THE SEDIMENTARY, METAMORPHIC, AND IGNEOUS ROCKS OF ENSAY.

BY

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Art. XI.—*The Sedimentary, Metamorphic, and Igneous Rocks of Ensay.*

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Section I.—Introduction.

In describing the rock formations of Swift's Creek and Noyang, I have treated of the intrusive areas which border the extensive tract of the metamorphic schists of Omeo. A Swift's Creek the intrusion of the plutonic rocks was at the very outside verge of the metamorphic schists, so that on one side the invasive igneous masses were in contact with the fine-grained mica schists of the Omeo series, and on the other with Silurian sediments, which are in places converted into varieties of hornfels. At Noyang the case is similar. The quartz-mica diorites and porphyrites of that locality are on their northern limits bounded by sedimentary rocks, which show metamorphic alterations approaching to mica schist; on the southern boundary of the intrusive rocks there are Silurian sediments converted into hornfels; so that, although the features are not so marked as at Swift's Creek, this area is clearly one of those which, as I have elsewhere pointed out, border the southern and eastern margin of the so-called regional metamorphic schists of the Omeo district.

In this paper I leave the tracts exterior to the metamorphic region, and enter upon the consideration of an area within it, wherein occurs a series of peculiar rocks, which not only differ from those which I have described as "contact schists," but which are in some respects peculiar, even when compared with the so-called "regional schists" of Omeo.

There is to be seen at the junction of the Haunted Stream with the Tambo River a part of the northern contact of the quartz-mica diorite group with the Silurian sediments. I have already elsewhere described this, and I now only refer to it as a convenient starting-point for a new departure.

In following up the Tambo River from its junction with the Haunted Stream the valley contracts between high and barren mountains, whose spurs interlock so much that it is equally difficult to travel, whether on the mountain sides, the banks of the river, or its bed. At a distance of about five miles in a direct line from the Haunted Stream the hills on the eastern side of the river suddenly become lower, their contours smoother, and the vegetation changes favourably with the change of formation. It is here that the Silurian sediments give place, on the eastern side, to intrusive and schistose rocks. At this place I observed that the schists have the character of phyllites, approaching to fine-grained silky mica schist, and not that of hornfels, as at Noyang. They resemble, therefore, the least metamorphosed examples of the Omeo schists; and I may say that here is their margin, in probably its most southern extension. The course of the Tambo River from Swift's Creek junction to this place is generally south; and it is to be observed that on the western side there are high, rough, and barren ranges of more or less metamorphosed Silurian rocks, rising steeply at a little distance from the river, which, however, flows over varieties of massive holocrystalline intrusive rocks of the quartz-diorite group. On the eastern side of the river the country is much lower than on the western side, and it is only at a distance of from seven to eight miles that it again rises into high mountains, such as Mt. Nukong or the northern peak of Mt. Elizabeth. This wide extent includes the watersheds of several streams, of which the Little River is the most considerable. Wherever I have traced up the courses of these streams I have found, with slight exceptions, as at the Little River and Watts Creek at Ensay, that they are over massive intrusive rocks. It is therefore to be noticed that in the stream-beds which show the deepest sections there are only to be seen holocrystalline rocks, while on the summits of some of the ranges there are traces of schistose and sedimentary formations.

In this part of the Tambo Valley I again find broadly those features to which I drew attention when speaking of the physical geology of Noyang. The river divides the regions of sedimentary from those of igneous rocks. Physical features such as these are found in other parts of the district, and are not confined to the Tambo River Valley.

Section II.—Analytical Examination of the Rocks.

In the area which I propose to describe in this paper there are but few sedimentary rocks in the immediate vicinity of

Ensay. Their great display is on the western side of the Tambo River, and thence to Castle Hill, which is the termination in that direction of the section accompanying this paper. They there occur in wide tracts, broken in places by the exposure through denudation of intrusive quartz diorites. The only part of the western moiety of the section which now needs any special reference is that portion which is at the western side of the Tambo, and where the Silurian sediments are well shown.

The Silurian rocks at this place are highly inclined at angles between 70° and 90° dipping to S. 20° to 30° W. This formation is continuous to Mt. Baldhead westward, and northward to the Gum Forest, which is part of the Swift's Creek intrusive area.

On descending from these hills towards the river the boundary of the invasive rocks is reached, at an elevation of about 300 feet above the stream, but the actual contact is not visible on the line of section.

I collected a number of samples of these sediments, and examined them, with following results. Speaking generally, they fall into two classes, representing the normal argillaceous and quartzose Silurian beds; but they differ from them, in so far that they have all been more or less metamorphosed.

Of the collected samples, I selected two for special examination. That which represents the argillaceous sediments is a minutely-spotted schistose rock, inclined to slaty cleavage, of a greenish-grey colour, a slightly silky lustre, and with here and there minute plates of alkali-mica, to be seen under the pocket lens in the otherwise crypto-crystalline mass of the foliations.

Under the microscope, thin slices of this rock showed that it is composed of two kinds of mica, together with granules of quartz and some black material (opacite). The spots are entirely composed of minute flakes of colourless alkali-mica, with some black material. The main mass of the rock is a mixture of the two micas, of which the second is a brown, magnesia-iron mica, which in places predominates, just as the alkali-mica does in others. The difference between the two, however, is that the brown mica occurs in the mass of the rock, and also radiates from the exterior of the spots. The quartz is in minute rounded grains. Here and there I observed colourless rod-like microliths, which must be apatite, and also rather stout colourless microliths, with oblique terminations. These have the form of tourmaline;

but I did not find them so pleochroic as I should have expected them to be.

I made a quantitative analysis of this sample, which I subjoin:—

No. 1.—Phyllite.

P_2O_5	·13
$Si.O_2$	56·33
$Al._2O_3$	22·94
$Fe._2O_3$	2·19
$Fe.O$	4·54
$Mn.O$	·tr.
$Ca.O$	·25
$Mg.O$	3·27
K_2O	6·10
$Na._2O$	·88
H_2O	3·87
	100·50
Hygroscopic moisture ...	·80
Sp. grav.	2·75

Allowing for the P_2O_5 and a corresponding amount of Ca.O as apatite, and for Fe_2O_3 and H_2O as hydrated iron ore, which in parts forms thin coatings in the rock, there remain the proportions of 1·877 Mol. $Si.O_2$, ·445 Mol. R_2O_3, ·293 Mol. R.O., and ·547 Mol. R_2O, which very nearly close when calculated as alkali-mica, magnesia-mica, and quartz, giving a proportion of 1·5 : 1·5 : 1, respectively; or of mica to quartz as 3 to 1.

The second sample which I selected for examination and analysis represents the sandstones. As seen in thin slices this rock has an approach to foliation; but this foliation also coincides with the planes of deposit. It is made up of a large number of angular grains of quartz, set in a groundmass of smaller quartz granules, together with a few grains of triclinic felspar, and, relatively, a considerable amount of micaceous material. In this rock the quartz grains have a tendency to lie with their longer diameters parallel to the obscure foliation of the rock.

The felspar fragments are of two kinds. One is comparatively fresh in appearance, and it is compound in structure, and with low obscuration angles. The other is dull looking, is simple in structure, and has the appearance of the orthoclase found in granitic rocks.* These felspars of both kinds are original clastic grains, and not regenerated by metamorphic action. They are just such as I have frequently observed in the Silurian sandstones of the district.

The quartz grains are of different sizes, but as a rule they have all their longer directions arranged one way, and linear to each other. This arrangement I find in ordinary sandstones of the district, and is partly due to the process of bedding; but in this case it has, I think, been increased by pressure during the mechanical movements of the rocks. Moreover, some grains have been broken across in directions perpendicular to the foliation. The quartz grains vary both as to the amount and nature of their inclusions. Some are almost free from any, others have bands of fluid cavities, and again others are full, not only of fluid cavities, but also of microliths. The intersticial material representing that which at one time was mud is now wholly converted into mica, partly in scales, but also here and there in well-marked flakes. This micaceous material forms foliations separating the quartz grains.

The quartz grains of these rocks are evidently of clastic origin, but I have observed cases where secondary quartz has been added to them, so that I could with difficulty say where the original grain ceased.

The quantitative analysis of this rock was as follows:—

No. 2.—Quartzose Phyllite.

$Si.O_2$	77·50
$Al._2O_3$	13·11
$Fe._2O_3$	1·62
$Ca.O$	·82
$Mg.O$	·98
K_2O	2·32
$Na._2O$	2·64
H_2O	2·08
	101·07
Hygroscopic moisture ...	·50
Sp. grav.	2·665

* I use the word "granitic" merely as a convenient term of description, implying no more than that the rock in question has the crystalline-granular appearance of the granites, quartz-mica diorites, granitites, &c.

This analysis may be calculated, after allowing for the ferric hydrate, as being of the composition of 1·995 Mol. free quartz, ·856 Mol. magnesia-mica, and ·400 Mol. alkali-mica, which is nearly in the proportion of 5 : 2 : 1; but in this calculation the small amount of triclinic felspar is disregarded.

As I have before said, it is extremely rare to find even traces of sedimentary rocks on the eastern side of this part of the Tambo River; that is to say, which can be determined at first sight as being such. There are nowhere those tracts of alternating argillaceous and arenaceous beds tilted at high angles, and otherwise showing the familiar facies of the Silurians of North Gippsland. Those schistose rocks on the eastern side which can be determined as more or less completely metamorphosed sediments are of limited extent, are much broken and disturbed, and in places so much involved with intrusive igneous rocks, and so greatly crystallised, that it becomes extremely difficult to determine whether certain samples are to be looked upon as the completely metamorphosed sediments, or as some of the schistose varieties of the intrusive masses. Such instances I have seen on the southern crest of Contentment Hill, where they adjoin well-marked examples of the holocrystalline quartz diorites of the character I have so frequently described as occurring in this district. The schists are so much broken up, that I was not able to find any portions so indisputably *in situ* that I could ascertain their dip or strike. Their actual contact with the quartz diorites may also be partly due to faulting. Although these rocks have a general resemblance among themselves, I observed on examination that there are two varieties at least—one resembling an indurated and much and minutely contorted argillite, the other having a more pronounced schistose structure. The former variety I found, when examined in a thin slice, to be much silicified, and with the argillaceous material converted into minute scales and flakes of mica, some of which, when examined by a high power, were fibrous. In these micaceous foliations there is black granular material, much of which, but not all, is removed, together with ochreous infiltrations, by digestion of the slice in hydrochloric acid. The quartz foliations are in places peculiar, for the crystalline grains of which they are formed are so arranged as to meet in the plane between the foliations of mica in the manner in which quartz crystals can be seen to form a gangue in some lodes.

This quartz contains very numerous fluid cavities without bubbles.

This rock has been so much crushed and contorted that the foliations are in places reverted over each other.

The second variety which I examined I found to be much more complex, and to show changes approaching to the condition of a minutely-foliated gneiss. The proportion between the quartz and the other component minerals is much more equal in this than in the last-described example. The rock is foliated, and the main part consists of micaceous materials mixed with quartz grains and enclosing minute crystals, which can scarcely be anything else than orthoclase; at any rate, they are not andalusite.

There are also some minute pinite pseudomorphs after this felspar. The quartz occurs in very numerous interlocking granules, which form foliations, and also veins, branching from one to the other across the micaceous foliations.

These rocks, although still bearing much the outward appearance of sediments, prove upon microscopic examination to have been so altered as to be almost within the bounds of the group of metamorphic schists of Ensay.

The only other remaining traces of rocks which can be referred to the less altered sediments rather than to the schists are at the sources of the Watts Creek, or rather, to be more correct, a little beyond them, where the track from Ensay to Gellingall crosses a small stream before rising on to the divide which falls to the Wilkinson River. I could not find these rocks *in situ*, but only as fragments in the bed of the stream, the sides of the hills being there covered with soil. So far as I am able to judge, I think that these sediments adjoin a diabase mass on the west side, and may therefore have been subject to two separate metamorphisms—first, in common with all the sediments of the district, and second, by the diabase.

The samples in this instance represent, as elsewhere, the argillaceous and the arenaceous sediments, and I now give the results of their examination.

The first example consists mainly of a micaceous mineral, having a fibrous structure, and thus resembling sericite-mica in appearance and in its reaction with polarised light. It is colourless, or of a pale greenish tint, where not stained by iron ochre. In some of the foliations the small masses have their fibres parallel to each other, whilst in others they are twisted and lie across each other in a felted manner. In rare cases the mineral is inclined to form plates resembling an alkali-mica. In this mass there are minute crystals of what I believe to be magnetite.

The second example is more quartzose, being a mixture of a yellowish micaceous mineral in irregularly-shaped overlapping plates and scales, together with quartz grains. Some of these latter are free from cavities, while others contain them in great numbers, so that one may conclude that there are two generations of them, one being probably original, clastic grains and the other secondary and metamorphic. The rock is much stained by infiltrated iron ore.

Besides these there are fragments of rock lying on the hillside which have a remarkable amount of a soft silvery mineral in small scales and plates showing on their planes of separation. This rock was too soft and decomposed to admit of being prepared satisfactorily as a thin slice, but the examination which I could make led me to the conclusion that it is a decomposed metamorphosed sediment containing much talc in minute scales on the planes of foliation.

In the plan which I have laid down for this present work, I now return to the line of section on the western side of the Tambo River. It was more convenient to take those rocks together which could be at all considered as being within the sedimentary group, without reference to their position in or near the line of section which I am describing. But in treating of the metamorphic schists, and of the igneous rocks connected with them, this plan would not be satisfactory, for they are so intimately mixed that it would only confuse were I to attempt to select the instances of each group separately. I shall therefore now take the rocks which I noted for observation in the section as they follow each other, leaving to later on the task of summarising the respective and characteristic features of each group.

In proceeding eastwards towards the junction of the Little River and the Tambo, from the contact with the sediments on the west side of the latter river, no rocks are met with *in situ* until it is reached, where there are unmistakable examples of massive quartz-mica diorites in its bed. At the junction of the Little River there is a mass of a red-coloured crystalline granular rock, composed of reddish felspar, quartz, and some chloritised magnesia-mica. This rock is allied to the aplites, which I shall note later on as of very frequent occurrence at Ensay.

About half-way between the junction of the Little River and Tambo and the crossing of the Omeo-road over the former there is a massive, rather light-coloured rock in the bed and on the banks of the stream. It is composed of felspars, quartz, some chlorite and apatite. The chlorite is probably derived from hornblende, for I observed a portion of that mineral in one case still intact. The chlorite is of the character usual in the massive rocks of this district, markedly dichroic in shades of green, and apparently filling the place of some other mineral (hornblende) of the first consolidation. In this chlorite there is always more or less epidote, but not those minute black needles or minute rods of iron ore which here almost always accompany the chloritisation of iron magnesia-mica.

The felspars are very much altered, being filled with flakes of mica and plates of chlorite, but enough remains of them intact to show that they were triclinic. The quartz is very plentiful in rather small grains, either singly or in interlocking groups. The apatite is in unusually stout crystals, some of which have been broken across.

Part of this rock has a micro-crystalline appearance, and I found it to be largely composed of colourless epidote granules and quartz, with traces of chlorite. The mass included a few triclinic felspars. This micro-crystalline portion of the rock resembles epidosite, and is analogous to the numerous similar veins which are to be seen in the rocks at Ensay.

The main rock is a much altered quartz diorite, of a slightly different type to the massive intrusive rock of the district. It has less quartz, and was, I think, compounded with hornblende, and not with mica.

My description now brings me to those rocks which I have separated from the sediments; that is to say, to the metamorphic schists of Ensay. It might be said that some examples which I have just described as belonging to the sedimentary group should be placed among the schists—as, for instance, the phyllites of Contentment Hill. Certainly those rocks are so metamorphosed that their argillaceous components are converted into mica; but, on the other hand, they have not lost their microscopic structure to any great extent. They are but one or two stages in advance of the sediments on the western side of the Tambo, and it has seemed to me best to draw the line there, and to count all the formations which are more schistose with the metamorphic group. Indeed, the phyllites stand between the argillites and the mica schists, and pass over into each of them.

The Ensay schists are of a peculiar character, occurring nowhere, so far as my investigations have shown me, at more than perhaps a mile, or at the outside a mile and a half, distant from the junction of Watts Creek with the Little River. There are three marked varieties—quartzose-schist, pinite-schist, and gneiss—to the latter being added some examples which are, unless examined on the large scale, apparently crystalline granular. The two former represent the arenaceous and argillaceous sediments, and the latter the same in a more completely metamorphosed condition.

The first of these schists occurs on the line of section about 20 chains before reaching the crossing of the Omeo-road over the Little River, at a low cliff at the mouth of a small rill from Ramrod Flat. They are bedded, and strike about N. 45° W., being vertical in position. One set of joints traverses them, dipping N. 60° W.; and a dyke of diabase porphyrite, with accessory amphibol, scarcely distinguishable from No. 37, described at page 100, about 3 feet in width, crosses them, dipping in the same direction as the joints.

This schist is porphyritic, by reason of orthoclase nodules forming "eyes" within the foliations, and there are also irregular veins of felspar and quartz. The main mass of the bed which I selected as typical is composed mainly of pinite, which is pearly or silvery on the face of the foliations, thus resembling the lustre of the basal planes of some pinite pseudomorphs. The cross fractures of the foliations are pale olive-green in colour, with a serpentinous appearance. In places there is a good deal of brown magnesia-mica forming part of the foliations.

To obtain a correct mental picture of this schist as a whole, it would require a large number of thin slices to average the composition. The sample which I selected represented the mass fairly. Excluding the orthoclase nodules and the veins of orthoclase and quartz, I found it to be composed almost entirely of pinite material, together with numerous divergent groups of colourless talc-plates. I also observed that the felspars had been involved in the alteration, for I found a portion of orthoclase of the micro-perthite structure still remaining intact in the centre, whilst externally the alteration to pinite was complete. In addition to these constituents there is also a little magnesia-mica and its chloritic alterations, together with a considerable amount of quartz, making up the remainder of the rock.

This rock is one of the characteristic schists of the district, and in its unaltered condition must have been a gneiss rich in magnesia-mica.

A quantitative analysis of this sample gave me the following results :—

No. 3.—Metamorphic Gneiss.

P_2O_5	·10
$Si.O_2$	55·94
$Al._2O_3$	23·39
$Fe._2O_3$	·45
$Fe.O$	4·69
$Ca.O$	·81
$Mg.O$	3·58
K_2O	6·98
$Na._2O$	1·45
H_2O	3·60
	100·99
Hygroscopic moisture ...	·43
Sp. grav.	2·777

Not far up stream from this place the river-bed becomes rocky, and affords an admirable study of the formations. From this spot I made a careful examination of the successive rock-masses for some distance, both up the Little River and Watts Creek. In order to fully note and illustrate the peculiar features of these rocks, I shall now describe them with some fulness. The numbers given refer to those upon the accompanying plan, Plate I.

1.—These schists are much distorted, and contain irregular quartz foliations. The foliations of the schist appear to coincide with former planes of deposit, and strike N. 35° to 40° W. Under the microscope this rock proves to be a quartzose schist, with a little triclinic felspar, two kinds of mica, and some pinite masses. The quartz forms foliations of irregularly-shaped grains.

The felspar is also in irregularly-shaped grains, resembling fragments of crystals. They are numerously compounded, and have the appearance of albite or oligoclase, and those obscuration angles which I could measure were low, being in the zone $OP - \infty \bar{P} \infty$ from 4° to 12°. These felspars are remarkably clear and fresh.

The two kinds of mica are associated together, one being a brown dichroic magnesia-mica, and the other a colourless alkali-mica. The latter is least in amount, and the former is partly converted into a pale-coloured chlorite, which is not very dichroic. This mica shows signs of being crushed, so that the folia are in places partly separated from each other. Where it has been completely chloritised innumerable minute black needles have been formed.

These two micas and the pinite form foliations separating the compound of quartz and felspar. I defer a more extended description of the pinite until I reach that part from which I obtained those typical examples, of one of which I give a quantitative analysis.

Adjoining these schists there is a mass of crystalline granular rock, which extends to 2. It is composed of the following minerals in their order of consolidation :—

(a) Large, simple crystals of felspar, with straight obscuration, which are much worn, or cavernous in places, or even broken or crushed. *(b)* Smaller polysynthetic felspars, with more perfect crystalline forms. These seem to be oligoclase. Some of them are of less size than the others, and all of them are later in consolidation than those before-mentioned. The alteration of all the felspars is micaceous, and in all of them there is a little viridite. *(c)* Chlorite, which seems to be the alteration product of mica. It is associated with epidote. Here the whole of the mica has been converted. *(d)* Quartz in rather large grains, being the residual component.

At 2 the crystalline-granular rocks are joined by a narrow band of schist, which is followed by a vein of pegmatite, or coarse aplite, beyond which the schists again extend to 3.

I examined a sample of the narrow band of schist, and found it to be composed of triclinic felspars, mica, pinite, and other alteration products, and quartz. The felspars and quartz, as in the former schist, form foliations separated by the mica, chlorite, and pinite. As before, the obscuration angles of the felspar are low.

The pegmatite vein is very light-coloured, approaching white, and can be seen microscopically to be composed of large, irregularly-shaped felspar crystals and grains of quartz. The latter have interfered with each other in crystallising, but conform to the outlines of the former. The felspar has, in places, straight obscuration, but the crystals do not obscure homogeneously, but in different parts successively. In the basal section of these felspars I observed numerous minute wedge-shaped crystals, arranged parallel, and perpendicular to the plane of symmetry. The larger ones I could see were twinned, and in places groups of these crystals suggested the grated appearance of microcline. As inclusions, there are also a few crystals of triclinic felspar and grains of quartz. These latter have rounded sides, and have much the appearance of pre-existing crystals enclosed in the felspar.

The quartz is in large masses, and is full of minute fluid cavities massed together or in layers.

The only other constituent is a colourless alkali-mica in small amount when compared with the quartz and felspar. Rarely it occurs in the felspar itself.

The schists, which recommence at 3, and extend thence to 4, are very characteristic. In saying that they are schistose, it must not be supposed that the foliations are either wide or strongly marked. On the contrary, in all the rocks of this kind the foliations are often very narrow, and only indicated to the eye by irregular stripes, differing from each other more or less in colour. The rock thus resembles in appearance some of the schistose varieties of hornfels. These remarks apply, however, only to the foliations of the mass of the rock, which seem to represent the original planes of deposition; and I may here note that where I found these foliations most regular they had a strike near that of the normal sediments of the district. They do not apply to the foliations of quartz or of crystalline-granular texture, which are a marked feature here. The term foliation is indeed often inapplicable to these, for I have observed that they frequently run, not only with the foliations of the rock, but also across them at all angles. The quartz veins are just such as are so commonly to be seen in the Omeo district in places where there is a passage from the sediments to the schists, and I have now come to look upon them as an unfailing indication of metamorphic alterations. The veins of crystalline-granular materials are more irregular than those of quartz. They not only run with or across the foliations, but also appear as isolated masses in them. No doubt this appearance of isolation may lead to the belief that portions of the schists have suffered complete metamorphism and recrystallisation, but I am now confident that such is not a true explanation of those cases, at least, where the line of separation between them and the schists is marked. When, however, one passes into the other, as I shall show later on, at p. 79, it is different. In the cases of which I am now speaking, I believe these apparently isolated masses are connected below with other veins and masses of intrusive kind. Such veins, therefore, as a whole, form a branching network, whose meshes are filled with schists or other rocks. Veins of this kind are clearly intrusive, while the quartz veins have been deposited from solutions probably during metamorphic processes. I give in fig. 1, Plate III., a rough sketch of part of this schist-mass, showing the features I have above spoken of. At 4 there is again a sudden change to crystalline-granular rocks resembling those at 1 to 2, extending to 5, with traces here and there of a schistose structure.

Similar rocks extend to 6, where there are massive crystalline-granular rocks, with joints dipping S. 45° W. at about 80°. I found this rock to be a holocrystalline compound of felspar, quartz, chlorite, with traces of black mica. The mica is very ragged and worn in appearance, and extensively converted into chlorite, together with colourless epidote granules. It is evidently the first formed of the constituent minerals; but beyond this all that can be said is that it has the character of the black iron-magnesia micas of the quartz-mica diorites of the district.

The felspars are next in order of generation, and are of two kinds, one most probably orthoclase, the other triclinic, and of a very compound structure. The quartz, which is the latest in order of formation, is in interlocking grains, filling in and conforming to the interspaces of the other minerals. This rock therefore belongs to the quartz-mica diorites, and is part of the invasive plutonic masses.

Adjoining this massive rock there is, again, a band of schist similar to those already described. The crystalline-granular rocks again reappear at 7, with two sets of joints, one dipping S. 60° E. at about 80°, the other vertical on a strike of S. 25° W. Crossing these rocks at 8 is a dyke of micro-porphyritic basalt about 5 to 6 feet in width, dipping S. 15° W. at 70°.

I found this basalt to have a ground-mass of numerous small triclinic felspar prisms crossing each other in all directions, and thus forming a network, in the meshes of which are numerous grains of yellowish augite, together with crystals of magnetite, either singly or forming characteristic groups. In this ground-mass are porphyritic crystals of serpentinised olivine and larger ones of colourless augite.

The crystalline-granular rocks, in a much jointed condition, extend to 9. Some of them are fine-grained; some coarser, and of a red or salmon colour. They are traversed by veins of pegmatite or coarse aplite, and also by compact veins of epidosite. I examined a sample of the fine-grained variety, which I found to be a crystalline-granular compound of felspar and quartz in nearly equal amounts, together with some brown magnesia-mica. The latter was first formed, and is extremely ragged, twisted, and, in places, much chloritised. It has a little magnetite associated with it. The felspars are of two kinds, somewhat large, very much eroded, even cavernous, crystals of orthoclase, and less-wasted, or even almost well-formed, crystals of plagioclase. The quartz fills in spaces. I have no doubt that this rock is intrusive.

From 9 to 10 similar rocks extend, where then commence some contorted schists, having in one place fibrolite and quartz as a lenticular foliation. These schists cease at 11, where they are cut across by a dyke dipping S. 10° W. at about 70°. This dyke is micro-porphyritic. It has a micro-crystalline ground-mass approaching to cryptocrystalline. This is composed of minute crystals of some mineral which I cannot further determine than by saying that it may be felspar. Besides these there are some crystals of magnetite and minute grains of augite. In this mass there are numerous small porphyritic colourless crystals of augite. Frequently these crystals are broken, and their fragments separated by the ground-mass. In other places several of these crystals form groups. This rock seems to stand among the diabases, very near to diabase-porphyrite.

The schists extend to 12, but towards that spot their foliation is less well-marked. They then give place to crystalline-granular rocks like those I have described between 5 and 6, and they contain patches of much-contorted schist. The schists then recommence. In places there is an alteration of schistose and crystalline-granular structure, very suggestive of a process of recrystallisation. I have attempted to give a representation of this appearance in fig. 3 of Plate III., but I fear not successfully. The passage from one structure to the other is more gradual than I have been able to delineate. I prepared slices of part of this rock. Under the microscope I found it to have obscure traces of schistose structure in a linear arrangement of the minerals. It is composed of rounded crystals of triclinic felspars and numerous angular grains of felspar and quartz; there are also magnesia-mica, chlorite, and small masses and veins of pinite. The felspars are in preponderance. The larger number are triclinic, and of first consolidation. Many of them are extraordinarily worn and eroded.

The chlorite is pale in colour, and but slightly dichroic, and is the alteration-product of a brown magnesia-mica, portions of which are still remaining. The quartz is the residual constituent in very numerous interlocking grains.

At 14 the schists become much distorted, and have coarse, and also fine-grained, crystalline-granular veins and foliations, which in places preponderate over the schist itself. From 14 to 15 there are no rocks visible in the stream, but they reappear at 15, which is close to the ford. The rocks at this place are very siliceous, grey or greenish-grey coloured, often much contorted schists, showing minute plates of a silvery alkali-mica here and there on the foliations. They also contain crystalline-granular foliations, and small masses of red felspar, quartz, and magnesia-mica, or chlorite, and in places also plates of a silvery alkali-mica. These schists are also crossed by strings and patches of quartz.

I examined, both microscopically and chemically, a sample of a schistose rock close to 15, and of which I have given a rough sketch on Plate III., fig. 2.

The schistose part is mainly composed of angular grains of felspar, and still more angular grains of quartz, which fill in all the spaces, and interlock with each other, like a puzzle-map. Parts of the mass are occupied by pinite pseudomorphs, after some mineral of which now not even the smallest unaltered portion remains. The schistose structure of this rock is marked by the winding, yet linear, arrangement of the plates of mica (and its alteration to chlorite), and successive patches of pinite, connected by veins of the same. The felspars are of two kinds. One is simple, having the appearance of orthoclase, and a good deal altered to mica and pinite; the other is a triclinic felspar, of an appearance suggesting oligoclase, as do also its low angles of obscuration, of which I obtained several measurements.

The mica is in small, ragged-sided crystals, and, so far as one can judge from its colour, and from the pale and only slightly dichroic chlorite which results from its alteration, it is a magnesia-mica, in which that base preponderates over iron.

No. 4.—Quartz-Schist.

$Si.O_2$	74·27
$Al._2O_3$	13·14
$Fe._2O_3$	1·01
$Fe.O$	2·11
$Ca.O$	1·33
$Mg.O$	2·56
K_2O	1·49
$Na._2O$	2·91
H_2O	2·13
	100·95

Hygroscopic moisture ...	·28
Specific gravity	2·85

I have not attempted to calculate the mineral percentages in this schist. Without knowing the composition of the alteration-products in it, the results to be so obtained would be, in a great measure, hypothetical.

The coarsely crystalline part of this rock (*b* in sketch) is a crystalline-granular compound of reddish felspar, quartz, chlorite, and alkali-mica. Under the microscope I found it to be as follows:—

The felspars are mostly triclinic, with low obscuration angles. None are perfect in form, but they are broken rather than rounded off. They give evidence of force with which they have been driven against each other during the movement of the mass. The felspars are much altered to mica, some of the plates being of sufficient size to be examined under the microscope, and I found them to react in all respects like one of the alkali-micas.

Some few of these felspars are not striated, and may possibly be orthoclase.

Chlorite occurs, representing magnesia-mica, and there is an alkali-mica, both in aggregates of small scales and in larger crystals.

The quartz is filled with innumerable minute fluid cavities, without bubbles, and also with greenish microliths, in flakes, whose nature I am unable to conjecture, unless they are chlorite.

I observed, also, as showing the mechanical changes which have occurred in this rock, that several crystals of felspar had been broken across in the same line, together with the interstitial quartz between them. The fissure thus formed had then been filled by a new generation of quartz grains, forming a wedge-shaped vein. In this secondary quartz there are very numerous minute and well-formed crystals of chlorite, of the variety which has been called Helminth, from its curious resemblance to larval forms.

Some of these crystals are geniculated, and show both the basal and prismatic planes. They are not strongly dich in shades of green to colourless.

I have mentioned the numerous crystalline-granular veins which traverse the schists at this place. I prepared a slice of one at the junction of Watts Creek. It is composed as follows :—(*a*) Felspars which are almost all triclinic and of very polysynthetic structure; none have any external planes remaining, but are broken and eroded in a great degree. Some of the felspars are much larger than others, and there are also mere fragments in the interspaces. The composition is mostly according to the Albite law, and the obscuration angles are low, being in the zone $OP - \infty \bar{P} \infty$ between 4° and 12°. (*b*) Chlorite chrystals after mica in small amount. (*c*) Quartz in considerable amount filling in all spaces.

This vein is a variety of aplite.

A second example from another vein here is, as seen in the hand specimen, a mixture of reddish felspar, quartz, and a little chlorite, with rarely plates of alkali-mica. In a thin slice I observed : (*a*) Very irregularly-shaped and broken crystals of orthoclase, which include a few rounded quartz grains ; (*b*) a lesser number of triclinic felspars ; (*c*) a very little chlorite after magnesia-mica ; (*d*) quartz as the residual mineral. The felspars are all more or less altered to mica, and the ultimate result seems to be pinite pseudomorphs, with some alkali-mica.

This rock is also an aplite.

I now proceed to trace up the Little River for a short distance before following Watts Creek, which lies along the course of the descriptive section.

Above the ford and on the south bank of the Little River (marked 16 on the plan), there are rocks which have characters intermediate between the schists which I have described and the other more massive metamorphic rocks. They are in places crystalline-granular, and in others schistose. They are much jointed, and also traversed by veins and strings of quartz, and contain some foliation, such as these I have already described, composed of reddish felspar quartz and a little mica or chlorite. As is commonly the case in the schists at this place, pinite is plentiful in small dark olive-green to blackish-green masses, and less frequently hexagonal crystals. The sample which I examined from 16 is a light-coloured crystalline compound of felspar, mica, chlorite, quartz, and apatite, with some pinite. The felspars are better formed crystals than is usually the case in these massive schists. They are all more or less altered to pinite, small masses of which are connected by veins running between the other constituent minerals. The magnesia-mica is ragged-sided, and in places crushed, and appears to be the first formed mineral of this rock. It has been much chloritised in the manner which I have already described. Crystalline-granular epidote is associated with the chlorite, and also occurs elsewhere in small spaces between other minerals. The quartz fills in spaces as the latest formed of the constituents.

This rock is one of the massive varieties of the schists, but in this sample shows scarcely any traces of foliation.

In following up the river from this place, there are small cliffs of rock on the left-hand side which approach in character some of the crystalline-granular, and some of the schistose examples which I have now described.

At 17 the rocks are crystalline granular, but contain lenticular patches, such as I have spoken of as occurring also in the schists; one of these I observed to be composed of fibrolite and quartz.

At 18 the schists again show adjoining the crystalline-granular rocks. They are much contorted and are reticulated with veins of red felspar, quartz, and pinite, or of quartz and pinite only. It was at this spot that I collected the samples of pinite for examination and analysis. The pinite veins are between schist foliations, and thin out at each end.

The colour of this pinite is dark green to greenish black at the edges, or in thin splinters it is slightly translucent. It is massive, or with a sub-micaceous cleavage, when the mineral occurs in stout prisms. The lustre is waxy, excepting when there is an imperfect basal cleavage, when it approaches a light pinchbeck colour. Hardness 2 to 2·5. Before the blowpipe it fuses in splinters to a grey enamel. The streak and powder are greyish white. It is partly decomposed by hydrochloric acid.

I found a few individuals showing crystalline planes, and the most perfect one which I could extract from the quartz-gangue was a stout prism, about ·5 x ·25 inches across the base, with the planes

$$OP\ (001),\ \infty P\ (\cdot 110),\ \infty Pn.\ (hko),\ \infty P \infty\ (100).$$

These planes were imperfect and with rough surfaces, excepting the basal pinnacoid, which, as usual, had a smooth surface and a somewhat sub-metallic lustre. The prismatic angles were near 120° and 60°.

These particulars indicate that this pinite is a pseudomorph after cordierite, but I cannot feel sure that all the other examples which I extracted from this vein were alterations of the same mineral species; and still more must this be doubtful as to pinite found in the rocks, for the numerous thin slices which I have prepared of the Ensay Rocks * show that other minerals have been pinitised, notably the felspars, and most probably also magnesia-mica, very extensively.

I found this pinite, when examined under the microscope, in a thin slice parallel to the basal cleavage, to have aggregate polarisation almost uniformly throughout, but in places there were small clear portions which obscured homogeneously. Numerous cracks traverse it, along which iron ochre has been deposited. In places connected with these cracks small divergent groups of colourless talc-plates have been formed. When examined by ordinary light, and with a high power, the slice is seen to be full of microliths, there being stout, somewhat short fibres, some straight and some curved. In places these are almost "felted." In other places they are grouped together.

A slice parallel to the prism was somewhat different to the one just described. A large part of this is homogeneous, and has straight obscuration parallel and perpendicular to the basal cleavage. This mineral is colourless and very faintly dichroic, the ray vibrating parallel to the axis $\overset{|}{c}$ being colourless, and the other (either $\breve{a}$ or $\bar{b}$) being pale yellow. The remainder of the slice shows aggregate polarisation, and iron ochre stains parts adjoining cracks. With a high power I observed the same short fibres arranged linearly parallel with the basal cleavage in those parts which have aggregate polarisation, but not in the homogeneous colourless

* I prepared seventy thin slices of the Ensay Rocks for the purposes of this paper.

parts. This sample shows clearly that the pinite of this vein has, in fact, resulted from the alteration of cordierite.

In order to gain some further insight into the composition of this pinite, and into the mode of its occurrence in this vein, I prepared a thin slice. Under the microscope this is seen to be composed of pinite individuals, quartz, and some alkali-mica. The pinite has, in some instances, when seen by polarised light, a peculiar meshed appearance, resembling that of serpentine. I have observed the same in samples of pinite from Bodenmais, in Bavaria, and Schneeberg and Aue, in Saxony. This kind of alteration proceeds evidently from the cleavages and cracks inwards. With a high power, all that I could make out, in addition to that which I have already said, was that some of the pinite is made up of minute colourless flakes, which are in places contorted and twisted together. In other places very numerous, yellowish-coloured, thornlike microliths occur in the basal sections, at all horizontal angles to each other.

The pinite individuals are evidently not all in the same state of change. In some there are still remaining portions of the unaltered cordierite, whilst others are so completely altered as to have only aggregate polarisation. In some there are included grains of quartz or plates of alkali-mica, and the latter almost always borders the pinite, and extends beyond into flaws which traverse the quartz. Magnesia-mica in chlorite pseudomorphs is only present in very small amount.

The quartz is full of fluid cavities, some of which have small bubbles.

The following is a quantitative analysis of a sample collected from this vein :—

No. 5.—Pinite.

$Si.O_2$	46·16
$Al._2O_3$	32·23
$Fe.O$	3·34
$Mn.O$	·01
$Ca.O$	·50
$Mg.O$	2·66
K_2O	8·75
$Na._2O$	·56
H_2O	5·08
	99·29

Hygroscopic moisture ...	1·67
Sp. grav.	2·756

Pinite is not a mineral of definite mineral composition. The numerous published analyses show this, while at the same time there is a general resemblance in the percentages given. The microscopical examination of the Ensay mineral shows that it has two varieties of structure : one which is compounded of minute scales, together with larger flakes of a colourless mica; the other somewhat resembles serpentine in its "meshed" appearance. Taking this as a basis, the following calculation may be made of the probable constituent minerals of this pinite :—

		Molicular Ratio.
Alkali-mica—	$Si.O_2$	1·252
	$Al._2O_3$	·626
	K_2O	·186
	$Na._2O$	·018
	H_2O	·422
		2·504

This leaves for the second constituent of the pinite the following :—

	Molicular Ratio.
$Si.O_2$	·325
$Fe.O$	·093
$Ca.O$	·018
$Mg.O$	·133
H_2O	·081
	·650

This calculation very nearly closes, leaving a deficiency of H_2O of ·061 Mol., and a surplus of $Si.O_2$ of ·039 Mol. If the interpretation is correct, the second mineral must be a massive talc, and the two minerals would be in the proportion of talc to alkali-mica as 1 to 3·85, or about 17 per cent. of the former, to 83 per cent. of the latter. I must, however, point out that, although the sample was collected within the space of a few inches, there was a slight perceptible difference between some of the pieces, showing that even in so short a distance there was probably some slight difference in composition. Either the colour varied in shade, or there was a difference in the completeness of the basal cleavage.

At 19 the rocks are again crystalline-granular and of two varieties. One is of finer texture than the other. The coarser-grained variety consists of felspar and quartz in nearly equal amount, with a very little brown magnesia-mica. A marked feature in this rock, as seen in a thin slice, is the angular and eroded appearance of the felspars. Some are mere remains of crystals. The larger individuals, which are also those which are most eroded, have the appearance of orthoclase. They include some small crystals of triclinic felspar. The remainder of the felspars are smaller in size, and are plagioclase. The quartz has not any peculiar features, and in appearance is like that of the intrusive rocks of the district.

The finer-grained variety, which is much intermixed with the coarser, is a micro-crystalline granular compound of felspar and quartz, with a good deal of brown mica in scattered flakes. The felspars are all in angular fragments, and, to judge from their structure and from their low obscuration angles, one of the more acid of the soda-lime group. They are very clear and unaltered. Besides these, there are other and larger porphyritic crystals, less numerously compounded than the others, being either Carlsbad twins, or else this combined with a few lamellæ according to the Pericline law.

This rock is traversed by very fine-grained light-coloured veins. I have before said that such veins are commonly to be seen in the Ensay Rocks, more especially the intrusive ones. This sample is composed almost wholly of almost colourless epidote in characteristic crystals, and also in masses of crystalline grains, the remainder of the mass being made up of quartz. The larger epidote crystals are in the centre of the vein, and the granular mixture of quartz and epidote is at the sides. Isolated epidote crystals occur in the rock bounding the vein.

These crystalline-granular rocks extend to 21, where is a binary compound of felspar and quartz, which at 20 contains portions of contorted schists, together with patches of coarser materials, such as I have described before.

Beyond this place the rocks to be seen in tracing the Little River up to the contact of the intrusive massive rock, which is near the Ensay homestead, are schists. Some have a massive character, while others are like much-altered phyllites. In order to learn something of the character of these schists, I prepared slices both of the schistose and the massive types.

Here, as elsewhere, two kinds of schist can be distinguished, one representing the arenaceous and the other the argillaceous sediments. I found a sample of the former to be composed of irregular foliations of quartz and felspar, mica and pinite. The micaceous foliations are comparatively narrow, and are in places mere partings. The quartzose foliations are made up of grains of quartz, which are in most cases, as seen in the thin slice, much longer than wide. As these grains can be seen in the slice to overlap, it is evident that they represent small discoidal or lenticular masses lying with their flat sides parallel to the foliations. Some of the quartz foliations bifurcate and again combine, enclosing micaceous portions.

The quartz is full of minute fluid cavities, some of which contain bubbles. Of inclusions there are few, and these are oval colourless to brown microliths and colourless minute rods or prisms, which are probably apatite.

The felspar grains are few in number, and as they are unstriated I consider them to be orthoclase, which in other respects they resemble. They are kaolinised and contain minute flakes of viridite. These felspar grains only occur in the quartz foliations.

The micaceous foliations are narrow, but in places widen out to "bulges," and include grains of quartz. Under a high objective the mica is seen to be of a light-brown colour and to be pleochroic. Much of this mica is chloritised.

The argillaceous variety I found to be composed of alternating foliations of quartz and of mica. This mica is partly in scales and partly in ragged fibrous flakes. There is also some chlorite.

The quartz grains are angular, and are arranged in a linear manner, thus forming foliations. They contain very numerous fluid cavities, with bubbles, and in parts many colourless minute prisms or needles of apatite, which throughout the slice all lie in, approximately, the same direction, parallel to the foliations.

This rock resembles the last described, but the proportion between the quartzose and micaceous materials is reversed. The magnesia-mica in this rock has also a distinctly fibrous structure, and is associated also with alkali-mica, which I did not observe in the other. In places the mica and quartz form a confused aggregate, and not foliations.

These rocks, it seems to me, have been completely recrystallised, for I am unable to satisfy myself that any of the quartz grains are of clastic origin; yet I can feel no doubt, after the extended examination which I have now made of the Ensay Rocks, that these schists were once sediments.

These two examples are from 22, and represent the schistose types. It yet remains to examine the massive variety. For this purpose I prepared slices of two samples—one collected at 23, and the other at 24.

The former is a compound of angular grains of quartz, brown mica, and micaceous alteration-products, in about equal amounts. I cannot say what the micaceous aggregates may represent, unless felspars, of which there is no trace in the slice. The mica is brown and pleochroic, and it is partly converted into a rather pale and not very dichroic chlorite, with the elimination of iron, in needle-like crystals. When examined by a high objective I find that the micaceous aggregates are full of minute stout, straight, or curved microliths. I might call them stout fibres, similar to those which I have spoken of finding in the pinite. In places these are arranged linearly, or in linear groups, so that they produce a fibrous effect.

The quartz grains are of two kinds—one which contains very numerous colourless hair-like microliths, the other without them. Where the microliths are absent there seem to be many more fluid cavities. This may, perhaps, indicate two generations of quartz grains.

The second sample is from the massive bedded schists at 24. Under the microscope it is seen to be composed of small masses, having aggregate polarisation, such as occur also in the last-described rock. There are also spaces filled by pinite; and a rudely foliated structure is produced by the association together of these with a little brown magnesia-mica, colourless alkali-mica, and divergent fan-shaped tufts of talc.

The quartz grains are numerous, and generally scattered irregularly in the mass, but also more or less lying between the foliations.

There are no felspars to be seen in this sample, but it may be that they have been wholly converted into the micaceous aggregates of the foliations.

At the spot marked 25 upon the plan there is a strong dyke having a meridianal strike. It probably extends much further to the north, for there is an outcrop of a similar but somewhat altered dyke close to the Ensay homestead, and, as it seems to me, in the line of strike of this one. To the southward, also, there is another dyke of the same kind close to the Omeo-road. These three occurrences, I suspect, are either of one and the same dyke or of separate dykes in the same strike.

The dyke-stone is greenish-grey in colour, with a compact ground-mass with porphyritic long-bladed crystals of hornblende, which are now much chloritised. In places there are also hexagonal crystals of chlorite after magnesia-mica.

Under the microscope this rock has a ground-mass containing a little yellowish-coloured basis, but the greater part is a micro-crystalline aggregate of felspar and quartz in grains. Throughout this ground-mass there is a good deal of chlorite in minute flakes and fibres. The ground-mass contains—(*a*) Rather large rectangular crystals of titanic iron, which all show more or less alteration to Leucoxen. Some of these crystals are what I can only describe as skeleton crystals, having partly-formed bounding planes, including ground-mass. (2) Eroded quartz crystals, which include magma. (3) Long-bladed, light-coloured crystals of amphibol, with broken terminations. They are pleochroic in shades of green. Intergrown with this amphibol, but on only a small scale, is a fibrous rhombic pyroxene, which is dichroic in shades of brown.

The alteration of the amphibol is to chlorite. The felspars are altered to a great extent to granular materials, which, together with flakes of viridite, make up most of their substance; but traces remain of their former structure, which show that they were triclinic. This rock is therefore a variety of quartz-diorite.

I now return to the junction of Watts Creek and the Little River, in order to complete the description of the rocks seen in tracing up the former stream in the line of the general section.

From the junction of Watts Creek to the spot marked 26 there are continuous outcrops of schistose and igneous rocks, intermixed more or less. The latter are mostly as veins, with the characters of aplite. At 26 there is a mass of schists with numerous foliations of quartz and small masses or irregular veins of mixed felspar and quartz, up to 6 inches in width. The schists resemble those which I have mentioned, and described at 1, but are more altered.

At 27 occurs another patch of much-contorted and winding vertical schists, but having perhaps an average strike to N.

20° W. These schists also resemble those at 1, but have suffered more alteration in so far that in places the schistose structure is almost obliterated in the finely crystalline-granular mass, with quartz foliations, quartz veins, and veins of felspar and quartz traversing it.

I found a thin slice, which I prepared from one of the most altered of the foliations in which the schistose structure was not quite lost, to be composed of innumerable grains of quartz fitting into each other and into the other minerals like a puzzle-map. Among the quartz grains some are much longer in the direction of the foliated structure than in the other, and in some of these I observed to be included small rounded grains of quartz. It has suggested itself to me that in these included grains one may perhaps recognise the remains of the former clastic quartz grains of the sediments, and in the larger ones surrounding them secondary quartz, deposited during the metamorphic processes. This view would require that the original quartz of the sediments should, under such conditions, have been dissolved and re-deposited. I shall later on return to this question, when considering the principal and characteristic features of the Ensay Rocks, which I am now describing in detail.

The mainly siliceous mass of this rock is rudely parted into foliations by irregular masses and connecting veins of pinite, with a little brownish magnesia-mica, and its resulting alteration to chlorite, which, as in other cases, has eliminated ores of iron, to be re-deposited in the basal section of the chlorite in the form of minute opaque black needles, crossing each other approximately at angles of 60° and 120°.

There are also felspars, as angular grains, some of which are orthoclase and others plagioclase. The former are much altered, and in places completely, to pinite. The latter are comparatively fresh, the only change which I observed being the production of flakes of mica along cracks and cleavage planes. These triclinic felspars are very compound, according to the Albite law, and their low obscuration angles suggest albite or oligoclase.

At 28 occurs another outcrop of schists which have some interesting features. Taken as a whole they are not siliceous, but belong in great part to that section of the group which I have spoken of before as pinite schist.

The schists are very much contorted, and are penetrated by veins of felspar and quartz, and also of crystalline-granular materials.

The strike of the schists is probably about N. 10° W., and the veins are intrusive.

I prepared examples of the two varieties of this schist, one siliceous and the other pinite. The former is grey in colour, with a tinge of olive-green. In the hand specimen one can see that the quartzose foliations are separated by narrow partings of basic materials. Under the microscope I observed it to be a schistose compound of quartz, felspars, two kinds of mica, pinite, and chlorite. The felspars are in angular grains, and are all triclinic, with low obscuration angles. The measurements which I made in the zone $OP - \infty \bar{P} \infty$ were between 1° 30′ and 11° 30′. The micas are magnesia and alkali micas, which in many cases are associated together. The former is much chloritised, but where intact the dichroism is not strong. The pinite occurs in irregularly-shaped masses. The quartz grains are such as I have before described in these schists, and make up by far the larger part of the rock.

The second variety examined is a pinite schist with quartz grains.

The pinite forms foliations separated more or less by irregular continuous partings of magnesia-mica with some alkali-mica. The pinite has the same appearance under the microscope which I have already described, but a few additional remarks may be made with advantage. In slices parallel to the foliations it has aggregate polarisation, and in places also a "meshed" structure, resembling that of serpentine. No unaltered parts of any original mineral remain, but in place there are what seem to be pseudomorphs after cordierite. When examined by ordinary light, and with a power of about 55 linear, such individuals are seen to be made up principally of minute bent and twisted flakes, which, as seen edgeways, have the appearance of fibres. The larger ones react like an alkali-mica.

In a slice across the foliations the pinite had a much more serpentinous appearance, the meshed structure being more marked.

The magnesia-mica is brown in tint, and not very pleochroic. It is very much intergrown with alkali-mica, not only by alternations, but also by the juxtaposition of the two micas. The quartz is in isolated rounded grains, almost in all cases in the micaceous foliations, and but rarely in the pinite.

In one slice I observed a patch of a colourless or grey fibrous mass. The fibres formed long-bladed crystals; or it might be said that the fibres were in bundles, and these lay across each other at acute angles, thus forming an approach to a radial aggregate. It has straight obscuration, and very much resembles pyrophyllite. Talc also occurs in divergent scales.

A little higher up the creek, at 29, there is another outcrop of similar schists, of which I examined the pinite variety both optically and chemically.

As seen in a hand specimen, the foliations have in them numerous small silvery scales, which yield to the nail, and have the appearance of talc. On a cross fracture the rock has a greenish tint, and at the edges is slightly translucent. The hardness of the rock is from 2· to 3·.

Under the microscope it proves to be a confused mixture of pinite material, magnesia-mica, alkali-mica, talc, and grains of quartz. The pinite does not differ from that just described. The magnesia-mica is here and there intergrown with alkali-mica, and is much altered to a pale-coloured chlorite. The quartz is in isolated rounded grains.

Subjoined is the quantitative analysis of this sample :—

No. 6.—Pinite Schist.

P_2O_5	·tr.
$Si.O_2$	45·72
$Al._2O_3$	24·31
$Fe._2O_3$	4·72
$Fe.O$	7·32
$Ca.O$	·61
$Mg.O$	4·27
K_2O	6·47
$Na._2O$	·77
H_2O	5·83
	100·02

Hygroscopic moisture ...	1·33
Sp. grav.	2·78

Without some more definite knowledge as to the constitution of the different minerals in this schist, it would be merely haphazard to attempt to calculate the percentages.

The analysis shows a marked resemblance to that of the pinite given at p. 85; and perhaps this much may be ventured upon, that the main part of the rock is composed of pinite. In this view, I have applied the name Pinite-schist to it.

From here the rocks seen in following up Watts Creek are less schistose, and more crystalline-granular. Of the former, some are so massive that it is only when looking at them *in situ* that their schistose character becomes evident, the hand specimens seeming to be crystalline-granular or porphyritic. Some schists have the structure of "Augengneiss."

I collected samples of the typical rocks which I observed at the place indicated, as before, in the map by numbers, up to the place at which undoubted invasive rocks appear—that is to say, where it is possible to place the contact boundary of the Ensay schists.

30.—There is here a mass of pale, flesh-coloured crystalline-granular rock, composed of reddish felspar and quartz, with very rare plates of alkali-mica. Under the microscope I determined it to have the following composition:—(*a*) Felspars. The most prominent felspar is orthoclase in much-wasted and eroded crystals, which obscured successively in different parts after the manner of the potassa felspars of some pegmatites. The second felspar is triclinic in crystals, compounded according to the Albite law. These are also very cavernous. The angles of obscuration which I could measure in the zone $OP — \infty \bar{P} \infty$ were low, being between 1° and 14°, and in a section approximately near $\infty \breve{P} \infty$ 19° 30′. This felspar seems, from these observations, to be oligoclase.

There is a very little chlorite and a few flakes of alkali-mica, and the remainder of the rock is made up of quartz granules.

This rock is an aplite, and, according to its appearance *in situ*, would have been formerly described as Eurite.

I also examined a similar rock near at hand. It resembled the one just described, with this exception, that it contained a rather larger amount of chlorite after mica, and that some of the felspars were pinitised.

In both examples the felspars, as also the residual quartz, contained small quartz grains.

The marked feature of these rocks, as also of others of the same class at Ensay, is the wasted and cavernous condition of the felspars.

31.—A massive, rather fine-grained, aplite occurs here. It is composed of reddish felspar, quartz, and a little magnesia-mica. It is traversed by east and west joints. Following it, and continuing up to 32, are coarsely foliated schists, with pinite. The partings of these rocks strike N. 20° W., and in places the schistose structure is very evident.

At 33 there is an outcrop of rocks which, it seemed to me, fairly represent the most completely metamorphosed schists in this part of Watts Creek, in which not only the sedimentary but also the more foliated schistose structure has been obliterated.

I found it to be composed of large felspars, mica, and quartz. The felspars are of two varieties. One is in large, ill-formed crystals, or, more properly, crystalline masses, in which the obscuration indicated orthoclase. One instance had veinlets of a second felspar included in it, as is the case with orthoclase perthites. These felspars are not uniformly altered, being in places kaolinised, and in others converted more or less into pinite and mica.

The other felspar is in smaller and more perfectly developed crystals. It is very compound, and the obscuration angles which I could measure I found to be in the zone $OP - \infty \bar{P} \infty$ between 1° 45′ and 16° 30′, suggestive of oligoclase.

The magnesia-mica is almost wholly chloritised, and it is associated with rounded, or nearly rectangular, pinite pseudomorphs. Alkali-mica is also present, accompanying the pinite.

The quartz is residual, filling in spaces, in rather large interlocking grains.

The microscopic examination of this rock shows that its features are those rather of the massive schists than of the intrusive rocks. The orthoclase felspars resemble those of the pegmatite contact veins; the magnesia-mica is poorer in iron than that of the intrusive rocks which I have examined, and the pinite pseudomorphs are just such as those I have already described.

Rocks which are somewhat more distinctly schistose extend to 34 on a strike north, where they again become more massive, and adjoin aplites.

These massive schists are in places porphyritic by reason of small masses of felspar and quartz, or of one or other, which form the centres of bulges in the schist foliations. In other respects a sample of this rock, when examined under the microscope, did not differ materially from that which I have just described.

35.—At this place the rocks are distinctly crystalline-granular, having a "granitic" appearance. They are traversed by winding veins of a reddish-coloured aplite, and by narrow veins of epidosite.

I examined samples of these two rocks. A slice of one of the most "granitic" samples I found to be a holocrystalline rock, formed of triclinic felspars, quartz, and chlorite. The last-named mineral is in large, ragged masses, of precisely the character of the chlorite after the Haughtonite mica of Noyang. The original mica is now all converted, but I can feel no doubt that it was the first-formed mineral after magnetite. The felspars came next in order of consolidation. They are in very compound crystals, with higher obscuration angles than any which I have had to record yet in this paper. I made measurements in the zone $OP— \infty \bar{P} \infty$, between 3° 30′ and 30° 30′, and in one section which was near the plane $\infty \breve{P} \infty$, the angle was as high as 40°. In this section, which was otherwise simple, there were a few short twin lamellæ interposed in one corner, not precisely in accordance with the Pericline law.

The quartz was last formed, and differed in no respect from that of the quartz-mica diorites of the district. A slice from a second sample from this place shows a well-marked crystalline-granular compound of felspar, with much dark-coloured hornblende and chlorite and some quartz. The first-formed constituent is hornblende, in very much wasted and cavernous crystals, which are in all cases more or less chloritised or replaced by crystalline masses of epidote. The felspars followed next in order of consolidation, mostly triclinic, but with a very few individuals of orthoclase. The triclinic felspars are not well bounded by crystalline planes, but are very compound, according to the Albite law, and also in some instances again after the Carlsbad and Pericline laws. The obscuration measurements were not satisfactory, but two in the zone $OP— \infty \bar{P} \infty$ were 13° 30′ and 30° respectively. The triclinic felspars in these rocks seem to be of the Labradorite group.

These rocks are clearly quartz-mica diorites, and also the first of what I may call the normal intrusive rocks of the district, which I have had to describe in following this section from Ensay.

The aplite veins which traverse these rocks are reddish in colour, and rather compact in appearance, showing in places a little grey-coloured quartz. They are themselves traversed by very small veins, almost mere partings of epidosite.

The felspar of the sample which I examined is mainly orthoclase, in large irregularly-formed masses rather than crystals, including quartz grains. This felspar is orthoclase. A second felspar is in few small and broken crystals, many of which are much wasted. There is a very little magnesia-iron mica, and the remainder of the rock is made up of quartz grains.

I made a quantitative analysis of this rock for comparison.

No. 7.—Aplite.

$Si.O_2$	75·74
$Al._2O_3$	12·45
$Fe._2O_3$	1·02
$Ca.O$	1·00
$Mg.O$	·08
$K_2.O$	6·77
$Na_2.O$	2·91
$H_2.O$	·33
	100·30

Hygroscopic moisture ... .47
Sp. grav. ... ... 2·635

In calculating the mineral percentages of this rock, I have kept in view the small amounts of epidote unavoidably included in the sample, the traces of magnesia-mica, and the hydrated iron ore which colours the rock. Allowing for these, there remain only constituents of the felspars, the surplus $Si.O_2$ representing free quartz.

On this basis a calculation is practicable which gives a result of felspar to quartz as ... ... 2· to 1·

Or, Orthoclase	41·80
Albite	25·72
Quartz	32·48
	100·00

In this are disregarded the amount of about 4 per cent. of the rock, which is composed of epidote, magnesia-mica, and ferric-hydrate.

At this place there is a strong diabase dyke which crosses the creek bed. The rock is much altered, most of the groundmass being serpentinised, and in the remainder chlorite has been produced together with very numerous minute colourless rounded grains with rough surfaces, which are doubly refracting, and which I think are epidote. The marked features of this rock, as seen in a thin slice, are the amount of unaltered augite in colourless or slightly reddish stout crystals, and also the paucity of felspars. The augite obscures up to angles of 36°.

36.—At this place there appears a typical example of the massive intrusive rocks of the district, and it is here that, I think, must be placed the approximate contact boundary between them and the metamorphic schists.

For the purpose of comparison, I have made a quantitative analysis of this rock, as well as examined it in a thin slice. Under the microscope I find that it consists of the following minerals, noted in their order of consolidation:—Amphibol is in cavernous crystals, which are pleochroic in shades of yellow to dark-green, the several rays being—c, dark green; > b, dull green; > a, yellow. The angle $c : C$ I found in a section near to $\infty \grave{P} \infty$ to be 26° 45′, and in a second, 29°. These angles are very high, but the characteristic prismatic cleavage of very nearly 124° 30′, and the strong pleochroism of the mineral, leaves no doubt as to its being amphibol. Mica is in ragged and crushed crystals, which in the slice become translucent in dark shades of yellow; macroscopically, they are black and shining. It is dichroic in shades of yellow to nearly black, and in places is intergrown with the amphibol. There are traces of chloritisation of this mica, which commence at the outside and follow the plates unequally. This mica contrasts with that of the schists by its large percentage of iron, which is evidenced by its more marked pleochroism; also by that of its resulting chlorite. It is probably, as is that of the Noyang quartz-mica diorites, a Haughtonite.

The felspars are all triclinic. There may have been two generations, if it is possible to draw such an inference from the observation that some felspars are very much broken and worn away at the sides, while others are tolerably well developed and intact. I obtained some fairly satisfactory measurements of the obscuration angles. Taking those which were in the zone $OP - \infty\bar{P}\infty$, I had measurements of 8° 30′, 14°, 18°, 20°, and 30°, and there were four sections which were approximately in accordance with $\infty\breve{P}\infty$, in which the measurements were 14° 45′, 15°, 16°, and 19°, but two other similar sections gave me angles of 28° and 35°. respectively. These angles cannot well indicate a felspar more acid than a Labradorite. The crystals are compounded, some after the Albite law, some after both it and the Carlsbad law. In some individuals zonal growth is well shown. The alteration of all these felspars is micaceous.

Quartz is in considerable amount, and of the usual character of that found in the massive holocrystalline quartz diorites.

The subjoined is a quantitative analysis of this rock :—

No. 8.—Quartz-Mica Diorite.

$Ti.O_2$	·tr.
P_2O_5	·tr.
$Si.O_2$	62·43
$Al._2O_3$	17·88
$Fe._2O_3$	1·78
$Fe.O$	3·53
$Ca.O$	3·43
$Mg.O$	4·50
K_2O	2·75
$Na._2O$	3·10
H_2O	1·37
	100·77

Hygroscopic moisture ... ·315
Sp. grav. ... ... 2·74

At this place the schists, which have been the special objects of this paper, cease. That is to say, there are from here onwards up the course of Watts Creek only here and there traces of schistose rocks, the whole tract being occupied with massive intrusive rocks. Of these I shall note a few examples as illustrating this part of the section, before proceeding to briefly note some rocks which occur in the latter part before it terminates on the eastern side of the Tambarra River.

In the upper part of Watts Creek there are numerous examples of intrusive dykes. Some are quartz porphyrites, others are basic dykes, which can only be distinguished from each other by means of microscopic examination. One such, which in appearance would formerly have been classed as Aphanite, I found to be a Diabase porphyrite, having a ground-mass of light-brown basis, and exceedingly numerous minute lathlike felspars. In this are short and isolated stout prismatic crystals or groups of crystals of an almost colourless augite, and a few large serpentine pseudomorphs, which may have been olivine, but which have not the marked rhombic outlines so frequently found with this mineral.

37.—This sample is taken from a mass of rock which fills up the whole bed of Watts Creek, at a distance of about half a mile from 36. It is composed of orthoclase, a little plagioclase, some chlorite and quartz, and a considerable amount of pinite material, with its usually associated alkali-mica. The felspars have been, as in many of the Ensay Rocks, considerably broken and crushed. I feel myself unable to determine whether this is a completely metamorphosed schist or an intrusive rock. Judging from its appearance *in situ* I incline to the latter belief.

Near this place there is a pegmatite vein composed of cleavable masses of yellowish felspar, glassy-looking quartz, and silvery alkali-mica; in fact, a typical example of a very common class of veins, which occur in the Omeo district in connection with the metamorphic schists, and less frequently in other parts of the mountains where there are contact schists of the hornfels type.

The felspar in this vein is in cleavable masses up to three inches in diameter. and I collected an example of it for both microscopic and chemical analysis.

I prepared several thin slices in three directions, from pieces struck from the most marked cleavage (OP), from others from the less perfect cleavage $\infty \breve{P} \infty$, and thirdly from slices as nearly perpendicular to those two directions as I could prepare them.

Sections prepared from the most perfect cleavage show a main felspar mass, which is, however, not homogeneous throughout. It becomes obscured in different parts as the slice is slowly rotated between the crossed nicols; but these areas are not sharply defined, but it is rather that the obscuration passes like a cloud from one part to the other. The limits of this variation in the obscuration angle I found to be about 2° 30′; for observations varied in different parts of the slice from 6° to 8° 30′ as referred to the trace of the second cleavage.

Numerous veinlets of a second felspar traverse the main mass approximately at right angles to the above-mentioned cleavage, and thus may be considered to agree in position with the macroaxis. This is further shown by their extreme irregularity in width, being in parts mere threads, and in others bulging out into small masses. Some veins bifurcate and others run out. This irregularity of structure is, I think, connected with the difficult separation of the felspar in the direction of the macropinnacoid. This second felspar is sharply twinned parallel to the edge $OP - \infty \breve{P} \infty$, and obscures on either side of that direction at angles, as measured in different parts of different slices from the same sample, of from 30′ to 3°.

I have attempted to show the structure of the felspars as I have now described it in fig. 4, Plate IV.

In the slices prepared from pieces of the second cleavage I found the same two felspars. The main mass obscured in the same partial manner as in the basal sections at angles which differed by 2°. These observations, as referred to traces of the basal cleavage, were from 6° 30′ to 8° 30′. Traversing the main mass there are veinlets of the second felspar, which are here also very irregular, both in width and extent, as will be seen from the sketch given in fig. 5, Plate II. As referred to the traces of the basal cleavage in the slice, the inclination of these veinlets was 63° from the direction of the axis c. These veinlets, therefore, follow the direction of the macropinnacoid, and, as I have said, their extreme irregularity conforms with the obscure cleavage in that direction. This second felspar obscured in different parts of the same slice at from 15° to 18°, as referred to the trace of the basal cleavage.

In one slice I observed some fine lines of a felspar which obscured at a position of the slice different to that of either of the others. I did not find it practicable to measure its obscuration angle, owing to the extreme thinness of the lamellæ. It may be, however, conjectured as being oligoclase, to which also the small percentage of Ca.O. in the analysis points.

The slices cut perpendicular to the planes OP and $\infty \breve{P} \infty$ showed, as might be forecast, features in conformity with the structure I have described. The main felspar obscured at angles as referred to the trace of the less perfect cleavage of 6° 30′ to 9°, thus agreeing fairly with the other observations, taking into the consideration that the slices were not precisely true to the intended direction. The second felspar showed in these slices in much larger amount than in those of either of the other directions, no doubt, owing to the slight angle which the slice formed with the veinlets. It is sharply twinned in very numerous lamellæ, the obscuration angles of which are from 10° to 14° on either side of the composition face.

In addition to this form of twinning, according to the Albite law, I also observed a number of twinned crystals, seldom compounded of more than two members, which were interposed according to the Pericline law. These crystals occurred singly or several near to each other, and their terminal planes were sharply marked, while the others were usually irregularly bounded by the walls of the veins themselves.

The only other inclusions which I observed in this felspar were a few small quartz grains, and several small divergent masses of talc plates. This felspar is entirely in accordance, in its characters, with the felspars which I have collected and examined from similar veins at Omeo, and in other parts of the district.

The main felspar does not obscure in the basal section parallel to the edge P.M. It is therefore not monoclinic; and this is also further shown by the inclination which I find the cleavage faces always have to each other. It has not the extinction angle usually given for microcline; but I have observed that in felspars such as this the angle is not a constant one, and I therefore class with microcline all those potassa felspars which are triclinic in form, although their obscuration angles may, as in this case, be less than 15° 30′. The second felspar is evidently albite; and the very small amount of the third felspar may, with fair probability of correctness, be designated as oligoclase. The felspar, as a whole, is a microcline-perthite.

The abnormal structure of this felspar, as indicated by the variation in the angles of extinction, shows quite clearly how very disturbed the conditions were under which these pegmatite veins were formed, in connection with metamorphic action. The great constancy with which these irregularities of structure occur in felspars of this kind in different localities, shows, moreover, that the processes of formation have also some degree of uniformity in their action.

I carried out a quantitative analysis of this sample, with the following results :—

No. 9.—Microcline-Perthite.

$Si.O_2$	63·55
$Al._2O_3$	20·36
$Fe._2O_3$	·tr
$Ca.O$	·35
$Mg.O$	·20
K_2O	12·00
$Na._2O$	3·52
H_2O	·52
	100·50
Hygroscopic moisture	·31
Sp. grav.	2·573

The $Mg.O$ and some of the H_2O in the above can be referred to talc, a few flakes of which occur in the sample. Some of the combined water belongs to kaolinised parts of the felspar. Disregarding these extraneous constituents, the remainder can be calculated out as potassa, soda, and lime felspars, in the molicular proportions of 2·040, ·904, and ·052 respectively. The last probably represents the third felspar, which I have mentioned as being determinable in the thin slices. Assuming it to be an oligoclase, and to have a normal constitution—for instance, of Alb. 3 to An. 1—I may then say, with some reasonable probability of being not far from the truth, that this microcline-perthite is composed of microcline, albite, and oligoclase, in the proportions of 10 : 3·6 : 1· nearly; or, taking the two latter felspars together, the proportion between microcline and albite, + oligoclase, would be nearly as 2 : 1.

This fairly agrees with the mental conception which I have formed by an inspection of the thin slices under the microscope. The sketches given in Plate IV. differ from this in so far that, as I intentionally selected a part of each slice in which the albite veins were more strongly formed than elsewhere, a false proportion between the two felspars may seem to be indicated.

Still further up Watts Creek from the contact I found some interesting massive crystalline-granular rocks, which are worth notice as being of a type which is occasionally, though rarely, met with in the intrusive areas of this district. The rock is exceedingly tough, and difficult to prepare as a thin slice. Under the microscope I found it to be composed of felspar and amphibol, with a little reddish-brown mica and quartz. The mica appears to have been of the first consolidation, but there is so little difference in the three minerals that I cannot feel confident on this point. The mica is reddish-brown in colour and not deep in tint, and it is dichroic in shades of the same to colourless. It is largely chloritised, and otherwise does not call for further notice.

The amphibol is of a peculiar character. It occurs broadly-bladed to fibrous. There are no defined crystals, but masses, which, when cut across by the slice, show the characteristic prismatic cleavage of amphibol on a minute scale. When lying more or less in the plane of the slice the long narrow blades rarely have the same direction, but lie across each other and extend to different lengths. In places the mineral forms bundles of long and very attenuated prisms, which, extending to different lengths, give the mass a ragged-ended appearance. This mineral is faintly pleochroic, and the obscuration angles reach in the highest measurements 18°. In places I have observed a mass which, although fibrous, shows twinning, the composition face of which crosses all the fibres, which reach as parts of the same mass on each side. This suggests that the bladed or fibrous structure has been superadded upon the original condition of the mineral. There are no traces of the form of augite in the masses of this mineral, and it can therefore scarcely be a true uralite, to which it has much resemblance, but more probably one of the amphibols similarly altered.

The felspars are all triclinic, but very few show any well-defined bounding planes. Their structure is very varied, as well as compound. Some crystals are twinned according to the Albite law, others according to this and also to the Carlsbad law. The greater number have either portions in which the lamellæ differ in width from the others, or extend only partly across the section. Perhaps half the individuals in a slice are compounded according to the Pericline law, in addition to the other two forms. These felspars have brilliant chromatic polarisation, and the appearance, physically and optically, of the basic Labradorites and the Anorthite felspars which I have observed in similar rocks at the Sheep Station Creek Gap, in the Swift's Creek district.

I could obtain but few obscuration measurements, but those confirmed the general conclusion, being, in the zone $OP - \infty \overline{P} \infty$, 24° to 31°, and in three sections approximately near $\infty \breve{P} \infty$, 30°, 33°, 37°. A slice digested in hydrochloric acid showed this felspar to be much attacked, but not completely destroyed.

The quartz is in large amount as an original residuary constituent filling spaces in the manner usually seen in the quartz diorites, to which group I assign this rock.

About three miles from the Ensay ford there is a small outcrop of schists, which is an unusual occurrence in the upper part of Watts Creek. I collected two samples. One is finely foliated and dark in colour, with rarely small orthoclase crystals forming bulges in the foliations, which are rather fibrous in places, and show also plates of dark-brown mica and scales of talc. Examined in thin slices, this rock proves to be composed almost wholly of pinite material, together with numerous flakes of brown magnesia iron-mica. With polarised light the slices have much resemblance to serpentine. This rock, therefore, is a variety of pinite schist. The second sample is foliated, lighter in colour and showing small grains of quartz and felspars in the foliations. It is composed, according to microscopic examination, of much pinite, which is partly the result of the alteration of orthoclase, the remains of which can be plainly seen in some of the masses. The mica is more or less converted into a pale slightly dichroic chlorite. The quartz is in foliations, separating the other constituents. This rock is therefore a variety of those quartzose schists which I have before described; and here again it is seen that there are two varieties of these schists analogous to the quartzose and argillaceous sediments.

The line of section crosses the high range at the sources of Watts Creek, where the Ensay and Gellingall track descends from it to a small stream before ascending the dividing ridge which falls toward the Wilkinson River. The granitic rocks continue from the sources of Watts Creek to this stream, where as I have already said, at p. 71, there are traces of sedimentary rocks. On the eastern side of this small stream there are some very interesting rocks of the Diabase group, which are evidently intrusive into the crystalline-granular acid rocks, and which extend over a large tract, probably not less than a square mile in area. There are several varieties of these rocks, of which I collected samples, the examination of which gave the following results:—

38.—This rock has a black colour and micro-porphyritic structure, as seen in a hand sample. Under the microscope the ground-mass is found to be composed of—(*a*) traces of micro-felsitic basis; (*b*) innumerable colourless acicular crystals lying at all angles; (*c*) very numerous rounded grains of devitrified magma; (*d*) very numerous crystals and grains of iron ore (magnetite or ilmenite), in clusters or groups; (*e*) many brown-coloured bladed crystals, which are sensibly pleochroic in shades of brown to colourless.

The obscuration in some is straight, and in others inclined. The mineral is therefore monoclinic; and when the slice is examined by a higher objective, it is seen that cross sections have the prismatic angles of amphibol, some with the planes ∞P only, others with those of ∞P and $\infty \bar{P} \infty$ combined. The same examination shows that many of the crystals are spindle-shaped, or perhaps with very steep pyramidal planes, the ends of most being ragged. This mineral is clearly an amphibol. It is the largest of the constituents of the ground-mass, and one of the most numerous. There are finally (*f*) minute grains of yellowish augite.

In this ground-mass are porphyritically—(*g*) a few completely serpentinised olivine crystals; (*h*) prismatic crystals of augite, which are almost colourless and non-pleochroic. The extinction angle is as high as 40°. Groups of crystalline grains of the same augite also occur. Both the olivine and the augite are quite free from inclusions. (*i*) Very irregularly-formed felspars, as to which all that can be said is that they are triclinic. This rock is an "Olivine diabase porphyrite, with accessory amphibol."

A second sample I found to have the following composition. The ground-mass is much altered, but it can be seen to be made up in great measure of minute prisms and fragments of felspar. They are extended in the direction of the edge $\infty \bar{P} \infty$ (100)- $\infty \breve{P} \infty$ (010). In the least altered individuals I observed that the obscuration angle is high, indicating, probably, a Labradorite felspar.

In this ground-mass are—(*a*) large, very cavernous augite crystals, some of which are twinned in the usual manner. These are of the first consolidation, but there is also a later generation of augite, in well-developed short prisms, with the planes $\infty P\ (110) - \infty \grave{P} \infty\ (010) - \infty \bar{P} \infty\ (100)$.

These crystals contain magnetite, and also colourless granules of magma, arranged in concentric lines of growth. The earlier augite crystals contain much fewer inclusions. (*b*) Rhombic pyroxene, both in irregular-shaped masses and prisms with rectangular terminations. This pyroxene is very fibrous, in some sections roughly fibrous, of a brown colour, and markedly dichroic in shades of brown and brownish yellow. The absorption is $c > b > a$. It does not contain any inclusions. It is traversed across the prism by flaws, from which alteration extends on either side. The smaller prismatic crystals, which may possibly be of a second generation, resemble the crystals of enstatite, which I have observed in the Diabase porphyrite at Buchan.

As the monoclinic and rhombic pyroxenes are about equal in amount, this rock can be considered to stand midway between Diabase and Norite.

Other samples are of very light colour, with outlines showing of felspar crystals. One sample I found to be composed of a ground-mass of triclinic felspars. In this are other triclinic felspars, as porphyritic crystals, but much altered to epidote. Besides these there is a little iron ore, but neither augite nor any other bisilicates. Traces of viridite and very numerous small apatite prisms complete the composition.

I also examined a sample which resembled the above; but the ground-mass in this case consists of small felspars and innumerable rounded granules of coloured doubly-refracting material, apparently devitrified magma. In this are traces of porphyritic plagioclase felspars, and also masses of epidote crystals and crystalline grains, which, I think, probably replace augite. These interesting rocks are also to be classed with Diabase, and the two types which occur here remind one, in some of their features, of those palæozoic Diabases which have received from Gümbel the names respectively of Proterobas and Leukophyr.

The Diabase rocks which I have now briefly noted have, in some respects, a strong family resemblance to the Diabase porphyrites of the Buchan district, and may be thought perhaps to represent one of the deeper-seated masses with which such palæozoic lavas have been connected.

I may now note further that in the line of this section, and between the Wilkinson and Tambarra Rivers, there is a second considerable exposure of porphyritic rocks, which, I think, will be found to belong to the above group, as I have provisionally noted in the section.

There remains but little to notice in the final part of the section. The massive intrusive rocks extend, only broken by the porphyritic Diabases which I have referred to, from the summit of the divide west of the Wilkinson to the summit of the mountains on the eastern side of the Tambarra River, where they are capped by tertiary basaltic sheets, and succeeded to the east by well-marked members of the Buchan beds, including both the fragmental, tufaceous and marine limestones of that series. In a former description of the Gellingall area I stated that the Buchan beds at that place were laid down on the granitic rocks.* Since then I have seen some reasons to doubt that such is the case, but that the positions of the two formations are perhaps more probably due to faulting. At present I must leave the matter uncertain.

The description of the samples collected in this final part of the section will conclude the account which I have to give of the rocks met with in its course.

39.—The granitic rocks are exposed in the bed of the Wilkinson River, where the Gellingall track crosses it. They are traversed by several basic dykes, and by joints, one set dipping S. 30° W. at 45°, and the other to N. 30° E. at 27°. The thin slice which I prepared shows—(*a*) an iron magnesia-mica, which has been almost wholly converted into chlorite, with exclusion of ores of iron; (*b*) felspars of two kinds, of which orthoclase is one, extending over a considerable part of the slice in large masses, and having in parts veinlets of a second felspar; it also includes mica and a few small well-formed plagioclase crystals, small serpentine pseudomorphs and quartz grains; (*c*) Triclinic felspars occur in large imperfectly-shaped crystals, some of which have been broken or have been rounded off; (*d*) quartz is in moderate amount, as the residual constituent. The most peculiar feature of this rock is the

* Notes on the Devonian Rocks of North Gippsland, Geological Survey of Victoria Progress Report, Part V., p. 117.

occurrence of a number of oval or irregularly-shaped serpentine pseudomorphs, in which no trace of the original mineral remains. Did they occur, for instance, in a basalt, I should feel very little doubt as to their representing olivine. This rock is probably a granitite.

40.—I collected this sample on the summit of the mountain, on the eastern side of the Tambarra River, where it shows out in large masses. It has the following composition:—(*a*) Mica, which is reddish brown with ordinary transmitted light in basal sections. In those parallel to the "c." axis it is dichroic, when examined over the polariser, in shades of brown and yellow. The only inclusions are magnetite crystals. The alteration is to chlorite. (*b*) Orthoclase. (*c*) Triclinic felspars, in crystals, which are better formed than the orthoclase, and compounded according to the Albite law. The few measurements of obscuration angles which I could obtain were not satisfactory, being in the zone $OP - \infty \bar{P} \infty$, between 2° 30′ and 24°. The alterations of all the felspars are micaceous. (*d*) Residual quartz, of the usual kind in such rocks. (*e*) A little apatite, and rarely titanite. This rock is also a granitite.

Principal Characteristics of the Rocks.

I have now described at some length the mineral composition of the rocks which I have found along a line of section crossing the Ensay district. These rocks fairly represent the formation of the whole district, of which Ensay is the central part.

It will now be well, for the sake of clearness, to summarise the principal and characteristic features of these groups of rocks, before proceeding to consider how they are related to each other.

It is to be first noted that the sediments which I have described have not the normal mineral character of the least altered Silurian formations of North Gippsland. These latter are best seen in tracts where there are no signs of the nearness of intrusive plutonic masses—as, for instance, in the valleys of the Wongungarra, or the Thomson River below the crossing of the Walhalla-road.

The mineral condition of the argillaceous and arenaceous beds in such localities is most certainly not such as one can imagine to have been originally that of the Silurian sediments when lying still, undisturbed, in a horizontal position ; but it is also far removed from the condition of those formations which have been subject to regional or contact metamorphism.

Broadly speaking, so far as my investigations have yet gone, the Silurian sedimentary rocks of Gippsland may be arranged under three types. The first is that of the Argillites, or those beds which are found where there are no signs of intrusive masses of plutonic rocks, and which, therefore, are least altered. The changes which I have observed are usually some degree of induration by silica, and the conversion of the argillaceous material into some mineral allied to chlorite. The second type is that represented by the well-known rock Hornfels, and includes the contact schists. In such rocks the argillaceous material has been converted into mica, which most frequently is a brown magnesia-iron mica with a subordinate potassa-mica. These rocks are far more indurated by silica than the argillites, and the original clastic grains of quartz are frequently surrounded by secondary silica, oriented in accordance with the older grains. The third type, which departs most in mineral character from the normal argillites, includes the so-called Regional Schists. In this group, the first sign of alteration is the minute wrinkling of the argillites, and the appearance of a silky micaceous lustre on the planes of bedding or of cleavage. Silica is also eliminated in the conversion of the argillaceous material into mica, and becomes deposited in strings or lenticular masses in or across the beds. The ultimate result of this type of metamorphic alteration is mica schist and gneiss.

The distinction between the argillites and the metamorphic schists, contact or regional, is that in the former the argillaceous material is converted into some mineral allied to chlorite, while in the latter it has been converted into mica.

The distinction between the contact and regional schists is the more foliated structure of the latter, and the prevalence in them of an alkali-mica.

Strictly speaking, all the schistose rocks which I have spoken of in this paper should be considered as metamorphic, but I have found it more convenient to separate the beds on the western side of the Tambo River, and to treat them as being sedimentary. In outward general appearance they are recognisable as being part of that great series of slaty and sandstone rocks, which I have spoken of under the general term Silurian Argillites. But their inner structure differs much from that of the normal type, and a principal distinction is that the argillaceous part has been converted almost wholly, if not entirely, into minute flakes of mica.

In some respects the less altered beds, and specially those which are minutely "spotted," resemble some of the less altered of the contact schists.

As a rule, the quartz grains of these beds have been little, if at all, affected, except in so far that in places they appear to have been arranged with their longer diameters in line, probably by pressure.

The least quartzose and the most altered of these beds, approach in their microscopical characters near to a mica schist, in which the structure is very minute; that is to say, they retain the outward general appearance of the argillites, but have been so far metamorphosed that there has been produced in them the structure and composition of a mica schist. In other words they are phyllites.

The rocks which, in accordance with the distinction I have now drawn, are to be considered as the true metamorphic schists of Ensay, are found in three main varieties. The *first* includes the quartz schists and the fine-grained mica schists; the pinite schists form the *second;* and the *third* includes the gneiss. The somewhat peculiar rocks found at Contentment Hill connect the phyllites and the mica schists.

The quartz schists always have either a magnesia-mica or its alteration-product, chlorite. An alkali-mica almost invariably occurs in connection with the small pinite masses and veins in these schists. These constituents would bring such a rock in its unaltered state within the term Mica-schist rich in quartz. But as I have found in almost all cases, in addition to the above-mentioned constituents, more or less of a triclinic felspar (albite or oligoclase), the schists might be considered even to be a variety of a very siliceous gneiss. Yet, as the micas are never absent, while the felspars are in some cases wanting, I think the term Quartzose Mica-schist is the most appropriate.

The quartz of these schists is peculiar, and its study has raised questions which it is not easy to answer satisfactorily. The schists are metamorphosed sediments, and of all their original constituents one might expect to find the quartz to be least altered. I have observed that in the contact schists, for instance in Hornfels, the clastic origin of the quartz grains is always more or less perfectly recognisable. But in the Ensay schists this is not the case. They are eminently schistose, and, broadly speaking, the quartz and the mica form separate foliations. Frequently the quartz is in crystalline grains, whose form is rudely rectangular. In places the sections of these grains merely touch each other, while in others they overlap in the direction of the foliation. In other cases the foliation is continuous or even branching, the quartz being traversed by cross-flaws. Such observations point to the grains being flattened parallel to the foliated structure, and to be probably, in some cases at least, discoidal in form. In some slices I have found all the quartz to be evidently of the same period of formation, as, for instance, where inclusions or fluid cavities are of the same character throughout the thin slice. I note such an instance wherein numerous fine, colourless, hair-like microliths lie in the quartz veins throughout the slice, and have all of them a uniform direction. In a few cases I have been able to distinguish two generations of quartz, and in others I have observed small rounded granules of quartz included in the larger grains of the foliations.

I have thus been led to the conclusion that during the metamorphism of these once sediments the original quartz grains have been taken into solution, and then finally redeposited between the micaceous foliations.

It seems to me that the silicification of these rocks could have scarcely been effected by extraneous solutions permeating them as a whole, for in such a case one should, I think, expect to find general and similar effects throughout. Such has not been the case in this instance ; but, on the contrary, one can observe that there are still two main varieties of these schists corresponding to the arenaceous and argillaceous sediments, and therefore the conclusion may be perhaps justified that the silica, if taken into solution during the metamorphic process, was, as they ceased, again redeposited mainly in the sets of beds from which it had been derived. If this view proves to be maintainable, it will have a strong bearing upon other questions as to metamorphism which await solution in the Omeo district as well as elsewhere.

The fine-grained mica schists show somewhat similar features, but as they are much more micaceous than quartzose, the peculiar appearances which I have just noted are not so apparent.

The pinite schists, so far as concerns the principal constituent, are evidently pseudomorphic, and it is probable that they are so after magnesia-mica mainly. In the examples which I have examined microscopically I have found two kinds of mica, in addition to the pinite material. One is a brown magnesia iron-mica, and the other an alkali-mica. The latter is in many cases, but not in all, greatest in amount, and is evidently in some instances of secondary origin. The analysis of the pinite schist shows that it is not far removed from the composition of the pure pinite mineral. The pinite in these schists when seen under the microscope and by polarised light, especially in slices across the foliations of the rock, has a "meshed" appearance, resembling that of serpentine, to which mineral it has also a resemblance macroscopically when the rock is examined on a cross fracture. In places these schists contain masses of alkali-mica flakes, and more rarely colourless, divergent, or fan-shaped clusters of talc plates.

On the whole, I can see no more probable conclusion than that these pinite schists are pseudomorphic alterations of a schist rich in magnesia-mica. The conversion of magnesia-mica to pinite has been recorded by Blum, Dana, and Vom Rath,* and it may have been the case here on a large scale. Yet I must notice, as not falling in with this view, that I have not met with a single instance in all the thin slices which I have prepared and examined wherein magnesia-mica has been partly, or indeed, so far as I could see, entirely converted into anything else than chlorite. That is to say, in all the slices I have referred to there have been numerous individuals of magnesia-mica, either intact or partly chloritised; others wholly converted into chlorite; but not one single flake which showed a partial conversion into pinite, such as is so commonly the case in the felspars. Therefore the complete proof of the origin of the pinite is still wanting.

The gneissic schists are characterised by the prevalence of a monoclinic potassa felspar, often in porphyritic crystals, or that mode of occurrence which gives occasion to the term "Augen-gneiss" of the German writers. This orthoclase has been the first formed of the felspars in

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* Quoted by Roth, *Allgemeine Chemische Geologie*, Vol. I., p. 332; Blum, *Pseudom*, I., 79, and III., 142; Dana, *Amer. J. of Sc.* (3), 8, 449, 1874; Vom Rath, *Zs. Geol. Ges.*, 27, 382, 1875.

these rocks, for it is very frequently crushed, broken, worn at the edges, and generally showing the effects produced by long subjection to heat, and also physical movements of the mass in which it existed in a crystallised form. Fragments of orthoclase also occur "jammed" into corners or included in the residual quartz.

The triclinic felspars are almost always in smaller and better-formed, much-compounded crystals.

It is characteristic of these gneissic schists to have two kinds of mica.

The earlier-formed one is a magnesia-mica, much poorer in iron than that of those gneisses which I have found elsewhere in the district as margins to the massive intrusive rocks. This mica of the gneissic schists is usually in the foliations with the felspars, but is also to be found included in the quartz. The second mica is a colourless alkali-mica, such as I have already mentioned when speaking of the mica schists, and I think that in many cases it is a secondary production. It is very characteristic of these gneisses that some of their constituent minerals have been altered to pinite. Some of the felspars certainly have; cordierite, also, so far as one can judge from pseudomorphs, and perhaps in the largest measure the magnesia-mica, which in an unaltered state is still plentiful in some of the foliations.

Many of the gneissic schists are so massive that it is only when they are examined *in situ* on the large scale that their character as metamorphosed sediments, and not varieties of igneous rocks, can be fully recognised.

Aplite is the first of the igneous rocks which I have to notice. Rosenbusch* defines aplite as a very fine-grained rock composed of quartz, orthoclase, plagioclase, and potassa-mica. Pegmatite includes the coarser-grained varieties. He includes both under the section "Muscovite granites." He notices as an exception the occurrence of magnesia-mica in the aplites of Cornwall.

My own observations in the Australian Alps show me that there are here also instances of aplites which have either magnesia-mica together with a potassa-mica or alone, but in all cases the former is in very small amount.

Besides the essential general characteristics of this rock, —namely, a paucity, or even almost absence, of mica, with

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* *Physiographie der Massigen Gesteine*, p. 19.

felspars and quartz all combined in a holocrystalline structure —the aplites at Ensay are marked by the abraded, fractured, and eroded state of the felspars. Both the orthoclase and plagioclase crystals show these signs of violence, and of long-continued action of the molten, or pasty and still moving, magma. Of the two the potassa felspar has usually been the first formed.

These appearances accord with my observations that the veins and masses of aplite were forced when in a plastic state into the already metamorphosed sediments. One may in some measure imagine what must have been the pressure and the temperature to which these rocks were then subjected by considering that at that time the locality in question was part of the plane of contact between the Silurian sediments and the invading plutonic masses.

With the aplites must be classed the pegmatite veins, for their distinction is mainly one of structure. There is, however, this distinction to be noted as regards Ensay: In the pegmatite veins the constituents are much larger individually than in the aplites, but the felspars do not form separate crystals, but are in compound cleavable masses. I have very rarely found any other felspar than an orthoclase or microcline-perthite. In the aplites, however, the monoclinic potassa and the triclinic soda-lime felspars have most frequently, if not always, been formed independently of each other.

The massive intrusive rocks of the Ensay district are of the quartz-diorite group. They are massive holocrystalline, and have either a magnesia-iron mica or hornblende, or both together. The samples which I have examined from Ensay do not differ materially from those collected elsewhere in the district, as, for instance, at Noyang.

The Ensay dykes belong evidently, with the exception of the rarely-occurring basalts, to two classes which correspond to the massive quartz diorites and to the massive diabases of the district respectively. Of the two groups the Diabase dykes are the younger.

Still more recent are the dykes of basalt, which may probably be referable to the time of the miocene volcanic lava flows of Gippsland.

I have not thought it necessary to enter into a longer description of the dykes found at Ensay than was necessary to bring them into relation with the other rocks. My principal object has been to work out, so far as I could do, the relations of the three great groups of sedimentary, metamorphic, and massive intrusive igneous rocks.

The Relation of the Rock Masses to Each Other.

At Ensay, as elsewhere in North Gippsland, the oldest rocks which can be discovered are members of the great series of auriferous argillites and sandstones, which is with fair certainty referable to the lower Silurian age. When a lengthened section is examined in almost any tract in the Gippsland mountains, it soon becomes clear to the observer that these sediments were once continuous in a crushed and folded condition throughout, but that by the combined action of faulting, denudation, and erosion, this continuity has been broken, so that while in places the whole country, down to some given datum line, shows no other formations than these tilted and slightly metamorphosed sediments, in other places their merest traces remain as distorted and fractured contact schists attached to the massive plutonic rocks which have invaded them.

In other papers upon the geology of North Gippsland I have insisted upon the clear evidence there is that the plutonic rocks have disturbed and metamorphosed the Silurian sediments, and to a greater or less extent melted off and absorbed, not only the lower part of the folds into which they had been previously forced, but also, so far as is yet known, every portion of the older formations, whatever they may have been, upon which they were laid down.

It is possible to note, by a few striking geological features, the sequence of the terrestrial movements which are indicated by the folding and crushing together of the Silurian sediments, their metamorphism and invasion by plutonic rocks, their denudation, and the subsequent laying down upon them of other formations, both sedimentary and volcanic.

In North Gippsland the Silurian formations, as a whole, have been folded more or less sharply together. The next succeeding sediments—namely, those of Middle Devonian age—have not been so generally and regularly affected; for while at Tabberabbera the beds have been folded much as have been the Silurians, the limestones of Buchan or Bindi remain comparatively level, as compared with the acutely folded older strata adjoining and inferior to them.

The Upper Devonian sediments, which are next in order, are entirely discordant with those of Middle Devonian age, and are in most places but little disturbed from a horizontal position.

The four groups—Lower and Upper Silurian, Middle and Upper Devonian—all show a marked decrease in mineralisation in the ascending order. Some of the nearly horizontal beds of the Iguana Creek Upper Devonians are little more than indurated clays or friable sand-rock.

So much in brief as to the sediments. Between the acutely folded Silurian and the much less folded Middle Devonian sediments there intervenes, in the chronological arrangement, as in the field, an immense thickness of igneous rocks, whose lower members rest upon the denuded edges of partially metamorphosed Silurians, while the upper beds pass as tufas into the Middle Devonian marine limestones of Buchan.*

On the grounds which I have now very briefly stated, I place the folding of the Silurian sediments and their invasion by plutonic masses at the close of the Silurian age. The Devonian volcanic rocks clearly followed this invasion, and I think that they may prove to have been connected with a second great series of younger igneous rocks, which are to be found in different parts of Gippsland, rising through both the Silurian sediments and the older plutonic masses. The younger igneous rocks are in most cases porphyritic, and I note, as instances, The Sisters and Mount Leinster, near Omeo, and Mount Taylor, near Bairnsdale. These younger plutonic rocks are probably all older than the Upper Devonian age, for the last named mountain is still capped on its denuded summit by nearly horizontal beds of the Iguana Creek series.†

Of the formations which I have now noted there are found at Ensay only the Silurian sediments, the older plutonic masses, and the metamorphosed representatives of the former. The later plutonic rocks are not met with, nor any of the Devonian sediments.

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* "Notes on the Devonian Rocks of North Gippsland"—Geological Survey of Victoria, Progress Report, I., p. 117. "Notes on the Diabase Rocks of the Buchan District"—Transactions of the Royal Society of Victoria, Vol. XVIII., p. 7.

† Geological Survey of Victoria, Progress Reports, II. p. 63, and III. p. 211.

It is to the close of the Silurian, or to the commencement of the Devonian, age that for the present I refer the igneous and metamorphic rocks of Ensay.

It remains now for me to consider what may have been the sequence in which the present relations of the Ensay Rocks have been brought about.

Although the sediments on the western side of the Tambo River are not continuous with the schists at Ensay, yet an examination of both groups *in situ*, and of samples in thin slices under the microscope, leaves no doubt in my mind that the latter are the very much metamorphosed forms of sediments which represented the latter. The schistose rocks of Contentment Hill, some of the very fine-grained mica schists at the Little River, and the altered sediments whose traces now only remain at the sources of Watts Creek, supply intermediate stages connecting the extreme examples. With these exceptions, the sedimentary rocks have been completely denuded on the eastern side of the Tambo River from the country crossed by the section.

The most interesting part of the locality, and the one to which I have desired to direct attention, is that at the junction of Watts Creek and the Little River. It is there that the schists have been preserved from denudation, either by having formed a depression below the general plane of contact, or by having been let down by faults. It is immaterial which may be the true explanation. That which is material is the very instructive manner in which the schistose and igneous rocks are associated. At first sight it seems that they are in complete confusion, but on further examination this seeming disorder is capable of explanation.

It is to be borne in mind that this locality is, as I have before said, part of the plane of contact between the sediments and the invasive igneous rocks. Taking a general view of the whole of the Australian Alps, I find that this plane of contact is a most irregular one. Its highest and lowest limits are beyond an accurate determination, for to estimate them it would be necessary to have a knowledge of the faults which have disturbed the continuity of the contact plane, of the probable thickness of the sediments where the contact is deep below the surface, and of the amount denuded from the highest points of the now protruding plutonic masses. The Ensay district is a good example of the difficulties in the way of such a determination. The Silurian beds at the west side of the Tambo River are at its level, while on the east side the massive igneous rocks rise in a vast tract of mountains to some 4000 feet higher in the Nunnyong tableland. One cannot tell to what depth the contact plane sinks on the western side of the Tambo River, or to what former elevation it rose at Nunnyong on the north-east.

The plane of contact is as irregular in the small scale as in the large. In the few places where I have been able to inspect it in vertical sections I have observed that the invasive plutonic rocks have affected the sediments in a manner which I can best illustrate by likening it to the action of warm water upon masses of ice. They appear to have eaten their way upwards in an irregular manner, leaving portions of sediment hanging down or detached in the heated materials.* That this action has been accompanied by great pressure of the molten masses against the sediments is evidenced by the fractured and, so to say, "dog-eared" state of the beds where they strike or dip against the former, and by the constant occurrence of masses and veins of the intrusive rock penetrating the sediments.

It is not necessary to consider whether this pressure was by expansive forces acting from beneath upwards, or whether it was by the downward pressure of parts of the earth's crust upon the molten masses, or by both combined. All that I am concerned with now is to point out the fact, that the action of the invasive plutonic rocks has been to force themselves, or to be forced, into the lower parts of the sediments, and to gradually metamorphose, melt off, and absorb them.

As seen at Ensay, the first igneous rocks which were forced into the sediments as veins and masses were varieties of aplites, which either penetrated between planes of bedding (foliation ?) or through cross fractures. In some places these aplite veins are very numerous, so that in a horizontal section they appear as small isolated masses surrounded by the schists, or as veins crossing or apparently interfoliated with them.

Following the aplites were those masses of plutonic rocks which are now the holocrystalline quartz-mica diorites.

The whole complex of rocks, metamorphosed sediments, veins, and masses of aplite and quartz diorite have been

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* I have given a sketch of such an occurrence at p. 77, Progress Report, Geological Survey of Victoria, Part II.

crossed by dykes of quartz porphyrite, and still later by dykes of diabase, finally in tertiary times by a few dykes of basalt.

The confused manner in which the various classes of rocks are "jumbled" together at Ensay, often within the space of a few yards, is due to their being part of an approximately horizontal contact plane, wherein they have been all welded into a complex whole.

Regional and Contact Metamorphism.

An important question now awaits some reply, What has caused the peculiar metamorphism of the Ensay sediments? That is to say—Why is it that, although in contact with intrusive igneous masses, metamorphism has, in this instance, converted the sediments into mica schist and gneiss, and not, as is the case in other intrusive areas in Gippsland, into rocks of the hornfels type?

It seems that there may be two alternative replies, one being that the schists were regionally metamorphosed before the plutonic masses invaded them, and the other that they are no more than abnormal instances of contact action.

The schists at Ensay are most probably the metamorphosed sediments of the district. Their mineral and structural character is that of the regional schists of Omeo, and not that of the contact schists. It seems that they were metamorphosed before they were invaded by the plutonic rocks, yet, like the contact schists, they are most altered in the neighbourhood of the igneous masses.

Any explanation which is satisfactory must reconcile these seeming contradictory phenomena.

I have already drawn attention, at page 110, to the three types of more or less metamorphosed Silurian sediments in North Gippsland, and of which the argillites are the least altered. Their molecular re-arrangement—that is to say, the re-crystallisation of their argillaceous parts—is one of the lesser stages of metamorphism as I observe it in this district. I note, further, that it is clearly connected with the folding together of the strata; for rocks of this class, which have been most disturbed, folded, and crushed together, are also most altered in their mineral structure. This may be observed in wide tracts, where there are no surface indications of the proximity of igneous rock masses to which such alterations might be attributed.

It might be thought that such mineral alterations as those I allude to in the argillites might be produced by the percolation downwards of surface waters. No doubt the action of such mineralised waters must not be lost sight of in any hypothesis which proposes to account for the present condition of rocks at the earth's surface.

But an explanation relying upon such solutions as a principal cause of even the lesser metamorphic changes will not account for the connection there is between the molecular regeneration of the sediments and the disturbance, dislocation, and compression to which they have been subjected. Nor will an explanation which relies upon the action of heated mineral waters from below be more satisfactory, and for the same reasons. The structural changes which the mineralised beds show point to other causes, which must be considered. It seems to me that an hypothesis to be satisfactory, in conforming to observed facts, must not overlook the forces brought into play during the vast tilting, folding, and especially crushing, to which, in Palæozoic ages, the Silurian sediments were affected: that is to say, during those periods of time when the mineralisation of the strata was effected.

It is quite certain that in Gippsland, at the close of the Silurian age, gigantic movements of the earth's crust folded the sediments together, and crushed them close. This certainly produced an amount of motion in the rocks which, within reasonable limits, it is difficult to overstate; and the question then is: What did this movement result in beyond the physical effects which can be seen still impressed upon the stubborn but bent and contorted strata?

In following out this train of thought one is easily led to the reply, that those vast movements must have generated an amount of heat proportioned to their own extent.

It must be borne in mind that the mere pressure of formations lying upon each other does not seem capable of producing such changes as those I refer to in the argillites of North Gippsland, even when many thousands of feet of beds are horizontally upon each other. But it is different where pressure causes the forcible movement of the rock particles among themselves, and especially the folding of the strata. It is under such circumstances that pressure can generate metamorphic action, and especially when the sediments acted upon are still permeated by the waters of the oceans in which they were laid down.

The sedimentary crust of the earth in Gippsland was subjected to such conditions as those I have just referred to at the close of the Silurian age, and they imply pressure, heat, mineralised waters, and vast periods of time, in fact all that which is requisite, so far as we know, to produce metamorphic action and mineral regeneration.

It appears to me to be very significant, when looked at from this standpoint, that the most crushed and contorted rocks in the Gippsland Alps are to be found in the area of regional metamorphism; in other words, where the sediments have been most dislocated and compressed, there it is that metamorphism has been most intense.

According to these views, the mineralisation of the argillites and the regional metamorphism of the sediments at Ensay and Omeo are respectively earlier and later stages of the same process, which, for want of a better term, might be spoken of as dynamical metamorphism in contradistinction to contact metamorphism.

These views lead to the further conclusion that places such as Ensay, wherein the sediments have been converted in limited areas into mica schist and gneiss before their invasion by the plutonic rocks, were localities in which the movements of the strata were greatest, where the temperature was consequently higher than elsewhere in the distorted crust, and where, as a direct consequence, metamorphism reached extreme stages.

Moreover, it seems to me to be quite conceivable that, under such conditions, those localities would be most readily invaded and absorbed by the plutonic rocks if the invasion was part of the same great range of operations.

As I see the evidence to be obtained in the Ensay district, dynamical metamorphism—as I have defined it—first produced an alteration of the sediments to the condition of argillites, next to phyllites, and finally to mica schist and gneiss.

The schists then being invaded by the plutonic masses were no doubt further affected by contact metamorphism; but in what manner, or to what degree, I am not at present in a position to state. Possibly some further light may be thrown upon this very obscure subject by work which still remains to be done as regards the Omeo district.

I have now briefly stated the hypothesis which I have ventured to bring forward as explaining the seeming anomalies of the Ensay schists. The belief that the crushing together of the strata has produced sufficient heat to set up metamorphism, is not at all new. Among others, Mallett worked it out to a great extent, and it seems to be now gaining ground among geologists in a somewhat modified form. The views which I have now recorded have been slowly forced upon me, so to say, during the progress of my investigations into the geology of the Gippsland Alps during many past years. If they have a foundation of truth, they will be maintained ; if otherwise, then, no doubt, justly they will fall to the ground. It is well that I should mention that I have, in formulating them, relied upon more than the evidence of the Ensay district alone. I have, to some extent, been influenced by evidence as yet unrecorded from the Omeo district. It might perhaps be thought that it would have been better to have waited until that evidence had been worked out, and laid before this Society. But in working out the Ensay evidence I found that I had before me just those problems in miniature which confronted me at Omeo on the large scale, and I therefore briefly sketched the results arising, not only from my Ensay work, but also from that in the Omeo district. Since the work which relates to the latter area consists mainly in the analysis and microscopical study of rocks collected there, it is not likely that the general conclusions to which the field work has led me will be in any great degree altered.

Conclusions.

The general results arrived at in the preceding pages may be shortly summed up as follows :—

(1.) Two kinds of metamorphism may be distinguished—dynamic metamorphism, or the effects produced by heat, resulting from vast movements within the earth's crust, upon the sediments and the mineralised waters included in them ; and contact metamorphism, or the effects produced on the sediments by masses of intrusive igneous rocks.

(2.) At the close of the Silurian age the sedimentary crust of the earth was tilted, folded, and crushed over an enormous region in the Australian Alps.

(3.) The sediments were metamorphosed during these movements. They were generally converted into argillites, and where the movement was greatest into mica schist and gneiss. The Ensay area is an instance of the latter.

(4.) Connected with or following these results of dynamical metamorphism, the more or less altered sediments were invaded from below by molten masses, which acted especially upon such areas as those referred to in conclusion 3, and also generally upon the argillites, producing the contact schists.

(5.) The period when the Ensay schists were formed may be placed at the close of the Silurian age, and in any case cannot be later than the close of the Middle Devonian period.

EXPLANATION OF PLATES III. AND IV.

Fig. 1. Horizontal section of schists at Ensay, about eight feet in width. (*a*) Schist, (*b*) quartz vein, (*c*) crystalline-granular intrusive rock.

Fig. 2. Horizontal section showing relation of schist and pegmatite vein. (*a*) Schist, (*b*) pegmatite, (*c*) aplite.

Fig. 3. Horizontal section of schist and crystalline-granular rock at Ensay. (*a*) Schist, (*b*) crystalline-granular rock.

Fig. 4. Microscopical section of microcline-perthite prepared from principal cleavage. (*a*) Microcline, (*b*) albite, × 55.

Fig. 5. Microscopical section of microcline-perthite prepared from second cleavage. (*a*) Microcline, (*b*) albite, × 55. The engraving gives the impression of striation in this albite, which is incorrect.

Figs. 4 and 5 drawn by polarised light.

Plate I.

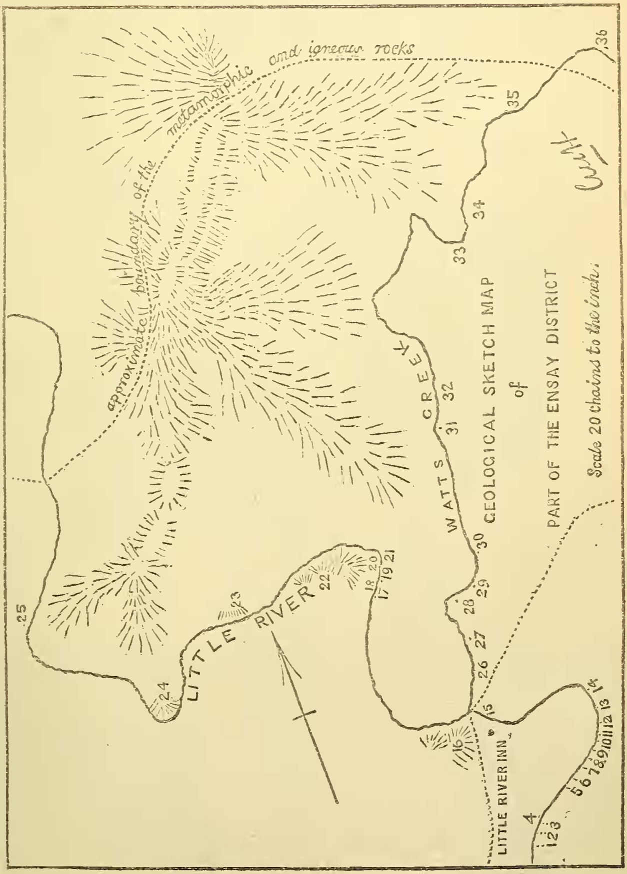
approximate boundary of the metamorphic and igneous rocks
LITTLE RIVER
WATTS CREEK
LITTLE RIVER INN
GEOLOGICAL SKETCH MAP
of
PART OF THE ENSAY DISTRICT
Scale 20 chains to the inch.

Plate II.

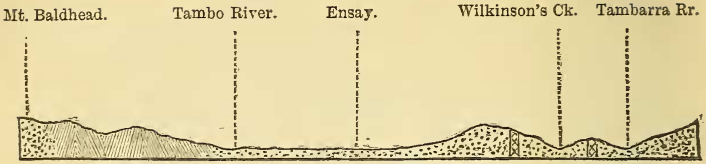

Diagram Section from Mount Baldhead to East of the Tambarra River.

Silurian — Igneous and Metamorphic — Diabase

Scale { Horizontal eight miles / Vertical 22,500 feet } one inch.

Plate III.

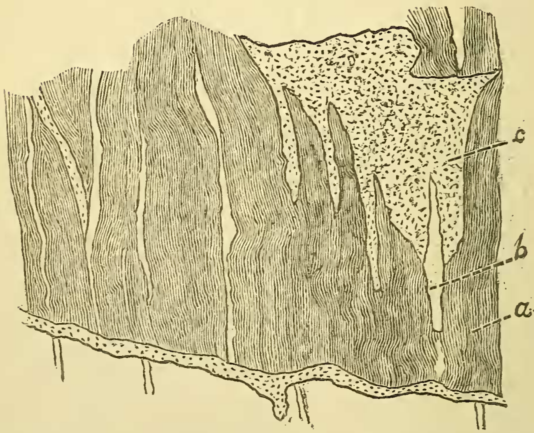

Fig. 1.

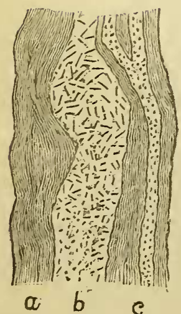

Fig. 2.

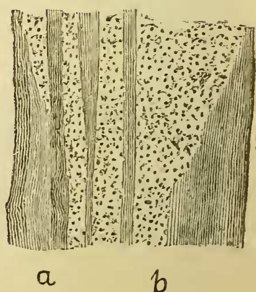

Fig. 3.

Plate IV.

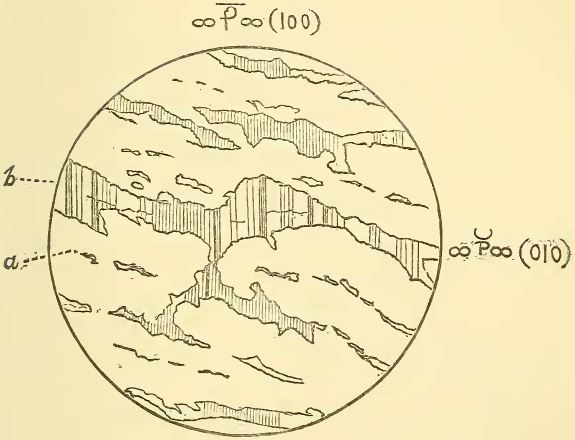

Fig. 4. × 5

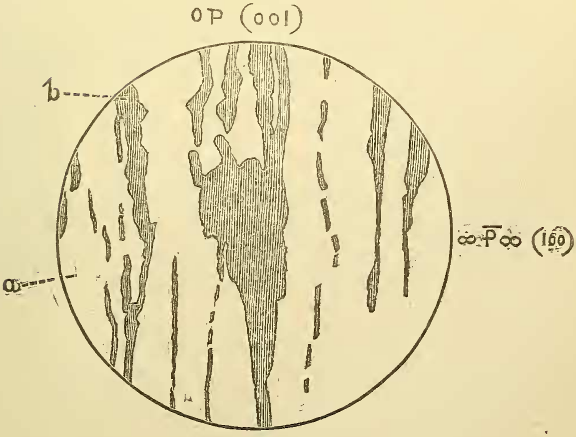

Fig. 5. × 55.