which, if polished, would be of a good black colour. It is remarkable how far less than 1 per cent. of graphite is capable of changing the colour of limestone. The calcite grains are very small when the carbon is most abundant, but in the lighter parts they range up to half a millimetre in diameter.

(31). Banded limestone much the same as last, but little coarser and of general lighter tint. Exhibits three beautiful little faults in one hand specimen 12 centimetres long, each one being filled by white calcite. Calcite grains reach half a millimetre in diameter.

(215). Same as last, but very finely stratified, and most beautifully exhibiting contortion equal if not superior to any piece of paleozoic or archæan mica schist. Calcite grains measure half a millimetre or more.

(32). Very finely banded carbonaceous limestone, differing from the last three only in the lighter part, being much more coarsely crystalline. Two sections were made of this rock. (Fig. 32, Plate XIII.), which shows the junction of fine and dark bands, with coarser and lighter bands. In the former the graphitic matter forms a trabecular network surrounding each grain; but in the latter, one or two rows of calcite grains are separated from their neighbours above and below by a band of graphite, which, in some cases, sends a branch in between the individuals constituting the particular band. The calcite crystals are very pure, only containing a few scattered, very small undeterminable microliths. They offer most beautiful examples of twining, banding, and the lines of cleavage are very marked, whilst a faint granular structure sometimes is evidently carefully manœuvring between crossed nicols and using the quartz plate. The crystals forming the coarser bands average two-thirds of a millimetre, whilst those of the finest have a diameter of about half of a millimetre.

(33). This specimen consists of a coarse-grained banded carbonaceous rock of lighter colour than those above described, whilst the other half is a beautiful snow-white, saccharoidal, compact, marble. It shows evidence of a more advanced metamorphism, and the white part is no doubt due to the removal of the carbonaceous matter. In the midst of the banded part a small druse may be seen, containing fused beads

Trans. Geol. Soc. Edin., 1893,

Vol. VI. Pl. XIII.

N.° 32.

x 24 diam.

N.° 40.

x 24 diam.

N.° 41.

x 24 diam.

EJECTED BLOCKS OF MONTE SOMMA

or tears of calcite crystals,¹ with a few milk-white ones of some other mineral. Attention is drawn to this specimen in relation with a group of geodic limestones to be described. The geode cuts through the stratification banding, and its walls consist of different layers of variously tinted limestone. The grains of the white marble attain as much as 1 millimetre or more in diameter, whilst those of the black part rarely exceed a half of that.

(35). Consists of a banded carbonaceous limestone, showing faulting, and forming about one-third of the specimen, whilst the remaining part is a white saccharoidal marble. This latter consists in part of very fine-grained rock, and another portion rather coarse. Separating these two portions is a thin band of a pink fibrous mineral. In this specimen its fibrous structure is not very evident, but in others it is more marked, and as it is of very common occurrence a graduated series of specimens can be obtained from this through beautiful silky to coarse fibrous varieties, and finally to a net-work of distinct wollastonite crystals. I have prepared microscopic sections of the more evidently fibrous varieties, and so far as they can, they exhibit the optical properties of wollastonite. The extinction in these varieties is always parallel with the axis of the bunch of fibres, but deeply embedded in these are numerous grains and crystals of white peridote, so that any attempt at a separation by heavy solutions would be quite unavailable. Amongst the eighty specimens of ejected blocks examined by Mierisch, this variety probably was not represented, as he makes no mention of it. Vom Rath had, however, a specimen upon which he expresses his opinion that the wollastonite was directly derived from the limestone. This band is separated from the carbonaceous portion by 3 to 4 centimetres of the white marble. At the junction of this latter with the former is a thin zone of dark granules, which appear to consist of periclase.

(42). This is a remarkable specimen—nearly a half is a coarse and fine grained stratified carbonaceous limestone, which passes into a very white saccharoidal marble, and this again into a banded mass of pink wollastonite and a green mineral, which in its turn is followed by more white marble. Microscopical preparations were made of this specimen. The banded limestone is very similar to 32, but one broad black band farthest away from the metamorphosed part is very fine grained, whilst the rest is very coarse, the grains being in some cases double the size of those in 32.

¹ Mierisch discusses these solidified drops of calcite, but I had already, some years before, explained their origin.—Q.J.G.S., 1884, p. 82.

Exceptions to this occurs in the dark band, where the presence of much carbon seems to have impeded the formation of large crystals. As the white saccharoidal part is approached, the calcite crystals become larger, and the carbon grains appear to be often enclosed within them. The saccharoidal part shows an aggregate of calcite crystals free from carbon and comparatively pure, only showing what appear to be streams of extremely minute gas pores, with a few scattered grains of peridote. The number of these latter appear less than is really the case, which is probably explicable by their being in part lost amongst the grains of calcite, where from their small size they are not very visible in polarised light. The matrix when dissolved in a dilute acid leaves a considerable deposit composed of these crystals, which contain numerous minute grains of a greenish-brown colour. Many of these are octohedrous. In the residue are unenclosed crystals of the same characters, with hollow faces. All are very minute, and only visible under $\frac{1}{8}$ objective. They are probably fluorite.

The silicate part consists of two bands, about half a centimetre wide, of pink, fibrous wollastonite, which include between them about 2 centimetres of fine, light green, banded rock, which, were it not for the colour, might be taken for the carbonaceous limestone. Microscopically, it consists of an agglomerate of light greenish peridote with a little calcite, whilst the banding consists of a mass of small grains, which seem to be a mica. Scattered here and there, and sparingly, are some structureless, colourless, irregular patches of a mineral which polarises in the first order of colours. It looks much like a monoclinic felspar, but if it is so, its associations are curious. There are also banded patches of a single refracting transparent crystalline substance, which I suspect to be fluorite. Lastly are a few stellate groups of galena. The before-mentioned pink bands are composed of a fibrous mineral, arranged in tufts at right angles to the bedding plane.

Where these wollastonite fibres project into the white crystalline limestone, they are mixed up with numerous peridote crystals. They afford an excessively opaque preparation, and it seems impossible to determine the angle of extinction of the fibres, so that I refer it to wollastonite, which it much resembles in its reactions, and in that it can be traced through intermediate specimens to undoubted examples of that mineral as already mentioned. No doubt this opacity is due to that stage of decomposition described by Mierisch (*op. cit.* p. 173), which results in the peg structure in the better defined crystals of this mineral.

It will be seen that in this specimen we have three degrees

of metamorphism in a certain order, *i.e.*—1, Carbonised limestone; 2, saccharoidal limestone, with peridote and fluorite(?); 3, limestone, nearly replaced by different silicates, sulphides, and fluorides. But another point of equal interest is that at one end of the specimen the saccharoidal encroaches on the carbonaceous limestone, and the former is in its turn invaded by the pink fibrous bands, and at the same time the banding of the silicate part is, to a considerable extent, obliterated.

(40). Is an extremely strongly marked stratified rock. First, we have about four centimetres of a dirty-white crystalline limestone, the outer third showing by varying tint and coarseness extremely fine banding. This limestone is in some parts marked by small brown radiating dendritic spots. It is very uniform in texture under the microscope, and exhibits a few scattered grains of white peridote. Abruptly in contact with it, we have about three centimetres of a dirty green rock showing by its varying tints much stratification, banding, and in some parts coarsely crystalline. At this point, long irregular spaces exist, into which project the crystals, which may be distinguished by the naked eyes as green biotite, with (what can be proved chemically to be) calcite. This green banding is seen under the microscope to be composed of a network of large crystals of nearly colourless pyroxene in a matrix of calcite (Fig. 40, Plate XIII.). Clear light yellowish-green biotite crystals are also abundantly intermixed. Near the open spaces, however, most beautiful long hexagonal prisms of the latter mineral project, so that often their length may be ten times their diameter. They are generally imbedded in some mineral apparently structureless, but polarising in the most brilliant colours. It was impossible to isolate this mineral, and, as it fills up irregular cavities, it could not be determined. Were it not for its associations, it might have passed for quartz, but which would lead one to refer it to peridote.

The pyroxene crystals polarise in unusually brilliant colours, but are remarkably irregular in structure, each individual appearing between crossed nicols as a beautiful variegated mosaic. It is the diversity of size of these, and the greater or less proportion of calcite and mica crystals, that determine the difference of tint and coarseness of structure of the different component bands of this silicate stratum. The largest crystals of pyroxene reach a millimetre in length, they are rather rounded at their extremities, and very irregular in structure. This irregularity, when examined under a high power, is constituted by a number of granules, but principally by a viriditic matter that permeates the crystals, apparently along fissures in it somewhat like moss-agate, but less regularly. There is also

a faint cleavage, parallel to one or more of the prismatic faces. In the calcite, a few most beautifully perfect cubic crystals occur, which, in all probability, are fluorite.

Separating this band from a similar one of about two centimetres in breadth, is one of limestone of about one-and-a-half centimetres, with the characters as the former one of this specimen. The silicate bands, however, in some places encroach on the limestone bands, and *vice versa*, and in the small silicate bands streaks of limestone are left.

(41). This is a small, but very remarkable specimen. It exhibits a most evident stratification, due to the great contrast in colour and structure of the different bands composing it. The most marked band of over two centimetres in thickness forms about half of the specimen. It is of dirty green grey colour, looking like a compact marly limestone, with minute detrites along its fracture planes, though between these it breaks with a feebly conchoidal fracture. It is much darker in colour in contact with a little syenitic (?) rock attached to it on its outer surface, but much more marked where it is joined to the next band. The principal constituent seems to be grains of calcite below $\frac{1}{250}$ of a millimetre in diameter. The mass is also traversed by a few minute veins of calcite. This rock dissolved in dilute acid leaves a fine grey powder, or skeleton, which is composed of microliths about $\frac{1}{400}$ of a millimetre in length, and a fourth or fifth of that broad. Although so small, these crystals polarise up to brown yellow in the first order of colours. There is little doubt that they are peridotite. This is the micro-felted structure observed by Mierisch (*op. cit.* p. 132) in drusy limestones, a hydrous silicate analogous to serpentine, but poor in iron.

The dark bands are much more marked microscopically, and are so insoluble in dilute acid as to retain their form after treatment with such. Judging from analogy rather than by certain facts, it would seem that these bands consist of a few minute grains of peridotite intermixed with greenish biotite microliths, that do not attain the $\frac{1}{100}$ of a millimetre in diameter. In striking contrast with the last described band is its immediate neighbour, separated abruptly from it, and consisting of more than a centimetre of coarse white saccharoidal limestone, with various colourless inclusions, besides grains of more or less dark colour. Some of these are rusty-looking, others metallic, consisting of decomposed pyrite and galena. Microscopically, the mass is composed of grains of calcite averaging from a-half to one-and-a-half millimetres in diameter, which show the most beautiful lattice polarisation. Mixed with these are the galena and decomposed pyrite crystals already

mentioned. There are a few scattered groups of peridote very much fractured, and the fissures threaded through and choked by what appears a dirty amorphous (?) matter, probably pilite or some other hydrous silicate nearly allied to serpentine (Fig. 41, Plate XIII.). Mierisch (*loc. cit.* p. 139) observed no inclusions in the forsterite, which is quite contrary to my experience, especially in large crystals such as those just mentioned, in which case there is little doubt that the substance is a decomposition product. In some points occurs a colourless mineral of irregular outline, but somewhat streaky on account of many enclosed gas and liquid cavities; it also shows faint banding like the teeth of a comb, also stallate acicular inclusions. One crystal showed a clean rectangular outline at one corner, with this banding parallel at its edges it afforded parallel extinction. Some of these crystal grains were isolated, when they are then indistinguishable from those of peridote.

There are a certain number of crystals of a bright green colour (seen best by dissolving the rock in weak acid), a few of which are well-formed. They show no pleochroism, and give extinctions such as to indicate pyroxene. Some enclose a brownish nucleus which gives no characters sufficient to distinguish what it is. One might at first suspect amphibole, but it may probably be referred to a different coloured pyroxene from its host.

Scattered about are also a number of fine prisms and plates of a light brown biotite which are quite transparent and free from enclosure. There are also certain spots where an aggregate of clear grains always remain black, whilst rotated between crossed nicols. There are also a few very minute octahedra enclosed in the crystals of calcite. Probably both of these are nothing more than fluorite. Both the pyroxenes and the micas are more abundant along the limits of their containing band. A few crystals may also consist of idocrase.

Next comes a thin stratum less than a millimetre in thickness, identical in structure with the dark band of microlitic biotite already described as limiting the crystalline band on the opposite side. This thin stratum contains some very minute black opaque stellate crystals of unknown composition.

Following the mica band, we have a stratum of about half a centimetre of fine granular calcite differing from its neighbour already described in many points. In the first place, the grains do not exceed the $\frac{1}{25}$ of a millimetre in diameter, or about thirty times smaller than the others: next, there are very few, if any, admixtures of other minerals, except one very narrow band of dark red colour, which microscopically seems to have consisted of pyrite grains which have undergone decomposition. The

calcite crystals contain a few impurities in the way of undeterminable grains and microliths.

Again comes another very thin though double microlitic mica band, followed by a stratum from two to three millimetres thick, resembling in general appearance and coarseness the thick coarse crystalline band already described. There are the same sulphides, pyroxenes, mica, and a few large calcite grains, but most of these are replaced by a clear colourless mineral, except for many inclusions, in equally large grains, but *all sections* remain dark between crossed nicols. The grains have no definite outlines. Some others identical in appearance and inclusions do polarise; there is therefore some doubt whether this mineral may not be tetragonal or hexagonal, rather than isometric, for in two cases it was possible to obtain a faint axial figure though very feeble and imperfect. So far as meionite goes, Mierisch (*op. cit.* p. 49) says it is most difficult to prove that mineral in sections. Grains were isolated and tested, but gave no fluorine reaction. It is not improbable then that the mineral is either nepheline or meionite. This stratum is separated by a thin imperfect band of microlitic mica from another layer of rather fine grained saccharoidal calcite.

(36). Presents the same order of carbonaceous saccharoidal, white saccharoidal, and stratified silicate rocks. The carbonaceous limestone part is very incoherent, crumbling down in the fingers to a fine sand. Otherwise the characters are the same as in other specimens already described, though the carbon is not distributed in bands. The white saccharoidal portion into which the last graduates exhibits the usual characteristics. This white marble terminates abruptly in the silicated part.

The silicated rock is of pale, dirty green colour, and at the distance 4 or 5 centimetres from the limestone becomes of a very coarse grained granitic structure, and somewhat cavernous. It is divided by a band of limestone, which in one half of the specimen has undergone very considerable conversion into silicates. The constituents of the mass show in grain and composition a very evident stratified arrangement, which, however, is much less distinct on the side where the limestone band is enclosed, thus indicating the direction from whence came the metamorphic action, and that the chemical change was only in part guided by the varying composition of different bands.

Microscopically and also macroscopically, this is a very complex rock. It is composed of irregularly shaped grains of various minerals, none of which show any approach to definite outlines. Beginning with the most recognisable, we have large prisms (these are the best formed crystals) of dirty green to brown biotite, which are most abundant near the limestone

bands ; they are apparently of late formation, as they occupy in part or wholly cavities amidst the other ingredients. Next, we have an agglomerate of crystals of white peridote of the usual type, and also crystals of calcite. These are variously mixed in the two bands with moderate to very large grains of a nearly structureless mineral, polarising in greys or brown yellows; some sections of the mineral remain dark; in all positions between crossed nicols there is no twining visible, so that the mineral is probably nepheline, which is further indicated by its solubility in dilute acids. Between crossed nicols much of the field becomes and remains obscured also by structureless and irregular crystalline grains, which are probably referable to some mineral with the similar characters as that contained in specimen 41. Lastly, there are a number of large white pyroxenes (?) some mottled with clear light green patches. Besides these are vast crowds of smaller somewhat greener crystals of the same, which range down to microliths and form numerous enclosures in the different other minerals already described, so that any attempt at separating the different elements according to their specific gravity, or an endeavour to employ micro-chemical methods, is rendered impossible. In addition to the above main constituents of the rock are a number of ochre patches, probably derived from decomposed pyrites, besides traces of galena. The minute fissures, some cavities, the interspaces between the crystals, and even within some crystals in special planes, occurs a brown or more properly buff granular matter insoluble (?) in dilute acid, which seems to bear some relation to the pink wollastonitic matter in some of the other specimens.

(37). Presents the usual order of alteration. The carbonaceous limestone part is more compact than in the last specimen, and possesses minute drusy cavities lined by carbon, which in the rest of the rock fills in a few interspaces between the grains. The white band resembles much the last in structure, except for the absence of the carbon. There are a number of minute black spots to be seen both in the white and grey limestone, which appear to consist of galena. Macroscopically, the silicate portion of the specimen is of a dirty greyish-green colour, compact in structure, breaking with an irregular crystalline and sheeny surfaced fracture. Large grains of galena and ochre patches from decomposed pyrites are scattered through the mass. The components of this rock are much the same as No. 36, except that the intermingling of the different mineral species with each other is still more intricate, whilst the nepheline which constitutes so much of the mass is not only crowded by the green augite microliths, but is in some cases traversed by large fan-like bunches of very minute curved

acicular crystals, whilst the calcites show very much of this fibrous inclusion, but exhibit hardly any characteristic twining, so as to render their determination rather difficult. The latter mineral seems to have separated out the last, and may in part be derived from the alteration of the fibrous wollastonite, as indicated by Mierisch (*op. cit.* p. 173).

(54). Here we have an exceedingly hard fine grained limestone, and where not influenced by fissures, it breaks with a porcelain-like fracture, which material it much resembles in appearance. No very evident signs of original stratification are distinguishable. Adjoining the limestone is an irregular band of dark green colour from a half to two centimetres thick, this latter thickness being due to tongues or spurs of the material projecting into the limestone. This band is composed of an intricate blending of minute biotite crystals of not more than a quarter of a millimetre across. The rest of the specimen is of a coarse granitic structured cavernous mass composed principally of biotite, calcite, and a greenish-white mineral mostly in irregular masses, some of which are a centimetre or more long; a few, however, remind one of sanidine crystals in outline (Fig. 54, Plate XIV.). The fracture of this mineral seems to be very irregular somewhat granular, but in one or two places there is a faint appearance of cleavage. The hardness is about that of oligoclase. This mineral occurs in patches, and in that situation envelopes the crystals of biotite. The mica is of dirty green colour, with a greyish tinge towards the centre of the crystals, which range up to three millimetres in diameter. In the majority of cases the crystals may be broken indifferently in any direction, basal cleavage, except at the surface, being almost abolished. Lastly, we have a number of white crystals of calcite, which partly or entirely fill up the interspaces between the biotite, and are scattered over the interior of the minute caverns.

Microscopical examination explains all these uncommon characters in the different compound minerals.

The biotites are crowded by minute prismatic microliths, polarising in strong colours, which rarely exceed the fortieth of a millimetre in length. Strangely enough, although forming the bulk of the crystal of biotite, so as to constitute a large nucleus, yet surrounding this nucleus is a thin zone of very pure mica substance, absolutely free from the enclosures. It is impossible to determine the nature of these microliths, since they are imbedded minerals. Not as in many other inclusions in mica do they follow the planes of cleavage, but are oriented in all direction and so act like pegs in the building up a shoe-heel, holding together the different layers of leather in one, or crystalline laminæ in the other, in consequence of which, the beauti-

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N.° 47.
x 24 diam.

PL

N.° 161.

PL

x 24 diam.

N.° 54.

N.° 200,a.
x 24 diam.

ful basal cleavage is almost totally destroyed in the crystals of biotite under consideration.¹

The greenish white mineral is in most cases so crowded with the microliths, that it becomes an almost opaque granular mass. In the clearest examples, it seems to polarise in brilliant colours.

The calcite occurs in large grains rarely showing any lattice structure, and although often very dirty, it is generally free from the microliths contained in its neighbours. There are a few other crystals, some of which resemble sanidine, and others that may be nepheline, which are also in great part filled by the small microliths.

As to the nature of these microliths, as already mentioned, little can be said. If examined with a high power, they are seen to be well formed, generally with an oblique termination, and I am inclined to think that they are minute pyroxenes.

The lower part of the specimen is composed of a pulverulent light green granular rock, which is arranged in a somewhat patchy manner in its relation to the already described granitic structured portion. It gives no effervescence with acid, and when sectionised, is seen to be an agglomerate of minute grains having the character of white peridot associated with very little amorphous binding (?) material.

The whole specimen shows somewhat indistinct stratification, and as already stated, contains many irregular cavities lined by somewhat green prisms of biotite, on which in some places are very minute rosettes of a light greenish-white opaque mineral, too small to be determined.

(161). Resembles much in structure and appearance the granitoid part of the last specimen (54). In this case, stratification is indicated by numerous bands of finer grained material. The component minerals are the same as in 54 with their same enclosures of microliths, except that the latter are much smaller and more ill defined. In the cavities are to be seen a clear structureless mineral, with often a nucleus of microliths; it polarises in grey and brownish yellow, with crystalline boundaries, which in one case in the section seemed to be hexagonal and dark between crossed nicols; this mineral I take to be nepheline.² Another mineral occurs polarising in dull grey, with many sections showing rectangular outlines, and also with a nucleus of microliths. From the small quantity of material at my disposal for examination, much doubt exists about this

¹ Mierisch (*op. cit.* p. 134) says that in the specimens he examined, which were chiefly drusy limestones, the micas very rarely exhibited inclusions. This is quite contrary to my experience in these altered stratified limestones, for here the mica is very rarely pure, and, in the specimen under discussion, probably more than half of the mass of the crystal is made up of a foreign mineral.

² Mons. Renard, to whom I showed the slide, was also of that opinion, and considered the following referable to the same species.

species, although it is certain that it extinguishes lengthwise parallel to one of the nicols. In (Fig. 161, Plate XIV.) one of these crystals projecting into a cavity is shown with a depressed centre and bounded by apparently numerous zones of very narrow facets, whether these are facets or accretion zones, it is difficult to say. They, and even the mineral, are almost invisible in ordinary light, owing to the index of refraction being very near that of Canada balsam.

There are also patches of the same fine granular peridotitic material, as in No. 54. Besides the above-mentioned minerals, some minute crystals of whitish pyroxene are rarely to be seen projecting into the rock cavities.

(200). This specimen consists of the three usual portions. The carbonaceous part is a compact crystalline dark grey limestone, composed of grains, which attain as much as two millimetres in diameter. Microscopically the carbon grains reach as much as a $\frac{1}{16}$ millimetre in diameter, and are chiefly enclosed within the crystals of calcite, which possess marked lattice structure, and also contain a few grains of white peridote. These latter inclusion increase in number and size, whilst the carbon grains proportionately diminish, as the second division or white limestone is approached. Near the junction of the grey and white portions of the limestone, many of the peridotites are attached to or enclose the carbon (Fig. 200*a*, Plate XIV.) This was made evident in a striking manner by dissolving the limestone in very dilute HCl., and washing the insoluble part immediately all the calcite was dissolved. Part of the residue was mounted in balsam, another portion was calcined in a stream of oxygen and mounted, and the third portion attacked by HF and H₂SO₄, washed and mounted. The first preparation shows, in a remarkably interesting manner, the peridote and its carbon enclosures, besides a few beautifully formed hexagonal plates of white mica; the second, the same minerals totally free from graphitic contents; and the third, the carbon residue which, examined by reflected light, displays the metallic lustre of plumbago, as it does likewise when rubbed between the fingers or on paper.

The silicate portion of the specimen is of dirty white colour, with large patches of pyrites, surrounded by a limonitic coat. The fracture is tough, and the surface very hard, with a considerable number of cleavage planes of silvery white mica. At many points stellate or radiate structure is discernible, much like what we see in certain quartz-bearing rocks.

Microscopically, nearly the whole mass consists of an intimate mixture of grains and deformed crystals of white peridote and white pyroxene, the crystals of the pyroxene becoming larger the farther we recede from the limestone portion. The order

of crystallisation seems to have been first olivine, then pyroxene and mica, and, lastly, the few interspaces are filled by calcite. The peridote, mostly in small rounded grains, assumes a rather marked radial form, and when viewed between crossed nicols, forms one of the most gorgeous rock sections one can see (Figure 200*b*, Plate xv.). The pyroxenes are mostly in moderately large grains, rarely showing any crystalline outlines, and hardly any cleavage planes, which, when present, are most irregular. In fact, it is an extremely difficult matter to distinguish the peridotites from the pyroxenes, the only way being by the angle of extinction, which, in very few cases, can be carried into practice, on account of the absence of crystalline borders. Much of the pyroxene contains more or less of the peridote grains. The same enclosures are met with in the white mica, which rarely shows definite outline. There are a few irregular black patches which may be magnetite, carbon or spinel, though there is little doubt that they should be referred to the spinel. The calcites in the silicate part are finer and polarise in feebler colours, and the lattice structure is less than in the marble part. Here it contains a few scattered colourless grains, with a double refracting crust and anisotropic nucleus, being crystals periclase altered on the surface to brucite.

(336). (Plate xv.) In this specimen, the limestone is white, somewhat chalky, but otherwise resembles that of 54. Between this portion and the silicate part, is a minute greyish finely crystalline band, about one millimetre thick. Adjoining occurs from five to seven centimetres of silicate rock, forming the bulk of the specimen, and consisting of fan-shaped radiating rods of a very light green mineral, interspersed with crystals of grey biotite. A distinct cleavage is discernible parallel to the long axes of the rods. These fans of crystals have their bases *away* from the limestone part, and their lines of growth always towards it with but at a slightly varying angle. That is, they indicate the direction metamorphic action extended. Lastly, we have an agglomeration of minerals almost identical with that of specimen 54, even to the pulverulent light green granular rock and the minute light green rosettes of an indeterminable mineral.

The thin band next the limestone consists of an agglomeration of minute grains of white peridote, the part away from the limestone being of a greenish hue, probably due to an admixture of biotitic material between the grains. In the limestone near this band are a number of outlying grains of peridote, as it were so many outposts, which diminish in number as the distance increases from the silicate portion. At the junction also are brown spots of limonite, probably from decomposed pyrites. The fibrous portion is a peculiar rock, and is not rare amongst

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N.° 200,b.
x 21 diam.

N.° 205.
x 21 diam.

N.° 336.
x 21 diam.

EJECTED BLOCKS OF MONTE SOMMA

the ejected blocks of Monte Somma (Figure 336, Plate xv.). One specimen in my mineral cabinet is traversed by thick veins of galena and traces of garnet, and at certain points small cavities occur into which the terminal rods project as minute crystals less than a millimetre broad. On detaching some of these, and measuring the angles of the prism, the determination of the species as being pyroxene was made certain. Sections of this rock form very beautiful preparations. The large radiating fibres polarise in most brilliant variegated colours, and when rotated between crossed nicols, the extinction sweeps across the field, showing aggregate polarisation. Many crystalline rods give an extinction near pyroxene.

To have an independent judgment I put the minute crystals in the hands of my friend Prof. E. Scacchi, who has taken much trouble to carefully measure them with the following results:—"The crystals examined are very small, their form is indicated in the adjoining figures, of which the upper represents a vertical projection of one of the crystals, and the lower the corresponding horizontal one. Their length is usually about a millimetre, and the greater thickness about $\frac{1}{4}$ of a millimetre. The crystals, according to their symmetry, are monoclinic and the faces met with are as follows:— A (100), B (010), C (001), m (110), n (101), o (111): Of them the most developed are A , m , o , C , e ; whilst the other two, *i.e.* B and n are very minute and often wanting. The faces o , A , m give with the goniometer a good image for measuring the angles, the others give images that are not very clear.

"From the inclinations found one concludes that the crystals are those of pyroxene. In the following table opposite the angles given in the first column, in the second column are the mean value obtained for them from the number of observations in the third column. In the fourth column are the respective values for the angles of pyroxene given by Des Cloiseaux (Manuel de Minéralogie, 1862, pages 52-54). The latter, for convenience, have been reduced to their supplements.

Angles.	Value.	Numbers.	(Des Cloiseaux).
$C : A = 001 : 100$	$74^{\circ} 9'$	4	$ph^1 = 73^{\circ} 59'$
$C : O = 001 : 111$	$33^{\circ} 59'$	2	$pd^1 = 33^{\circ} 50'$
$C : m = 001 : 101$	$79^{\circ} 41'$	2	$pm = 79^{\circ} 23'$
$C : n = 001 : 110$	$31^{\circ} 27'$	1	$pa^1 = 31^{\circ} 23'$
$A : o = 100 : 111$	$53^{\circ} 51'$	2	$h^1d^1 = 53^{\circ} 50'$
$A : m = 100 : 110$	$46^{\circ} 25'$	2	$h^1m = 46^{\circ} 27\frac{1}{2}'$
$A : B = 100 : 010$	$89^{\circ} 57'$	1	$h^1g^1 = 90^{\circ} 0'$
$o : o' = 111 : 111$	$48^{\circ} 37'$	2	$d^1d^1 = 48^{\circ} 33'$

"EUGENIO SCACCHI."

In fact this specimen combines the character of 54 and 200. The rods have very irregular surfaces, and all parts of the same rods do not extinguish at the same angle. The interspaces between the rods and bunches are filled by biotite, and in the latter case this mineral occurs in comparatively large clear crystals of a beautiful well-marked bottle-green colour. Also in a few spaces, small portions of calcite and nepheline (?) occur.

For the remaining part of the specimen, nothing need be said except that the mica prisms show a somewhat radial arrangement, and exhibits, though to a less degree, the same microlithic inclusions as this mineral does in 54.

(49). Is a small specimen consisting of a fine grained grey carbonaceous limestone, a white marble band which contains much white peridote, and while this is most abundant, a band about $\frac{1}{2}$ to 1 centimetre thick of finely crystallised pyroxene. It is only this pyroxene band that gives any particular interest to the specimen, and that is due to the bright pistachio verging on emerald green colour. In two specimens in my mineral cabinet a white limestone contains this variety of pyroxene beautifully crystallised. In this specimen, on account of the

absence of crystalline boundaries to the mineral, the defective cleavage and much internal tension of the crystalline fragments, it might be easily mistaken for peridot.

(337). This specimen consists of the following portions:—About 1 centimetre of white crystalline marble; one and a-half centimetres of a compact, coarse crystalline green band; two to three centimetres of very coarse crystalline rock, consisting of large grains of calcite, three or four millimetres in diameter, with a buffish white granular mineral. Besides these is a small crystal of idocrase and a patch of garnet. Then comes a centimetre of the same rock, with much green mineral and bits of garnet and idocrase. Lastly, we have again the same rock, though much coarser, with less of the green mineral, but with many large crystals, a centimetre or more in diameter of garnet.

Microscopically, the marble portion shows nothing new, but the remainder is very interesting, and may be described in general, as the banding is simply due to the prevalence of the green mineral.

One of the first species that seems to have crystallised has been the white peridot, which has separated out in bunches of flattened prisms, so as to be quite pointed in section, and project into the calcite. This mineral is split up by numerous fissures, filled by a fibrous substance or pilite. On one half of the section that has been etched by weak acid, the surface of the mineral is exposed, and is covered by markings both in colour and lustre, like a layer of dried and cracked gum. Some crystals, however, are very slightly altered or fissured, and they then polarise most brilliantly.

Especially in the green parts are large numbers of crystals and microliths of dark grass-green pyroxene, many of which are perfectly formed, and possess fairly well-marked cleavage. They exhibit a slight amount of pleochroism and polarise—in very strong colours. Their extinction angles are high. They form chains, patches, and form inclusions in all the other minerals, and seem to be the further development of the analogous microliths in specimen 54, &c.

There are a few crystals in the green bands of greenish brown biotite. Very considerable also are the nephelines, which are moderately clear, and in many cases have fairly distinct outlines. The garnets are of light straw colour in section, and are much inter-crystallised with sodalite and peridot, though this last seems to have been the earlier to separate. Neither of these species are mentioned by Mierisch (*loc. cit.* p. 145) as inclusions in garnet. Besides this, the garnets are much zoned, and some of these layers are separated by a stratum

of pyroxene crystals. The garnets show weak double refractions, and have no definite boundaries, so that to the naked eye they seem to graduate into the surrounding rock.

Where the garnets are most abundant, that is, farthest from the limestone, are large grains of sodalite with irregular contours. This mineral is very rich in minute enclosures, which seem to be of the nature of crystalline grains when examined under a high power, though they appear to be isotropic. The calcite grains fill up the interspaces; they show good ribbon and lattice structure.

This rock still shows with sufficient distinctness indications of its original stratification structure. It may be regarded as a more advanced stage of metamorphism of the type of specimen 41, and is one of the most remarkable examples of the passage from a sedimentary limestone to the characteristic mineral aggregates constituting the rich mineral-bearing ejected blocks of Monte Somma, and yet at the same time retains those indications of stratification which is an index guiding our investigations through the obscure and intricate processes of mineral replacement. Another important point about this specimen is that a number of its mineral components have been elaborated from limestone by the introduction of the necessary materials without any local disturbance, and not from detached fragments of lava constituting the druse materials upon which so much stress is laid by Mierisch. In fact, a number of these species were considered by that author to occur only in the druse filling materials. I propose to discuss this question in another paper.

(46). This is a unique specimen of metamorphism with which I have met with at Monte Somma, but it is necessary to describe it, as it may bear some relation to a somewhat similar change in some massive limestones from the same locality. It consists of a series of fine and coarse strata, some consisting of a dirty white, chalky-looking, compact limestone interlaminated with a white translucent material. In this specimen one side has been exposed to percolating waters, which seems to have dissolved away to a less extent, the chalky-looking part, which stands out, and is traversed by numerous open fractures, so as to look quite brecciated. These fractures, however, do not extend into the interior of the mass, which is very hard and tough under the hammer. The white portion seems to have consisted of anhydrite, which, on the surface especially, has become hydrated, and in expanding has split and separated the intervening limestone, giving it the above-mentioned brecciated appearance; at any rate, the intervening alabaster-looking substance, gives the qualitative tests of hydrated calcic sulphate. Near the upper

part of the specimen, the colour becomes slightly grey probably from a small quantity of graphitic carbon.

Microscopically, the rock is seen, with natural light, to be composed of minute grains suspended in an amorphous transparent matrix and collected in strata. In polarised light, however, this apparently homogeneous matrix breaks up into a patchy-looking mass by polarising in various shades of grey in a very thin section. Scattered very sparsely, are a few grains of white peridote, and with a little greater abundance, smaller ones. The presence of this latter mineral, taken together with that of graphitic matter, is sufficient evidence of the metamorphic origin of the composition of this rock, since otherwise it might be supposed to consist of some sedimentary deposit in which calcic sulphate and carbonate had been alternately thrown down.

(51). Is a highly saccharoidal marble, most of the constituent grains being a millimetre in diameter. About half the specimen is white in colour, but exhibits rather markedly fine stratification as indicated by bands of whiter or more opaque colour, which prove, on microscopical examination, to depend on enclosure within and between the calcite grains of white peridote, and minute octahedra of brucite pseudomorphous, after periclase. In the other half of the specimen are well marked bands of brown grey and dirty greenish blue colour. These bands are composed principally of an abundant admixture of periclase and resultant brucite, together with more peridote. The periclase grains rarely exceed an eighteenth or twentieth of a millimetre in diameter, and possess a faint dirty greenish tinge. They remain clear between crossed nicols, but exhibit a granular structure, in consequence of which, they really have been evidently changed to brucite, resulting from their hydration. There is yet another still more interesting metamorphic change that has taken place, for some of the bands suddenly pass from the grey green to a blackish grey colour. This change is seen beneath the microscope to consist of the conversion of the periclase into black spinel. Although the stratum is as well marked in its limits as in the other parts of the specimen, the spinels have been arranged in laminae contorted within itself, a condition not observable in the periclase portion of the same band, which, on the contrary, show parallelism with the planes of stratification. Some of the ex-periclase crystals are stained by limonitic matter, but only in isolated and irregular patches. That the change of the periclase is independent of peridote is proved by treating the rock with not too dilute acid, which dissolves the periclase and its alteration products, but not the peridote grains within the rock. The calcite of this

specimen exhibits rather rarely either ribbon or lattice structure except on that side where the spinel exists, and therefore where the metamorphic action proceeded from, and consequently where it exerted a more powerful influence.

(47.) Resembles much in appearance the last specimen, except that the marble grains are still coarser. It is traversed about its middle by a brownish band which to the naked eye appears to be composed of minute ochreous spots. Microscopically, in the white marbly part, there are a few peridot grains to be seen, but near the coloured band are more numerous, and are accompanied by transparent though granular-looking octahedra, which in ordinary light appear homogeneous, but on crossing the nicols an isotropic black nucleus appears surrounded by an anisotropic crust, so that we can see the gradual conversion of periclase to brucite (Fig. 47, Plate XIV.). In some crystals, under a high power and polarised light, the periclase nucleus is seen to be composed of a trabecular network of that mineral. Treating the rock with dilute HCl, the residue consists of irregular grains of white peridot and octahedra of periclase, which seem to resist the solution, as had been noticed by Cossa in his researches. Some also show minute spots of strong double refraction that leave the suspicion on one's mind that they may in part be changed to peridot. Cossa ("Sulla Predazzite periclasifera del Monte Somma," *Atti d. R. Accad. dei Lincei*, Vol. IV., 2nd series, 1875-1876, p. 3) observed that the somewhat singular rock gave an alkaline reaction and afforded good reasons to show that the magnesia did not exist as a double carbonate with lime. Besides, he pointed out that the rock he examined contained much water of hydration as all the periclase nearly seems to have been converted to brucite.

(50). At first sight, this specimen resembles much No. 48, but looking closer at it, it exhibits a fine granular or feebly saccharoidal rock of dirty white colour, with contorted and faulted bandings in grey. Some of the bands are very coarsely crystalline, or more properly, consist of fissures lined by crystals of humite up to a millimetre in diameter, upon which are posed minute black grains of octahedral form as discernible with a magnifying glass.

Microscopically, we find the mass consists of small grains of dirty calcite, and the smaller dark bands to consist of minute octahedra of periclase, chiefly enveloped in the calcite grains. Many white peridotites occur, scattered throughout the rock, and in some cases enclose the octahedra of periclase within them. Along the larger bands the humite is seen polarising in very brilliant colours, and practically indistinguishable from the

white peridote.¹ The spinels, which seem to be the last formed, are very small and usually badly crystallised. The periclases seem to be little, if at all, altered.

(44). This specimen is perhaps one of the most interesting, it illustrates how metamorphism, acting at right angles to the stratification planes, converts a bedded limestone into one that shows no traces of such mechanical arrangement by the introduction or increase in quantity of many minerals which, associated together, constitute perhaps the largest group of ejected blocks of Monte Somma. At the same time, it exhibits how, in some cases, the formation of Mierisch's zonal structure is quite independent of bedding. The composition of the specimen is as follows: (a) a band of coarse, friable, glistening, white saccharoidal marble, showing by size of grains distinct stratification,—this measures about one and a-half centimetres; (b) the same, but much finer grained,—this measures about three centimetres; (c) the last half centimetre becomes increasingly grey in colour from the presence of periclase and, possibly, peridote; (d) then there is a fibrous-looking band of probably white peridote, followed by more periclase-bearing rock, and then more white marble.

Band (a) passes at one end of the specimen into a very coarse saccharoidal marble. Band (b) is separated from the same material by a thin stratum of periclase-bearing material arranged at right angles to the bedding planes. On the contrary (c) still retains its character farther, but is eventually bent up and lost in the same mass of granular marble, and remaining bands follow the example of (c). Thus we have the well-marked stratified arrangement at one end of the specimen entirely obliterated, and a mineral aggregate representing it without any definite arrangement.

On the opposite side of the specimen this is much more marked, so that the white peridote band seems to have been in a state of fusion and to have been squeezed into the neighbouring mass so as to form a minute dyke. In fact, I strongly suspect that this band is not original but an intrusive one, being forced in as a juice, and setting up chemical changes along its borders, for it is here that the limestone is richest in oxides and silicates. The surface of the specimen towards the metamorphic focus is covered by a thick dark green crust of peridote, spinel, augite (?), and biotite, in the order that it occurs in the walls of drusy limestone as described by Mierisch (*loc. cit.* p. 121).

¹ Mierisch (*loc. cit.* p. 141) found the same difficulty. By isolating some of the grains a fluorine reaction can be easily obtained, and even with very small quantities the micro-chemical test with fluo-silicate of soda I found to be very characteristic.

CONCLUSIONS.

Such are the specimens of stratified limestones which are to serve as clues to the remarkable series of reactions that have converted cretaceous limestones into a series of rocks that, by themselves, one would hardly dare to suppose once to have been nothing more than an impure dolomitic limestone. I do not doubt that it will be argued that changes that occur in such small specimens should not be used as a guide to what occurs in large masses. To this it may be answered that the greater number of chemical phenomena that occur in the mineral world can be studied on the smallest scale in the laboratory. But beyond this these very same metamorphic changes may be traced on a much grander scale amongst the ejected blocks of Monte Somma, and I propose to confirm and extend these few notes in another paper on the massive limestones and their derivatives.

Further, when we extend our investigations to the contact phenomena of such a region as the Tyrol, which are probably of less importance than what is really going on beneath Vesuvius, and from thence pass to areas of regional metamorphism, we are struck by the great similarity in the changes that have taken place. It must, however, be borne in mind that three important factors enter into the question, namely, the composition of the rock to be acted upon, that of the magma acting, and the time, circulation, and quantity of the latter. And equally imperative is it to remember that such rocks which reach the surface by denudation of the overlying materials have been exposed to so many fresh changes as sometimes to be no longer recognisable.

The changes that take place in an impure limestone seem to be, in the first place, the carbonisation of the bituminous contents with the conversion of them into graphite. Almost coincidentally re-crystallisation seems to have taken place, for what was an extremely fine-grained rock begins to approach the saccharoidal structure. This re-arrangement or re-crystallisation seems to have occurred without the rock having become fused, or even pasty, since the most delicate stratification, banding, faulting, and contortion structure is preserved. At this stage a few grains of peridotite begin to make their appearance, chiefly as inclusions within the calcite crystals. The next process is the destruction of the graphite, and in some cases its apparent replacement by peridotite, as in specimen No. 200. In the early stages of carbonisation the graphite exists between the grains, but later gets enclosed within them, as if they had undergone fusion. With the disappearance of the graphite, what remains

is a more or less coarse-grained, dazzling white marble. This saccharoidal marble, containing more or less white peridote, passes somewhat abruptly into a mass of peridote and white pyroxene, wollastonite, or biotite. Why, sometimes it is one or sometimes another mineral that borders on the white marble, I feel inclined to attribute to the impurities in the original limestone in the absence of alumina, with a supply, though limited, of silica, with much lime and magnesia, so that either Forsterite or Monticellite may result, and, if much iron, even true Olivine may separate out. If only silica and lime are present, then we must look for Wollastonite. Likewise, the presence of fluorine may determine the crystallisation of Humite instead of Peridote. In the same way we understand how the other minerals may separate. Now, in a stratified limestone, some bands will be more argillaceous, silicious, ferriferous, or magnesian, or two or more of these impurities may abound, so that in a stratified rock of this kind, the minerals developed in one band will differ from those in another, as is so strikingly shown in specimen No. 41.

This metamorphism is selective only in the early stages, for (as in 36, 54, and 40) we have the silicate bands encroaching upon the intervening marble strata; whilst in 44, the well stratified portion, toward the metamorphosing focus, is fused (?) up into a fairly homogeneous mass of coarser grains and larger crystals of the same minerals as in the undisturbed part, together with the addition of others. Yet that the composition of the bands has a strong determining influence on the results is well illustrated in No. 51.

The order in which the new minerals seem to develop is the following:—

- (1) Peridote, Periclase, Humite.
- (2) Spinel, Mica, Fluorite, Galena, Pyrites, Wollastonite.
- (3) Garnet, Idocrase, Nepheline, Sodalite, Felspar.
- (4) Calcite (secondary).

Although in some cases there is an approach to the order of mineral species found in the druse walls described by Mierisch (*loc. cit.* p. 121), yet these are exceptional, and open up for our investigation a far wider field of facts.

It is evident that any researches as to the purely chemical changes that take place in the process of metamorphism would be useless in stratified limestones unless it were possible to know the composition of each band. It will therefore be better to consider these questions where treating of the massive limestones and their derivatives.

Then also, it is necessary to study the changes that have taken place in the minerals originally replacing the limestone.

We have distinct evidence of the conversion of Periclase into Brucite, and of Peridot to a whitish fibrous mineral or Pilite (?) The Biotite, Nepheline, Felspar (?) and Peridot may be crowded with microliths, which there is good reason to believe consist of Pyroxene.

Another point of interest is that I have not so far noticed the presence of periclase in any rock where graphite could be detected. This might well be explained by the fact that so long as free carbon remained, the magnesia would be maintained as carbonate, and only on its loss of the CO_2 could it take up the SiO_2 to form forsterite, or, with the addition of lime, monticellite; or should silica be absent, to combine with any alumina and to separate as spinel.

Specimen 51 indicates, at any rate, that the latter result is subsequent to the former. Certainly 200 is curious, as showing an apparent displacement of the carbon grains by peridot, although it may be that that mineral simply occupies the spaces left by the disappearing carbon.

It is also necessary at the same time to remember the chemical relationship of carbon and silicon. Another point is, that in all probability the first minerals produced by metamorphism are elaborated from materials contained within the rocks themselves; but eventually other constituents are added, or are removed, by the circulation of water, by vapours, or by diffusion from neighbouring rock masses or igneous magma. Cossa found that he could reproduce periclase by heating for some hours magnesian sulphate and sodic chloride, and obtained still larger crystals by adding a little ferrous sulphate. This, however, is hardly likely to be the process of formation in the rocks beneath Vesuvius. Deville reproduced periclase by acting on magnesia by hydrochloric acid gas, and Daubrée by the action of magnesian chloride on lime. There is good reason to believe that it was by one or both of the latter processes that resulted in the production of periclase in the magnesian limestone, especially when we take into consideration the great abundance of hydrochloric acid and chlorides contained within the neighbouring incandescent lava of Vesuvius. The artificial reproduction of forsterite by Ebelmen probably is a near imitation of what occurred in its natural production.

In fine, we see a definite order of chemical changes occurring in jurassic and cretaceous limestone, which may convert that rock into a granitic mass of crystallised basic silicates and oxides, &c., which may in their turn by decomposition, give rise to a group of rocks in which the original constituents would be represented by serpentine and its varieties, Tremolite, Brucite, &c., an association which prevails amongst metamorphic rocks

that are exposed at the surface by that series of precarious events constituting denudation.

With regard to the removal of the lime in these metamorphosed rocks, Mierisch (*loc. cit.* p. 187) supposes the excess to have been carried off as chloride by fumarolic action, and thinks that the small quantity deposited around fumaroles proof of such being the case. Without laying stress on the latter, we may admit that this is very probable; may it not, however, be that much of the lime is retained in the lava, being utilised in the formation of some or all the lime-bearing crystal components, whilst the HCl would volatilise, as we know it does do, very largely from the volcanic vent.

As Mierisch has to a great extent exhausted the description of the drusy limestones, it is proposed in the next paper to treat of the massive limestones, their alteration, metamorphism, and their derivatives.

EXPLANATION OF PLATES.

PLATE XIII.

Figure 32. Section of altered graphitiferous limestone. Magnif, 24 diameter. Light normal.

Figure 40. Section of metamorphosed limestone showing part of a silicate band, which is here composed chiefly of white pyroxene, a little biotite with all interspaces filled by calcite. Magnif, 24 diameter. Light normal.

Figure 41. Section of metamorphosed limestone. The part shown is the coarse crystalline broad band, in which is enclosed a much fissured crystal of perodite traversed by pilite, and surrounded and enveloped in calcite with well-marked lattice structure. Magnif, 24 diameter. Light normal.

PLATE XIV.

Figure 47. Section of coarse crystalline metamorphosed limestone. The sections show large grains of periclasé (black), surrounded by a crust of breccite. Many small grains of peridotite are visible and distinguishable by their lighter colour: one is seen enclosed within the periclasé crystal just above the centre of the figure. Magnif, 24 diameter. Polarised light, nicols crossed.

Figure 54. Section of silicate part of specimen. The upper portion consists chiefly of biotite clear at the edges, but towards the centre crowded with microliths. One or two prisms of that

mineral free from enclosures are visible in this preparation. The left lower half is composed of the felspar-like mineral remarkably clear, but including an increasing number of microliths towards the edge of the field. At its lower part it includes calcite crystals (seen faintly, whilst a large part, *i.e.*, the clear part) of the right lower half of the field consists of that mineral, though very dirty. Magnif, 24 diameter. Light normal.

Figure 161. Unknown mineral with zoned or fluted structure and microlithic nucleus. Above it are two crystals of peridote (slightly out of focus). Beneath microlithiferous biotite and a bit of nepheline (?). Magnif, 24 diameter. Light polarised, and nicols crossed.

Figure 200. Taken from the white marble part close to the grey portion. Large calcite grains, with well-marked lattice structure and cleavage planes, enclosing white peridote and graphite grains, either separately or the former enclosing the latter. Magnif, 24 diameter. Light normal.

PLATE XV.

Figure 200b. Silicate part of specimen. This preparation shows the grains of peridote without definite crystalline form, but arranged in a radiate form around nuclei, two of which are seen in the figure. Magnif, 24 diameter. Light normal.

Figure 205. Bituminous limestone traversed by veins of white calcite, and composed almost entirely of minute shells and forameniferae. Two nautiloid ones are very clearly seen to the left and downwards from the centre of the figure. To the right is seen in section a comparatively large trochiform shell. Magnif, 24 diameter. Light normal.

Figure 336. Fibrous pyroxene. The spaces between the fibres is principally filled by biotite, seen as patches of medium tint. Also vacant spaces are visible. Observe the irregular and broken up structure of the fibres. Magnif, 24 diameter. Light normal.