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THE PETROLOGY OF THE JERVOIS RANGE MINING AREA

by

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ABSTRACT

The majority of the specimens collected by W.A. Robertson in the Jervois Range Mining are metamorphosed and metasomatized rocks, comprising pelitic and semi-pelitic schists and gneisses of the staurolite zone of regional metamorphism, calc-silicate rocks, and "magnetite"-quartz granulites. Some are igneous rocks. Some of the pelitic rocks carry "anti-stress minerals", i.e., cordierite and andalusite, and it is suggested that these were caused by during the mineralization of the regionally metamorphosed schists. The granulites are thought to have been formed by the metasomatism of pre-existing quartzose schists. From evidence, based mainly on microscopy, presented by the specimens examined, the following conclusions were arrived at:-

(a) The rocks of the area suffered regional metamorphism.

(b) The resulting schists were folded, and a false cleavage was imparted to them. The metadolerites were emplaced.

(c) Mineralization of the rocks took place, and porphyroblasts were formed in certain schists.

INTRODUCTION

During the 1958 field season of the Bureau of Mineral Resources, W.A. Robertson was engaged on the detailed mapping of the geology around the Reward (Plate 2), Marshall and Attutra (Plate 3), Green Parrot (Plate 4), Cox's (Plates 5 and 6), and Bellbird (Plate 7) mines in the Jervois Range area, Northern Territory. The plates referred to may be found in Robertson's report (1959). The mapping was done over the area shown by aerial photograph Numbers 5008 and 5210, in runs 10 and 11 respectively, of the Huckitta four-mile sheet.

Robertson collected numerous specimens during his work, and eighty-three were sent for petrographical examination. This record embodies detailed descriptions of these samples, and conclusions arrived at from the investigation.

The area mapped is one composed of regionally metamorphosed rocks which have been intruded by granites, and by some more basic rocks. Certain of the metamorphosed rocks contain ore bodies, and the purpose of this investigation is to throw some light on the mode of origin of these rocks. This report is written mainly from the point of view of microscopy, and any conclusions arrived at by the author must be viewed in this light.

In the chapter giving detailed descriptions of the individual specimens, the locality of each rock is referred to sections of the above-mentioned aerial photographs, and to the maps given in Robertson's report. Thin section numbers are used throughout, and Appendix II relates them to Robertson's field numbers.

Appendix I is a report on the mineragraphy of certain opaque ores by W.M.B. Roberts.

DETAILED PETROGRAPHY

1. METAMORPHOSED AND METASOMATIZED ROCKS

A. Non-Calcareous

i. Metamorphosed rocks showing little or no metasomatic alteration.

4163. Photograph 5008, section 6. Attutra, Plate 3.

The hand specimen is seen to be a silvery-grey, fine to medium grained and close-cleaved schist, composed mostly of a white mica, with some quartz. Numerous small dark granules, shown in section to be garnet, occur. The specimen has slight staining of hydrated iron oxide.

In thin section the texture is seen to be fine to medium grained and lepidoblastic, with small porphyroblasts of garnet. The parallel lines of mica flakes are slightly "folded", giving the effect of a series of waves. Muscovite occurs as long, thin idioblastic flakes, 0.2 mm. long and 0.02 mm. wide, with preferred orientation. Biotite occurs as rather more squat flakes, often lying obliquely to the cleavage. It is biaxial negative, with $2V = 5-8^{\circ}$, and is pleochroic: X = light fawn; Y = brown; Z = dark brown, occasionally greenish. Biotite is sometimes tinged with green, although its birefringence remains high. Occasionally, the margins of biotite flakes are altered to green chlorite: this mineral is length fast, showing it to be optically positive. Quartz occurs as xenoblastic grains, which, in the mica-rich areas, occur as isolated crystals with a tabular shape, the longer axes arranged parallel to the schistocity. A few quartz-rich bands are present, running parallel to the schistocity, in which the quartz occurs as rather more equidimensional grains. Garnet forms idioblastic porphyroblasts, ranging between 0.2 and 0.5 mm. in size. It is faintly pink, and is possibly almandine. It is often filled with numerous minute opaque and colourless inclusions, except at the margins, which are clear. Very occasionally, it has been altered to greenish biotite. The mica flakes neighbouring garnet do not wrap around this mineral. Black iron ore occurs as idioblastic "cubic" crystals in the groundmass. A few small, xenoblastic grains of apatite are present.

The estimated quantities of minerals present are:- muscovite 50%, quartz 20%, biotite 17%, garnet 10%, the remainder 3%. The rock is a garnet-biotite-quartz-muscovite schist.

4164. Photograph 5008, section 6. Attutra, Plate 3.

A fresh surface of the hand specimen shows it to be medium-grained and granular. It contains quartz, with lesser quantities of biotite and a pink garnet. On a weathered surface, the specimen is stained with dark hydrated iron oxide.

In thin section, the texture of the specimen is seen to be medium-grained, granoblastic and subidioblastic. There is a rough lineation of mica flakes. Quartz occurs as inequigranular, xenoblastic crystals showing sub-tesselate boundaries, and ranging in size between 0.06 mm. and 0.33 mm., occasional grains reaching 0.75 mm. in size. The crystals have a slight elongation parallel to the mica lineation. Biotite occurs as xenoblastic flakes of about 0.3-0.5 mm. average size. It is "uniaxial" negative, and is pleochroic with X = light fawn; Y = brown; Z = darker brown.

Biotite is sometimes found included in garnet. Two forms of chlorite occur in the section. One is an alteration product of biotite, partly or wholly replacing that mineral. Its refractive index is greater than that of biotite, and it is pleochroic: - X and Y = apple green; Z = very light brown to colourless. It is biaxial positive, with 2V = 5-10°, and its birefringence is 0.008. The other chlorite is included in garnet, and although sometimes found adjacent to biotite which is also included in that mineral, it is more often found as smaller flakes indiscriminantly strewn about the garnets and being possibly altered from the last-named mineral. Its refractive index is just higher than that of biotite, Nz of biotite only being slightly less than Nz of the chlorite. This chlorite is nearly isotropic, even in a section normal to the cleavage. It is pleochroic: X = colourless; Y and Z = green, and is biaxial negative, with 2V = 1-3°. This latter chlorite is probably penninite, according to the classification of Hey (1954); the former chlorite is more difficult to place, as in this section we can place no upper limit to the refractive index, although by estimation it seems likely to be below 1.62; on this limit it suggests corundophyllite. Muscovite occurs very occasionally as flakes associated with biotite. Garnet forms idioblastic to xenoblastic, faintly pink crystals about 0.4 mm. in size, often partly or wholly poikiloblastically enclosing quartz and biotite. Besides these inclusions it encloses minute fragments of an opaque material, and has been irregularly altered slightly to penninite. Spinel, coloured green, and isotropic, is present. Within the section it is rarely seen to be associated with garnet. Quite often it is partially enclosed by biotite and chlorite, and commonly it is bounded by quartz, though no reaction rim between the two is present. Spinel is subidioblastic to idioblastic, having a "cubic" shape, and occurs as crystals up to 0.15 mm. in size. Its refractive index is slightly less than that of garnet. Black iron ore occurs usually as subidioblastic, cubic-shaped crystals, about 0.1 mm. in size, though larger, xenoblastic masses, up to 1.2 mm. in size are present. A few minute euhedra of tourmaline are present, it is pleochroic:- o = green; e = very pale green. Some minute euhedra of a mineral with fair relief and low birefringence occur, it is probably apatite. Both tourmaline and (?)apatite are enclosed in quartz. Associated with biotite and (?)corundophyllite, and causing pleochroic haloes in them, are some minute minerals, one being colourless, with high relief - this may possibly be zircon; the other is greenish-brown, possibly being allanite. Occasional staining by hydrated iron oxide is present.

An estimation of the percentages of the various minerals present is: quartz 47; biotite (and corundophyllite (?)) 20; garnet (and penninite) 25; spinel 3; black iron ore 4; the remainder 1. The rock is a garnet-biotite-quartz schist.

Cutting the rock is an irregular zone, running obliquely across the direction of mica lineation. It is 0.75 mm. wide, and the micas have been elongated parallel to its direction, and cracks are present in quartz, running in a similar direction. There has been an enrichment of irregular grains of black iron ore in this zone.

4167. Photograph 5008, section 6. Green Parrot, Plate 4.

The hand specimen, on a fresh surface, is seen to be fine- to medium-grained, and equigranular. It contains granular quartz, and flakes of biotite which show preferred orientation. Some pink garnet is seen to be present. The weathered surface is stained with hydrated iron oxide.

In thin section, the texture is seen to be medium grained and granoblastic-lepidoblastic. Quartz occurs as xenoblastic angular grains, of 0.1 mm. average size, with tesselate margins, and has a faintly undulose extinction. Biotite forms xenoblastic, sub-poikiloblastic flakes, whose average size is 0.3 mm. by 0.8 mm., and which commonly has a parallel orientation although occasional flakes lie obliquely to this direction. It is pleochroic:- X = light fawn, Y and Z = dark greenish brown. It has, occasionally, very small inclusions of a mineral which is slightly pleochroic in yellow, and which makes intense pleochroic haloes in the biotite: this mineral is probably allanite. Biotite is sometimes partially or wholly altered to a chlorite, which is pleochroic: X = colourless; Y and Z = apple green. The chlorite is optically positive, its refractive index is less than that of canada balsam, birefringence of 0.002. Muscovite occurs very occasionally as small flakes enclosed in biotite, and often with the length of the flake lying normal to the direction of schistocity. Garnet occurs as idioblastic crystals, often in small clusters of four to seven. The crystals have an average size of 0.12 mm. Garnet has minute inclusions of an opaque, dusty mineral, and of quartz; occasionally hydrated iron oxide is included. Black iron ore forms subidioblastic crystals. Hydrated iron oxide is present in places as an intergranular staining. Minute euhedra of tourmaline occur, it is pleochroic with o = grey green; e = colourless.

An estimation of the mineral content is: quartz 40%; biotite 30%; garnet 20%; black iron ore 8%; the remainder 2%. The rock is a garnet-biotite-quartz schist.

4199. Photograph 5008, section 5, point 239. Plate 1.

On a fresh surface, the specimen is seen to be a glistening, grey-black, fine-grained rock, consisting of dark mica, quartz, and a white powdery mineral, shown in section to be sericite. The specimen has a schistosity, parallel to which are lenticles of quartz rich rock, 2 - 3 mm. wide, and up to 2 cms. long. The schistosity has been buckled into "folds" whose amplitudes may be measured in inches. These are seen best on the weathered surface, which is stained with hydrated iron oxide.

The thin section shows the rock to be fine-grained, rather equigranular, and granoblastic-lepidoblastic. Quartz occurs as granoblastic grains with sub-tesselate margins. It may be concentrated into lenticles, but most commonly it occurs with the other minerals. Sericite forms masses of minute flakes grouped into xenoblastic grains, with random orientation, giving the impression of pseudomorphing a pre-existing felspar. It commonly occurs in the quartz-rich lenticles, but is not confined to these areas. Biotite occurs as small xenoblastic flakes showing a preferred orientation: it is pleochroic with X = pale straw, Y = Z = very dark brown. In places, muscovite may be seen intergrown with it

Some more rare accessory minerals are present. Epidote occurs as fine, tabular, pale green-yellow crystals. Tourmaline, pleochroic with O = dark smoky blue, and e = pale pink, is present as small prisms. Apatite forms minute acicular crystals enclosed in quartz. The most common accessory is black iron ore, which occurs as granoblastic to octahedral crystals, sometimes more concentrated into the more quartz-rich, lenticular bands.

An estimation of the quantities of minerals present is: - quartz, 30%; sericite, 35%; biotite, 30%; black iron ore, 3%; the remainder 2%. The rock is a quartz-biotite - sericite-schist.

It is of interest to note that apart from the quartz - rich lenticles, band rich in sericite and biotite, and layers with roughly equal proportions of quartz, sericite and biotite are present.

4204. Photograph 5210, section 3. Cox's North, Plate 5.

In hand specimen the rock is an iron oxide-stained, rather friable porphyroblastic mica schist. It is medium-grained, and contains quartz, white mica, and some biotite. The porphyroblasts tend to be elongated, with random orientation, and measure up to 15 mm. length.

Thin section shows the rock to be medium-grained, lepidoblastic-granoblastic, and porphyroblastic. In the groundmass, quartz occurs as rather angular grains having sub-tesselate margins, with a slight elongation of shape parallel to the schistocity. Muscovite forms rather thin "acicular" flakes, with a preferred orientation. They are wrapped around the porphyroblasts. Biotite, present in lesser quantities, has a similar habit. It is pleochroic, X = brownish yellow to olive brown, Y = Z = brown-black. In layers which are rather more quartz-rich, the micas tend to have a more random orientation. Black iron ore occurs as rather irregular grains, and also as small granules associated with biotite. Hydrated iron oxide is present as intergranular dust.

The porphyroblasts are formed of staurolite, and of garnet. The former mineral occurs in clusters of small porphyroblasts, with quartz, in zones about which mica is wrapped. The crystals are xenoblastic, and poikiloblastically enclose quartz. They are pleochroic: X = almost colourless, Y = pale yellow, Z = golden yellow. Its birefringence is 0.013, and it is biaxial positive with a large 2V. Staurolite has hydrated iron oxide along its cracks and crystal margins. Garnet (almandine) is now largely replaced by hydrated iron oxide; large masses of the latter mineral occur, with small remnant grains of the very pale pink garnet, poikiloblastically enclosing quartz.

An estimate of the percentages of minerals present is: quartz: 50, muscovite: 20, biotite: 15, staurolite: 7, almandine and hydrated iron oxide: 5, black iron ore: 3.

The rock is a porphyroblastic garnetiferous staurolite-biotite-muscovite-quartz schist.

4207. Photograph 5210, section 3. Cox's South, Plate 6.

The hand specimen is a friable, ferruginous and porphyroblastic mica schist, the lineated flakes of white mica being wrapped around porphyroblasts of iron-stained garnet, and vaguely tabular staurolite. Quartz is present in about equal proportions to mica, and is granular.

Thin section shows the rock to be medium-grained, with a porphyroblastic, lepidoblastic-granoblastic texture. Quartz occurs as xenoblastic crystals, approximately 0.12 mm. average size, which have tesselate margins. The crystals are elongated slightly in the direction of schistocity. Muscovite forms colourless flakes, which have a preferred orientation, and whose average size is about 0.24 mm. by 0.1 mm. The porphyroblasts tend to have layers, 0.5 mm. thick, composed of muscovite, wrapped around them; but normally, the flakes are interspersed with quartz. Biotite is present in much smaller quantities than white mica. It forms xenoblastic flakes, proportionately shorter and wider than those of muscovite: its pleochroism is: X = light olive brown, Y = Z = deep brown, nearly black. The groundmass tends to be stained with hydrated iron oxide dust.

The porphyroblasts consist of very pale pink garnet, and lesser amounts of yellowish staurolite. The former mineral occurs as large, poikiloblastic crystals measuring up to 5 mm. across. It encloses rather irregular grains of quartz, which are sometimes arranged in deformed trains suggesting anticlockwise rotation. Quite frequently the garnet (probably almandine) shows incipient to almost complete alteration to hydrated iron oxide. Staurolite forms vaguely tabular, but exceedingly poikiloblastic crystals which are pleochroic from colourless to golden yellow. The inclusions are mainly of quartz.

An estimation of the amounts of the various minerals present is: quartz:35%, muscovite: 35%, garnet (with hydrated iron oxide); 15%, staurolite: 10%, biotite: 5%.

The rock is a porphyroblastic biotite-staurolite-garnet-muscovite-quartz-schist.

4210. Photograph 5210, section 3. Bellbird, Plate 7.

The hand specimen is a finely fissile, greenish schist, composed almost entirely of chlorite, with very small amounts of quartz.

Thin section shows this to be true. Chlorite, most usually, forms long thin flakes, 0.6 mm. long by 0.1 mm. wide, arranged parallel to one another. However, short, squat flakes occur in small, lenticular bands, roughly parallel to each other, but the strike of the flakes being at an approximate right-angle to that of the main schistocity. Small lenticles of quartz, 1.5 mm. long and 0.1 mm. thick, consist of small, somewhat elongated grains of quartz, with rather irregular margins.

The optical properties of the chlorite are: its pleochroism is X = Y = pale apple green, Z = very pale fawn. The refractive index Y is 1.582 approximately. It has a birefringence of 0.008, and is uniaxial positive. These properties suggest that it is clinochlore, according to Winchell (1951), and that it is rich in magnesium and alumina.

The rock is a chlorite schist.

4218. Photograph 5210, section 3. Bellbird, Plate 7.

The hand specimen is medium-grained, and is silvery mottled with pale green. It has a granular to schist-like texture. The rock is very friable, in fact it may be easily crumbled by one's fingers, hence a thin section was not made. Some of the sample was crushed, and examined in oils, and some minerals were identified. Greenish chlorite occurs in felted masses, with muscovite, separated by more granular areas containing quartz. The chlorite is pleochroic with X = Y = apple green, Z = pale fawn. It is biaxial positive, with a small 2V. Occasional crystals of pink garnet are present. A few prismatic crystals of tourmaline, with o = black, e = pinkish grey, were noted. Also present is a pale emerald green mineral in the hand specimen, which, under the microscope, has a golden brown colour, and has fairly strong birefringence, with a biaxial positive figure whose 2V = 30^{o}-40^{o}. Irregular areas of malachite are present.

The rock appears to be a cupriferous garnetiferous muscovite-chlorite-quartz schist.

4225. Photograph 5008, section 6. Reward, Plate 2.

The hand specimen is greyish, with rather lenticular, sub-parallel mottled brownish red bands. The whole is medium-grained and granular. The dominant mineral is quartz, but in the brownish-red areas, staurolite forms rather elongated crystals. Flakes of mica are present, and some garnet.

The specimen's texture, in thin section, is medium grained, inequigranular, and granoblastic, tending to nematoblastic. It is somewhat foliated. Quartz forms a background mosaic of xenoblastic grains, which range in size between 0.1 mm. and 0.7 mm: some regular, banded, variation in grain size is present, parallel to the staurolite elongation. Quartz has rather undulose extinction. Staurolite forms xenoblastic, sometimes vaguely tabular crystals measuring up to 2.4 mm. long by 0.15 mm. wide, and showing some preferred elongation of shape, though it has random optical orientation. It poikiloblastically encloses smaller grains of quartz, and black iron ore, and partially encloses garnet, though the inclsuions are not numerous. It has high relief, and is pleochroic with X = colourless, Y = yellow, Z = slightly darker yellow, i.e. Z>Y>X. The birefringence is 0.015, and the mineral is biaxial negative, with 2V = 85°-90°. Garnet (almandine) is colourless, or very pale pink, and completely isotropic. It forms subidioblastic, rather granular crystals ranging between 0.1 mm. and 0.5 mm. in size. Small inclusions of quartz are present near the centres of the crystals. Biotite occurs as subidioblastic flakes, oriented roughly parallel to the lineation. It is pleochroic with X = light fawn, Y = Z = brown. Occasionally it is altered to penninite, but more commonly to hydrated iron oxide. Occasional flakes of muscovite may be seen. Black iron ore occurs as cubic or octahedral crystals, approximately 0.2 mm. in size: they tend to form trains parallel to the foliation. Veins of hydrated iron oxide, 0.1 mm. wide, cut the rock in the direction of the foliation.

An estimation of the approximate amounts of minerals present is: quartz = 50%, staurolite = 25%, garnet = 15%, black iron ore = 7%, biotite and muscovite = 3%. The rock is a (biotite-muscovite) - "magnetite"-garnet-staurolite-quartz-gneiss.

4231. Photograph 5008, section 6 Marshall, Plate 3. (Figure iii)

The hand specimen consists of two parts. Firstly there is a medium-grained metamorphic rock, dark grey, mottled with pink which consists of granular quartz and pink garnet, and flakes of biotite, the latter showing some preferred orientation. Secondly, there is a coarse-grained vein which cuts the first rock. This consists of coarse grained quartz and clusters of greenish flakes of chlorite and biotite.

In thin section, the metamorphic rock is medium-grained and rather inequigranular, and is granoblastic-lepidoblastic. Quartz forms a mosaic of xenoblastic grains, with angled corners and subsutured margins. Faintly pink to colourless garnet (almandine) occurs as subidioblastic crystals, except where they neighbour, or are partially enclosed by biotite; here they frequently have a slightly "corroded" boundary. The centres of garnet crystals are commonly filled with colourless inclusions. Biotite occurs as xenoblastic flakes with a rough preferred orientation. It is pleochroic, with X = orange brown, Y = dark brown, Z = brown, or nearly black. Pleochroic haloes are present. Black iron ore forms xenoblastic to subidioblastic crystals, sometimes showing octahedral shape. An estimation of the percentages of minerals present is: Quartz = 50, garnet = 25, biotite = 20, black iron ore = 5. The rock is a biotite-garnet-quartz-schist.

As the rock is traced closer to the boundary of the vein the schistocity becomes more pronounced: all through the rock it is parallel to the vein. Biotite becomes somewhat chloritized, and garnet also shows alteration to chlorite. The junction with the vein is quite sharp. The chlorite altered from the biotite is pleochroic with X = Y = pale apple green, Z = light fawn. It has a uniaxial positive figure, and its birefringence is very low, approximately 0.002-3, showing anomalous brown and brownish purple interference colours. Its refractive index is slightly higher than that of biotite. A very small amount of muscovite is present on the schist boundary.

The vein is coarse-grained inequigranular and xenomorphic. Quartz forms anhedral crystals ranging in size between 0.21 mm. and 4.08 mm. The grains have sutured margins, and show foliated undulose extinction. Biotite and its alteration product chlorite occur in clusters of coarse flaky crystals. Biotite is pleochroic, with X = pale fawn, Y = Z = brownish-green, tending to be olive at crystal edges. It is biaxial negative, with 2V = $0^{o} - 5^{o}$. Chlorite is pleochroic with X = Y = pale green, Z = very pale fawn: it has a very low birefringence, and is uniaxial positive. Its refractive index is rather higher than Y of biotite, suggesting that it is penninite. Muscovite and octahedra of black iron ore are sporadically associated with biotite and chlorite.

4260. Photograph 5210, section 3. Cox's North, Plate 5.

The rock, in hand specimen, is seen to be a medium-grained ferruginous gneiss, in which muscovite and biotite tend to form layers separated by quartz: muscovite shows a lineation. Porphyroblasts of red garnet are present, and small grains of a non-magnetic black ore may be seen. In general aspect the rock is reddish, gneissic, and rather friable.

In thin section the specimen is medium-grained, but inequigranular. It has a granoblastic-lepidoblastic, and gneissic texture, with a mosaic of quartz grains forming a background to rude layers of muscovite and biotite.

Quartz forms xenoblastic crystals with crenulate margins: it has foliated strained extinction. Muscovite occurs as sub-tabular flakes with a rough preferred orientation, tending to be concentrated in layers. Biotite shows little preferred orientation, and although not entirely excluded from the muscovite folia, it is somewhat concentrated into layers of its own. It is uniaxial negative, and is pleochroic, with X = very light straw-brown, Y = Z = olive brown, the crystal edges and cleavage planes turning nearly black. Pleochroic haloes are present around (?) zircon, and around minute crystals of an opaque mineral. Infrequently, biotite has been altered to chlorite, which is pleochroic: - X = light straw-fawn, Y = Z = apple green. Its refractive index is approximately 1.59, and it is uniaxial negative, with a birefringence of 0.006.

Garnet (almandine) occurs as large, rather irregular poikiloblastic pale pink porphyroblasts, which tend to be elongated along the foliation. They enclose small granules of quartz. Frequently garnet is altered along its cracks and boundaries to a mixture of magnetite and hydrated iron oxide: some crystals are so altered as to leave small, isolated grains of garnet enclosed in very irregular masses of black iron ore. Some cracks in garnet contain a chlorite similar to that described above. Subidioblastic, octahedral crystals of opaque ore are present. A coarse, poikiloblastic crystal of tourmaline was noted, elongated parallel to the foliation. It is pleochroic, with O = light smoky grey, and e = smoky bluish grey.

An estimate of the percentages of minerals present is: quartz: 50, muscovite: 15, biotite and chlorite: 13, "magnetite": 10, almandine: 10, tourmaline: 1.

The rock is a "magnetite"-garnet-biotite-muscovite-quartz gneiss.

ii. Pelites and semi-pelites bearing porphyroblasts of cordierite, andalusite, and biotite.

4161. Photograph 5008, section 6. Attutra, Plate 3. (Figure i).

On a fresh surface the hand specimen is rusty pink, mottled with grey in the groundmass. It is fine to medium-grained, and schistose in texture, with large grey porphyroblasts of "cordierite" occurring, pushing apart the schisty cleavage. The groundmass consists mainly of white mica, with some quartz, and some small grains of a dark mineral. On a weathered surface, erosion has emphasized the schistocity, and the large porphyroblasts.

In thin section, the specimen is seen to be medium-grained, lepidoblastic and porphyroblastic in texture. Quartz occurs as xenoblastic, roughly rectangular grains, 0.1 mm. average size, with sub-sutured margins: the longer axes of the grains are oriented parallel to the schistocity. Muscovite is present as thin, subidioblastic, parallel flakes measuring 0.06 mm. by 0.22 mm. Chlorite forms subidioblastic flakes ranging up to 0.24 mm. by 0.48 mm. The flakes are rarely exactly parallel to the schistocity, more often they cut across it; chlorite is pleochroic: X = pale green; Y = green; Z = colourless. It is "uniaxial" positive. Its refractive index is slightly less than that of muscovite, and its birefringence = 0.010. In the classification of M.H. Hey (1954) this would be sheridanite. Sheridanite often has inclusions of quartz and muscovite. Albite occurs as xenoblastic grains of similar shape and size to quartz. Its refractive index is less than that of Canada balsam, and it is biaxial positive, with $2V \pm 70\text{-}80^{\circ}$ Little trace of either simple or multiple twinning may be detected. Albite is altered to kaolin and sericite. Black iron ore, possibly magnetite, occurs as subidioblastic, often roughly tabular shaped grains, whose longer axes are parallel to the rock's schistocity. The average size of the grains is 0.09 mm., although grains up to 0.7 mm. do occur. Tourmaline is present as small idioblastic crystals; it is pleochroic:- o = green-grey, e = colourless. Occasionally they have a core of darker tourmaline, which is pleochroic: - o = black, e = light grey-green. The two grade into one another. Occasional minute prisms of zircon may be seen. Some prismatic euhedra of apatite also occur.

The groundmass crystals, especially the micas, are wrapped around large porphyroblasts, which consist of a mixture of fine grains of sericite and chlorite, enclosing round, fine crystals of quartz, and occasional groundmass-size flakes of chlorite. These minerals appear to be pseudomorphing cordierite.

An estimation of the composition of the rocks is: quartz 30%, muscovite 25%, "cordierite" 20%, albite 15%, chlorite 5%, the remainder 5%. The rock is chlorite-albite-"cordierite"-muscovite-quartz schist. The specimen is cut by a vein containing apatite, chlorite, fluor-spar, and black iron ore.

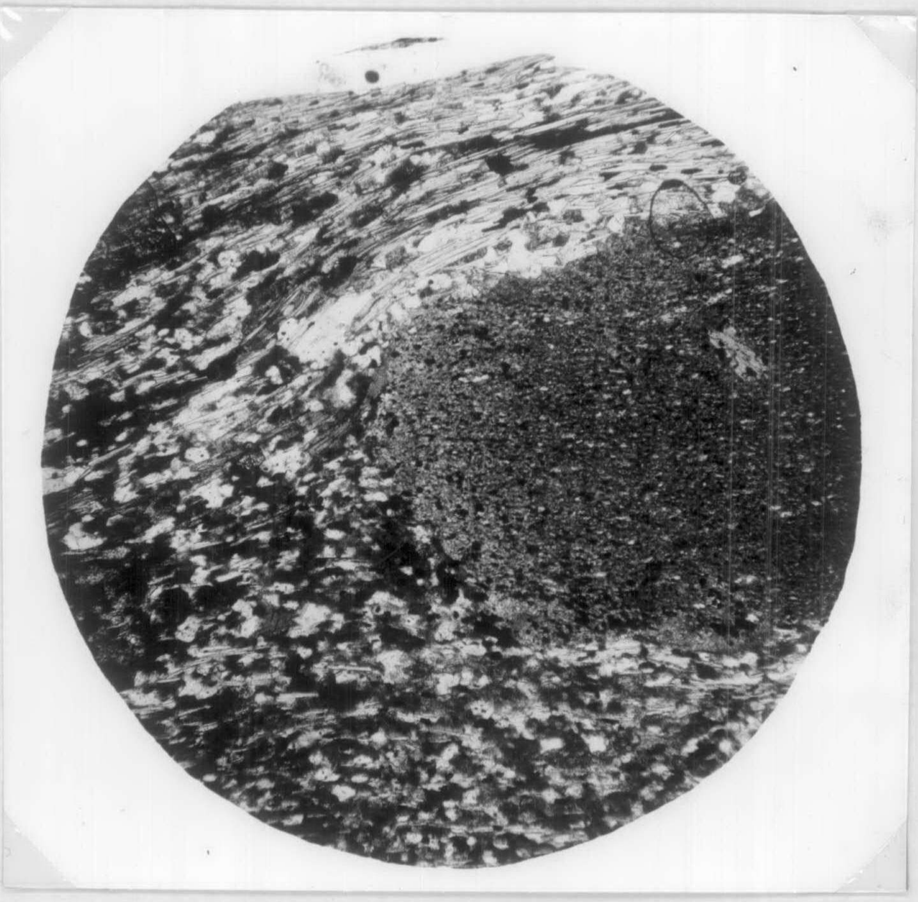

Fig. i. Specimen 4161: albite-"cordierite"-muscovite-chlorite-quartz-schist. The photograph shows a porphyroblast of pinitized cordierite at the right centre, with the schistocity of the groundmass wrapped around it. Quartz forms the white grains with no cleavage: muscovite forms the white elongated and cleaved flakes: albite forms greyish angular grains: chlorite forms the dark elongated flakes: the black grains are black iron ore. Ordinary light, X25.

<u>4187</u>, Photograph 5008, section 9, point 134, and <u>4198</u>, photograph 5008, section 7, point 233. Plate 1.

Both hand specimens are knotted porphyroblastic mica-schists. The porphyroblasts consist of "cordierite", andalusite, and biotite. "Cordierite" forms large xenoblastic crystals, measuring up to 2 - 5 cm. long, and elongated in the direction of schistosity; they are now altered to quite soft material, easily scratched by glass. Andalusite forms similar, but rather smaller, porphyroblasts. Biotite occurs as porphyroblastic crystals measuring up to 5 mm. in size, and having random orientation. It frequently grows within andalusite and "cordierite", especially in 4197. The schistosity of the groundmass is both transgressed and pushed aside by the porphyroblasts. A false cleavage runs in a direction of 30° to that of the schistosity. The groundmass consists of white mica and quartz, and is fine- to medium-grained. Though quartz and muscovite have a general distribution throughout the specimen, occasional clots composed solely of lineated muscovite are present.

Both rocks were difficult to section, and only in 4198 was the groundmass preserved. Here it consisted of a fine to medium-grained lepidoblastic-granoblastic mass of muscovite and albite, and quartz, with occasional felted zones of muscovite, the latter showing a false cleavage.

Of the porphyroblasts, "cordierite" now consists of a mass of minute pale brown mica flakes with random orientation. This mica has a refractive index slightly greater than that of biotite, and has a fairly strong birefringence. "Cordierite" encloses granules of quartz, and flakes of muscovite and biotite. Andalusite forms xenoblastic, colourless porphyroblasts showing a pronounced sieve-structure, enclosing numerous granules of quartz, with some black iron ore. It is often associated with false-cleaved muscovite and appears to pseudomorph that mineral, as it contains trains of inclusions reflecting the wavy false cleavage, although it is not deformed optically. Biotite porphyroblasts show little preferred optical orientation, though some elongation of shape parallel to the schistosity may be seen. Some of the crystals are very poikiloblastic; commonly, where biotite has grown, muscovite is absent, both as inclusions, and for a short distance around the porphyroblasts. Also, in some places, the groundmass quartz has recrystallized as a granular mosaic in the vicinity of the biotite porphyroblasts. Biotite is apparently unaffected by the false cleavage, although their direction of growth appears to have been controlled by it.

Black iron ore occurs as fine to medium-grained octahedra in the groundmass and enclosed in the porphyroblasts. A very small amount of chlorite is present with muscovite. Rare tourmaline may be seen.

An estimation of the percentages of minerals present in 4198 is: - quartz and albite 33; muscovite, 35; "cordierite", 15; andalusite, 10; biotite, 5; black iron ore, 2; with traces of the accessory minerals. In hand specimen, 4198 is seen to have rather more biotite and "cordierite" than 4187.

Both rocks are <u>porphyroblastic, andalusite-"cordierite"-quartz-muscovite schists</u>.

<u>4200</u>. Photograph 5008, section 6, point 261, Plate 1.

The hand specimen is a fine- to medium-grained, porphyroblastic, crenulated, quartz-mica schist. The porphyroblasts (of andalusite) measure up to 1 cm. in diameter, and the schistosity is wrapped around them. The weathered surfaces are brightly stained with hydrated iron oxide.

In section the rock is seen to be fine- to medium-grained, lepidoblastic-granoblastic, and porphyroblastic. In the groundmass, quartz forms xenoblastic grains with tesselate margins; the grains tend to be elongated in the direction of schistosity. Biotite is pleochroic with X = misty fawn, Y = Z = dark foxy brown. It forms stubby flakes measuring up to 0.5 mm. in length, most of them showing preferred orientation. Colourless muscovite occurs as much smaller, thin flakes, again showing preferred orientation. Black iron ore is present as octahedral grains in the groundmass.

The section shows that there appear to be mica-rich, felted layers, approximately 2 - 3 mm. thickness, which grade laterally and transversely into more quartz-rich layers. The schistosity is wrapped around the porphyroblasts, and in the "corners" of the "eyes" so formed, there occur small patches where the texture is more granoblastic than schistose.

The porphyroblasts are extremely poikiloblastic andalusite, which enclose all the minerals of the groundmass, and rare crystals of faintly pink garnet. The latter mineral forms idioblastic crystals measuring up to 0.7 mm. in size. In this section it was not observed in the groundmass, but only in andalusite. The long axes of most of the biotite books contained in andalusite lie at a high angle to those of biotite in the neighbouring schist.

Two thin, irregular veins were seen cutting the rock parallel to the schistosity, and appeared to consist of (?)fluorspar.

An estimation of the percentages of minerals present is:- quartz, 25; biotite, 30; muscovite, 25; andalusite, 15; black iron ore, 3; garnet, 2. The rock is an <u>porphyroblastic - andalusite-quartz-muscovite-biotite schist</u>.

<u>4213</u>. Photograph 5210, section 3. Bellbird, Plate 7.

The hand specimen has a rusty-pink, fine-grained, apparently platy groundmass, enclosing large porphyroblasts of dark mica, which are randomly oriented; some pink garnets are also present, and white porphyroblasts which were found to be andalusite. The rock is rather friable.

In section the rock is seen to consist of biotite, andalusite, quartz, and (?)almandine garnet. Texturally the rock is porphyroblastic, and nematoblastic-granular. Biotite occurs mainly as large porphyroblasts, ranging between 0.3 mm. and 3.5 mm. in size. The crystals are xenoblastic, and have random orientation. The poikiloblastically enclose small grains of quartz, which run as lines through biotite, continuing the lineation of the rock. Biotite is pleochroic, with X = pale orange brown, Y = Z = dark brown-black. Idioblastic porphyroblasts of colourless almandine are sparsely scattered in the rock: they push aside the lineation of the groundmass minerals, and frequently have inclusions at their centres, roughly parallel to the direction of the groundmass. Andalusite forms extremely poikiloblastic and xenoblastic grains, which enclose quartz, and occasional small crystals of biotite. Inclusions may locally be more plentiful than the host mineral. The andalusite has a preferred orientation, parallel to the trains of quartz grains enclosed in biotite. It is not found enclosed in biotite.

In the groundmass, quartz forms a mosaic of fine-grained xenoblastic grains with tesselate margins. Small crystals of biotite, with similar pleochroism to the porphyroblasts occurs as xenoblastic flakes with parallel orientation. Black iron ore forms subidioblastic, octahedral crystals. Some hydrated iron oxide staining is present.

An estimate of the percentages of minerals present is: biotite, 35; andalusite, 35; quartz, 20; garnet, 5; black iron ore, 5.

The rock is a porphyroblastic garnetiferous quartz-andalusite-biotite-schist.

4219. Photograph 5210, section 3, Point 123; Plate 1. (Figure ii).

The hand specimen is a medium to coarse-grained, rather friable, and somewhat ferruginous schist or gneiss, which fractures parallel to the foliation of the minerals. It contains andalusite and granular quartz. Occasional crystals of red garnet may be seen.

In thin section the specimen is roughly gneissic, and has a porphyroblastic texture, with a lineation of andalusite parallel to the gneissic foliation.

Xenoblastic crystals of quartz, whose average grain size is 0.12 mm., and which have sub-tesselate margins, forms a medium to fine-grained mosaic away from andalusite. In small, lenticular quartz-rich bands, biotite occurs as small xenoblastic flakes, showing some preferred orientation parallel to the foliation. However, most of the biotite present forms large poikiloblastic flakes, of up to 2.1 mm. in size, some of which have both elongation and cleavage traces running parallel to the foliation: more commonly however, their cleavage traces are more randomly oriented, though the elongation of the flakes is frequently parallel to the foliation. Biotite encloses abundant quartz, but rarely, if ever, andalusite. The enclosed quartz commonly shows a parallel tabular or spherical elongation, though little crystallographic orientation. Small, parallel flakes of biotite may also be enclosed. Biotite is pleochroic with X = straw fawn, Y = deep brown, and Z = dark brown: frequently, small tabular crystals of zircon make pleochroic haloes. Rare chlorite may be seen altering from biotite. Roughly tabular, subparallel crystals of poikiloblastic andalusite occurs between the biotite-rich bands. It encloses quartz, and much less frequently, small biotites: often, the inclusions are so numerous that the various parts of any one crystal appear disconnected. Andalusite is length fast along the cleavage parallel to the length of the crystal. It is biaxial negative, with $2V \simeq 80^{\circ}$. The garnet (almandine) is colourless, or faintly pink. It is completely isotropic, and frequently shows alteration along its margins and cracks to hydrated iron oxide. Inclusions of quartz contained within it often show a lineation, frequently running in an oblique direction to that of the foliation: this may be due to rotation. Occasional small crystals of muscovite are present enclosed in andalusite and associated with biotite. Black iron ore occurs in two forms: firstly as large subidioblastic crystals (0.5 mm size) surrounded by a rim of hydrated iron oxide; and secondly, as minute tabular crystals, elongated parallel to the foliation, enclosed in andalusite; this latter one may be ilmenite.

An estimation of the percentages of minerals present is:- quartz, 20; biotite, 25; andalusite, 45; garnet, 5; black iron ore, 3; muscovite, 1. The rock is a porphyroblastic garnetiferous quartz-biotite-andalusite gneiss.

Thin, rather irregular veins, 0.02 mm. to 0.05 mm. thick, cut the rock, and contain pale pink and isotropic fluorspar.

4223. Photograph 5008, section 6. Reward, Plate 2.

The hand specimen is a friable, silvery quartz-mica schist, containing felted mica and quartz-rich bands. Some slip-strain cleavage may be seen. Large porphyroblasts of possible cordierite occur: they are dark, and rounded, and measure up to 8 mm. across. Owing to the friable nature of the rock, a thin section was made only with difficulty.

The section shows that the rock has a medium-grained, lepidoblastic texture, and consists mainly of flakes of colourless muscovite, and granoblastic quartz: there appear to be quartz-rich bands, separated by rather thick layers of felted muscovite, commonly showing false cleavage. Octahedral crystals of black iron ore are present, often showing alteration to hydrated iron oxide. Idioblastic crystals of tourmaline, having a random orientation, may be seen: they are pleochroic, with o = dark green, e = greyish or colourless. Some flakes of biotite are present, a few of which form small porphyroblasts.

The major porphyroblasts are pinitized cordierite: they are crowded with inclusions of small granules of black iron ore, hydrated iron oxide, quartz, and prismatic tourmalines. Larger cubes of black iron ore are present, occasionally fringed by muscovite.

The rock is a porphyroblastic cordierite-quartz-muscovite schist.

iii. Iron-Enriched Granulites, with or without Iron, Copper, and Lead Sulphides.

4172. Photograph 5008, section 6. Green Parrot, Plate 4.

The hand specimen is dark-coloured, medium-grained, granular and friable with numerous cavities which appear to be intergranular. It consists mainly of quartz; this mineral often has a coating of a pale cream, dusty, substance. The rock is stained with hydrated iron oxide.

In thin section the specimen is seen to consist mostly of quartz. It forms a mosaic of inequigranular, xenoblastic crystals, whose size ranges between 0.08 mm. and 0.64 mm. Their margins are tesselate to sub-tesselate. A slight undulose extinction is present. Hydrated iron oxide dust occurs, often forming the boundary between quartz grains. Where quartz is on the edge of a cavity, it appears to have enlarged a short way into the cavity, since a line of hydrated iron oxide dust occurs in any particular grain, parallel to the edge of the cavity, enveloped in a rim of quartz, which is in optical continuity with the remainder of the grain: this rim has probably been added since the formation of the iron oxide dust. Larger, irregular masses of hydrated iron oxide are present in the specimen, interstitial to, and partly enclosing quartz. They appear to run in roughly parallel veins.

An interesting fact arising from this examination is that of the cavities, and the enlarged quartz grains neighbouring them. It is possible that another mineral has been removed from there.

The rock is a limonitic quartz-granulite.

4205. Photograph 5210, section 3. Cox's south, Plate 6.

The hand specimen is medium-grained, and dark grey, stained dull red. It consists mostly of quartz, with subordinate iron oxide, and some chloritic flakes. Small, irregular infillings of chrysocolla are infrequently present.

In thin section, the specimen is medium-grained inequigranular, and granoblastic. A mosaic of angular quartz grains showing slight strained extinction, and having sub-sutured margins, forms a background to highly irregular fragments and some octahedral crystals of black iron ore, probably magnetite. The magnetite forms highly complex, almost symplectoid intergrowths, seemingly showing little relationship to the quartz boundaries; it is partially altered to haematite, both marginally and internally. Small amounts of green chlorite are present as xenoblastic to tabular flakes, sometimes associated with the haematite. It is pleochroic, with X = pale greenish fawn, Y = Z = apple green, and its birefringence is very low, approximately 0.002, showing anomalous dark blue colours. An interference figure showed it to be uniaxial negative. Its refractive index is very approximately 1.59; the chlorite is probably penninite. Occasionally, small amounts of biotite may be seen associated with it. Minor amounts of muscovite are present as tabular flakes. Colourless garnet is a rare accessory; some aggregates of hydrated iron oxide may represent altered garnet. A little chrysocolla was noted in a number of places.

An estimation of the percentages of the minerals present is: quartz, 65; "magnetite", 25; chlorite, 7; muscovite, chrysocolla and biotite, 3.

The rock is a chloritic and haematitic garnet-biotite-"magnetite"-quartz-granulite.

4206. Photograph 5210, section 3. Cox's South, Plate 6.

The hand specimen may be divided into two parts, separated by a thin zone of veining. One part is fine to medium-grained, and granular, consisting mostly of quartz, with subordinate garnet and chlorite. The second part is rather more coarse-grained and distinctly more micaceous and ferruginous, though there is apparently no preferred orientation of the mica flakes. The zone of veining appears to be very ferruginous, and has malachite deposited along it. Malachite also appears in irregular cavities and patches in the rock.

The thin section cuts across both parts of the rock. Quartz, throughout the rock, occurs as a granoblastic mosaic of grains with subtesselate margins, of roughly equal size i.e. 0.10 to 0.15 mm. In the apparently fine-grained region the texture is granoblastic-lepidoblastic. Idioblastic crystals of colourless garnet (almandine), 0.1 mm. average size, are present.

They are commonly partly altered to hydrated iron oxide, and to green chlorite. Biotite, now largely chloritized, forms small, roughly parallel flakes, 0.03 mm. wide by 0.15 mm. long. It is pleochroic with X = light straw brown, Y = Z = brownish black, although it often has a greenish tinge. Some biotite has been altered to nontronite. Small octahedra of black iron ore are present. In this part of the slide, quartz forms 70% of the rock, biotite, etc., 15%, garnet, 10%; and black iron ore, 5%.

In addition to quartz, the "coarser"-grained part of the specimen contains large sub-poikiloblastic crystals of biotite, chlorite and hydromuscovite. No preferred orientation is present. Biotite is pleochroic with X = orange brown, Y = Z = deep red-brown. Chlorite, which is associated with biotite, is pleochroic with X = very pale fawn, Y = Z = green. It is uniaxial negative, and has a very low birefringence, showing anomalous blue colours. Its refractive index is approximately 1.58. Very pale green hydromuscovite forms fairly large poikilitic but rather fibrous crystals. It has a refractive index of approximately 1.60, a birefringence of 0.035-7, and is uniaxial, or biaxial with a small 2V which is negative. Idioblastic octahedra of black iron ore ("magnetite") are present, often in small clusters. The percentages of minerals occurring in this part of the rock are: quartz, 50; "magnetite", 18; biotite, 10; chlorite, 10; hydromuscovite, 10; muscovite, 2.

The vein zone is greatly enriched in black iron ore, which forms very irregular grains of varying size, the large ones poikiloblastically enclosing quartz. Malachite is sometimes associated with it. The zone is also enriched in large flakes of biotite, chlorite, and hydromuscovite, all enclosing granules of black iron ore. These minerals tend to be elongated parallel to the vein near its centre.

The specimen is composite, the finer grained portion being a <u>garnetiferous-chlorite-quartz schist</u>, and the more coarse region is <u>hydromuscovite-chlorite-biotite-"magnetite"-quartz-granulite</u>.

<u>4209</u>. Photograph 5008, section 6. Green Parrot, Plate 4.

The hand specimen is a hard compact, fine to medium-grained and ferruginous-quartz rock, with some red garnet, and flakes of a micaceous mineral. The specimen is dark grey, fringed with red, and has ferruginous staining on the weathered surface.

In section, the rock is found to be fine-to medium-grained, and granoblastic, and contains some 40% of quartz, 35% of black iron ore (largely or entirely "magnetite"), 20% of garnet, the remainder being biotite. Quartz forms granoblastic grains with tesselate margins. Black iron ore occurs as rather irregular, sub-poikiloblastic grains. Garnet (probably almandine) is sub-idioblastic, and rather stained with hydrated iron oxide. Biotite is present as xenoblastic flakes, frequently enclosing small grains of black iron ore, and moulding itself against the larger grains. It tends to be idioblastic against quartz. It is pleochroic: X = extremely light fawn, Y = Z = smoky fawn - it is rather pale in every position.

The rock is a <u>(biotite)-garnet-"magnetite"-quartz-granulite</u>.

4211. Photograph 5210, section 3. Bellbird, Plate 7.

The hand specimen is a medium to fine-grained quartzite which is apparently veined by coarse-grained quartz, and irregular masses of haematite, of varying size, the largest measuring over 3 cms. across. Haematite envelopes quartz grains, and contains cavities sub-divided by very thin walls. Haematite and hydrated iron oxide show a vague tendency to form a boxwork structure, enclosing areas more free of iron oxide.

In thin section, the rock consists quite simply of quartz (75-80%) and "magnetite" (15-20%). In the quartzitic region, quartz forms xenoblastic crystals with tesselate margins, showing little strained extinction. "Magnetite" occurs as subidioblastic octahedral crystals of similar size to quartz, i.e., 0.10-0. 20 mm., and which are pseudomorphs after magnetite. Occasionally it is made over to hydrated iron oxide, which may also be seen around quartz crystal boundaries. The quartz veins are formed of large, xenoblastic crystals showing foliated strained extinction. Large, irregular masses of haematite are present.

The rock is a "magnetite"-quartz-granulite.

4212. Photograph 5210, section 3. Bellbird, Plate 7.

The major part of the hand specimen consists of a dark greenish-grey, fairly fine-grained quartzose chloritic schist, which contains small irregular patches and flecks of (?) chrysocolla. Quartz-rich bands, about 0.5 mm. to 1 mm. thick run through the rock, and are apparently parallel to the schistocity. Part of the specimen has a "vein" 2cms. thick consisting of coarse-grained quartz and chlorite, with haematite and hydrated iron oxide.

In thin section the schist is seen to be granoblastic-lepidoblastic, and medium to fine-grained. Quartz occurs as xenoblastic grains, which are roughly equal in size (i.e., about 0.1 mm.). Chlorite forms xenoblastic flakes showing some lineation: they are roughly equal in size to the quartz grains. It is pleochroic with X = green, Y = paler green, Z = colourless: $X > Y > Z$, and is biaxial positive, with a small 2V. Its birefringence = 0.002, and its refractive index is rather less than that of biotite. Black iron ore forms idioblastic octahedra, of similar size to the quartz grains. Biotite occurs sparingly, as xenoblastic flakes, apparently being altered to chlorite; a few small porphyroblasts frequently enclosing octahedra of black iron ore, are present. It is pleochroic with X = rusty brown, Y = Z = dark rusty brown.

The "vein" consists partly of relatively coarse quartz grains measuring up to 0.75 mm., which have tesselate margins, and a slight andulose extinction. Very irregular masses of black iron ore and hydrated iron oxide are present, commonly enclosing chlorite, quartz and (?) chrysocolla.

The iron ore tends to be concentrated towards the margins of the vein, as does the chlorite. The latter mineral forms coarse, frequently clustered, xenomorphic flakes, with random orientation. It is pleochroic with X = Y = pale green, Z = colourless, and its birefringence is 0.001. It is optically positive, with a very small axial angle. Much of the chlorite is stained with hydrated iron oxide dust. (?) Chrysocolla occurs as rather irregular, small masses associated with iron ore.

Along one edge of the vein, two or three enclaves of schist are present, having an irregularly elongated shape parallel to the vein sides. One enclave appears to have been rucked slightly, and its schistocity is puckered in agreement. The presence of these enclaves suggests that the vein has been intruded into the schist, and possibly associated with the pegmatite mineralization in this area.

The rock is a cupriferous chlorite-"magnetite"-quartz granulite, which veins a biotite-"magnetite"-chlorite-quartz-schist.

4214. Photograph 5008, section 10. Green Parrot (shaft), Plate 4.

The hand specimen is a dark grey, fine to medium-grained granular rock consisting of quartz, garnet and a little micaceous material. Fairly large (2-3cms across) areas of diffuse ferruginous material are present, they tend to be cavernous. Minute flecks of green copper mineral occur, shown by reaction with hydrochloric acid to be malachite.

Thin section shows that the rock is fine to medium-grained, inequigranular and granoblastic, with an indistinct lineation of chlorite flakes. Quartz is xenoblastic and forms a mosaic of interlocking grains; their size ranges between 0.06 mm. and 0.5 mm. Colourless or faintly pink almandine forms sub-idioblastic crystals ranging between 0.03 and 0.2 mm. in size. Occasional rather larger porphyroblasts of garnet, ranging up to 0.5 mm. in size are present; these have a faint grey-buff colour. Xenoblastic flakes of chlorite, of greatly varying size, tends to have an indistinct lineation. Frequently, the flakes are clustered, and poikiloblastically enclose garnet, though not quartz. Chlorite is pleochroic with X = pale greenish fawn, Y = Z = brunswick green. Its birefringence = 0.003, and it is uniaxial negative. Black iron ore is commonly associated with chlorite. Sometimes, very fine-grained, pale green fibrous malachite may be present in the chlorite clusters. It is also present in minor quantities intergrown with large crystals of black iron ore. The latter mineral sometimes forms large, xenoblastic areas, up to 3 mm. in size, which poikiloblastically enclose garnet and quartz. Sphene, which is invariably enclosed in chlorite, is a rather rare accessory.

An estimation of the percentages of minerals present is: quartz, 57; garnet, 25; chlorite, 15; black iron ore, 3.

The rock is a ferruginous and cupriferous "magnetite"-chlorite-garnet-quartz-granulite.

4215. Photograph 5008, section 10. Bellbird (shaft), Plate 7.

The hand specimen is medium to coarse-grained and granular, consisting mainly of quartz, with black iron ore, and small amounts of calcite, the latter occurring in small, indistinct veins. The carbonate reacts on application of dilute hydrochloric acid. Small flecks of green copper mineral are present. Occasional cubes of galena may be seen.

In thin section the rock is seen to consist mostly of a very inequigranular mosaic of quartz crystals, showing subsutured to amoeboid boundaries. It has foliated strained extinction. The grain size ranges between 0.1 mm. and 2.1 mm. Black iron ore forms very irregular grains, tending to be interstitial to quartz, and enclosing small grains of that mineral. Some of it is altered to hydrated iron oxide. Small, irregular grains of carbonate are enclosed by black iron ore.

A thin, rather discontinuous vein of calcite also cuts the rock.

70% of the rock is quartz, the remainder is mostly black iron ore, with a little calcite. The rock is a lead-bearing "magnetite"-quartz-granulite.

4216. Photograph 5008, section 10. Bellbird (shaft), Plate 7. (Figure iv).

The major part of the hand-specimen consists of a fine-grained, dark, rather granular but somewhat schistose rock, which contains lineated mica, with quartz and felspar. Some flecking and veining by a secondary copper mineral is present. An almost mica-free massive, fine-grained rock borders the schist; this contains more iron ore than does the schist.

In section both parts of the rock are represented: (A) the schist, and (B) the massive rock.

(A). Here, the rock has a granoblastic-lepidoblastic texture, and is fine-grained and equigranular. Quartz and felspar form a mosaic of xenoblastic crystals with tesselate margins, their average grain size being 0.06 mm. Felspar, away from any veins cutting the rock, shows slight sericitization. Its refractive index is slightly greater than that of Canada balsam, and it is biaxial negative with a large optic angle. In a few grains multiple albite or pericline twinning was seen. It is, therefore, possibly oligoclase or sodic andesine. Biotite occurs as small subidioblastic flakes, roughly 0.03 mm. by 0.15 mm. in size, and is pleochroic, with X = light straw, Y = Z = faintly greenish black. Black iron ore forms octahedral grains 0.06 mm. average size. Very occasional idioblastic and faintly pink to colourless crystals of garnet are present. Several small veins cut the rock, obliquely to the cleavage. One such vein, approximately 0.25 mm. thick, consists of black iron ore, which tends to enclose felspar crystals. The enclosed felspar, and that lying a short distance either side of the vein, is strongly sericitized. This vein sends out minor offshoots. Two or three very thin and rather sinuous veins cut the specimen almost parallel to the schistocity, sericitizing the felspar; along them, biotite is apparently replaced by a green copper mineral. These veins appear to cut the black iron ore vein. Other zones of alteration of felspar occur along minor slip-planes running obliquely to the schistocity, displacing biotite flakes.

The schist has the following estimated proportions of minerals present: plagioclase, 35%; quartz, 20%; biotite, 35%; while the remainder is black iron ore, and rare garnet. The specimen is a cupriferous-"magnetite"-quartz-biotite-plagioclase-schist.

(B). In the massive rock the texture is granoblastic, and is fine-grained. It contains about 13% of quartz, 35% plagioclase, 40% magnetite, 10% garnet, and 2% of biotite. Quartz and felspar form a xenoblastic mosaic of grains slightly larger than those in the schist. The felspar is similar to that in the schist: an extinction angle measured on a section normal to the X-bisectrix gave a composition of An_{26}. It shows some sericitization, especially where veins from the schist cut into the massive part. Black iron ore forms octahedral crystals. Slightly pink to colourless garnet forms subidioblastic crystals which have unequal distribution, tending to be clustered into groups. Rare biotite forms small flakes with random orientation. The rock may be conveniently called a granulite.

The veins contained in the schist appear to spread on intercepting the granulite: a black iron ore vein in the schist is continued in the granulite by an area rather more rich in black iron ore octahedra. Likewise, a sericite zone intersecting the schist spreads out to a much wider zone in the granulite. One difference may be noted here - the biotite of the granulite is chloritized in the sericitized zones - no chlorite is seen in like zones in the schist. The rock is a <u>biotite-garnet-quartz-oligoclase-"magnetite"-granulite</u>.

<u>4221</u>. Photograph 5008, section 6. Reward, Plate 2.

The hand specimen is medium-grained and granular, consisting mainly of quartz with some red garnet. Ferruginous matter is present as rather large, irregular masses which enclose quartz and garnet grains. Calcite is associated with the ferruginous material, this reacting with dilute hydrochloric acid. Bands of green malachite, 0.5 to 2mm. thick run through the rock, roughly parallel to one another. The specimen as a whole is compact and hard, and is of a dull reddish grey colour, with green banding. Surfaces parallel to the banding are speckled with glistening white mica flakes.

In thin section, the rock is seen to be medium- to coarse-grained, inequigranular, and is granoblastic. Quartz forms a mosaic of grains with sutured margins. Coarse and medium grained layers occur, the grains in the coarse bands ranging between 0.15 mm. and 0.6 mm. and in the finer layers, between 0.05 mm. and 0.25 mm. Slight elongation of the grains occurs in the finer bands.

In the finer zones, muscovite forms small (0.075 mm. long), colourless flakes oriented parallel to the layering. Elsewhere, muscovite occurs as larger flakes (0.3 mm. long), often clustered, with a more random orientation. At one place, in a finer quartz band, a layer of mixed muscovite, calcite and hydrated iron oxide dust, 0.9 mm. thick, is present; the mica has random orientation of flakes. Colourless garnet forms sub-idioblastic crystals ranging between 0.1 and 0.6 mm. in size: it shows some alteration to hydrated iron oxide, and much less frequently, to chlorite. Many garnets are enclosed within large masses composed of intergrowths of calcite and hydrated iron oxide. In these masses small areas of calcite are rimmed by hydrated iron oxide, and appear to pseudomorph garnet. Apart from these apparent pseudomorphs, calcite and hydrated iron oxide from large irregular masses enclosing quartz (?) cuprite and garnet; in part the masses are arranged roughly parallel to the layering: elsewhere they are irregular in distribution, tending to form random "veins" which are roughly intergranular. The two minerals show symplectic to amoeboid intergrowth with one another. (?)Cuprite forms sub-idioblastic crystals of cubic form, and is possibly an alteration product of chalcopyrite. Malachite is present in small quantities associated with cuprite. Small, irregular crystals of calcite are sparsely distributed in the surrounding groundmass: thin veinlets of calcite cut quartz grains.

Small flakes of biotite, pleochroic from light straw to nearly black, are present in the coarser quartz areas: they have a preferred orientation lying obliquely to that of the muscovite. It is sometimes altered to chlorite. Little octahedra of black iron ore are also present. Small masses of a finely crystalline, greyish mineral, which may be an alteration product of felspar, or cordierite, are present in interstitial areas. A very minor amount of a mineral slightly pleochroic in green with high birefringence and a uniaxial negative interference figure occurs associated with hydrated iron oxide and calcite. Small amounts of tourmaline, forming xenoblastic crystals and pleochroic from smoky grey to blue-grey, are present.

An estimation of the amounts of the various minerals to be seen is: quartz: 55%, hydrated iron oxide: 20%, calcite: 15%, muscovite: 5%, biotite; 1%, black iron ore: 1%, and the remainder: 3%.

The rock is a cupriferous and ferruginous carbonated muscovite-garnet-quartz granulite. The coarser-grained zones give the appearance of having replaced the finer-grained lineated parts.

4224. Photograph 5008, section 6. Reward, Plate 2.

The hand specimen is a reddish brown, slightly friable, ferruginous rock which is granular and medium-grained. It consists mostly of quartz: white mica is present, showing some preferred orientation. Occasionally, reddish garnets may be seen. Hydrated iron oxide occurs as a film around the quartz grains.

In section the dominant mineral present is quartz, which occurs as amoeboid grains with sub-sutured margins. It has strained extinction, and the grains show some cracking. The grain-size ranges between 0.1 mm. and 0.6 mm. Muscovite forms xenoblastic, sub-parallel colourless flakes measuring up to 1.26 mm. Biotite occurs as rather smaller crystals with random orientation, and is pleochroic with X = light olive fawn, Y = Z = dark brownish-black. Xenoblastic crystals of colourless garnet, 0.2 mm. in size, are sometimes partially replaced by hydrated iron oxide. Idioblastic crystals of octahedral or cubic black iron ore are present, most frequently forming small crystals, 0.2 mm. in size. Sometimes, however, these crystals appear to coalesce, forming large, somewhat irregular grains up to 1.0 mm. in size. Hydrated iron oxide occurs as a fringe about black iron ore, and as an intergranular film.

Approximately 60% of the rock is quartz, 15% is muscovite, 15% is black iron ore, the remainder being biotite and garnet.

The rock is a garnetiferous biotite-"magnetite"-muscovite quartz-granulite.

4228. Photograph 5210, section 3. Cox's south, Plate 6.

The hand specimen is fine-grained and granular, containing quartz and magnetite, with some garnet: some flakes of a mica-like mineral may be seen. The specimen is stained irregularly by hydrated iron oxide.

In thin section, quartz forms a rather equigranular mosaic of xenoblastic grains. It is sometimes cracked, and frequently shows strained extinction. The grains have an average size of 0.12 mm. Black iron ore occurs as sub-idioblastic to idioblastic, cubic crystals of a similar average size to that of quartz. Sometimes the crystals coalesce in small clusters to form rather irregular, larger, masses. Sericite is present as xenoblastic, somewhat interstitial flakes with random orientation, though with some tendence to occur in rather broad, diffuse layers, the concentration varying from layer to layer. Sericite is colourless, or very faintly green, and has a very small negative optic axial angle. Chlorite, unlike sericite, forms flakes with a preferred orientation. The flakes are xenoblastic, tending to be interstitial, and oriented parallel to the sericite layering. They range in length between 0.08 mm. and 0.3 mm. Chlorite is frequently associated with black iron ore. It is pleochroic, with X = Y = very pale green, Z = very pale fawn: the interference figure is uniaxial positive, and the mineral has a birefringence of 0.004. The refractive index Z of chlorite is rather greater than Z of sericite. Colourless garnet occurs as subidioblastic crystals, 0.05 mm. average size, sometimes showing slight alteration to chlorite. Minute crystals of prismatic apatite are enclosed in quartz. A few brown, very fine granular crystals of (?)allanite, are enclosed in chlorite.

An estimation of the percentages of minerals present in the specimen are: quartz: 40, sericite: 20, chlorite: 15, garnet: 5, black iron ore: 20, with traces of apatite and (?)allanite.

The rock is a quartzose garnet-chlorite-sericite-"magnetite"-quartz-granulite.

The distribution and form of the sericite gives the impression of its having been altered from felspar ((?)plagioclase) and the chlorite may be an alteration product of biotite. Hence, the rock may have been a garnetiferous biotite-plagioclase granulite which has been altered by the metasomatizing influences of the invading pegmatites. This, then, would account for the random orientation of the sericite, alongside the lineated chlorite.

4229. Photograph 5210, section 3. Bellbird, Plate 7.

The hand specimen is a highly ferruginous quartz rock, which appears to consist of an original medium to coarse-grained quartzite, now traversed by mylonitized zones with small lenticular "augen" of rather coarse quartz grains surrounded by fine-grained quartz. Some pyrites, and other sulphide minerals, are present which have mostly weathered to hydrated iron oxide, leaving many cavities in the specimen. The cavities are so numerous that if the specimen is immersed in water, air can be seen escaping for quite a minute after immersion. On removing from water, a noticeable increase in weight is apparent.

In thin section, the quartz "augen" are seen to be rather coarse-grained and inequigranular, the grains ranging between 0.15 mm. and 1.0 mm. in size. The quartz grains are xenoblastic and amoeboid, with sub sutured margins. Only small amounts of hydrated iron oxide are present here.

The finer-grained portion consists of inequigranular, interlocking quartz grains. Irregular areas of interstitial hydrated iron oxide are present, very often zones of this mineral enclose widely separated quartz grains.

The rock is a limonitic "magnetite"-quartz-granulite.

4230. Photograph 5008, section 6. Marshall, Plate 3.

The hand specimen is pink, medium-grained, granular and porphyroblastic. It contains granular quartz and flakes of white mica, the latter being present in thin, somewhat lenticular and discontinuous layers. Reddish, iron-stained porphyroblasts of garnet, measuring up to 1 or 2 mm. across, are present.

Thin section shows the rock to be medium-grained, granoblastic and porphyroblastic. Quartz forms a rather inequigranular mosaic of xenoblastic crystals with sub-tesselate margins. The crystals range between 0.1 mm. and 0.5 mm in size. Black iron ore occurs as subidioblastic, octahedral crystals, of a similar size to quartz. Sericite forms xenoblastic flakes, often clustered, and commonly showing some preferred orientation. It has a negative figure with a low optic axial angle. Colourless garnet (almandine) is present as porphyroblastic and somewhat poikiloblastic crystals enclosing quartz and some sericite. Some intergranular hydrated iron oxide is present.

An estimation of the proportions of the various minerals present is: quartz: 70, black iron ore: 18, sericite: 11, garnet: 1.

The rock is a garnet-sericite-"magnetite"-quartz-granulite.

4261. Photograph 5210, section 3. Cox's south, Plate 6. (See Appendix I).

The hand specimen consists almost entirely of black iron ore, speckled with small grains of quartz, and flakes of white mica. Occasional larger, irregular grains of milky quartz are present, sometimes forming short veins. Frequently small irregular cavities are present in the rock.

A thin section of the rock consists almost entirely of opaque ore, with small, interstitial cavities filled with quartz and hydromuscovite. The latter mineral has a small, negative optic axial angle. The specimen is a hydromuscovite-quartz-haematite rock.

4262. Photograph 5210, section 3. Cox's South, Plate 6. (See Appendix I).

The hand specimen consists of black ore, stained with hydrated iron oxide, and veined by malachite: the veins are thin (less than 2 mm.) and irregular, in one or two places giving the impression of dendritic growth. Odd flecks of chrysocolla are distributed throughout the specimen. Flakes of mica are scattered through the specimen, commonly with the malachite bands.

In thin section, probably 75% of the rock consists of black ore, about 15% of malachite, the remaining minerals being chlorite and muscovite. Green malachite occupies irregular areas, ranging from minute to much larger interstitial cavities arranged in broad trains, probably as discontinuous veins. Both chlorite and muscovite may be associated with the veins, and also occur as irregular grains with a roughly regular distribution through the rock. Muscovite is biaxial negative, with $2V = 30\text{-}40^\circ$. Chlorite is biaxial negative, with a small optic axial angle. It shows some kind of zoning in both its pleochroism and its birefringence. Most usually the pleochroism is more intense at the margins, against black ore, though occasionally, intense pleochroism occurs at the crystal centre as well. Likewise, the birefringence is higher where the pleochroism is more intense. X = pale fawn, with brown-green at the edges: Y = Z = pink green, with dark brown green at the edges (and occasionally centre). The birefringence ranges from 0.002 in the less intensely pleochroic areas to 0.004 in the more intense. Its refractive index is roughly equal to Y of muscovite. The specimen is a cupriferous haematite rock.

4263. Photograph 5210, section 3. Bellbird, Plate 7. (See Appendix I).

The hand specimen is a rather cavenous dull red rock, consisting of haematite enclosing irregular areas of granular quartz, the latter mineral having a medium grain-size. The weathered surfaces are stained with hydrated iron oxide; one surface has an intricate fine-grained "boxwork" of this mineral.

In section, black iron ore is seen to enclose small irregular masses consisting of inequigranular mosaics of quartz: the grains have sub-sutured margins and show undulose extinction. Occurring with the quartz are small octahedra of black iron ore.

4264. Photograph 5210, section 3. Bellbird, Plate 7. (See Appendix I).

The hand specimen is a highly ferruginous quartz rock containing medium-grained granular quartz, veined by haematite and hydrated iron oxide, and by some veins of malachite. Haematite forms a layer 1 to 2 cms. thick, from which extend minor veins forming a meshwork in the quartz. Malachite, which reacts on application of dilute hydrochloric acid, is present in lesser quantities, and forms thin veins lying along apparent joint surfaces. It appears to have been emplaced later than the haematite.

The thin section shows that the rock is basically composed of a mosaic of interlocking xenoblastic quartz grains which are very inequigranular, their sizes ranging between 0.06 mm. and 1 mm. The coarse grains tend to be grouped in clusters, with the finer grains about them, the latter showing some parallel elongation of shape. Haematite and hydrated iron oxide form an irregular meshwork of veins, ranging from major veins of up to 0.75 mm. thickness, to minor intergranular "threads" 0.01 mm. thick. Occasionally, iron ore forms vaguely octahedral crystals from which the veins radiate. Thin veins of malachite cut both quartz and iron ore, and the carbonate is frequently seen to occupy cavities in the latter mineral. A few rather tabular areas are occupied by a colourless, apparently serpentine-like mineral whose refractive index is rather greater than that of quartz, and which has a very low birefringence. Its habit is fibrous, like that of serpentine. It is biaxial negative, with a small to moderate 2V.

The rock is a cupriferous goethite-quartz-granulite.

4265. Photograph 5210, section 3. Bellbird (Shaft), Plate 7. (See Appendix I).

The hand specimen is medium-grained and granular consisting of quartz enclosing irregular areas of a yellow metallic sulphide. The rock is speckled with malachite.

In thin section quartz forms a medium to coarse-grained mosaic, the grains having tesselate margins. Occasionally, small aggregates of a faintly green, apparently fibrous mineral which has a negative refringence, is uniaxial positive, and which has low polarization colours, are present. The sulphide mineral occurs sometimes as small octahedral and cubic crystals, but more often as large, irregular masses enclosing odd quartz grains. The rock appears to be a siliceous sulphide ore. Some black iron ore is present.

4266. Photograph 5210, Section 3. Bellbird (Shaft), Plate 7. (See Appendix I).

The hand specimen is a ferruginous quartz-rock, which appears to have granular quartz with intergranular hydrated iron oxi . Irregular patches of a green secondary copper mineral are present, also some chalcopyrite. A vein, which in this specimen is 2-4cms. thick, contains two or three sulphide minerals at its centre. Red hydrated iron oxide is scattered in intergranular position throughout the specimen. Malachite occurs as irregular patches and veins.

The thin section contains both the quartz-rock and the vein. The quartz-rock consists of an inequigranular mosaic of somewhat interlocking xenoblastic quartz grains. The grains range between 0.05 mm. and 0.3 mm. in size. Intergranular hydrated iron oxide is present: it also forms irregular veins 0.3 mm. thick, and a few irregular grains 1 mm. in size are present. Small, tabular flakes of (?)chlorite, 0.08 mm. long by 0.02 mm. wide, may be seen; they have a preferred orientation in a direction approximately 60° to that of the vein. Thin veinlets of carbonate cut the quartz grains.

Towards the vein there is an irregular zone, approximately 2.5 mm. thick, in which the amount of ferruginous matter increases. Inside this zone is another irregular zone, ranging between 0.9 mm. and 4.2 mm. in thickness, and containing muscovite and pale green chlorite with intergrown hydrated iron oxide. The muscovite and chlorite occur as somewhat distorted flakes of greatly varying size (ranging from 0.1 mm. to 1.5 mm. length). Hydrated iron oxide occurs along the cleavage planes, and as symplectite-like intergrowths. The vein itself consists of sulphide minerals. Thin veins of green secondary copper mineral are associated with the hydrated iron oxide.

The rock is a cupriferous and ferruginous chlorite-muscovite "magnetite"-quartz granulite.

4267. Photograph 5008, section 6. Reward, Plate 2. (See Appendix I).

The hand specimen is dull orange brown, mottled with large blackish zones. It consists of areas of medium-grained, granular, brownish garnet, which are intricately intergrown with black iron ore. Irregular areas of granular quartz are present.

Thin section shows the rock is medium to coarse-grained, inequigranular and granular. Quartz forms somewhat interlocking xenomorphic grains, sometimes coarsely intergrown with hydrated iron oxide and black iron ore, as though filling irregular cavities. Brown-orange garnet ((?)andradite) occurs as xenomorphic crystals of varying size, which are anhedral against black iron ore, but tending to be subhedral against quartz. In the black iron ore it appears to be filling cavities. Hydrated iron oxide appears to be replacing the garnet. The ore apparently encloses all the other minerals. Small flakes of very pale (?) chlorite may occasionally be seen enclosed in garnet.

The rock is a ferruginous quartz-garnet granulite.

4268. Photograph 5008, Section 6. Reward, Plate 2. (See Appendix I).

The hand specimen is a reddish, coarse-grained rock consisting of coarse, granular quartz, sometimes stained red, which tends to be enclosed by veins of black iron ore.

In thin section the rock is seen to be composed of an aggregate of inequigranular quartz grains, often having sutured margins against each other, and showing foliated strained extinction, with some cracking. Trains of opaque dust are enclosed in quartz, though the direction of the trains varies from grain to grain. Black iron ore and hydrated iron oxide form irregular masses of varying size, the larger ones tending to enclose quartz grains, the smaller ones being interstitial to this mineral, and sending off very thin veins into cracks in it.

The rock appears to be a quartz-"magnetite"-granulite.

4269. Photograph 5008, section 6. Reward, Plate 2. (See Appendix I).

The hand specimen consists of dark-coloured haematite, altered to, and stained with, hydrated iron oxide. Fine quartz grains are scattered through it. Thin section confirms these observations. Quartz forms irregular small blebs, sometimes rather intergrown with haematite. The specimen is a quartz-haematite rock.

iv. Other Metasomatized Rocks.

4178. Photograph 5210, section 6, point 44. Plate 1.

The hand specimen is a medium - to fine-grained dark grey rock, with thin folia (2 - 3 mm. thick) of micaceous and tourmaline-rich material separated by more quartz-rich regions. In addition there are thinner layers (1 - 2 mm.), composed of medium-grained, granular quartz, which tend to be lenticular, and which are usually 5 - 6 mm. apart. The mica is pale, and seems to have random orientation: tourmaline forms rather acicular, prismatic crystals oriented, in general, parallel to the foliation. A small crushed sample treated with a hand magnet showed the presence of magnetite. Weathered surfaces emphasize the foliation, and are stained with hydrated iron oxide.

In thin section the specimen is found to be fine-to medium-grained, granoblastic-nematoblastic, and porphyroblastic, with an inequigranular groundmass. The rock is roughly foliated into mica and tourmaline-rich layers, and layers more rich in quartz. In the groundmass, quartz forms a fine-grained mosaic of xenoblastic crystals having sub-sutured margins. Magnetite occurs as octahedra, which sometimes coalesce to form small irregular "knots". It is concentrated in the mica rich bands. The groundmass grain-size ranges between 0.06 mm. and 0.12 mm.

Muscovite and protolithionite occur as flakes with random orientation, both in the groundmass, and as porphyroblasts, the latter measuring up to 1 mm. in size. The flakes are normally equidimensional. The two minerals occur together concentrated in layers, and are intimately associated with each other, either as intergrown crystals, or, in places, as single crystals in which protolithionite grades into muscovite, both being in optical continuity. The relationship is not zonary in the sense that a crystal core is of one mineral, and the edge is of the other: in actual fact, one end of a crystal is muscovite, and the other is protolithionite: the latter is often surrounded by small protolithionite flakes. Both minerals poikiloblastically enclose magnetite, apatite, and the smaller tourmalines. Muscovite is colourless, and is biaxial negative with $2V = 35^{\circ}$.

Protolithionite is pleochroic with X = colourless, Y = Z = pale brown. Its birefringence = 0.032, and it is biaxial negative with 2V = 1-5°. These data agree with protolithionite, an iron-rich variety of lepidolite.

Tourmaline occurs as idioblastic prismatic crystals ranging in size between 0.1 mm. and 1.0 mm. long. The crystals lie in random directions in the plane of foliation, and normally enclose few grains of apatite and magnetite. It is pleochroic with o = pale pink, and e = dark smoky blue: some faint zoning of colour is seen in basal sections. Apatite forms subidioblastic crystals in the groundmass, and has irregular distribution. A little zircon is present, creating rare pleochroic haloes in protolithionite.

Rather discontinuous and lenticular veins of quartz are present, ranging between 0.25 mm. and 0.75 mm. thickness. The grains are equidimensional, having an average size of 0.3 mm. in the thicker veins. Occasionally they include mica and tourmaline may be found in the veins, with the mica occurring as somewhat broken flakes, suggesting that the veins were emplaced subsequent to the formation of mica and tourmaline.

An estimation of the percentages of minerals present is:- quartz 25; muscovite 24; lepidolite 24; tourmaline 10; magnetite 15; apatite 2; with traces of zircon. The rock is, on field evidence, a metasomatized schist, or gneiss: in its present condition it may be called a tourmaline-magnetite-muscovite-lepidolite-quartz gneiss.

4203. Photograph 5210, section 3. Cox's North, Plate 5.

The hand specimen is greyish-black, mottled with red on a fresh surface, and is stained with hydrated iron oxide on weathered surfaces. It breaks with a sub-conchoidal fracture, and consists of quartz, with subordinate red garnet, tourmaline, and haematite. The rock is medium grained, and some slight foliation of minerals may be detected.

The foliation is a little more obvious in section, where the coloured minerals tend to be arranged in layers, 0.5 to 2 mm. apart. Otherwise the texture is granoblastic. The rock is medium grained, but inequigranular, the grain sizes normally ranging between 0.05 mm. and 0.6 mm.

Quartz is extremely xenoblastic, forming a mosaic of interlocking grains with sutured margins. It has foliated strained extinction, but is uniaxial positive. Extremely pale pink almandine forms xenoblastic grains of rather smooth outline, which are often elongated parallel to the foliation. Infrequently it poikiloblastically encloses small granules of quartz. Commonly, almandine has altered to hydrated iron oxide along its cracks and boundaries. Less frequently, alteration has taken place to green chlorite, similar to that in 4260. Very occasionally, pseudomorphs of chlorite after garnet may be seen: this is especially noticeable where garnet neighbours, or is enclosed by, tourmaline. The latter mineral occurs as xenoblastic crystals, poikiloblastically enclosing quartz, as well as almandine. It tends to be elongated parallel to the foliation, and may have replac biotite, though there is no direct evidence of this. Tourmaline is pleochroic, with o = smoky greenish black, e = very light grey. Its birefringence is 0.032, and is uniaxial negative. A few muscovite flakes are present, with a rough lineation parallel to the foliation. Black iron ore occurs as subidioblastic, octahedral crystals. A vein of hydrated iron oxide cuts across the foliation.

An estimation of the percentages of minerals present is: quartz: 60, almandine (with chlorite): 15, tourmaline: 10, black iron ore: 10, muscovite: 5.

The rock is a (muscovite)-"magnetite"-tourmaline-garnet-quartz-granulite.

4208. Photograph 5210, section 3. Cox's South, Plate 6.

The hand specimen is dark, mottled with white, and is coarse-grained, with a vague lineation, and is composed almost entirely of tourmaline and quartz. The former mineral occurs as acicular, prismatic crystals, which vary greatly in size, the larger attaining 15 mm. length, by 2 mm. wide. They have a rough preferred orientation, though not sufficient to give the rock a schistose aspect. Quartz forms irregular aggregates of coarse granular crystals, the aggregates being lenticular in shape, and having a rough parallel elongation: the quartz lenticles measure up to 40 mm. length, and 6 mm. wide, and are not sufficient in quantity to give the rock a foliation. The hand specimen has 70% tourmaline and 30% quartz.

In thin section the rock is seen to be coarse-grained, and very inequigranular. Quartz occurs as xenoblastic, somewhat interlocking crystals showing strained extinction, and ranging in size between 0.4 mm. and 10 mm. The larger grains totally enclose small tourmalines, and black iron ore. Tourmaline forms xenoblastic to idioblastic crystals varying greatly in size, the smallest being 0.15 mm. long, while the largest does not attain the length of some of those seen in hand specimen. Most usually the crystals are prismatic, tending to acicular shape, and containing few inclusions: some, however, have no crystal shape, and show pronounced sieve structure, enclosing small, rounded granules of quartz. Tourmaline is intensely pleochroic with O = dark smoky blue, and e = pale pink. Many sections show zoning, very often with paler material occupying crystal centres, though very frequently "oscillatory" zoning is present. Its birefringence is 0.032. A few rounded to octahedral grains of black iron ore and some hydrated iron oxide are present. A single, small, grain of garnet appears in the slide, and hydrated iron oxide appears to have replaced a few other grains.

The rock is a pegmatitic quartz-tourmaline-gneiss. Tourmaline has probably replaced some previous mineral, such as biotite, or felspar.

4222. Photograph 5008, section 6. Reward, Plate 2.

The hand specimen is a slightly friable brownish rush-stained schist containing granular quartz, and white mica, which has preferred orientation: prismatic crystals of black tourmaline are scattered through the rock.

In thin section the rock is found to be medium to coarse-grained, and is rather foliated, with a granoblastic-nematoblastic texture. It is rather inequigranular. Quartz occurs as xenoblastic grains, ranging in size between 0.1 mm. and 0.6 mm. Muscovite forms xenoblastic flakes arranged in parallel, rather discontinuous layers, and have a rough preferred orientation along the layers. Tourmaline is present as subidioblastic prismatic crystals 0.75 mm. by 1.5 mm. in size, tending to be elongated along the foliation. They are pleochroic, with o = black, and e = brownish grey. Occasionally, small xenoblastic, somewhat altered crystals of colourless garnet (almandine) are present, partially replaced by hydrated iron oxide. Very infrequently, one may see small xenoblastic flakes of biotite, pleochroic from deep brown to black. The flakes are oriented parallel to the schistocity. Small octahedra, and larger, more irregular crystals of black iron ore are present, often showing some alteration to hydrated iron oxide.

An estimation of the percentages of minerals present is: quartz: 55, muscovite: 23, tourmaline: 7, garnet: 2, black iron ore: 8. The rock is a tourmaline-"magnetite"-muscovite-quartz schist.

4227. Photograph 5210, section 3. Cox's South, Plate 6.

The hand specimen is dark grey, mottled with reddish-brown and is medium-grained, with granular quartz forming a background to randomly oriented, somewhat tabular porphyroblasts of staurolite. Black crystals of tourmaline are also present.

Thin section shows the rock to have a fine to medium-grained xenoblastic groundmass, enclosing subidioblastic, rather poikiloblastic porphyroblasts of staurolite.

In the groundmass, quartz forms a rather equigranular mosaic of xenoblastic crystals, with sub-tesselate margins, but showing slight amoeboid intergrowth in places: the average grain size is 0.2 mm. Black iron ore forms subidioblastic, rather octahedral crystals, commonly having a thin rim of hydrated iron oxide. The crystals range between 0.05 mm. and 0.35 mm. in size. Some of the grains have coalesced to form larger, irregular zones. Tourmaline occurs as subidioblastic, slightly poikiloblastic crystals, enclosing small grains of quartz. The roughly tabular crystals are, on an average, 0.5 mm. long and 0.2 mm. wide. They are pleochroic, with o = dark smoky green, and e = light fawn-grey. The birefringence is 0.034. Small, xenoblastic flakes of biotite often poikiloblastically enclose black iron ore, and the smaller crystals of tourmaline: in fact the latter mineral seems to be frequently associated with biotite, apparently replacing it. Tourmaline is sometimes surrounded by pleochroic haloes in biotite. The normal pleochroism of biotite is: X = light fawn, sometimes almost colourless, Y = Z = dark greyish brown, nearly black. A few small and irregular flakes of muscovite are present. Rare garnet forms idioblastic crystals partially replaced by hydrated iron oxide: it is colourless, or very faintly pink, suggesting almandine.

The porphyroblasts in the rock are composed of staurolite, which is optically similar to that in specimen 4222. In the present specimen, however, it forms subidioblastic to xenoblastic, roughly tabular crystals with random orientation, enclosing fine granules of quartz, and larger crystals of garnet and black iron ore, very occasionally partially enclosing tourmaline. Commonly, long, rod-like inclusions of quartz, 0.05 mm. thick, occur close to the centres of the staurolites, surrounded by crowded, fine quartz inclusions arranged in lines. The porphyroblasts measure up to 2.5 mm. in length.

The estimated quantities of minerals present are: quartz 40%, staurolite: 30%, black iron ore: 13%, tourmaline: 12%, biotite: 3%, with traces of garnet and muscovite. The rock is a tourmalinized staurolite-"magnetite"-quartz-granulite.

B. Calcareous and Magnesian Rocks.

i. Marbles

4169. Photograph 5008, section 6. Green Parrot, Plate 4.

The hand specimen consists of a mass of coarse crystals of xenoblastic pink calcite, which reacts on the application of dilute hydrochloric acid. Small amounts of irregular masses of a black mineral are present.

In thin section the rock is seen to consist almost entirely of a mosaic of very coarse calcite crystals, showing sutured margins to each other. Occasional small rounded grains of quartz are present. Some hydrated iron oxide occurs as dendritic growths, and as an alteration product surrounding black iron ore. The latter mineral occurs as irregular masses apparently deposited in cavities opened along the cleavage planes of calcite. Particles of an opaque dust are present included in calcite. The rock is a marble.

4173. Photograph 5008, section 6. Green Parrot, Plate 4.

The hand specimen is seen to be fine-grained, with a dark chocolate brown colour: on application of dilute hydrochloric acid a strong reaction takes place, suggesting calcite. Sparce galena forms larger crystals, up to 2 mm. in size. The rock appears to be highly ferruginous and also manganiferous. Thin veins, up to 3 mm. wide, of more coarsely crystalline calcite cut the rock. A positive chemical reaction for manganese was obtained by S. Baker.

In thin section in texture the rock is medium-grained, inequigranular and xenoblastic, and consists of angular grains of calcite, normally separated from one another by an intergranular "meshwork" of a mixture of black ore and hydrated iron oxide, the latter probably being an alteration of some of the former. Galena forms fairly large (1.3 mm.) irregular masses, after partly or wholly enclosing calcite. Galena has altered along thin, fairly regular cracks, to a mineral whose refractive index is approximately 1.5, and whose habit tends to be fibrous, elongated parallel to the length of the cracks. Its birefringence = 0.005, while it is biaxial negative, with 2V 20°. It is length slow. These measurements, and its occurrence, agree with the mineral apjohnite ($(MnAl_2(SO_4)_4.22H_2O$, a sulphate produced by the action of sulphuric acid on ores (Winchell, 1952). A thin irregular vein composed of a mixture of calcite, black ore, finely intergrown quartz, and a little galena cuts the rocks.

An estimation of the mineralogical composition of the rock is: calcite 65%, black iron ore, hydrated iron oxide, and (?) pyrolusite, 30%; galena 5%. The rock is a galena-bearing ferruginous and manganiferous marble.

4174. Photograph 5008, section 6. Green Parrot, Plate 4.

The hand specimen is very similar to appearance to 4173, and also reacts strongly on application of dilute hydrochloric acid. No galena was seen in this specimen, but it is more strongly veined by black iron ore, and (?)pyrolusite. A positive chemical test for manganese was obtained.

In thin section the specimen is medium-grained, and consists of xenoblastic grains of calcite separated from one another by an intergranular mixture of black ore and hydrated iron oxide. The latter minerals are often concentrated into fairly thick veins, enclosing small fragments of calcite. The calcite grains throughout the rock appear to have had their margins corroded, as they present serrated edges to the iron oxide. Very often thin veinlets of the oxides have found their way into calcite, while sometimes blebs of black ore occur in calcite, giving the impression of a symplectite. A mineral rather similar to that ((?)apjohnite) occurring in galena in specimen 4173 is enclosed in the black ore of this specimen. It is colourless, with a refractive index of approximately 1.50-1.53, it is length slow along the cleavage, and its extinction is 23°. Its birefringence is 0.009. A reasonable interference figure could not be obtained, but it is possibly biaxial negative with a large 2V.

The rock is a ferruginous and manganiferous marble.

4197. Photograph 5008, section 6. point 225. Plate 1.

The hand specimen is a medium-grained, grey, granular rock consisting of calcite (it reacts vigorously on application of dilute hydrochloric acid), and containing cream segregations of fibrous amphibole. Black flakes of chlorite, and silvery-grey grains of galena are scattered through the rock. A small, elongated cavity has fibrous crystals of amphibole projecting into it. The weathered surfaces are patchily stained with hydrated iron oxide.

The thin section shows a rock with a medium-grained, xenoblastic texture, consisting of a mosaic of interlocking grains of calcite. Flakes of colourless chlorite are sporadically scattered in this specimen, sometimes in small aggregates; this mineral has parallel extinction, and has a refractive index rather less than 1.65. Its birefringence is 0.004-5, and it is uniaxial, or biaxial with a small 2V, and is positive. Tremolite occurs as isolated, rather fibrous crystals, or as quite large aggregates, commonly showing some alteration to (?)talc. Tremolite is colourless and is length slow, with Z C = 20°. Its birefringence = 0.025 - 28, and it is biaxial negative, with a large 2V. Black ore occurs as very irregular grains normally apparently intergrown with calcite.

Calcite forms 80% of the rock, tremolite, 10%, and chlorite and black ore each 5%. The rock is a galena-bearing chlorite-tremolite marble.

ii. Garnet and Vesuvianite-Rich Rocks.

(a) Granulitic Rocks.

4164. Photograph 5008, section 6. Attutra, Plate 3.

On a fresh surface the hand specimen is seen to be composed of a finely crystalline black mineral, enclosing a pink-orange garnet. Numerous irregular cavities are present. A small fragment of the black mineral was attracted by the hand magnet, hence it is thought to be magnetite. The weathered surfaces have a thin coating of hydrated iron oxide. The powered rock soils the hands, and suspected manganese was confirmed chemically by S. Baker.

The thin section shows an irregular intergrowth of garnet and black ore (magnetite and (?)pyrolusite). Garnet occurs as xenoblastic crystals, often enclosing smaller granules of ore, and cut by a network of cracks, along which chlorite has formed. Magnetite appears as xenoblastic crystals, similarly traversed by cracks. It has suffered a little alteration to hydrated iron oxide. Magnetite, on the whole, appears to enclose garnet, and an estimation of the composition of the rock is: magnetite 50%, garnet 45%, chlorite and hydrated iron oxide 5%. The rock is a manganiferous magnetite-garnet skarn. It is possible that the garnet contains some of the spessartite molecule, and that the (?)pyrolusite has been formed from it by alteration.

4166. Photograph 5008, section 5. Attutra, Plate 3.

The hand specimen is seen to be medium-grained and granular, and consists of pink-cream garnet and quartz grains, split by a quartz vein about a centimetre thick. Very thin veins of malachite are present, they are not seen to cut the quartz vein, though flecks of malachite may be seen in both the rock and the quartz vein. Some epidote is also present in a thinner quartz vein which is present: epidote occurs as small, irregular masses.

In the section the texture is seen to be medium-grained, equigranular and granoblastic. Grossularite forms subidioblastic to xenoblastic crystals of 0.2 mm. size, and sometimes forms masses of interlocking crystals, with the exclusion of quartz. The latter mineral, however, occurs in some quantity, and forms xenoblastic, interlocking grains partially enclosing garnet. Quartz forms a diffuse band, approximately 4 mm. thick, running across the centre of the slide. The remainder of the slide consists almost entirely of grossularite. A small area of the slide contains calcite in addition to quartz, having similar textural characteristics as quartz, except that all the apparently separated calcite grains are in optical continuity. The area containing calcite measures 5 mm. by 3 mm. in the section. Garnet quite often shows slight alteration to a greenish chlorite, which occurs in very small flakes included in, or partly enclosing, garnet. Occasionally it is stained by hydrated iron oxide: where this has happened a large mass of intergranular poikiloblastic opaque ore occurs. The ore encloses garnet and chlorite. Minute inclusions of opaque ore and apatite occur in quartz. A few interstitial patches of malachite are present.

Some thin veins of quartz and pale green chlorite may be seen cutting the rock.

An estimate of the composition of the specimen is: grossularite 70%; quartz 25%; the remainder 5%. The specimen is a quartz garnetite.

4176. Photograph 5008, section 6. Green Parrot, Plate 4.

The hand specimen is seen to be medium grained, tough and granular, and contains mostly quartz and garnet, with a little black iron ore. The garnet is pink-orange, and occurs as irregular, granular masses enclosed by quartz. The section has been cut across a garnet-rich mass.

In thin section the rock is seen to be medium-grained and granoblastic, with quartz crystals being on the average a slightly larger size than garnet. Garnet ((?)calcium-rich) occurs, in quartz-poor areas, as a mosaic of granular, xenoblastic crystals, their boundaries commonly marked by a thin film of hydrated iron oxide. Where garnet neighbours quartz, it presents sub-idioblastic faces to that mineral. Very often garnet is altered to a greenish chlorite on its edges, and in cracks. Garnet contains minute opaque and reddish inclusions in some areas. Quartz is xenoblastic and interstitial, often partially enclosing garnet: where two or more quartz crystals are neighbours, they have tesselate margins. Chlorite occasionally occurs as fairly large platy crystals, tending to enclose one or two garnets, as well as being a marginal alteration product of that mineral. It is "uniaxial" negative, and is pleochroic: X = pale green brown; Y = pale olive green; Z = olive green. Its birefringence is 0.010. Black iron ore occurs as sub-idioblastic square shaped crystals, often slightly larger than garnet, commonly in clusters. Some times it is present as smaller, irregular masses included in chlorite. A little hydrated iron oxide occurs.

An estimation of the amounts of minerals present is: quartz 50%; garnet 40%; black iron ore 7%; chlorite 3%. The rock is a garnet-quartz-granulite.

4185. Photograph 5210, section 3, point 121. Plate 1.

The major part of the hand specimen consists of fine- to medium-grained, buff garnet, which encloses small aggregates and irregular veins of greenish, fibrous amphibole. Small irregular areas are seen to be composed of octahedral magnetite.

In thin section, the garnet ((?)andradite) is very pale buff, and forms a mosaic of subidioblastic grains whose average size is 0.1 mm. Quite frequently they are slightly stained by hydrated iron oxide. Actinolite occurs as masses of fibro-prismatic crystals interstitial to garnet. Its crystals range in length between 0.06 mm. and 1.0 mm. Actinolite is pleochroic with X = colourless, Y = Z = pale green. It is length slow, with Z∧C = 26°, and its birefringence is 0.022; it is biaxial negative, with 2V = 80° - 85°. Quartz forms xenoblastic grains, interstitial to garnet, and sometimes enclosing it. Magnetite occurs as fine to very coarse irregular and interstitial masses; it is partly altered to hydrated iron oxide.

An estimation of the percentages of minerals present is:- garnet, 70; actinolite, 20; magnetite, 7; and quartz, 3. The rock is magnetite-actinolite garnetite.

(b) Rocks Containing (?)Grossularite, or Vesuvianite, or Both Minerals.

4160. Photograph 5008, section 6. Attutra, Plate 3.

The hand specimen is coarse-grained, and mottled buff-yellow, with patches of greyish black. It is composed of large crystals of yellowish garnet, enclosing roughly prismatic crystals of amphibole. A small amount of quartz is present. Odd irregular flecks of malachite may be seen, interstitially placed in the groundmass. A joint surface is stained with a thin layer of malachite.

In thin section, the rock is seen to consist of: grossularite = 80%, tremolite = 3%, quartz = 10%, hydrated iron oxide = 5%, and malachite = 2%. Garnet occurs as yellow, completely isotropic, and apparently very large crystals. Though it is traversed by cracks, few crystal boundaries may be seen: two sets of "partings" occur at right-angles to one another, as well as other less regular cracks. Along one set of parallel cracks, the garnet is cut by hydrated iron oxide: in small zones, reticulate meshworks of hydrated iron oxide veins occur. Colourless tremolite occurs as rather fibrous, elongated crystals, often enclosed by quartz; it is length slow, with $Z \wedge C = 15^{\circ}$, and birefringence = 0.027. Quartz fills interstitial "cavities" in grossularite, moulding itself around idioblastic faces of the garnet. Green malachite frequently has a similar occurrence, and appears to enclose quartz, the latter mineral sometimes forming euhedral hexagonal crystals in it.

The rock is a cup-iferous and ferruginous tremolitic quartz garnetite.

4165. Photograph 5008, section 6. Attutra, Plate 3.

On a fresh surface the hand specimen is seen to be coarse-grained, and has a mottled green and cream colouration. The more green parts are a copper mineral, probably malachite, lying interstitially to the remainder. A green-grey coloured, anhedral ferro-magnesian mineral appears to be dominant, and patches of cream-pink garnet may be seen quite clearly. The weathered surface is stained with hydrated iron oxide: one surface has this staining to a depth of a centimetre.

In thin section, the texture of the specimen is very coarse-grained, xenoblastic, and inequigranular, and consists mostly of rather intergrown crystals of garnet and vesuvianite, with lesser amounts of epidote, zeolite, apatite and malachite. Garnet ((?)grossularite) is a very pale yellow to almost colourless, and forms irregular grains which, nevertheless, quite often have flat faces borderir vesuvianite, although they do not have regular crystallographic arrangement. Garnet is slightly altered to a greenish chlorite along cracks. It also encloses irregular patches of epidote. Vesuvianite occurs as large, irregular crystals, the average size being 2 mm., although crystals of up to 4.5 mm. were seen in the section. It is colourless, with a high relief, the refractive index being slightly higher than that of epdiote, and lower than that of garnet. It shows a good cleavage in one direction and its extinction is parallel. Its birefringence is 0.003, and it is very slightly biaxial and negative. Epidote forms irregular grains, 0.09 mm. to 0.1 mm. in size, enclosed in grossularite and vesuvianite, and in thin veins cutting both these minerals. Its birefringence is 0.058. It is biaxial negative, with $2V \simeq 75^{\circ}$. Apatite is present as subidioblastic, prismatic crystals enclosed in vesuvianite: Zeolite, possibly scolec[illegible]e, occurs in small, irregular areas, seemingly as an alteration product of vesuvianite, as it appears in cracks in that mineral. It also cuts the rock in thin veins. Its refractive index is less than that of Canada balsam, and it is biaxial negative, with $2V \simeq 40^{\circ}$. It is length fast, with $X \wedge C = 16^{\circ}$. Some indistinct twinning may be seen. Scolecite is mentioned by Winchell (1952) as occurring in contact zones. Malachite occurs as a few highly irregular masses of relatively small size, occupying spaces in the rock. A little hydrated iron oxide staining is present. An opaque mineral, possibly chalcocite, is occasionally present, occupying veins in the specimen, and sometimes surrounding malachite in cavities.

The rock has the following estimated composition: vesuvianite 45%; grossularite 35%; epidote 15%; the remainder 5%. The rock is a grossularite-vesuvianite (?)skarn.

4182. Photograph 5210, Section 3, point 115. Plate 1. (Figure V).

The hand specimen contains large irregular areas of greenish, coarse-grained vesuvianite, and of white, fibrous wollastonite. The wollastonite fibres tend to show slight radial structures. Small veins of quartz are present; exposure to an ultra-biolet lamp showed the presence of small amounts of scheelite.

In thin section, vesuvianite forms very coarse-grained crystals, which are xenoblastic to idioblastic. They frequently give the impression of being strained, as many show patchy extinction, and their cleavage planes seem to be bent. Vesuvianite has a high relief, with a low birefringence, and it is uniaxial negative. Wollastonite forms masses of colourless, coarsely acicular to fibrous, subradiating crystals which tend to enclose and vein vesuvianite. It has N_Z = 1.627 (approximately), and is length slow, with $Z \wedge C = 34^o$. It has a birefringence of 0.020, and it is biaxial negative, with $2V \simeq 30^o$. Multiple twinning is common. Identification was confirmed by X-ray diffraction methods by W.M.B. Roberts. It is easily distinguishable from the small amounts of diopside enclosed in it; this mineral has a much higher relief, and is biaxial positive, with a $2V \simeq 50^o$.

Diopside forms xenoblastic grains showing irregular margins to wollastonite; it also occurs occupying "cavities" in vesuvianite. Calcite cuts the rock in irregular veins, and occupies interstitial spaces. Scheelite occurs as medium-to coarse-grained granules enclosed in vesuvianite and wollastonite, and also in veins, replacing calcite. Scheelite has an extremely high relief, and is uniaxial positive. Rare quartz occurs interstitially in vesuvianite. Small granules of opaque ore may be seen.

The rock contains the following percentages of minerals: vesuvianite: 55; wollastonite: 25; calcite: 10; diopside: 5; scheelite: 3; and opaque ore and quartz: 2. The rock is a scheelite-bearing wollastonite-vesuvianite (?)skarn.

4202. Photograph 5008, section 10, point 268. Plate 1.

The hand specimen is a mottled pink, grey and green, coarse-grained rock, containing pinkish buff garnet, grey vesuvianite, colourless to purple fluorspar, with scattered grains of a green secondary copper mineral. Exposure to an ultra-violet lamp revealed the presence of scheelite.

The thin section shows that the rock has a background of pale grey, sometimes faintly buff garnet, which forms medium-size grains, and of coarse-grained, xenoblastic grains of colourless vesuvianite. The latter mineral has very high relief, with a low birefringence and straight extinction, and it is uniaxial negative. Enclosed in the garnet and vesuvianite are xenoblastic grains of plagioclase whose refractive index is greater than that of balsam, and which is biaxial negative. The felspar is now largely altered to sericite. Occasionally some coarse, xenoblastic grains of epidote are found with felspar. With some of the felspar grains a pale greenish mineral occurs in small rounded blebs; within the blebs it appears to form fibres arranged concentrically. It has low birefringence, and its refractive index is greater than that of sericitized felspar. It may be a chlorite.

The whole of this "background" described above gives the impression of having been broken up during the emplacement of fluorspar, which appears to have veined and fractured the rock, so that it now encloses numerous fragments of the previously described minerals. Fluorspar is pale pink to colourless, and has a strong negative relief; it is completely isotropic. It may be distinguished from garnet by its cleavage and relief.

Scheelite occurs as medium-grained granules, most usually enclosed by vesuvianite and garnet. It has very high relief, which gives it a greyish colour, and it is uniaxial positive. Occasionally it may be seen in thin veins.

A green secondary copper mineral (malachite) occurs in small veins, and as irregular grains sometimes intergrown with, or enclosed by, the other minerals in the rock.

An estimation of the percentage of minerals present in the rock is: - fluorspar 30; garnet, ((?)grossularite), 25; vesuvianite, 30; altered felspar, 10; scheelite, 3; epidote, 2. The rock is a Scheelite-bearing garnet-vesuvianite-fluorspar-skarn.

(c) Rocks containing zoned (?)andradite-grossularite garnet.

4168. Photograph 5008, section 6. Green Parrot, Plate 4.

The hand specimen is buff-coloured, in places mottled with green. It appears to consist mainly of garnet, with a few grains of epidote, and a little interstitial malachite. It is medium-grained, and, when handled, is friable.

The thin section shows that the rock consists of 90% of pink-orange garnet, which occurs as a mosaic of medium to coarse-grained crystals. The colouration shows some zoning, the margins of the crystals being of a deeper colour than the centres. It is probably andradite-grossularite. The garnet is often slightly altered to a pale greenish chlorite, numerous minute flakes of this mineral being included. A few granules of epidote are present. Occasionally, large irregular masses of black iron ore now largely altered to hydrated iron oxide, may be seen. Some intergranular malachite is present. Nontronite (?), a platy mineral with parallel extinction, yellowish colouration, and moderate birefringence, occurs as rather large masses, enclosing fragments of garnet, and apparently an alteration product of it.

The rock is a garnetite.

4170. Photograph 5008, section 6. Green Parrot, Plate 4.

The hand specimen is rather coarse-grained, but inequigranular. It has a pink-buff colour, with small areas of green. It consists mostly of granular garnet, but grains of black iron ore are present, as are fairly large (up to 8 mm.) but irregular areas of a green amphibole. Some epidote may be seen.

The texture, in thin section, of the specimen is rather coarse-grained, and xenoblastic. Garnet is commonly a pale yellow colour, showing some zonation. It forms a mosaic of xenoblastic crystals, except where other minerals are present, when it presents idioblastic faces to them. Large areas consist almost entirely of garnet, with small grains of black iron ore.

However, certain places in the slide, which are of irregular shape, and measuring up to 7 mm., consist of xenoblastic, sometimes fibrous, amphibole. Green actinolite forms roughly prismatic crystals, and is pleochroic: X = colourless; Y = pale green; Z = pale bluish green. It is length slow, with $Z \wedge C = 22^{\circ}$, and it is biaxial negative, $2V \simeq 75^{\circ}$. Often the crystals of green actinolite are fringed with colourless tremolite, with a refractive index slightly less than that of actinolite, and whose extinction = 18°. Tremolite, sometimes having a pale green colouration, also tends to form rather fibrous crystals. A few small, irregular, masses of carbonate with high relief(?) are present. The garnet is altered to a green chlorite on its margins. Veins of this mineral also cut the rock. Finely granular epidote occurs associated with the amphibole as irregular masses and thin veins cutting that mineral. Small amounts of interstitial quartz are present.

An estimation of the rock's composition is: garnet 70%; amphibole 20%; the remainder 10%. The rock is an <u>actinolite-garnet-skarn</u>.

<u>4175</u>. Photograph 5008, section 6. Green Parrot, Plate 4.

The hand specimen consists mostly of a granular, buff-coloured garnet. Amphibol and black iron ore are present in large irregular masses often partly or wholly enclosing the garnet. Small amounts of epidote and a white mineral are present, also as irregular masses.

In texture the thin section is seen to be very inequigranular, and subidioblastic, most of the minerals present being coarse-grained. Andradite garnet occurs as idioblastic, polygonal crystals, and is often altered to chlorite along its cracks. Black iron ore and hydrated iron oxide often lie in veins along the cracks. These cracks are up to 0.06 mm. thick, the crystals ranging between 0.5 mm. and 4.5 mm. in size in the section. The black iron ore veins in the garnet often connect with rather large irregular masses included in the garnet. Andradite is a pale yellow, often deepening towards the crystal edge. It is faintly birefringent, and polysynthetic twinning may be seen. Tremolite forms prismatic, rather acicular euhedral crystals, and, in places, rather more stubby, anhedral crystals. The latter are seen to be intergrown with carbonate, and to be sub-opaque, being filled with hydrated iron oxide dust: sometimes prehnite is associated with the intergrowth. Tremolite is colourless, or faintly tinged with green, and is length slow, with $Z \wedge C = 22^{\circ}$. It is biaxial negative, with $2V \simeq 80^{\circ}$. The birefringence is 0.023. The acicular crystals are quite often slightly bent and strained. Prehnite occurs as masses of minute, anhedral grains, and occasionally as sub-radiating aggregates of acicular crystals, all lying interstitially to garnet. At one place a large acicular crystal of tremolite occurs which merges into, and is replaced by, prehnite: the black iron ore dust contained in this crystal is however, continued on into the prehnite. Within areas of prehnite, other tabular formations of black iron ore dust occur, possibly being remnants of tremolite. A little quartz is present, as irregular "pools" lying interstitially to tremolite. Mixtures of black iron ore and hydrated iron oxide, as well as being associated with andradite, occurs as rather coarse irregular masses with tremolite.

The anhedral tremolite, mentioned above, is probably an alteration product of andradite. It occurs as anhedral masses, enclosing irregular grains of carbonate, the latter having heavy margins made up of hydrated iron oxide dust: the carbonate grains are separated by tremolite in what appear to be much enlarged cracks of the original garnet. Some of the garnets present have rims of this anhedral tremolite-hydrated iron oxide-carbonate material. The euhedral tremolite does not have this relationship with carbonate or garnet, and so was probably part of the rock prior to alteration.

The rock is a <u>tremolite-garnet skarn</u>.

*<u>4196</u>. Photograph 5008, section 6, point 224. Plate 1.

The hand specimen is coarse-grained, and is buff, mottled with green. The major part of the specimen appears to consist of garnet enclosing large granules of quartz and epidote. Some chlorite and amphibole are present, forming indistinct layering. Parallel to this is a band, ranging between 0.5 cm. and 2 cm. in thickness, composed of epidote and quqrtz. Scheelite was shown to be present on exposure to ultra-violet rays.

In thin section, quartz and epidote are seen to occur together apparently filling irregular, or six-sided cavities in a background of garnet. The whole gives the impression that garnet is being replaced by epidote and quartz. Many of the "cavities" coalesce to make even larger, very irregular forms. Pale green chlorite occurs as xenoblastic crystals interstitially to the other minerals. Sometimes, relict grains of actinolite are enclosed in chlorite. Irregular grains of (?)cerussite, black iron ore, and scheelite are present, and some crystals of sphene may be seen.

The garnet is a pale buff colour, and is probably andadrite containing some of the grossularite molecule. Epidote is pleochroic from a very pale fawn to yellow. Its birefringence is 0.048, and it is biaxial negative, with $2V = 85^{\circ} - 90^{\circ}$. The chlorite is pleochroic with X = Y = green, Z = pale fawn. It has negative elongation and a very low birefringence, showing anomalous blue colours.

The major part of the layer running through the hand specimen consists of granular, coarse-grained epidote, with interstitial quartz, and small amounts of scheelite.

In the specimen as a whole, the estimated percentages of minerals present are: epidote, 35; quartz, 30; garnet, 25; chlorite and actinolite, 8; scheelite, cerussite, sphene and black iron ore, 2. The rock is a <u>scheelite-bearing garnet-quartz-epidote-skarn</u>.

<u>4217</u>. Photograph 5008, section 10. Green Parrot (Shaft), Plate 4.

The hand specimen contains large amounts of a buff-yellow garnet, which enclosed irregular zones of fibrous black amphibole. Short, lenticular zones of green epidote are present. Small, irregular patches of calcite are revealed by application of dilute hydrochloric acid.

In thin section, the major part of the rock is composed of probable grossularite, which forms a mosaic of rather small xenoblastic crystals, 0.25 mm. in size, and has a buff-yellow colour, deepening towards the junctions with actinolite, suggesting a part change to andradite. Highly irregular zones, rather diffuse veins, and many very small areas are occupied by calcite. The garnet, next to these zones, shows rather rounded and fretted boundaries, as though being corroded; frequently, small islands of grossularite remain as "outliers" surrounded by these minerals.

Besides actinolite and calcite, other minerals present consist of quartz, haematite, diopside, (?) phlogopite, soda tremolite and (?)vesuvianite. Actinolite is the dominant mineral in quantity, and forms masses of intergrown acicular, fibro-prismatic crystals, having irregular granules of black iron ore associated with it. It is length slow, with Z $\wedge$ C = 19°, and is biaxial negative, with 2V ≏70°. The pleochroism is: X = colourless, Y = very pale olive green, Z = very pale green. Actinolite gives way to, and is intergrown with, a mush of calcite, and some fine-grained, dusty opaque material: occasionally corroded crystals of colourless (?)diopside may also be seen. It has a large extinction angle, and is biaxial positive, with a 2V of approximately 50° - 60°. Quartz, and occasionally (?) phlogopite, are present as "interstitial" xenoblastic crystals in the mush. The latter mineral is colourless, and has a biaxial negative figure, with 2V = 5°-10°. Small amounts of (?)vesuvianite are present as granules in grossularite.

Soda tremolite occurs as small xenoblastic crystals enclosed in grossularite. It has Z $\wedge$ C = 24°, and is biaxial negative with a moderate or large 2V. It is pleochroic from colourless to very pale grey blue. Very occasionally small idioblastic crystals of apatite are present.

An estimation of the percentages of minerals present is: grossularite = 60, actinolite = 20, calcite = 10, and haematite diopside, quartz, soda tremolite, (?) phlogopite, vesuvianite and apatite are all approximately 10. The rock is a calcite-actinolite-grossularite skarn.

4226. Photograph 5008, section 7, point 279. Plate 1.

The hand specimen is a medium to coarse-grained, buff-yellow rock mottled with green, which consists of granular garnet, enclosing small and large irregular areas of epidote and quartz with some chlorite. The specimen is cut by a thin vein of coarse epidote and quartz. Small flecks of malachite are present, and the weathered surfaces are stained by hydrated iron oxide.

In thin section the rock is seen to be fairly coarse-grained, but inequigranular. Buff-yellow, faintly zoned garnet ((?)andradite) occurs as a mass of cracked xenoblastic crystals: it is sometimes weakly birefringent. Epidote, pleochroic in yellow, and is biaxial negative with a 2V ≏80°; it forms large, interstitial xenoblastic grains, and is also present as masses of smaller, granular crystals. Smaller amounts of green chlorite may be found interstitially, sometimes intergrown with epidote. Quartz is found interstitially. Apatite forms euhedral crystals enclosed in epidote and garnet. Black iron ore occurs as small irregular masses associated with garnet.

A coarse-grained vein composed of epidote and quartz, with some garnet, cuts the rock.

An estimation of the percentages of minerals present is: garnet 55; epidote 25; quartz 10; chlorite 7; apatite and black iron ore 3. The rock is a quartz-epidote-garnetite.

iii. Assemblages with Amphibole

4180. Photograph 5210, section 7, point 80. Plate 1.

The hand specimen is of an apparently coarse-grained, gneissic, greenish-grey rock composed of coarse quartz, granular pale green epidote, rather fibrous dark green amphibole, and aggregates of white, powdery sericite. Quartz forms isolated, lenticular bodies with parallel orientation, ranging in size between 1 cm. long by 0.3 cm. wide (the common size) and one long band 1.5 to 2 cm. thick, its length being greater than that of the specimen. In these bodies, quartz is coarse-grained, and inequigranular. Surrounding the quartz are masses of much finer-grained, fibrous amphibole. Epidote appears to form granular crystals of medium size, and is present in relatively minor quantities in the quartz and amphibole areas. The sericite powder occurs in compact rounded areas, apparently pseudomorphing a pre-existing mineral.

In thin section, quartz is seen to form coarse interlocking grains, ranging between 0.25 mm. and 1.6 mm. in size. They show foliated strained extinction. Tremolite forms masses of fibrous to fibro-prismatic, partially radiating crystals with a preferred orientation parallel to the foliation. The crystals range in size between 0.06 mm. by 0.5 mm. long. Although tremolite occurs in areas with practically no other minerals present, some fine-grains of quartz may be seen, sometimes as thin fine-grained layers. Tremolite is almost colourless, though sometimes faintly green: its absorption is:- $Z > Y > X$. It is biaxial negative, with $2V = 75^o - 80^o$, and its birefringence $= 0.033$. It is length slow, with $Z \wedge C = 18^o$. In the quartz-rich areas, isolated subidioblastic crystals of tremolite are sparingly present.

Epidote forms sub-idioblastic, roughly tabular crystals which occur sparingly in the quartz, and tremolite areas. It is faintly pleochroic in yellow, and has a birefringence of 0.023, and is biaxial negative, with a $2V = 80^o - 85^o$. Sericite forms masses of fine-grained flakes, occasionally coalescing to make a single large crystal. The masses of crystals occupy rounded areas, ranging between 0.05 mm. and 0.65 mm. in size, as though pseudomorphing as pre-existing mineral - possibly felspar. Sericite is almost always found occurring in the quartz-rich areas.

An estimate of the relative amounts of minerals present is:- tremolite 45%, quartz, 40%; sericite = 10%, epidote, 5%. The estimate was made mainly from the hand specimen, as the section gives an incorrect view of the proportions present. The rock is quartz-tremolite gneiss.

4181. Photograph 5210, section 3, point 114. Plate 1.

The hand specimen is a coarse-grained pale cream-grey rock, mottled with pale green and pink. Rather irregular, lenticular masses of fibrous green amphibole are enclosed by coarse, granular crystals of pyroxene, the latter mineral sometimes being stained pale pink. The amphibole forms sub-radiating fibres, with only a little tendance to parallel orientation. Very rarely small irregular masses of fluorspar are present as roughly cubic masses, with a deep purple colour.

In thin section the rock is found to be coarse-grained, though inequigranular, and has a xenoblastic texture. It consists almost entirely of diopside and tremolite with smaller amounts of zoisite, epidote, sericite, (?)prehnite, and sphene. Diopside forms a mosaic of interlocking grains whose sizes range between 0.15 mm. and 3.5 mm. It is colourless and N_Z approximately equals 1.695. The mineral is biaxial positive, with a 2V = 50°, and it is length slow, with Z /\ C = 39°. Tremolite is colourless and occurs as fibro-prismatic crystals concentrated in a band running across the section. The crystals are sub-parallel along the band but have a tendency to radiate from several centres. Occasionally, small grains of diopside are enclosed by tremolite, with a rim of small tremolite crystals around them. N approximately equals 1.625, and Z /\ C = 22°. It is biaxial negative, with 2V = 80 - 85°. Sericite, possible prehnite, and relict grains of felspar occur as masses of fine flakes and grains in large, irregular areas, or in small inclusions in diopside. The sericite and (?)prehnite are probably the result of alteration of felspar. The latter mineral is biaxial negative, and in one grain, repeated twinning was seen, suggesting it to be plagioclase. Zoisite forms small tabular crystals with parallel extinction and low birefringence enclosed in sericite, or occasionally as small, irregular masses, enclosing smaller tremolite grains. Sometimes, epidote is enclosed by zoisite. Rare crystals of sphene, and a little quartz, may be seen.

An estimation of the relative amounts of minerals present is:- diopside 60%; tremolite 25%; sericite and (?)prehnite 13%; the remainder = 2%. The rock is a <u>tremolite-diopside (?)skarn</u>.

<u>4183</u>. Photograph 5210, section 3, point 119. Plate 1.

The hand specimen is a dark greyish-green, coarse-grained rock containing amphibole, pyroxene, and epidote. The two latter minerals are granular, and enclosed by the more dominant amphibole. The amphibole forms sub-radial fibrous crystals, with their crystallographic C - axes randomly orientated in one plane, giving the rock a schistose aspect. Irregular veins of a very fine-grained mineral (shown in section to be talc) cut the rock parallel to the "schistosity". The section is cut across one of these veins.

In thin section, all minerals except talc are seen to be coarse-grained, and are xenoblastic. Tremolite forms colourless, rather fibrous crystals, often apparently replacing diopside. It is biaxial negative, with 2V ≏ 80° and Z C = 22°. Diopside occurs as xenoblastic grains, sometimes partially enclosed by tremolite, and showing irregular margins to that mineral. Diopside is length slow, and has Z /\ C = 41°. It is biaxial positive, with 2V = 50° - 60°. Veins of fine-grained, flaky talc cut the rock, often enclosing both tremolite and diopside, both of which, in this case, have very ragged margins, as though the talc were replacing them. Epidote, pleochroic in yellow, sometimes occurs associated with tremolite and diopside, but more commonly forms tabular, subidioblastic crystals enclosed in talc. It is biaxial negative, with 2V = 75° - 80°. Occasionally, small crystals of zoisite, with parallel extinction and very low birefringence, may be seen somewhat intergrown with tremolite. A little apatite is present as prismatic crystals. Some quartz is associated with talc.

The rock appears to have been a tremolite-diopside schist, which has suffered retrograde metamorphism, resulting in the formation of talc (a hydrated magnesian silicate). The lime and alumina of tremolite and diopside presumably have gone to epidote - with any small amount of iron present; it is considered from this, and from textural considerations (the occurrence of epidote mainly with talc, and epdiote's subidioblastic habit, that epidote was formed along with talc. Whether the original diopside - tremolite schist is itself a result of an earlier phase of metasomatism, or is the result of the metamorphism of a very siliceous dolomite, cannot be told from this specimen. The rock is at present a diopside - tal - tremolite schist.

4185. Photograph 5008, section 9, point 132. Plate 1.

The hand specimen is a pale greenish-grey, medium to coarse-grained rock. It appears to be composed mainly of green epidote, which, on weathered surfaces, and for a short distance into the specimen from these surfaces, are stained pink by hydrated iron oxide. Smaller amounts of quartz and calcite are present, intergrown with epidote. The rock is cut by veins consisting of quartz and calcite. The latter mineral reacts on application of dilute hydrochloric acid.

The thin section shows the rock to be a medium-to coarse-grained, xenoblastic intergrowth of crystals composed mainly of epidote, but with smaller amounts of tremolite, quartz, and calcite. The whole is cut by veins consisting of quartz and calcite. Epidote forms granular to very irregular grains, in places seen to be replacing tremolite. It is colourless or very pale yellow, and has a moderate birefringence: it is biaxial negative, with $2V = 80^{o} - 90^{o}$. Tremolite occurs as xenoblastic, colourless grains, very often with rather fibrous terminations. The crystals have little acicular shape, and show very irregular edges to epidote. A little (?)talc may be seen in places associated with tremolite: possibly it is a by-product from the formation of epidote. Quartz and calcite occur as small interstitial, often tenuous bodies, showing some parallel orientation. The whole is cut by veinscomposed of quartz and calcite, the latter mineral tending to occur at the vein boundaries, sometimes having quartz intergrown with it. Quartz occupies the vein cores.

The rock is a tremolite-epidote (?)skarn.

4189. Photograph 5008, section 2, point 170. Plate 1.

The hand specimen is a dark green schistose rock consisting almost entirely of very inequigranular fibrous crystals of amphibole. Odd flecks of a green copper mineral may be seen, shown by reaction with dilute hydrochloric acid to be malachite. The weathered surfaces are stained with hydrated iron oxide.

The thin section is seen to be composed mostly of actinolite, or pale green hornblende. In texture the rock is fine to medium-grained, with some lineation of groundmass grains, though these are wrapped around large porphyroblasts. The average groundmass grain-size is 0.2 mm., and the porphyroblasts may attain a size of 9 mm. The porphyroblasts show little preferred orientation. The actinolite crystals have a fibro-prismatic habit. Actinolite is pleochroic with X = colourless, Y = pale green, faintly olive, Z = faintly bluish green; the colours tend to be less intense towards crystal centres, and sometimes, at the latter places, schiller inclusions of black iron ore may be seen, with a "halo" of more intense colour. The mineral is length slow, and has $Z \wedge C = 27^{o}$, and it is biaxial negative, with a large 2V. Intergrown with actinolite is a pale chlorite which is pleochroic with X = Y = pale grey-blue, Z = colourless. It is biaxial positive, with a small 2V. Fine octahedral grains of black iron ore are scattered throughout the rock. Malachite is present as xenomorphic grains, sometimes apparently intergrown with actinolite. At one place it occurs along an apparent minor fault.

77% of the rock is actinolite, 20% is chlorite and the remainder is black iron ore and malachite. The rock is chlorite actinolite schist.

4201. Photograph 5210, section 3, point 123. Plate 1.

The hand specimen is dark, greenish-black, and composed almost entirely of amphibole, with some pale green epidote. The amphibole forms fairly squat, prismatic crystals with a preferred orientation. The weathered surfaces are stained with hydrated iron oxide.

In thin section the rock is seen to be medium- to coarse-grained, and inequigranular, the actinolitic-hornblende showing some tendency to lineation (the thin section is cut nearly at right-angles to the schistosity of the hand specimen). Its crystals range between 0.75 mm. and 3.0 mm. in size, and form sub-idioblastic, roughly prismatic crystals, often with rather ragged terminations. It is pleochroic with X = pale olive, almost colourless, Y = brunswick green, Z = bluish-green, and it is length slow, with $Z \wedge C = 28^{o}$; its sign is biaxial negative, with $2V = 80^{o} - 85^{o}$. Occasional granules of epidote pleochroic in pale yellow-green are present, sometimes intergrown with actinolitic-hornblende, or as infrequent, isolated grains enclosed in this mineral. It is biaxial negative, with a large 2V. Small irregular masses of black iron ore, very often partially altered to hydrated iron oxide, are associated with actinolitic-hornblende; very often the latter mineral is stained with hydrated iron oxide dust.

Actinolitic-hornblende forms 90% of the rock, and epidote 10%. The specimen is an epidote-actinolitic-hornblende schist.

iv. Epidosites

4159. Photograph 5008, section 6. Attutra, Plate 3.

On a fresh surface, the hand specimen has a dark grey to brown colour, mottled with green. It is fine to medium-grained, and consists of quartz, epidote and garnet. The last-named mineral appears to have been concentrated into one or two clots, about 5 mm. across, and has a brownish colour. Quartz is concentrated into layers 1-3 mm. thick, often of lenticular shape, enclosed by areas containing equal amounts of quartz and epidote. Epidote itself is likewise concentrated into bands. The layers are undulatory, giving the impression of small folds. Along one side of the specimen is a coating of malachite. On the weathered surface, the rock is stained with hydrated iron oxide.

In thin section, the rock has a medium-grained and granoblastic, inequigranular texture. A rough grading of grain-size of both epidote and quartz may be seen from one side of the slide to the other in relation to the hand specimen; the finer grain size is nearest to the surface coated with malachite. The direction of grading is normal to the direction of layering.

Quartz occurs as a xenoblastic mosaic of grains, whose average size ranges between 0.1 mm. in the coarser material, and 0.06 mm. in the finer. The mineral sometimes shows slight undulose extinction. Epidote forms xenoblastic grains, often showing an amoeboid partial enclosure of quartz. Throughout the slide it is of a slightly more coarse grain size than quartz. It is pleochroic: - X = colourless; Y and Z = very light yellos, and is biaxial negative, with $2V \simeq 80^{\circ}$. The birefringence is 0.053. Garnet occurs as colourless, or very light yellow, idioblastic crystals of a "hexagonal" shape, with an average size of 0.08 mm. It tends to be confined to the epidote layers, but is by no means entirely so. It has numerous opaque and colourless inclusions of a very small size, though its margins are entirely clear for a distance of 0.02 mm. into the crystal. The colourless inclusions appear to be quartz. The opaque ininclusions tend to be rod-like and parallel, not only in a single garnet, but the inclusions of neighbouring garnets are parallel. The garnets are often cracked, the cracks extending for a short distance outside the crystal into the surrounding groundmass. These cracks are filled with a faint green, chloritic-looking substance.

Small euhedra of prismatic apatite occur enclosed in quartz. A few small flakes of chlorite are present, pleochroic in pale green: they are length fast, indicating a possible positive interference figure. Several irregular to wedge-shaped grains of sphene are present, associated with epidote: they are pale brown in colour, and very slightly pleochroic.

An irregular vein, 0.03 mm. thick, cuts the rock, consisting of malachite, with borders of hydrated iron oxide: occasionally the malachite fades out, leaving the latter mineral alone in the vein. The vein occasionally sends minor off-shoots into the groundmass.

The rock has the following estimated composition: epidote = 45%; quartz = 35%; garnet = 16%; the remainder 4%. The rock is a garnetiferous epidosite.

4171. Photograph 5008, section 6. Green Parrot, Plate 4.

The hand specimen is pale in colour, consisting mainly of quartz, but it is flecked with green epidote, and intergranular, orange, hydrated iron oxide. The rock is granular, and medium grained, and tends to be friable.

The texture of the rock in thin section is medium-grained, and xenoblastic-granular. Quartz forms xenoblastic grains with sub-tesselate margins. It has an undulose extinction. Very often it has numerous opaque inclusions. Epidote occurs in idioblastic crystals, and as rather small, interstitial masses, connected by thin veins. It is colourless, with a high relief, and has an oblique extinction. It is biaxial positive, with a $2V \simeq 85^{\circ}$. The birefringence = 0.014. Pale green chlorite occurs as masses of tiny, rather fibrous, crystals, interstitially to the other minerals, sometimes enclosing them. Sometimes it is stained with hydrated iron oxide.

The specimen has by estimation, the following mineralogical composition: quartz 60%, epdiote 25%, chlorite 15%. The rock appears to be an chlorite-epidote quartz-granulite, or epidosite.

4184. Photograph 5210, section 3, point 121. Plate 1.

The hand specimen is a pale greenish-cream, fine- to medium-grained rock consisting mainly of quartz, with some epidote; dark "spots" sparsely and irregularly distributed throughout the rock appear to consist of clusters of small amphibole crystals.

In section, the major mineral present, quartz, is seen to form a fine- to medium-grained mosaic of xenoblastic grains with tesselate margins. The grain size ranges between 0.05 mm. and 0.4 mm. Epidote occurs as very small granules, whose average size is 0.032 mm. The grains show some concentration into layers. Epidote is slightly pleochroic in greenish yellow. Green hornblende is present as prismatic, rather acicular crystals arranged radially in clusters, the clusters measuring up to 1.5 mm. across. The individual crystals are frequently poikiloblastic, enclosing minute granules if quartz and epidote. It is pleochroic with X = yellow-green, Y = green, Z = blue-green, and is length slow, with $Z \wedge C = 23^{\circ}$; its birefringence is 0.027, and it is biaxial negative, with a large 2V. Occasionally, flakes of a greenish-brown biotite may be seen intergrown with hornblende. Close to the centres of a few of the clusters a completely isotropic, brownish garnet ((?) andradite) is present, showing ragged margins to the hornblende, as though the latter were replacing it.

An estimation of the percentages of minerals present is:- quartz, 65; epidote, 20; hornblende and biotite, 15; with traces of garnet. The rock is a garnetiferous hornblende epidosite.

4193. Photograph 5008, section 6, point 194. Plate 1.

The hand specimen is a dull green, fine-to medium-grained, granular rock with a sub-conchoidal fracture. It appears to consist almost entirely of quartz and epidote. The weathered surfaces are stained with hydrated iron oxide.

In thin section the rock is seen to be fine- to medium-grained, equigranular and granoblastic. Quartz forms xenoblastic, somewhat interlocking grains, whose average size is 0.21 mm. It has slight undulose extinction. Slightly pleochroic, pale yellow epdiote occurs as very xenoblastic grains, often partially or wholly enclosing quartz. The average grain-size is similar to that of quartz. Its birefringence = 0.045, and it is biaxial positive, with $2V = 85^{\circ} - 90^{\circ}$. Some actinolite is present, forming xenoblastic grains, sometimes intergrown with epidote. It is faintly pleochroic in very pale green, and has $Z \wedge C = 20^{\circ}$. Rare apatite occurs as small, rounded granules. "Magnetite" xenoblastic to octrahedral crystals.

An estimation of the relative amounts of minerals present is: quartz, 40%; epidote, 45%; actinolite, 10%; black iron ore, 4%; and apatite, 1%. The rock is an actinolite-epidosite.

2. POST-REGIONAL METAMORPHISM IGNEOUS ROCKS

A. The Metadolerites

4179	Photograph	5210,	section	7,	point	13
4188	"	5008,	"	9,	"	134
4190	"	5008,	"	2,	"	161
4194	"	5008,	"	6,	"	203
4195	"	5008,	"	6,	"	205.

All may be found on Plate 1.

The Hand Specimens

All five specimens are greyish-black, apparently basic igneous rocks. They consist of black amphibole, and pale creamish-grey felspar; 4195 has quartz in addition. The specimens are medium- to coarse-grained. Hornblende occurs as subhedral prismatic crystals. Felspar, in 4188 and 4190, is tabular; in 4179 and 4194 it is interstitial to tabular, and in 4195 it is granular and mingled with quartz. A grain of chalcopyrite was noted in 4188. All specimens are stained with hydrated iron oxide.

Mineralogy

Felspar, in all specimens, has a refractive index greater than that of Canada balsam, and it is biaxial positive, with a high 2V. The compositions of the felspars are listed, with the method of determination:-

4179 - An45 - section normal to the Z-bisectrix.

4188 - An50 - section normal to the X-bisectrix.

4190 - An59 - symmetrical extinction angles.

4194 - An45 - section normal to the X-bisectrix.

4195 - An47 - section normal to the X-bisectrix.

The optical properties of hornblende are fairly constant for all the specimens. The pleochroism is:- X = pale olive fawn, Y = green, Z = bluish-green. Hornblende is length-slow, and $Z \wedge C$ ranges between 25^{o} and 31^{o}. Its birefringence = 0.024 - 6, and it is biaxial negative with a large 2V. In all the specimens except 4195, 40%-45% of the rocks is hornblende, and 45%-50% is felspar. In the exception, felspar forms 37% of the rock, and hornblende 35%; most of the remainder is quartz.

Of the accessory minerals, black iron ore forms 3% to 5% of all specimens except in 4190, where it is rare. In that specimen, and in 4188, a carbonate with high relief is associated with hornblende and black iron ore - only small amounts are present. Rare granules of epidote occur in 4194 and 4195, and in all specimens small amounts of apatite are present. A little biotite, and minor amounts of a colourless, fibrous mineral with parallel extinction is associated with hornblende in 4188.

Textures

(a) 4188 and 4190. These are generally similar to one another in that their texture is hypidiomorphic-granular, with plagioclase forming tabular crystals which show some alteration to sericite in 4188, and which are strongly sericitized in 4190. Hornblende forms small subhedral to euhedral clustered crystals, the clusters seeming to have an ophitic relationship to plagioclase. Black iron ore is rare in 4190, but in the other forms anhedral crystals often associated with hornblende; some grains are partly or wholly surrounded by a rim of carbonate, and a little biotite is present, associated with hornblende. Quartz and biotite are absent in 4190.

(b) Specimen 4195 is somewhat more coarse-grained, and contains granular quartz, intermixed with granular felspar. However, much of the felspar occurs as laths, containing numerous small blebs and streaks of quartz, commonly elongated parallel to the felspar's (001) cleavage. Hornblende forms randomly oriented and somewhat acicular crystals.

(c) 4179 and 4194. The former specimen is medium-grained, xenomorphic granular and porphyritic. The sparse phenocrysts are subhedral and tabular, though with ragged, somewhat granulated margins; they are slightly sericitized and kaolinized. The groundmass felspar forms small rounded grains, showing very little secondary alteration, and is mostly untwinned. Hornblende occurs as subhedral, prismatic crystals showing some lineation, and an apparent flowage around the phenocrysts. Black iron ore is present as subhedral to octahedral crystals, sometimes associated with hornblende.

4194 has larger crystals of fibro-prismatic hornblende; felspar forms thin, tabular crystals, many of which have partly or wholly broken down to granules, resulting in a texture similar to that of 4179; in fact, 4194 appears to be a stage part-way to that of the other. In some of the unaffected felspars of 4194, small blebs of quartz occur in a similar way to those in 4195. A similar relationship of quartz and plagioclase was described by Wiseman (1934, p. 386) and Gindy (1951, p. 56), but no explanation for it was offered by these authors.

Summary.

The rock appear to be metadolerites. They are emplaced in schists and gneisses which have obviously suffered regional met orphism, and that have consequently received a pronounced schistocity. Since the metadolerites show no schistocity or foliation (except for a probable relict flow texture in 4179), it seems likely that they suffered thermal metamorphism, possibly at the same time as the mineralization.

B. Acid Igneous Rocks

4177. Photograph 5008, section 6. Green Parrot, Plate 4.

The hand specimen is white, speckled with pink and dark crystals. It is a coarse-grained acid igneous rock, hypidiomorphic and rather inequigranular in texture. The minerals present are quartz, white feldspar and white mica: the small pink areas appear to be due to hydrated iron oxide staining.

The thin section of the specimen, in texture, is seen to be holecrystalline, coarse-grained, hypidiomorphic and rather inequigranular. The plagioclase feldspar laths tend to show a slight flow texture. Quartz occurs as anhedral, interstitial crystals, ranging between 0.2 and 1.9 mm. in size, partly enclosing albite and muscovite. It has very slightly sutured margins, both with other quartz crystals, and with albite: its extinction is slightly undulose. Albite occurs as euhedral tabulac of 1.2 mm. by 0.3 mm. average size, and shows albite, carlsbad and pericline twinning: some crystals show a form of fourling twinning, i.e. diagonally opposite corners of a tabular crystal extinguish together. Its refractive index is less than that of Canada balsam, and it is biaxially positive, with 2V 85°. An extinction angle measured on a section normal to the X-bisection shows a composition of An_4. Muscovite occurs as subhedral flakes of general orientation, partly enclosing albite, but enclosed by quartz. The flakes range between 0.1 and 0.7 mm. in size.

Albite is very slightly altered to kaolin. Some small crystals of feldspar are present in no great quantity, which are badly altered to kaolin: they are of anhedral shape, and have a refractive index less than Canada balsam. One such crystal gave a biaxial negative figure, with a $2V \simeq 70^{\circ}$. This feldspar is probably orthoclase. Minute, often acicular, euhedra of apatite are often included in all the above mentioned minerals. A single, small grain of biotite was noticed, having a dark brown colour; it is biaxial negative, with a $2V \simeq 5^{\circ}$: it was 0.3 mm. in length. Granules, and small irregular areas of hydrated iron oxide are present.

An estimation of the mineralogical composition is: Quartz 30%, albite 50%, muscovite 15%, orthoclase 3%, the remainder 2%.

The rock is an <u>muscovite-albite granite</u>.

<u>4191</u>. Photograph 5008, section 2, point 159. Plate 1.

The hand specimen is seen to be a coarse-grained, rather gneissic granitic rock containing anhedral, granular quartz and pink felspar, and small flakes of dark mica, strung out in roughly parallel lines between the other grains. The rock is stained with ferruginous matter.

In thin section the rock is seen to be medium- to coarse-grained, xenomorphic, and inequigranular. Quartz and felspar form irregular grains showing cracking, straining, and granulation. The presence of cross-hatch albite and pericline twinning in much of the felspar shows that it is microcline. Come plagioclase, with a refractive index roughly equal to that of Canada balsam is present; it forms rather tabular and granular crystals, and is rather more kaolinized than the potash-felspar, and is partly sericitized. Its almost parallel extinction suggests that it is oligoclase. Slightly altered biotite, pleochroic with X = rusty brown, and Y = Z brownish black, occurs as small, subhedral flakes very often interstitial to felspar. A little muscovite is present. Black iron ore is associated with biotite.

An estimation of the percentages of minerals present is:- microcline, 35; quartz, 30; plagioclase, 33; biotite and muscovite, 2; with traces of black iron-ore. The rock is an <u>adamellite.</u>

<u>4192</u>. Photograph 5008, section 2. Point 159.

The hand specimen is a pinkish-grey, medium-grained aplitic rock, with a fairly obvious preferred elongation of the quartz grains. Pink felspar is the other major constituent. The weathered surfaces are stained with hydrated iron oxide.

The thin section shows the rock to be medium-grained, and to have a xenomorphic-granular texture, with a quite prominent elongation of grain shape in one direction. Quartz and felspar form rather irregular grains with somewhat irregular and rather rounded edges, though some of the felspar is tabular. The felspar consists of both microcline and albite, the former being biaxial negative, the latter biaxial positive, both having a large 2V. Albite probably has a composition of An_7. A few small flakes of muscovite are present. Black iron ore, now partly altered to hydrated iron oxide, occurs as irregular grains.

An estimation of the percentages of minerals present in this specimen is:- quartz, 27; microcline, 40; albite, 30; black iron ore, 2; muscovite, 1. The rock is an <u>aplitic granite</u>.

3. <u>ROCK RESULTING FROM SECONDARY ACCUMULATION</u>.

<u>4220</u>. Photograph 5008, section 6. Reward, Plate 2.

The major part of the hand specimen consists of sub-prismatic crystals of dark pinkish brown pyromorphite. Numerous intergranular spaces are partly or wholly occupied by chalcedony, with some cerussite, and a little quartz. Pyromorphite exhibits hexagonal prismatic faces to these cavities, the faces commonly having a coating of green-stained chalcedony, if the cavities are not completely filled by this mineral. A small amount of rust-coloured mineral is present, occurring interstitially to pyromorphite. Chemical tests for lead and phosphate were made for pyromorphite, and for lead and carbonate in the case of cerussite by A. McClure.

In thin section pyromorphite occurs as inequigranular subidioblastic to xenoblastic crystals ranging between 0.2 mm. and 4.5 mm. Neighbouring crystals have straight to somewhat irregular contacts but where grains border upon cavities, commonly crystal faces are present. Less commonly, the faces next to the cavities show some corrosion. Very often small crystals of pyromorphite are isolated in the cavities: they show rough and pitted idiomorphic faces. Pyromorphite has a very high relief, giving it a greyish colour the surface of the mineral having a rather pitted appearance. Its birefringence is 0.010, and it is uniaxially negative. Under crossed nicols, individual crystals show an andulose, or broken extinction, reminiscent of the extinction in strained crystals of quartz.

The cavities occurring between pyromorphite crystals are occupied by fine quartz and fibrous pale green chalcedony. The latter mineral commonly forms fibres elongated at right-angles to the pyromorphite crystal faces actually at that mineral boundary, but farther into the cavities colourless, fine-grained quartz occurs ranging in diameter from 0.3 mm. near the cavity edges to very minute grains present in the cavity centres. Some more coarse xenomorphic crystals of quartz are present in the cavities, enclosed by chalcedony: their margins appear to be corroded. At one point, a cluster of quartz crystals show amoeboid intergrowth.

Cerussite, where it is present, is enclosed partly by chalcedony, or itself partly encloses idioblastic, non-corroded faces of pyromorphite. It forms medium-grained mosaics of anhedral crystals, very slightly coarsely intergrown with one another.

Distinctly pale pink and (rarely) gold buff garnet forms xenoblastic crystals, enclosed in both pyromorphite and chalcedony. One garnet is partly enclosed in quartz, but has a very narrow vein of chalcedony between it and the quartz.

Some hydrated iron oxide occurs as small inclusions in pyromorphite, and around its borders.

The rock has some 70% pyromorphite, 17% chalcedony, 6% cerrusite, 5% garnet and 1% quartz. It is a secondary lead ore consisting mainly of pyromorphite and chalcedony, together with some cerussite. The specimen is a garnet-cerussite-chalcedony-pyromorphite-rock.

SUMMARY AND CONCLUSIONS

In this chapter the characteristics of the various rock types will be summarized, and the possible origins of the rocks will be discussed. Some brief remarks will be made on the metadolerites, and the acid igneous rocks.

1. Metamorphosed and Metasomatized Rocks

A. Non-calcareous.

i. Pelitic and semi-pelitic metamorphic rocks showing little or no metasomatic alteration. These rocks are chiefly garnetiferous mica-quartz-schist and gneisses belonging to the staurolite zone of regional metamorphism. They have been affected to a certain degree by retrograde metamorphism, e.g., biotite and garnet often show slight alteration to chlorite, and garnet in other rocks is partly replaced by hydrated iron oxide.

It is considered that the chlorite schist represented by slide 4210 is not due to the effects of retrograde metamorphism. It consists almost entirely of chlorite which is rich in magnesia and alumina. Little or none of the materials necessary for the formation of mica, or garnet is present: this may explain the occurrence of this specimen among rocks of moderately high grade metamorphism (Harker, 1932, pp. 216 and 277). As this chlorite is fairly rich in alumina, it seems more likely that the rock is derived from a sediment than from an ultrabasic igneous rock (Harker, loc. cit).

Slide 4164 is seen to be of a garnetiferous mica-quartz schist, which contains a green spinel in close association with quartz. This association is rare (C.E. Tilley, pers. comm.), and it is hoped, later, to isolate the spinel and examine its properties.

ii. Pelites and semi-pelites bearing porphyroblasts of cordierite, andalusite and biotite. The seven specimens whose character is summarized here have a fine- to medium-grained lepidoblastic-granoblastic groundmass containing granular quqrtz and lineated mica. Biotite is found in the groundmass of all except 4198, and muscovite may be seen in all but 4213 and 4219. Albite forms xenoblastic grains in the groundmass of slides 4161 and 4198. Biotite is seen to be chloritized in slide 4161.

In slide 4161 the only porphyroblastic mineral present is pinitized cordierite. This mineral and biotite may be seen in slide 4223, and both these minerals, with andalusite, may be found in slides 4187 and 4198. Slides 4213 and 4219 are seen to contain porphyroblasts of andalusite, biotite and garnet, and garnet, and in slide 4200, andalusite, with a little garnet, may be found.

In making an examination of Plate 1 of Robertson's report, it is seen that the porphyroblastic schists represented by these specimens occur as long, narrow bands elongated parallel to the schistocity: several of these bands are present. This at first suggests that they were formed during the period of regional metamorphism. If this is so, then conditions of relaxed shearing stress must have been prevalent to account for the presence of the so-called "anti-stress" minerals andalusite and cordierite (Harker, 1932, pp. 230-35). However, it is to be noted that every outcrop of these rocks upon the map is accompanied by mineralization (ore bodies, quartz-tourmaline veins) or by intruded pegmatites. There is, therefore, the contrary suggestion that the formation of the porphyroblasts took place after the formation of the schists, i.e., it is associated with the mineralization.

There is some evidence to support the latter suggestion: (a) Contrary to the preferred orientation of the groundmass micas, biotite porphyroblasts have a random orientation (e.g., fig. ii). Again, in some of the specimens (e.g., 4213), andalusite is elongated parallel to the schistocity, although it has random optical orientation: in other slides (e.g., 4198), it also has random orientation of shape. These facts show some lack of correspondence between the texture of groundmass and the form of the porphyroblastic minerals, though by themselves are not definite evidence of the later formation of the porphyroblasts.

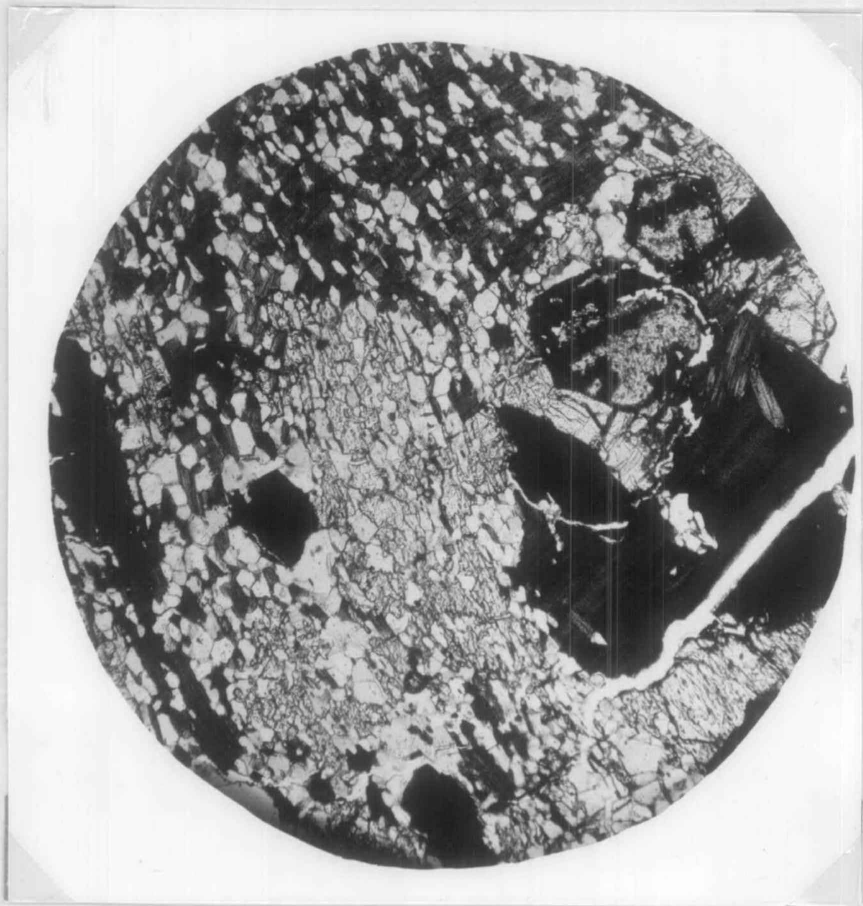

Fig. ii. Specimen 4219: garnetiferous quartz-biotite-andalusite-gneiss. A dark porphyroblast of biotite showing seive-structure may be seen in the upper centre of the picture. Greyish andalusite, with high relief occupies the centre of the photograph as a poikiloblastic grain; some is present in the lower left side. Two idioblastic crystals of garnet, partly altered to hydrated iron oxide, are present in the upper right of the picture. The white grains with low relief throughout the photograph are quartz. The grey-black areas throughout are biotite. Ordinary light X28.

(b) Slide 4198 contains zones of felted muscovite, which show a pronounced false cleavage running in a direction of approximately 35° to that of the schistocity. In places, andalusite is seen to have grown in muscovite, apparently replacing it: trains of inclusions of pre-existing quartz in andalusite appear to reflect the trends of the false cleavage, although andalusite itself is not optically deformed. Biotite porphyroblasts, although very often neighbouring the false-cleaved muscovites, show very little deformation. On the evidence seen here, it is apparent that the andalusite and biotite porphyroblasts were formed later than the false cleavage. It therefore appears that the rocks of the area suffered metamorphism under conditions of fairly high temperature and stress. They then suffered deformation by stress, with apparently low temperatures, causing the false cleavage. This was followed by a period of higher temperatures, with low shearing stress, resulting in the formation of the porphyroblasts. Therefore, the series of processes must have been either a part of one long complex period of metamorphism or alternatively, the three events are distinct from each other. It is considered that the latter alternative is the correct one, from the evidence to be offered next.

(c) On Plate 1 of Robertson's report, it will be seen that the schists have been folded into a J-shape, i.e., between the Green Parrot and the Bellbird mines, the schistosity has been turned through 180°. The false cleavage has, at the Green Parrot Mine an approximate north-westerly trend; at the Bellbird Mine it has a northerly trend: the false cleavage has turned through only 45°. The inference from this is that between the period of regional metamorphism, and that of the formation of the porphyroblasts, the schists were folded and false-cleaved.

Hence, the evidence, however slender it may appear, points to the formation of the porphyroblasts being an event distinct from that of the regional metamorphism. We are therefore left with two alternative explanations, firstly, that they were formed by contact metamorphism; or secondly, that they were caused by metasomatic activity. If one were to appeal to contact metamorphism only as an explanation, then one would have to envisage an invading magma as using preferred horizons in the schist during its intrusion, heating and altering the rocks in advance of its approach along these horizons, so that the porphyroblastic rocks at present represent the expression of the higher points of the intrusion on the land surface.

However, Plate 1 of Robertson's report shows that the porphyroblastic schists coincide with intrusions of pegmatite and the formation fo zones of mineralization. Here, then, we see the possibility of the porphyroblasts being formed by metasomatic means, either by the importation of some of the materials necessary for their formation, or merely by the redistribution of the materials already in the rock by hot solutions. The fact remains, however, that the porphyroblasts were probably formed under conditions of fairly high temperature, but with a low shearing stress.

Fairly idioblastic crystals of garnet, possibly almandine, showing some alteration to hydrated iron oxide may be found in slides 4200, 4213 and 4219. The crystals frequently contain strings of inclusions running in a direction oblique to that of the schistocity, suggesting rotation of the garnets during growth. This would presumably indicate that they were formed during the regional metamorphism. Tilley (1926, p. 50) stresses the point that almandine garnets which have survived a regional metamorphism are generally somewhat manganiferous, but on to suggest that in addition abundant water in the rocks being thermally metamorphosed may be a factor aiding their formation (or survival). In 1935 (p. 192), whilst discussing the paragenisis of a very poorly manganiferous almandine occurring in a Cornish hornfels, he suggests that wet conditions may have been largely responsible for its formation. Hence, we have possible explanations for the survival of garnet in the Jervois rocks described here.

iii. Iron-enriched granulites, with or without iron, copper and lead sulphides. This group of twenty-two specimens consists of "magnetite"-quartz granulites, whose content of "magnetite" ranges between 5% and 90%. A few contain sulphide minerals. In texture, these rocks are seen to be granoblastic; if any micaceous minerals are present, they may, or may not be lineated.

In these specimens, quartz forms a mosaic of more or less interlocking grains. "Magnetite" occurs as octahedra, but if it is present in large quantities, the crystals coalesce to form large irregular masses. Garnet (usually (?)almandine, but in slide 4267 it appears to be andradite) is often present as idioblastic crystals commonly showing partial alteration to hydrated iron oxide. Biotite, often partly or wholly chloritized, and muscovite are commonly present. Slide 4216 is seen to contain substantial quantities of plagioclase, in places partly sericitized. One or two other specimens (E.G., 4228) contain sericite, possibly pseudomorphing felspar.

It is suggested, from microscopic examination, that these rocks are the result of the metasomatism of quartzose schists by hydrothermal solutions. In the following paragraphs, four examples will be taken in an attempt to show that this has taken place. It must, however, be emphasized that the rocks concerned will bear further detailed field examination and sampling to refute or confirm this conclusion.

The four examples to be taken are slides 4231, 4212, 4221 and 4216. The first one is described in detail in the chapter on Petrography under Pelitic and semi-Pelitic rocks, and the remainder are described under the granulites.

Slide 4231 (Fig. iii) is seen to be a garnetiferous mica-quartz schist cut by a vein parallel to its schistocity: the vein contains quartz and almost completely chloritized biotite; some octahedra of black iron ore are also present. The vein biotite has random orientation. The mica of the schist is chloritized along the vein margin. Here, therefore, is an almost unaltered schist cut by a hydrothermal vein: this may represent a very early stage of the metasomatism of these rocks.

Slide 4212 shows a vein composed of coarse-grained quartz, some randomly oriented chlorite, and much hydrated iron oxide. It cuts across a quartzose biotite schist, and encloses two or three enclaves of the schist. Within the schist, biotite is partially or wholly chloritized, and in the groundmass tends to have a preferred orientation: some small porphyroblasts of biotite, having random orientation, are present in the schist, and it is also enriched in black iron ore. This example appears to be a stage further than the previous one, in that the vein seems to have caused some metasomatism of the schist, as shown by presence of abundant octahedra of magnetite.

Fig. iii. Specimen 4231: the biotite-garnet-quartz-schist at the right of the photograph is cut by a vein, part of which is shown on the left, consisting of quartz and chlorite. Quartz is white, with low relief: garnet forms subidioblastic grey grains with very high relief. Chlorite is dark grey, and biotite forms very dark grey flakes. Ordinary light X20.

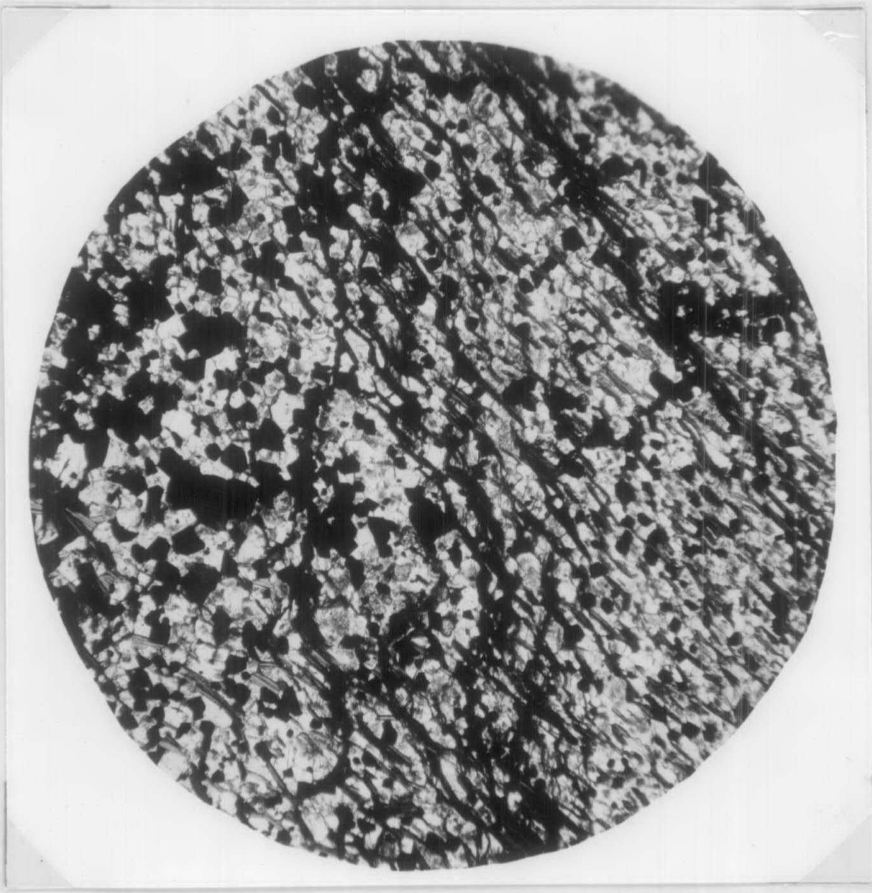

Fig. iv. Specimen 4216. The quartz-biotite-plagioclase schist at the upper, lower and right parts of the photograph is in junction with garnet-quartz-oligoclase-"magnetite" granulite, seen on the left side of the picture. Quartz is white, plagioclase is light cloudy grey, biotite forms dark grey-black flakes, garnet forms grey grains with high relief, and magnetite forms black octahedra. The dark line running across the upper right part of the photograph, parallel to the schistocity, contains malachite. Ordinary light X23.

Slide 4221 is of a finer-grained garnet-mica-quartz-granulite in which the mica is lineated: some tourmaline is present. It appears to be replaced in zones parallel to the lineation by a coarser-grained granulite containing quartz, calcite, and magnetite, with some garnet and cuprite; the last named mineral possibly replaces an original copper sulphide.

In slide 4216 (Fig. iv) a quartz-magnetite-plagioclase granulite is seen in association with a quartz-biotite-plagioclase schist. The same quantities of quartz and plagioclase are present in each part of the rock. The granulite is enriched in magnetite and garnet, and contains much less biotite than does the schist. The junction between the two parts transgresses the schist's lineation. The schist is cut by thin, magnetite-rich veins, which sericitize the felspar locally around them. The veins give the appearance of originating in the granulite, because where a vein intersects the schist-granulite boundary, it immediately spreads out and becomes lost in the granulite. The felspar of the granulite is rather more altered than that of the schist. Hence, the schist in this specimen has the appearance of being metasomatically altered to a garnet- and magnetite-enriched granulite.

It therefore seems from these four examples that the schists have been invaded by hydrothermal solutions, rich in iron, which firstly cut the rocks as veins, and later became sufficiently active to metasomatize them. However, this notion comes solely from microscopic examination of the specimens supplied. To test it, a return should be made to the field, and in the examination of the rocks, an attempt should be made to note the distribution of hydrothermal veins in relation to the granulites, and to examine in detail the contacts between the granulites and the schists.

It is implied that the garnet which is present in the granulitic portion of slide 4216, and which is probably almandine, is of metasomatic origin. Some parallel may be drawn between this occurrence and that of a manganese-poor garnet described (Alderman, 1935, p. 42) from Botallack, Cornwall. In discussing its paragenisis, Tilley (1935, p. 191) considers that it has resulted from the iron metasomatism of a greenstone hornfels. Tilley's comments on the environmental conditions have been summarized on p. 52 of this Record. Hence it seems likely that almandine may be formed by metasomatic processes.

Some sulphide minerals have been emplaced in these rocks: during the course of his minerographic descriptions of the opaque ores, W.M.B. Roberts (Appendix I) made an X-ray spectrometic analysis of the pyrites contained in specimen 4265, and found that it contained about 2% copper in solid solution. He says "The presence of such a high percentage of copper as solid solution in the pyrites is indicative of a magmatic source for this mineral". If this is so, it may be taken as additional evidence for the activity of hydrothermal solutions in the formation of these rocks.

Roberts' conclusion, after minerographic investigation of specimens containing fairly large amounts of haematite, is "that the bulk of the haematite in these specimens.....is derived from magnetite originally deposited from a solution having an epigenetic source". Roberts' conclusion is based upon a study of polished sections of the opaque minerals, and of their tectural characteristics (Appendix I).

The final conclusion, therefore, is that the granulites are the result of metasomatic replacement caused by hydrothermal solutions of magmatic origin.

(b) Other metasomatized rocks. Five slides, numbers 4170, 4203, 4208, 4222, and 4227, are seen to contain tourmaline in large quantities, suggesting metasomatic activity. Minor amounts of tourmaline may be found in other slides. In number 4227, tourmaline is replacing biotite, and in 4203, it may have replaced biotite. In the latter specimen, garnet crystals enclosed in tourmaline are seen to be partly or completely altered to chlorite. Slide 4208 is composed almost entirely of quartz and tourmaline, with rare garnet: it has a lineation and foliation, which may be a relict texture of a completely metasomatized schist.

Slide 4178 shows the effects of both boron- and lithia-metasomatism. It contains tourmaline, with protolithionite and muscovite: the two latter minerals occur as sub-parallel, or otherwise intimately associated flakes. The specimen has a foliation, along which thin veins of quartz have been emplaced.

All the specimens except 4208 show some enrichment in "magnetite".

Here, therefore, is some additional evidence for metasomatic activity affecting the schists. In any future work it would be instructive to note the distribution of rocks of this type in relation to the ore-bearing rocks and the pegmatites.

E. Calcareous and Magnesian Rocks.

i. Marbles. The four specimens of marble described (i.e., 4169, 4173, 4174, and 4197) are all medium- to course-grained, and consist mainly of a mosaic of xenoblastic grains of calcite.

Slides 4173 and 4174 contain a mixture of black iron ore and (?)pyrolusite forming an intergranular meshwork. The margins of the enclosed calcite grains are commonly serrated, as though corroded. Some galena occurs in slides 4173 and 4197. The latter specimen contains colourless chlorite and tremolite in minor quantities.

ii. Garnet- and vesuvianite-rich rocks. If, as has been postulated in previous sections, the pelitic and psammitic rocks of the area have suffered contact metamorphism and metasomatism, it would be natural to suspect the latter process of having also played a part in the formation of the calc-silicate rocks. Here, a summary of the characters of skarn-like calc-silicate rocks of this area is given. Some contain material, such as fluor-spar and scheelite, which is undoubtedly introduced: other minerals are possibly the products of metasomatic processes, but the evidence obtained from petrography alone makes it by no means certain. All but one of the specimens included here contain calcium garnet, with other minerals. The exception (4182) contains vesuvianite and wollastonite as its main minerals. In this summary, the account will be divided:-

(a) Granulitic rocks

(b) Rocks containing (?)grossularite or vesuvianite, or both minerals.

(c) Rocks containing zoned andradite-grossularite garnet.

(d) Conclusions.

(a) Four specimens have a medium-grained, granulitic texture. Slides 4166 and 4176 contain (?)grossularite with subordinate quartz: the garnet shows some alteration to chlorite. Slide 4185 has (?)grossular-andradite, with smaller amounts of actinolite and black iron ore. The fourth specimen, 4162, contains garnet, possibly rather manganiferous; 50% of this specimen consists of granular "magnetite". The presence of the latter mineral suggests that, as in the "magnetite"-quartz granulites described previously, enrichment in iron has taken place.

(b) Coarse-grained and xenoblastic grains of vesuvianite and (?)grossularite are the major constituents of slides 4165 and 4202, and both contain minor amounts of plagioclase. 4165 contains small amounts of epidote, zeolite and apatite. The zeolite (scolecite) appears to be replacing vesuvianite. Slide 4202 contains a substantial amount of fluor-spar, which gives the appearance of having been introduced while the pre-existing garnet and vesuvianite was being fractured. Calcite is present in veins, and some has been replaced by scheelite: this mineral also forms small, irregular masses in the rock.

Slide 4160 is seen to be of a coarse-grained rock consisting of (?)grossularite, with small amounts of tremolite, and minor quantities of quartz.

Vesuvianite and wollastonite are seen to be the major constituents of slide 4182. It also contains a little quartz and diopside; some scheelite is present, either as grains, or in replacing calcite in veins (Fig. v).

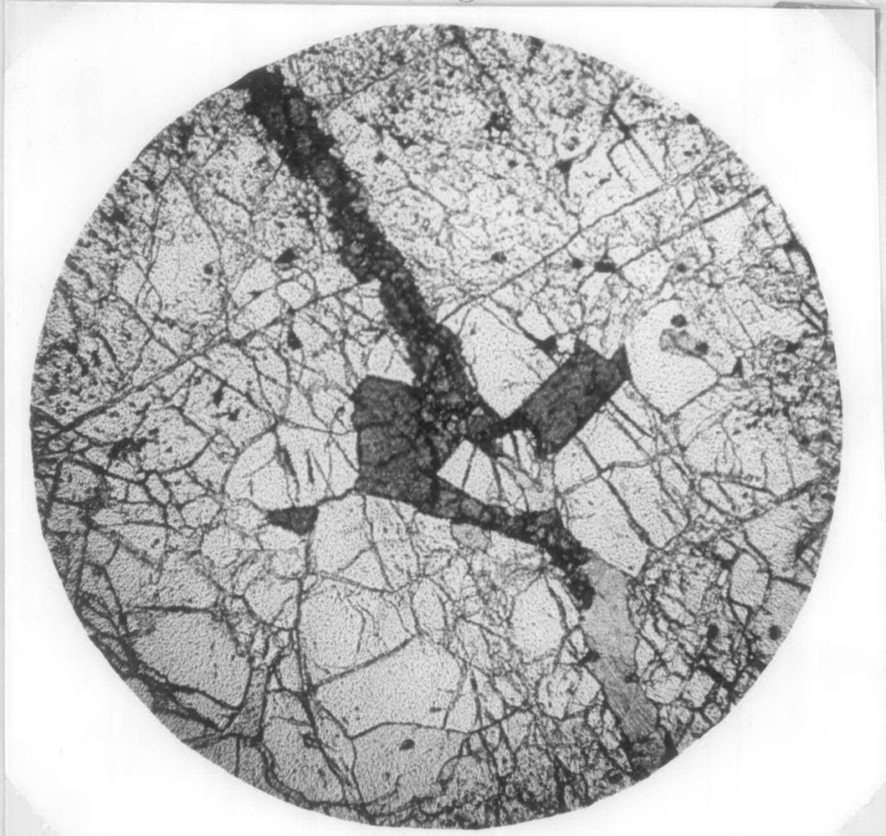

Fig. V. Specimen 4182. The photograph shows scheelite, dark grey with high relief, in a vein cutting vesuvianite; calcite (medium-grey) which is being replaced by scheelite, occurs in the vein in the lower right-hand side of the photograph. Ordinary light. X25.

(c) Six thin sections (i.e., numbers 4168, 4170, 4175, 4196, 4217, and 4226) are characterized by containing zoned (?)andradite-grossularite garnets. Tremolite or actinolite are present in all but slides 4168 and 4226: in slide 4176, some of the tremolite appears to be replacing garnet, and is, in turn, replaced by prehnite.

Epidote forms large, xenoblastic, grains in slide 4226. In 4196 it occurs with quartz, the two apparently replacing garnet. The mineral is present in small quantities in slides 4168 and 4170, and is absent in the other slides.

Minor quantities of other minerals are seen to be present in these slides. Chlorite occurs in most specimens, and in some appears to partly replace garnet. Quartz, where it occurs, forms xenoblastic grains. Small amounts of apatite and fluor-spar are seen to be present in slide 4226, and scheelite and black iron ore in 4196. Slide 4217 contains small amounts of diopside, phlogopite, soda tremolite and vesuvianite.

(d) According to Turner (1948, p. 125), true skarns are formed in contact zones by reaction between reasonably pure limestone, and iron- and silica-bearing solutions or gases from intrusive masses. The major constituents to be expected in skarns are andradite and hedenbergite, but if the original rock was at all dolomitic, diopside, tremolite and phlogopite may be expected. Other minerals, such as fluor-spar, may be present.

In the rocks considered in this discussion, minerals which could constitute skarn rocks are present, apart from hedenbergite. However, little evidence has been produced by microscopy to say definitely whether the major minerals, i.e., garnet, vesuvianite, wollastonite, etc., are due to metasomatism or isochemical metamorphism. Field observations by W.A. Robertson do not record any gradation between pure marble and calc-silicate rocks.

There is, however, evidence to show that some metasomatic activity has taken place. Iron metasomatism is suggested in the case of specimen 4162, which contains a large amount of magnetite. The introduction of tungsten is shown by the presence of scheelite in specimens 4182, 4196, and 4202. (Fig. v). Fluorine metasomatism has taken place in specimen 4202, which contains fairly large amounts of fluor-spar. Smaller quantities of this mineral are present in slide 4226. Fluorine may also have been introduced to form phlogopite in slide 4217, and possibly to form the small amounts of apatite to be seen in slides 4165 and 4226.

Metasomatic activity is suggested by the zoning of the (?)andradite-grossularite garnets, mention in (c) above. However the remainder of the minerals may well have been formed by isochemical metamorphism of very impure limestones, possibly (with the exception of wollastonite) even during the period of regional metamorphism prior to the intrusion of the pegmatites and granite (Tilley, 1927).

In conclusion, we may say that these rocks have been metamorphosed, and that metasomatic activity is strongly suspected in the formation of the calc-silicate minerals, but not proven on present evidence.

iii. Assemblages with amphibole. The slides dealt with here are numbers 4180, 4181, 4183, 4186, 4187, and 4201. They are characterized by the presence of amphibole, and by the absence of garnet and vesuvianite. The rocks are of two types: slides 4180, 4181, 4183 and 4186 are possible contact metamorphic rocks, and numbers 4189 and 4201 are of apparently regionally metamorphosed rocks. A brief summary of the petrography of the rocks will be given, followed by some remarks on their possible origins.

Slide 4180 is seen to be a gneissic rock, containing coarse-grained, xenoblastic quartz in lenticular layers: the layers are enclosed by masses of sub-radiating, fibrous crystals of tremolite. Minor amounts of epidote are present, and a little sericite is seen, possibly pseudomorphing felspar.

Specimens 4181 and 4183 are seen to contain coarse, granular crystals of diopside, and fibrous crystals of tremolite. In the former specimen, smaller quantities of sericite, (?)prehnite, epidote, and zoisite are present in rather finely crystalline intergranular masses, apparently replacing plagioclase. A little sphene is present. In slide 4183 much of the tremolite and diopside is altered to talc, producing minor amounts of epidote in the process. A little quartz and apatite are present.

Slide 4186 is seen to consist of a xenoblastic intergrowth of epidote and tremolite, with minor quantities of quartz, calcite, and talc.

With regard to slides 4180, 4187, 4183 and 4189, we are faced with problems similar to those which assailed us when dealing with the garnetiferous calc-silicate rocks, i.e., we have no real evidence, from microscopy, to say whether metasomatism was a small, or a large, factor in their formation. From their non-schistose textures, it is possible that they result from contact metamorphism: if this is the case, the gneissic structure of slide 4180 would probably be relict from the preceding regional metamorphism. In slide 4181, the felspar has been saussuritized.

The formation of talc as seen in slide 4183 is probably a result of retrograde metamorphism. Tilley (1948, p. 272, and 1951, p. 175 has shown that its formation is the earliest known step in the progressive metamorphism of siliceous dolomitic limestone, giving place to tremolite at higher temperatures. He also demonstrated (1948) that talc may be formed by diaphthoresis from tremolite. In the case of the specimen under consideration, epidote has been formed, apparently as a by-product of the reaction.

Slides 4189 and 4201 differ from the rocks described above in that they contain actinolite and actinolitic hornblende respectively; the former contains subordinate chlorite, and the latter, epidote. They appear to be little affected by metasomatic activity.

iv. Epidosites. The specimens summarized here are numbers 4159, 4171, 4184 and 4193. They have quartz and epidote as their dominant minerals. In all the slides, quartz is seen to be granoblastic: epidote has a similar habit, except in slide 4171, where it is seen to occur as more idioblastic crystals, apparently connected by veins of the same mineral.

Actinolite is seen to be present in slide 4193, forming xenoblastic grains which are sometimes intergrown with epidote. In slide 4184, hornblende occurs as clusters of sub-radiating acicular crystals, sometimes intergrown with biotite. At the centres of some of these clusters, (?)andradite is present.

A garnet may also be found as idioblastic crystals in slide 4159: it shows some alteration to chlorite. In slide 4171, xenoblastic flakes of chlorite are present. Some sphene may be seen in slide 4159; and in slide 4193, minor quantities of apatite, and octahedral crystals of magnetite are present.

According to W.A. Robertson, the rocks from which these specimens are taken form lenticular masses enclosed in schists: they are probably derived from calcareous and somewhat aluminous sandstones (Harker, 1932, p.268).

2. Post-Regional Metamorphism Igneous Rocks.

A. The Metadolerites.

A brief discussion only of the conclusions will be given here. The rocks are considered to be metadolerites which have suffered only thermal metamorphism as a foliate texture is lacking in them; this may be compared with the surrounding schists in which they are emplaced. Sutton and Watson (1950, pp. 253 and 275, and 1951, pp. 29-30) have noted that in the advanced regional metamorphism of dolerites that are intruded into the Lewisian complex of north-west Scotland, "A marked planar or linear orientation of the hornblendes is developed," and that the original texture of the rocks is destroyed. Thus, in specimens 4195 and 4194, the original texture is almost completely destroyed, and yet there is no plan orientation of the hornblendes. Hence, it is considered that their metamorphism is thermal, possibly associated with the mineralization.

B. The Acid Igneous Rocks.

Only three specimens were received for examination. That represented by slide 4177, a muscovite-albite-granite, is, according to Robertson, part of an aplite cutting the schists, and may be related to the source of the mineralization of the area. Robertson considers that the rocks represented by slides 4191 (adamellite) and 4192 (aplitic granite) are not related to the mineralization.

3. Minerals Resulting from the Action of Groundwater and Weathering.

The specimens examined commonly contain secondary minerals resulting from the action of groundwater upon primary minerals. These will be briefly covered here.

Malachite occurs as small flecks, or in thin veins cutting the rocks. It appears to occur indiscriminantly in the schists, calc-silicate rocks, and in the mineralized rocks. Cuprite is seen to occur in slide 4221 as sub-idioblastic crystals of cubic form, in association with malachite, calcite and hydrated iron oxide: it may be an alteration product of chalcopyrite.

Hydrated iron oxide commonly forms thin veins surrounding grains of "magnetite". Less commonly it forms irregular masses and intricate box-work structures, as in specimens 4211 and 4263: in this case it may be the result of alteration of iron pyrites.

Slide 4220 is seen to consist of a concentration of prismatic crystals of pyromorphite, with some cerussite. The rock is presumably a concentrate of secondary lead ore brought about by the weathering of primary lead minerals.

Felspar, in some rocks, shows alteration to sericite, and some of this may be the result of groundwater action.

Possible pyrolusite is present as intergranular material in the marbles represented by slides 4173 and 4174.

4. Summary of Conclusions.

The author's conclusions are based mainly upon facts obtained by microscopy, aided by examination of Robertson's maps, and by discussions with Robertson himself. A series of events is seen in the formation of these rocks, and they are summarized, with a little discussion, in the following paragraphs.

(a) Firstly, the area suffered regional metamorphism, resulting in rocks which belong to the staurolite zone. The mineral assemblages present are suggestive of the staurolite-kyanite sub-facies of the amphibolite facies (Turner, 1948, p. 81), though there are some retrogressive features (e.g., chlorite replacing garnet) which render the assemblages unstable at the present time.

(b) After the regional metamorphism, it can be seen, from an inspection of Robertson's maps, that the schists were folded. A false cleavage was possibly imparted to the schists at this time. The metadolerites were emplaced.

(c) Mineralization of the rocks took place, and porphyroblasts were formed in certain schists.

i. With regard to the mineralization, belts of quartzose schists were replaced by "magnetite"-quartz granulites. In the thin sections studied, certain schists were slightly to strongly tourmalinized, and one slide shows the presence of lithia mica. Fluor-spar was emplaced in some of the schists and calc-silicate rocks, and scheelite may be seen in three of the latter. Some saussuritization and sericitization of plagioclase, and formation of talc from tremolite, was noted.

ii. Apparently concurrently with the mineralization, porphyroblasts of cordierite, andalusite, and biotite, were formed in the schists in areas accompanying the mineralization. Due to the areal distribution of the porphyroblastic rocks, it is difficult to picture their forming a contact aureole around a hidden intrusion. It is possible that they were formed as part of the metasomatism by the action of hot solutions helping to redistribute the materials in the rocks necessary for their formation. The mineralization and the growth of porphyroblasts took place along preferred zones, parallel to the schistocity.

The porphyroblastic rocks bear mineral assemblages which are possibly in unstable equilibrium, although without chemical analysis it is not possible to say for certain. An example here is probably to be found in slide 4198, which contains "cordierite", biotite, muscovite, and andalusite - however, stability appears to have been regained by the pinitization of cordierite. The assemblages are suggestive of the cordierite-anthophyllite sub-facies of the amphibolite facies. This is further borne out by the occurrence of wollastinite in specimen 4182, whose formation, according to evidence cited by Turner (op. cit., p. 79), occurs at a temperature relatively high in the range embraced by the cordierite-anthophyllite sub-facies.

However, Bowen (1940) states that some caution should be exercised in using this (and other lime-minerals) as a temperature indicator, as it may be formed at a much lower temperature if the concentration of carbon dioxide is lowered by circulating solutions, thus enabling the necessary reaction between calcite and quartz to take place. He does state that his condition would be exceptional. The last point tends to be confirmed by Harry (1951, p. 400-1). He described an occurrence, at Glen Dessarry, Scotland, of regionally metamorphosed marble and its associated calc-silicate rocks. The latter rocks are of the same grade of metamorphism as the gneisses surrounding them, suggesting that there was no loss in CO_2 concentration. Their grade of metamorphism remained unchanged by the intrusion of migmatitic pegmatites into the surrounding gneiss; the pegmatites caused only small veinlets to form in the calc-silicate rocks. However, Tilley (1948, p. 274) has shown that in the contact aureole around the Beinn and Dubhaich Granite, which is intruded into dolomitic cherty limestone at Skye, Scotland, local loss of CO_2 concentration has resulted in the rare formation of forsterite in rocks in which tremolite has normally formed. Thus, though this condition is exceptional, it can occur.

iii. On evidence of microscopy alone, it is not known whether the calc-silicate rocks were formed by the metasomatism of relatively pure limestone, or by the isochemical thermal metamorphism of impure limestones. In the tentative overall picture of metasomatic activity that is suggested by the writer, it seems likely that metasomatism played an important part.

iv. The origin of the metasomatic activity, is considered to be magmatic, related to the pegmatites observed by Robertson in the field. The ultimate source rock is apparently not exposed.

(d) Subsequently, there was partial re-distribution of ore-material by the action of groundwater.

5. Future Work.

The writer has shown that certain events have taken place, and he has tried to explain some of the happenings. He does not pretend to have given the whole story: such a thing would require a full scale research project. In this section, a few points for future study are given.

(a) A comparison of petrofabric analyses of the quartz axes in specimens representing unmineralized schists, and the mineralized granulites, may lend support to the notion that the metasomatism of the granulites took place in a period after that of the regional metamorphism. If the temperature was sufficiently high during the metasomatism of the granulites, any fabric held by the quartz grains might have been destroyed. If this is true, care should be taken in chosing the sampling locality of the schist, in case its quartz fabric has been destroyed, if the sample is taken from a point too close to the metasomatized rocks.

(b) A stereographic analysis of the false cleavage directions and dips, compared with an analysis of the dips and strikes of the schistocity, may show if the false cleavage and the fold in the schistocity are in any way related.

(c) Further examination of thin sections showing the relationship between the porphyroblasts and the false cleavage would perhaps confirm the evidence given in slide 4198, i.e., that the porphyroblasts are younger than the false cleavage.

(d) The ideas expressed by the writer on the origin of the "magnetite"-quartz-granulites would be disproved, or proved, by a study of their contacts with the schists, and by finding their relationships to the pegmatites and quartz mica veins.

(e) Further examination of the calc-silicate rocks could be made, in an attempt to determine whether or not their present mineral assemblages are due to metasomatic activity.

(f) During this work, time did not permit accurate identification of certain doubtful minerals, e.g., the varieties of garnet which are present in these rocks. Such work would make the writer more sure of the chemical characteristics of the rocks he was dealing with, and would aid in working out the origin of these rocks.

6. Acknowledgements.

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APPENDIX I

EXAMINATION OF SPECIMENS FROM THE JERVOIS RANGE MINERAL FIELD, N.T.

by

W.M.B. Roberts.

Nine specimens were submitted by W.A. Robertson for identification of the opaque minerals and if possible to obtain some idea of the mode of origin of the deposits.

Specimen J.H.A. 55

Consists of fairly fine-grained hematite, derived from original magnetite. Both the crystalline form and the III cleavage of the magnetite is still preserved although no trace of the original mineral remains. No other opaque minerals are present.

Specimen J.H.A. 57

The mineral assemblage of this specimen is similar to that of specimen J.H.A. 55 except that the hematite after magnetite is subhedral to euhedral in form, and some magnetite residuals remain in the grains. Some calcite is present as a gangue mineral.

Specimen J.H.A. 87

The specimen was found to consist of large subhedral goethite crystals which are fairly obviously pseudomorphs after original pyrite. These pseudomorphs differ from the hematite in the previous section in that there is no III cleavage evident in any of the grains. Also, small residual grains of pyrite remain scattered throughout the goethite masses. The lack of any magnetite structures, the presence of residual pyrite, and the crystalline form suggest that the geothite is a weathering product of pyrite rather than magnetite.

The hydrated iron oxide is cut by numerous veinlets of colloform hematite.

Small areas of colloform malachite are randomly distributed throughout the iron oxide; this malachite gives the appearance of having been deposited as the result of the breakdown of the original pyrite to iron oxide and the concurrent removal of a copper impurity in the pyrite structure. (See sect. J.H.A. 109).

Specimen J.H.A. 109

The specimen consists entirely of fractured pyrite intimately associated with a crystalline quartz gangue. One small area of chalcopyrite was observed enclosed in pyrite; this measures 0.02 mm across. The majority of the fractures in the pyrite are filled with colloform hematite. X-Ray spectrographic analysis of the pyrite showed that it contains in solid solution about 2% copper.

Specimen J.H.A. 127

In this specimen subhedral pyrite grains measuring up to 2.5 across are moulded by chalcopyrite. Both these minerals have been strongly fractured, apparently having been deposited in the same period of mineralisation prior to a fairly intense shearing stress. The chalcopyrite is altered along its fractures to blue chalcocite, whereas the pyrite remains unaltered. Some coarsely granular marcasite moulds the pyrite masses but its relationship to the other minerals is obscure. Superficially it appears to have been formed after the period of shearing - it bears no signs of any large-scale fracturing.

Specimen J.H.A. 133

Similar to specimen J.H.A. 57. Hematite is formed after magnetite in a quartz matrix.

Specimens J.H.A. 145, J.H.A. 86, J.H.A. 144

These specimens again consist entirely of finely crystalline hematite derived from magnetite in a quartz matrix. Specimen J.H.A. 144 shows the best development of the III cleavage of the original magnetite dominating the growth of the hematite alteration.

The examination clarifies two points: they are:

1. The bulk of the hematite in the specimens is not of lateritic origin, but is derived from magnetite originally deposited from a solution having an epigenetic source.

Only the thin colloform veinlets of this mineral which cut the geothite are possibly lateritic in origin.

2. There has been some hydrothermal introduction of sulphide minerals prior to a period of shearing Pyrite was the first deposited, and was followed by chalcopyrite. Both these minerals are strongly fractured and show fairly extensive alteration. The presence of such a high percentage of copper as solid solution in the pyrite is indicative of a magmatic source for this material.

APPENDIX II

Relating W.A. Robertson's specimen numbers to the laboratory thin section numbers.

Field No.	Thin Section No.	Field No.	Thin Section No.	Field No.	Thin Section No.
JHA.1	4159	JHA.93	4186	JHA.91	4213
JHA.2	4160	JHA.94A	4187	JHA.101	4214
JHA.3	4161	JHA.94B	4188	JHA.103	4215
JHA.4	4162	JHA.95	4189	JHA.105	4216
JHA.5	4163	JHA.96	4190	JHA.106	4217
JHA.6	4164	JHA.97A	4191	JHA.110	4218
JHA.7	4165	JHA.97B	4192	JHA.125	4219
JHA.8	4166	JHA.98	4193	JHA.134	4220
JHA.9	4167	JHA.111A	4194	JHA.135	4221
JHA.10	4168	JHA.113	4195	JHA.136	4222
JHA.11	4169	JHA.117C	4196	JHA.137	4223
JHA.12	4170	JHA.118A	4197	JHA.138	4224
JHA.13	4171	JHA.119	4198	JHA.139	4225
JHA.14	4172	JHA.120	4199	JHA.143	4226
JHA.15	4173	JHA.123	4200	JHA.147	4227
JHA.16	4174	JHA.124	4201	JHA.148	4228
JHA.17	4175	JHA.142	4202	JHA.152	4229
JHA.18	4176	JHA.44	4203	JHA.154	4230
JHA.19	4177	JHA.47	4204	JHA.155	4231
JHA.59	4178	JHA.49	4205	JHA.43	4260
JHA.60	4179	JHA.51	4206	JHA.55	4261
JHA.62	4180	JHA.52	4207	JHA.57	4262
JHA.65	4181	JHA.53	4208	JHA.86	4263
JHA.67	4182	JHA.58	4209	JHA.87	4264
JHA.68	4183	JHA.88	4210	JHA.109	4265
JHA.69B	4184	JHA.89	4211	JHA.127	4266
JHA.69C	4185	JHA.90	4212	JHA.133	4267
				JHA.144	4268
				JHA.145	4269