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THE MINERALOGY OF SOME MT. PAINTER BRECCIAS

REPORT MP 2714/76

YOUR REFERENCE:	Application dated 12/3/76.
MATERIAL:	Sixty nine drill core samples
LOCALITY:	Mt. Painter area, S.A.
IDENTIFICATION:	P1061/76 - P1129/76 c737 RS
DATE RECEIVED:	17/3/76
WORK REQUIRED:	Petrography and mineragraphy to determine the mineralogical history of the breccias.

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THE MINERALOGY OF SOME MT. PAINTER BRECCIAS

CONTENTS

the paragenetic sequence in haematite breccias is same as for hydrothermal as listed in Edwards Textures of ore Minerals P136
ie magnetite, haematite, molybdenite, pyrite, chalcopyrite, sphalerite bornite, galena
This is also order of decreasing temp - Edwards P160

SUMMARY AND CONCLUSIONS

Sixty nine specimens of granitic and hematitic breccias, associated finer-grained sediments and basement rocks from the Mt. Painter area have been examined with the aim of determining the order of crystallization of the constituent minerals, and as much as possible of the origin and history of the hematitic breccias and of the uranium contained in some of them. Although this has been a laboratory investigation only, it has been possible to establish several facts which must be fitted into any theory concerning the origin of these breccias.

1. The basement rocks examined are composed mainly of quartz and microcline with minor sericite and mica, traces of apatite, altered ilmenite and zircon. Locally they have been extensively replaced by chlorite. Except in a few places where some altered basement rocks are in contact with, or have been exposed to hematitic breccia, they contain little or no iron oxide and could not have been the source of the hematite now occurring in high concentration in some of the breccias.

2. Disregarding the iron oxides, sulphides and uraninite etc. in the hematitic breccias, all clastic material in both granitic and hematitic breccias and associated hematite-bearing siltstones and sandstones was derived from basement granitic or gneissic rock. Fragments of 'foreign' rock types are absent from most of the breccias and therefore an external source of clastic detrital iron oxide can be eliminated.

   It follows from 1 and 2 that the iron must have been introduced in solution and, at this stage of investigations, hydrothermal solutions, hot springs and/or volcan[ic] emanations seem most probable. The mode of occurrence of the iron oxides strongl[y] suggest that heat was involved.

3. This investigation has shown that magnetite was the first iron oxide to crystallize and much of it formed relatively large, zoned crystals which have been extensively replaced by moderately coarsely crystalline, specular hematite probably very early in the history of these oxides. It is possible that magnetite and specular hematite may have crystallized simultaneously or alternately in some places but, although there is abundant evidence of magnetite replaced by hematite, no examples of hematite replaced by magnetite were found. Some specular hematite did not pseudomorphously replace magnetite. And therefore some haematite was primary and not "secondary" replacing magnetite
   Some magnetite, martite and specular hematite contain small inclusions of pyrite and very few of chalcopyrite and one martite 'crystal' was found partly enclosing molybdenite. This indicates that some sulphides crystallized before, or simultaneously with the magnetite, or were already present in the environment in which the magnetite crystallized.

   From the evidence available from these specimens it has not been possible to determine exactly where and under what conditions these iron oxides crystallized but the textures are not those of metamorphic minerals. Intergrowths of specular hematite crystals suggest crystallization under hydrothermal conditions either in veins or hot pools.

   Relatively minor amounts of magnetite are present in some partly altered granitic and gneissic basement rocks in contact with hematitic breccia and also in some fractured or brecciated granitic rocks, which were probably exposed to the action of solutions.

Reworked clasts of martite, partly oxidized magnetite, abundant, dispersed specula hematite and a few fragments of unoxidized magnetite occur in some breccias and in the associated finer-grained sediments. Evidence suggests that the finer-grained sediments possibly formed by local reworking under relatively low energy conditions of material derived from the breccias.

4. Monazite was present early in the history of these breccias and a few fragments are enclosed by specular hematite. Some monazite also crystallized in fractures in granitic rock adjacent to contacts with hematitic breccia and this introduced monazite is commonly associated with introduced chlorite and locally with introduced iron oxide. ∴ two monazites (1) early ∴ pre-spec. haem. (2) Later ∴ with chlorite

5. The presence of some molybdenite partly enclosed by martite suggests that this was also an early mineral; however, most of it occurs as separate, deformed flake which give no evidence of relative age.

6. Moderately coarse-grained pyrite is present in many hematitic breccias, particularly those which have a chloritic matrix and much of this pyrite has an unusual crystal form with a tendency to develop curved crystal faces against the chloritic matrix. In some samples there is textural evidence showing that at least some coarse-grained pyrite crystallized after specular hematite and after oxidation of magnetite and this indicates a return to reducing conditions in at least some of the hematitic breccias.

A few clasts of pyrite are present in reworked material in some of the finer-grained, hematite-bearing sandstones .

Some coarse-grained pyrite has been extensively fractured, veined and partly replaced by carbonate, quartz and copper-bearing sulphides.

7. Many hematitic breccias have a matrix of chlorite or of red, ochreous hematite which has probably replaced chlorite. The chlorite has penetrated fractures in monazite and it has locally replaced some specular hematite but its relationship to the coarse-grained pyrite is not certain. A few specimens contain a vermiculite mineral very similar in texture to the chlorite and possibly this represents a stage in the alteration of chlorite. The vermiculite is commonly associated with, or stained by, ochreous or very fine-grained and microspherular hematite typical of that deposited under supergene conditions.

8. Uraninite occurs in some of the hematitic breccias which have a matrix of chlorite or of ochreous hematite and chlorite. Uraninite was found enclosing dispersed fragments of monazite and filling interstices between these fragments and this uraninite also contains swarms of inclusions or remnants of hematite (confirmed by the electron probe). This suggests that uraninite probably crystallized after at least some of the specular hematite. Some uraninite however, has been partly surrounded by later, finer-grained hematite which also occurs as overgrowths on both hematite and magnetite in some breccias.

No evidence was found to show the relationship between uraninite and coarse-graine pyrite or between uraninite and the chloritic matrix.

Check Exoil pets to see if uraninite is more common in haem breccia c̄ chlorite or without chlorite

Although fragments of broken crystals of magnetite and martite, hematite, monazite and molybdenite are common in the breccias, no broken fragments of uraninite were found but because this mineral is relatively unstable and clearly partly altered, the apparent absence of broken fragments may not be very conclusive. However, the general appearance of uraninite crystals in these samples suggests that it crystallized within these breccias possibly after movement of some of the constituents.

A trace of late, colloform pitchblende was found encrusting some deformed molybdenite and also penetrating cleavage planes in the molybdenite.

Minor uraninite or pitchblende was found in one sample of fractured and altered granitic rock. This rock has been partly replaced by chlorite and also contains some magnetite and fluorite.

Cu_2S CuS Cu_5FeS_4

9. Migratory copper-bearing sulphides, including chalcocite, covellite, bornite
$CuFeS_2$ and chalcopyrite, fill a few interstices in some breccias and some of these sulphides have penetrated and partly replaced fractured pyrite crystals. Some chalcocite and covellite also occur in partly altered uraninite.

Copper has been mobile late in the history of these breccias.

10. Trace amounts of fluorite occur in a few breccias and also in fractures in granitic rock. This has crystallized relatively late in the history of these rocks, after the matrix chlorite and also after some clay. Some fluorite is included within late, interstitial quartz.

Traces of another fluoride mineral, bastnaesite ($CeCo_3F$) were found in the specimen of fractured and altered (chloritized) granite which was found to contain uraninite and fluorite (referred to in 8).

11. Many breccias and finer-grained sediments contain more than one generation of quartz. Fragments of quartz crystals occur in some breccias and sandstones, and where these also contain later, interstitial or cementing quartz, some of the late quartz occurs as overgrowths on the earlier crystal fragments.

Many of the finer-grained sediments and also a few breccias have been extensively silicified and many of the breccias now contain at least some late, interstitial quartz, which has crystallized after matrix chlorite, after fluorite and locally even after some ochreous hematite. As hot springs are active in the area at the present day it is possible that some of this quartz may be of relatively recent age.

12. There has been movement within many of these breccias, causing additional fracturing and deformation and this has obliterated or rendered unrecognisable, original textures which may have provided evidence as to the exact origin of the breccias.

Some of the samples of granitic breccia submitted are tectonic breccias in which quartz has been granulated and recrystallized to a finer grain size and some microcline also shows evidence of recrystallization.

THE MINERALOGY OF SOME MT. PAINTER BRECCIAS

1. INTRODUCTION

This report contains the results of petrographic and mineragraphic investigations of sixty nine drill core specimens from the Mt. Painter area in South Australia. Most of the specimens are of granitic breccia and associated hematite-bearing breccias which locally contain concentrations of uranium and the main purpose of the present investigation has been to establish the order of crystallization of the various minerals and, if possible, the origin and mineralogical history of the hematite-bearing breccias and of the uranium now contained in some of them.

The Mt. Painter area has clearly had a complex geological history and, although some of the hematite-bearing rocks are reported to occur as veins or intrusions, other hematitic breccias are associated with, or are interbedded with siltstones, shales and tillites of undoubted clastic sedimentary origin. The tillites are tentati ly correlated with Sturtian tillites occurring elsewhere in South Australia. It is possibly significant that in some other localities in eastern South Australia Sturtian tillites are associated with the Braemar Iron Formation which contains concentrations of magnetite and hematite.

The sixty nine specimens submitted were microscopically examined in either thin section or polished section and several were examined in both thin and polished sections. Selected areas in some sections were analysed by the electron probe to confirm the identity of significant minerals. The identity of chlorite-like minerals in the matrix of two specimens was determined by X-ray diffraction. Photomicrographs are included to show significant mineral association and intergrowths.

2. GENERAL DESCRIPTION

The samples are from drill holes at East Painter (EP), underground East Painter (UE Mt. Gee Prospect (MG), Armchair Prospect (AG), Streitberg Ridge Prospect (SR), Minerva Heights Prospect (MH) and Hodgkinson Prospect (JDH). They include many specimens of breccia rich in specular hematite and also many of the associated granitic breccias. There are a few specimens of the finer-grained sediments, including hematit bearing siltstones and sandstones and also a few specimens of basement rock underlying hematite-bearing breccia.

The basement rocks, granitic breccias and clasts of granitic rock included in the hematitic breccias are all composed predominantly of quartz and microcline with minor sericite which probably replaced plagioclase and locally, trace to minor amounts of muscovite or altered biotite. Accessory minerals are mainly apatite, zircon and altered ilmenite.

Many of the granitic breccias are believed to be of clastic sedimentary origin, such as scree or talus deposits but the specimens submitted also include some tectonic breccias in which adjacent fragments can be matched and in which much of the quartz has been granulated and recrystallized to a finer grain size under conditions of tectonic stress (Plate 13).

Some of the granitic rocks, including breccias and also basement rocks have been partly or extensively replaced by chlorite, and granitic rocks in contact with hematitic breccias have also been invaded by minor amounts of other minerals including iron oxides, monazite and fluorite. The occurrence of magnetite (or martite) in some basement rocks and granitic clasts is described in more detail under Section 3.1.1

Most of the granitic breccias have been cemented by migratory or secondary quartz which has crystallized after the invading chlorite and fluorite.

The hematitic breccias contain clasts derived from the granitic rock associated with varying concentrations (but generally abundant) specular hematite and this investigation has shown that much of this hematite was derived from, or has replaced, earlier, moderately coarse-grained magnetite. Most of the hematitic breccias also contain a few fragments of monazite and some contain traces of apatite; a few contain flakes of molybdenite and some contain flakes of muscovite and/or chloritized biotite. Many of the hematitic breccias also contain moderately coarse-grained pyrite (or oxidized pyrite) and some contain uraninite. Locally, there are trace to minor amounts of late, migratory copper-bearing sulphides and one or two samples were found with traces of sphalerite and galena.

Many of the hematitic breccias have a matrix of, or are cemented by, authigenic chlorite or by ochreous hematite which has very probably replaced chlorite; others are cemented by quartz and a few contain interstitial carbonate generally associated with quartz. A few contain traces of migratory fluorite which crystallized relatively late in the history of these rocks.

Many specimens of breccia both granitic and hematite-bearing show evidence of late fracturing accompanied or followed by some differential movement of fragments and clasts and this has commonly obscured or obliterated evidence of earlier relationships between clasts and matrix.

The finer-grained, hematite-bearing siltstones and sandstones contain varying concentrations of fragments of specular hematite, a few of recognisable martite and also a few of monazite. Similar sediments have been described in detail in previous reports. All available evidence indicates that the fragments of hematite and martite were derived from hematitic breccias already in existence and reworked under relatively low energy conditions. Many of these finer-grained sediments have been silicified.

3. DESCRIPTION OF MINERALS

3.1. Magnetite, Martite and Specular Hematite

The hematitic breccias now contain very little magnetite and most of this occurs as small inclusions or remnants within hematite but relict textures in many of the polished sections show that magnetite was once moderately abundant. It was almost certainly the first iron oxide to crystallize and much of it was moderately coarse-grained with crystals 1 to 3 mm in size. Some of these magnetite crystals contained small inclusions of pre-existing pyrite and very few inclusions of chalcopyrite and one specimen was found (P1117/76, AG31 127'10") with an aggregate of molybdenite flakes partly enclosed by oxidized magnetite (Plate 9a, b). These inclusions indicate that some sulphide minerals were present, at least locally before crystallization of the magnetite.

Many of the magnetite crystals were zoned and where they have been partly oxidized, zones containing remnants of magnetite alternate with zones now composed of hematite and in completely oxidized crystals there are zones of porous hematite alternating with zones of dense hematite (Plate 1). Many of the zoned martite 'crystals' are now porous and a possible explanation is that, if partly oxidized crystals were exposed to percolating solutions the remaining magnetite would be preferentially leached leaving the more stable hematite. This zoning suggests varying conditions during growth of the magnetite crystals and does not indicate a metamorphic origin.

Most of the magnetite has been extensively replaced by bladed or specular hematite and textural evidence in several polished sections suggests that much of the now dispersed specular hematite in these breccias was probably derived from the mechanical break-down of slightly porous and possibly friable aggregates of hematite crystals which had replaced magnetite (Plate 2). All gradations can be found from recognisable, coarse-grained martite (oxidized magnetite) through groups or aggregates of tabular hematite crystals showing traces of former octahedral patterns to completely dispersed plates of hematite. Many of these plates of hematite still contain small remnants of magnetite and some also contain a few small inclusions of pyrite. As noted above, one clearly recognisable martite 'crystal' has some partly enclosed molybdenite.

Relict textures in these breccias suggest that most of the original magnetite probably occurred as separate crystals and not as crystalline aggregates and only very few possible exceptions to this were found in this present investigation. In Sample P1089/76, basement gneiss in contact with overlying hematitic breccia appears to have been encrusted with magnetite for a distance of 5 mm (Plate 5a) and in Sample P1063/76 granitic breccia which has been extensively replaced by chlorite contains a crystalline aggregate of coarse-grained magnetite associated with pyrite. This magnetite in P1063/76 differs from that in the hematitic breccias in that it has not been replaced by bladed or specular hematite but has been partly oxidized to very fine-grained hematite as in normal weathering.

Not all of the specular hematite in these hematitic breccias has replaced magnetit[e]. Some specimens contain aggregates of specular hematite crystals showing parallel or slightly radiating growth patterns and, in places, the crystals are intergrown with apparently random orientation (e.g. Plate 3b, 7d). Some of this specular hematite is intergrown with quartz as in quartz-hemetite veins and where aggregates of this specular hematite occur in some breccias it is possible that they are portions of relatively large clasts.. Locally, some of these aggregates of specular hematite show evidence of deformation.

Although there is clear evidence that moderately coarse-grained magnetite was once abundant it is not yet possible to determine exactly where and under what conditions it crystallized. It is also not yet possible to determine precisely the time-lapse or history of these iron oxides between crystallization of the magnetite and crystallization of the specular hematite, much of which has replaced magnetite. However, where both martite and specular hematite fragments have been reworked as in th[e] hematite-bearing siltstones and sandstones, it is clear that the magnetite was partly o[r] completely replaced by hematite before it was fractured and the reworked fragments incorporated in the hematite-bearing sandstones and siltstones and also in some breccia[s] (Plate 4b). The magnetite was therefore probably replaced by bladed or specular hematite very soon after it crystallized and it is possible that some magnetite and hematite may have crystallized simultaneously. [eg MP349-695R1] Although no evidence was found in any of the polished sections of hematite being replaced by magnetite, in the polished secti[on] of specimen P1076/76 there is portion of a relatively large aggregate of porous and leached iron oxide which appears to have contained some martite and also a crystal or fragment of specular hematite. This aggregate is over 5 mm long and the portion contained in a polished section is surrounded by, or encrusted by zoned martite which locally shows re-entrant angles. This suggests the possibility of some alternate crystallization of magnetite and hematite interrupted by periods of reworking of materi[al] however, it is felt that this evidence from only one small portion of one polished sect[ion] is not sufficient to be conclusive. Confirmation of this is desirable. check Exod Del... ? Amadeus Shelf

The basement granitic rock which contributed the bulk of clastic material now comprising the breccias, contains little or no iron oxide except for rare exceptions described below and this basement rock could therefore not have been a source of clasti[c] magnetite or hematite. As the breccias contain few if any clasts of 'foreign' rock types an external source of clastic, detrital iron oxide derived from earlier magnetite-bearing rocks is likewise excluded.

Whitten (1970) suggested that iron oxides in the Braemar Iron Formation which may be stratigraphically equivalent to these hematitic breccias "was formed by chemical precipitation of iron oxides in a cold sea" (page 28). However, magnetite in the

Braemar Iron Formation is very much finer-grained than the magnetite which was formerly present in the Mt. Painter rocks and clearly these iron oxide minerals have not crystallized under similar conditions (see report MP 3181/76). The Braemar Iron Formation shows evidence of low grade metamorphism.

The relatively coarse grain size and also the texture of much of the specular hematite in the Mt. Painter rocks strongly suggest crystallization under hydrothermal conditions, either in veins or in solutions from thermal springs or hot pools. Crystallization from thermal spring solutions could also explain the apparently layered structure of some of the hematite-rich rocks and their association with material of clastic sedimentary origin.

In some specimens there is evidence of a later generation of finer-grained, specular hematite, some of which occurs as fringes or fine overgrowths on plates of specular hematite and also on fragments of magnetite and martite (Plate 3a, 11c). This later generation of fine-grained hematite crystallized within the hematitic breccia after fracturing and movement of hematite and martite fragments. Most of the specimens showing this hematite also contains uraninite.

3.1.1 Magnetite in basement rocks and granitic clasts.

Two specimens from the Mt. Gee area (P1089 and 1098/76) contain gneissic rock, either as clasts or in contact with overlying hematitic breccia and in this gneissic rock most or all of the silicates have been replaced by sericite, chlorite and minor calcite. Another basement rock from the same area (P1092/76) is coarser-grained and shows less evidence of alteration but all three of these rocks which are in close contact with hematitic breccia contain up to 5% of magnetite, some of which is intergrown with altered ilmenite (Plate 5c, d). There is, however, an increase in concentration of this magnetite near the actual contact with hematitic breccia (Plate 5b, 6b) and in Sample P1089/76 some coarse-grained magnetite has apparently partly encrusted the basement gneiss along this contact (Plate 5a). From available evidence it is not possible to determine whether or not all or part of this magnetite was present in the gneiss before it was associated with, or overlain by, the hematitic breccia and further investigation of the granitic basement rocks may prove helpful.

In some of the hematitic breccias there are a few clasts of granitic rock containing moderately fine-grained magnetite (Plate 6c, d). This occurs mainly in microcline which is finer-grained than usual and has probably been granulated and recrystallized under conditions of tectonic stress. Most of this magnetite is dispersed through the microcline but in a few clasts its distribution suggests that it may have crystallized along small fractures. Samples in which granitic clasts contain some magnetite are P1069, 1084, 1086, 1115 and 1129/76. It is therefore possible that some magnetite was introduced into the granitic rock or microcline clasts but it is nowhere abundant, and at the present stage of investigation appears to be of little significance. However the presence of magnetite in some granitic clasts and in basement rock in contact with hematitic breccia does suggest the possibility that some zones of granitic rock may have been exposed to solutions from which magnetite crystallized.

3.2. Monazite

This is a minor but persistent constituent of the hematitic breccias and angular fragments were found in many of the samples submitted. It was found to be more abundant in some of the hematitic breccias just above contacts with underlying basement rocks, particularly in the Mt. Gee area,but probably an insufficient number of specimens from these locations have been examined for this evidence to be conclusive Traces of monazite have also been found along joints and grain-boundaries in some granitic rocks near contact with hematitic breccias, e.g. P1092/76 and 1113/76 (Plate 10 These granitic rocks have also been invaded by chloritic material and iron oxide and in P1113/76 the chloritic material occurring in a joint has clearly crystallized after the monazite. (Plate 10a).

In the hematitic breccias textural evidence shows that monazite was present very early in the history of these rocks and, although a few crystals contain some very small inclusions of iron oxide, some fragments of monazite were found enclosed by hematite (Plate 10b). Some of the monazite in the basal hematitic breccias occurs as crystalline aggregates which do not appear to have been transported but many crystal and crystalline aggregates have been fractured and disrupted by later movements. Fractured monazite has been invaded by the chloritic matrix in a number of specimens and in Sample P1100/76 some disrupted and slightly dispersed monazite fragments have been partly enclosed by uraninite which has filled interstices between the fragments (Plate 11a).

From available evidence it is therefore concluded that monazite crystallized very early in the history of these hematitic rocks; it tended to be concentrated in basal hematitic breccias and also crystallized in adjacent granitic rocks in contact with these breccias. No evidence was found to show its relationship to magnetite but fragments have been found included in specular hematite and it was certainly present before crystallization of uraninite. As it was an early constituent of these breccias the investigation of fluid inclusions which may be present within some monazite crystals could give useful information concerning the conditions prevailing at the time it crystallized. Sample P1118/76 contains some of the coarsest-grained monazite found in thin sections of the specimens submitted and Sample P1089/76 contains a moderately large mass of extensively fractured monazite near contact with the basement.

~~martite crystal is partly enclosed~~

3.3. Molybdenite

Some hematitic breccias, particularly in the Mt. Gee area,contain flakes of molybdenite. Almost all of these occur as separate, deformed flakes mixed with fragments of specular hematite, martite, monazite and locally some pyrite and, in a few samples, some of this molybdenite is included in, or partly enclosed, by the cementing quartz.

In Sample P1107/76, flakes of molybdenite, fragments of tabular hematite and also elongate fragments of monazite all show a preferred orientation (Plate 9c, d) which could be a direction of bedding but this suggestion is tentative. In all of the sections examined, only one example was found in which some molybdenite is actually intergrown with another mineral and this is in Sample P1117/76 where a group or aggregate of molybdenite flakes is partly enclosed by coarse-grained martite (Plate 9a, suggesting that at least some molybdenite predated some of the moderately coarse-graine magnetite, or crystallized simultaneously with the magnetite. The molybdenite therefore, does not appear to be related to the moderately coarse-grained pyrite present in many of these specimens but it could be related to the pyrite and chalcopyrite found in minor amounts as small inclusions in some of the magnetite and hematite.

In conclusion, the available evidence indicates that molybdenite was an early constituent of these breccias but there is no definite evidence as to its actual origin.

3.4. Pyrite

Mineragraphic evidence shows that there were at least two generations of pyrite. Many of the clasts and crystals of coarse-grained, oxidized or partly oxidized magnetite and also the larger crystals of specular hematite contain small inclusions of pyrite which probably crystallized simultaneously with, or before, the magnetite. The abundance of this pyrite in the 'original environment' cannot be determined from the available evidence but there is some moderately coarse-grained pyrite associated with crystalline aggregates of magnetite in granitic breccia in Sample P1063/76 suggesting that at least locally pyrite may have been moderately abundant. However, pyrite does not appear to be common in other specimens of basement rock which contain, or have been invaded by magnetite, and no evidence was found to suggest that the coarse-grained magnetite or martite occurring in the hematitic breccias was intergrown with even moderately abundant, early pyrite. Most of the evidence suggests that there were only minor amounts of pyrite included within the magnetite and/or specular hematite

Many specimens of hematitic breccia now contain minor to moderate amounts of medium-grained pyrite and in some specimens there is textural evidence to show that this crystallized after some specular hematite and after oxidation of magnetite (Plate 7 Some crystals of this pyrite contain small included fragments of hematite and martite (Plate 8b) and very few contain small inclusions of magnetite (Plate 8a). In a few pyrite crystals there are inclusions of quartz and of other non-opaque minerals, some with a high refractive index. In some samples (e.g. P1110/76 and P1118/76) some of this pyrite has partly enclosed small zones of matrix material now mainly chlorite (Plate 12b). The pyrite in Sample P1110/76 has now been completely replaced by goethit but relict textures are clearly preserved and show included portions of matrix material containing small fragments of hematite (Plate 8c, d). In Sample P1119/76 the appearanc under low magnification suggests that pyrite is probably encrusting part of the surface of a large (5 to 10 mm) clast which contains martite and specular hematite.

It is not yet clear whether or not all of the medium-grained pyrite is of the same generation. Although much of the evidence shows that it crystallized after oxidation of the magnetite and crystallization of the specular hematite, a few reworked fragments of apparently similar pyrite were found in some associated hematite-bearing sandstones (Plate 4b).

c. pyrite crystallised with or after the chlorite

Much of the medium to coarse-grained pyrite has an unusual form and it commonly forms crystals which have curved faces against matrix chlorite. Its presence indicates a return to reducing conditions in at least some hematite-rich breccias.

Some coarse-grained pyrite has been extensively fractured and invaded by carbonate and/or quartz and also by late migratory, copper-bearing sulphides, including chalcopyrite, bornite, chalcocite and covellite. One fractured pyrite crystal was found with a small vein of galena. Plate 8a shows pyrite intergrown c̄ galena

3.5. Uraninite and Pitchblende

Crystals of uraninite showing evidence of partial alteration and leaching are present in some of the hematitic breccias and, in general, these crystals are surrounde by matrix material and late, ochreous hematite and therefore show no indication of their relative age. A few crystals are surrounded or partly surrounded by some specular hematite crystals as in Sample P1068/76 (Plate 12d) but this evidence is regarded as inconclusive as to time relations of the two minerals.

no evidence in this description

In Sample P1110/76 some uraninite clearly encloses fragments of monazite (identity confirmed by the electron probe) and has also filled interstices between monazite fragments (Plate 11a). Some of this uraninite also contains zones where there are numerous small inclusions or remnants of hematite (Plate 11b) which appears to have been extensively replaced by the uraninite. The composition of these hematite inclusi was also confirmed by the electron probe.

Sample P1101/76 contains two crystals of uraninite which are of interest. One irregular uraninite crystal partly encloses a fragment of specular hematite (Plate 11c) which is free of overgrowths or fringes of fine-grained, later hematite found on adjace fragments of specular hematite and, in the same section, another zoned crystal of uraninite showing a hexagonal cross section is partly surrounded by the fine-grained, second generation specular hematite which has almost certainly crystallized after the uraninite. (Plate 11d). This apparently zoned crystal of uraninite encloses two, relatively large, dark areas, showing very poor polish and analysis of these areas by the electron probe showed only iron oxide. The evidence from this section, therefore, suggests that uraninite probably crystallized after fragmentation of specular hematite and before the overgrowths of later-generation, fine-grained hematite. It is clear from Sample P1110/76 that uraninite crystallized after fragmentation of monazite.

no evidence in this description

Although clasts or fragments of magnetite, martite, specular hematite, monazite, molybdenite and pyrite have been found in abundance in the hematitic breccias, no broken fragments of uraninite have so far been recognized; however, because of the relative instability of this mineral it is doubtful how conclusive this evidence may be

In the specimens submitted, uraninite occurs only in hematitic breccias which have a chloritic matrix or a matrix of ochreous hematite which, it is believed, has probably replaced chlorite. Traces of uranium oxide were also found in one sample of fractured and partly chloritized granitic rock (P1116/76).

Traces of colloform pitchblende were found in Sample P1108/76 encrusting a few deformed flakes of molybdenite (Plate 12c). This pitchblende probably formed relatively late in the history of these rocks and could represent migratory uranium derived from some altered uraninite and therefore its occurrence is probably of little significance.

Traces of torberite are present in some specimens but this represents uranium which has migrated and recrystallized under weathering conditions and its distribution and relationship to earlier minerals does not provide any useful information concerning the origin of the uraninite.

In conclusion, the available evidence shows that uraninite crystallized after fragmentation and dispersion of monazite and probably also after fragmentation of some specular hematite but before overgrowths of finer-grained, later generation hematite. It is very tentatively suggested that it probably crystallized within the breccia after fragmentation and movement of some of the earlier constituents. Although it probably crystallized after the bulk of the specular hematite, its relationships to the later or second generation, coarse-grained pyrite and the matrix chlorite remain undetermined. The presence of these minerals suggests reducing conditions in at least some of these breccias after crystallization of specular hematite and conditions may then have been favourable for precipitation of uranium from migrating solutions.

3.6. Chlorite and Vermiculite

Many hematitic breccias have a matrix which is now fine-grained, authigenic chlorite and this commonly shows patches of dark brownish staining of undetermined origin. Some is associated with clastic flakes of chloritized biotite as in Samples P1097, 1099, 114, and 1118/76 and some of the chlorite showing fine, colloform banding is associated with small, microspherular patches of very fine-grained hematite (Plate 14b). Fractured monazite has commonly been penetrated by this matrix chlorite.

In Sample P1118/76 chlorite has apparently partly replaced specular hematite (Plate 12a) and in this same section some colloform chlorite has crystallized from portions of matrix enclosed by irregular pyrite crystals (Plate 12b). Other chloritic material has, however, penetrated fractures in similar pyrite in the same section.

This effect may only be due to embayments in pyrite - see description of Plate 12b.

In some granitic rocks chlorite has replaced all, or practically all, of the microcline and some of the quartz - this type of alteration has been described in greater detail in Report MP1621/76, Sample P373/75. Chlorite has penetrated fractures in granitic rock in contact with breccias and it has also replaced microcline in some clasts within breccias.

Armchair Creek

There are a few breccias in which the matrix now contains a mineral of similar grain size and texture to the chlorite (Plate 14a) but which has a higher birefringence and a more brownish or yellowish green colour. This has been identified by X-ray diffraction as probably a vermiculite (or less likely a montmorillonite) and possibly it represents a stage in the alteration of chlorite. In the samples submitted, vermiculite occurs in the matrix in P1111/76 (AG8 at 93'10") and P1114/76 (AG13 at 132'0"). In Sample P1112/76 (AG8 at 135'10" - i.e. 42' below P1111/76) the green matrix mineral was identified as a hexagonal chlorite.

In this investigation time did not permit a closer investigation of the chlorites and of the possible relationship between matrix chlorite and chlorite which has replaced or partly replaced granitic rocks. In the breccias, much of the chlorite has crystallized or recrystallized after specular hematite and possibly after at least some of the coarse-grained pyrite. Where the hematitic breccias have become exposed to the action of oxidizing, sub-surface solutions, evidence suggests that the matrix chlorite has been partly to completely replaced by extremely fine-grained or ochreous hematite. In places, some of the matrix or interstitial chlorite has been included within late, interstitial quartz and, in a few places, ochreous hematite, believed to have replaced chlorite, has also been included within this late, interstitial quartz.

3.7. Base Metal Sulphides

Copper-bearing sulphides occur in trace amounts in many of the hematite-bearing breccias. Most occurs as irregularly-shaped, porous aggregates of chalcocite and/or covellite in some late interstices (Plate 14d) and textural relationships show that copper has migrated and recrystallized late in the history of these rocks. These sulphides have also been found filling small fractures in some of the coarse-grained pyrite and in some samples traces of these copper-bearing sulphides are present in partly altered uraninite. Some samples contain late, migratory chalcopyrite, which has also filled interstices and penetrated fractures in pyrite. There are also traces of bornite.

Some magnetite, martite and coarse, specular hematite contain a few, very small inclusions of chalcopyrite generally associated with small inclusions of pyrite. The presence of these inclusions suggests that there was an early generation of chalco- copper-bearing sulphide, probably associated with pyrite in the environment in which magnetite first crystallized. This chalcopyrite does not appear to have been very abundant.

Trace amounts of galena were found in two specimens and a trace of sphalerite in one specimen. Sample P1112/76 contains trace amounts of both galena and sphalerite and both of these minerals have migrated and recrystallized late in the history of these rocks. Galena occurs in fractures or veins in some pyrite and the sphalerite occurs mainly in interstices where it is associated with, or contains, small inclusions of very fine-grained chalcopyrite. A trace of galena was found in Sample P1123/76 where it is intergrown with some of the coarse-grained pyrite which contains inclusions or fragments of magnetite (Plate 8a).

3.8. Fluorite

This occurs sporadically in hematitic breccias and also in granitic breccias and in brecciated granitic rock. Some of it shows a patchy purple colour. In several thin sections it can be seen to have crystallized after matrix chlorite (Plate 14c) and also after chlorite which has penetrated fractures in granitic rock. Where samples contain vermiculite in place of chlorite the fluorite shows the same relationship to vermiculite as it does to chlorite.

In a number of samples fluorite is associated with late, interstitial quartz and, in general, the fluorite is enclosed by, or included within this late quartz. Some late, interstitial quartz in Sample 1111/76 contains an inclusion of a small crystal of fluorite and also small patches or remnants of chlorite or vermiculite.

3.9. Carbonate

Very little carbonate was found in the specimens submitted and therefore useful conclusions cannot be given. Some calcite is present in altered basement rocks in contact with hematitic breccias e.g. P1089/76 and 1092/76 and it occurs in fractures in some other specimens of granitic rock.

Carbonate is associated with quartz crystals in interstices in some breccias containing specular hematite but very little was found in the thin sections examined. Textural relationships show that it crystallized after the specular hematite and early quartz but its relationship to other minerals is not clear. Some carbonate occurs in, and appears to have locally replaced, extensively fractured pyrite and some is associated with late, copper-bearing sulphides. No definite evidence concerni it relationship to late interstitial quartz was found in these specimens under investigation but in some samples described in earlier reports there is evidence that some vein-carbonate has been replaced by late quartz.

3.10. Quartz

Many of the breccias contain two or more generations of quartz. Disregarding the quartz present in clasts of granitic or basement rock there is evidence of an early generation of quartz occurring as euhedral or subhedral crystals commonly associated with specular hematite which does not appear to have pseudomorphously replaced magnetite. Relatively coarse-grained quartz has also filled interstices

P1102/76 Plate 3b

in some crystalline aggregates of specular hematite and it is possible that clasts of such material occur in some of the breccias. Whether or not these were derived from quartz-hematite veins is a matter for speculation. Some breccias and also the finer-grained, hematite-bearing sandstones and siltstones contain clasts of euhedral or subhedral quartz crystals and also fragments of such crystals but they are not generally abundant.

Many of the breccias and also the finer-grained sediments are now cemented or partly cemented by interstitial quartz, much of which has crystallized late in the history of these rocks but it is possible that not all of this quartz has been of the same generation. A few rocks have been very extensively silicified and in Sample P1108/76 this late quartz has replaced much of the specular hematite formerly present (Plate 3d).

Late, interstitial quartz has been found with inclusions of matrix chlorite, fluorite and even some late, ochreous hematite and, in the samples submitted, it has been the last mineral to crystallize. As hot springs are known to be active in the region at the present day it is possible that at least some of this quartz is of relatively recent age.

3.11. Ochreous Hematite and Goethite

This occurs in the matrix of some hematitic breccias and is associated with clay, possibly some goethite and locally with remnants of chlorite and/or vermiculite. It occurs mainly in samples which have apparently been exposed to oxidizing, surface or sub-surface solutions and weathering and probably much of this ochreous hematite has replaced matrix chlorite or vermiculite. Some of it occurs as minute microspherular aggregates (as in Plate 14a, b) and some of it occurs as staining on chloritic material.

It is possible that the ochreous hematite is not all of the same age but, in general it has been a late mineral and has only been included within a little late, interstitial quartz.

plate 8 c,d

Goethite has replaced pyrite in some specimens and it is probably also associated with some of the ochreous hematite.

4. Brief descriptions of Specimens

? clastic martite & spec ...

Sample: P1061/76 PS24603 EP2 - 223'10" RS 174	Hematitic breccia containing clasts of granitic rock, coarse-grained martite (0.5 to 3 mm) and finer-grained, specular hematite which could have crystallized in situ. Some of this hematite is deformed. Martite contains a few small inclusions of pyrite and very few of chalcopyrite. The porous matrix is partly cemented by interstitial quartz.
Sample: P1062/76 PS24604 EP3 - 148'7" RS 175	Hematitic breccia in contact with a zone of coarse-grained carbonate which has crystallized in situ in a fracture or void. The carbonate contains a few small inclusions of pyrite, chalcopyrite and covellite and also a few remnants of quartz and hematite.
Sedim't layers in haem. breccia	The breccia contains minor recognisable martite, a trace of monazite, abundant specular hematite and some finer-grained, second generation hematite, some of which forms overgrowths on the larger specular hematite fragments. There are some parallel layers 2 to 3 mm thick containing hematite of different grain sizes, suggesting a layered sediment and much of the coarser-grained, specular hematite is parallel to this apparent layering. The hematitic breccia is cemented mainly by quartz.
Sample: P1063/76 PS24605 TS35609 EP3 - 261'11 RS 176 magnetite	Granitic breccia extensively replaced by chlorite or vermiculite - this alteration has obscured the nature of the breccia. The altered breccia also contains some moderately coarse-grained magnetite associated with pyrite and these two minerals are locally intergrown. They very probably crystallized within this rock and have since been extensively fractured and partly oxidized but this specimen is unusual in that there is no specular hematite associated with the magnetite and pyrite. There are a few crystals or fragments of sphene. The chloritic material or vermiculite has been variably to heavily stained by reddish-brown iron oxide.
Sample: P1064/76 PS24606 EP1 - 116'9" RS 177	Hematitic breccia with minor clasts of granitic rock, some quartz crystals, coarse-grained martite (partly dispersed) and specular hematite. The rather porous breccia is cemented partly by quartz and partly by ochreous hematite which possibly has replaced chlorite.
Sample: P1065/76 TS35538 PS24607 EP1 - 142'10" RS 178	Hematitic breccia containing coarse martite, specular hematite, some quartz with inclusions of magnetite, minor coarse-grained pyrite (not intergrown) and a trace of monazite. The matrix contains abundant chlorite and very fine-grained, microspherular hematite. Textures show that at least some of this ochreous, microspherular hematite was later than the chlorite and probably this ochreous hematite is replacing the matrix chlorite.
Sample: P1066/76 TS35539 UEP1 - 348'2" RS 179 ? clastic haem.	Hematitic breccia overlying a finer-grained layer which is rich in ochreous hematite. Both layers contain clasts of granitic rock, quartz and hematite and traces of monazite. The coarser-grained layer contains some oxidized pyrite and the finer-grained layer has some mica.
	The matrix has been largely replaced by ochreous hematite but there is no evidence to show the identity of the mineral replaced by this hematite. Much of the feldspar is stained by ochreous iron oxide.

Sample: P1067/76
TS35540
UEP4 - 177'2"
RS180

Granitic breccia with a chloritic matrix. It also contains specular hematite, minor martite?, pyrite, apatite and a trace of monazite. A crystalline aggregate of monazite occurs in the border zone of one granitic clast. Some granitic or gneissic clasts which have been extensively replaced by chlorite contain fine-grained magnetite and altered ilmenite.

Sample: P1068/76
PS24608
UEP8 - 19'0"
RS181
2 generations of pyrite

Hematitic breccia containing some coarse-grained martite, coarse-grained and finer-grained, specular hematite (some deformed) and some coarse-grained pyrite. A little pyrite is intergrown with or partly enclosed by some coarse-grained hematite but some of the coarser-grained pyrite encrusts aggregates of martite and specular hematite. Some pyrite contains inclusions of quartz and other non-opaque mineral grains with high refractive index.
Plate 12d - crystal of partly altered uraninite partly surrounded by specular haematite

The matrix contains clay and there are traces of chalcocite and covellite.

Sample: P1069/76
TS35541
PS24609
UEP8 - 129'0"
RS182

Hematitic breccia containing abundant clasts of granitic rock. Some microcline in a few granitic clasts contains fine-grained, partly oxidized magnetite.

The breccia also contains clasts with coarse-grained martite, minor specular hematite and some coarse-grained pyrite.

The matrix contains chlorite and some late, interstitial quartz.

Sample: P1070/76
TS35542
UEP10 - 56'9"
RS183
s.st. + siltst.

Hematitic breccia with clasts of granitic rock containing some partly altered mica.

The matrix contains patches of disturbed, hematite-bearing sandstone and siltstone. There are also a few larger clasts containing martite and some coarser-grained, specular hematite.

Sample: P1071/76
TS35543
PS24610
UEP10 - 91'3"
RS184

Hematitic breccia containing clasts of granitic rock, coarse-grained martite, specular hematite and a trace of monazite. The matrix has been partly replaced by late, interstitial quartz but there are patches of clay and ochreous hematite which have probably replaced chlorite.

Sample: P1072/76
PS24611
UEP12 - 14'9"
RS185

Hematitic breccia containing some clasts? of coarse-grained martite, coarse-grained and finer-grained specular hematite and minor, oxidized pyrite as well as abundant clasts of granitic rock. Some martite and specular hematite contain small inclusions of pyrite and traces of chalcopyrite. There are remnants of magnetite in much of the martite.

Sample: P1073/76
TS35544
UEP12 - 84'-85'
RS 186

Finely laminated sandstone and siltstone composed mainly of quartz and feldspar with a few heavy mineral grains, including zircon, apatite, sphene, monazite? and a few opaque grains. There is no specular hematite.

Very few layers show some evidence of graded bedding.

The rock is now cemented by secondary quartz.

Sample: P1074/76
PS24612
UEP12 - 136'3"

Hematitic breccia with some late torbernite in leached voids.

It contains some coarse-grained, partly dispersed martite grading to aggregates of specular hematite and also abundant, finer-grained specular hematite. Granitic clasts contain some altered ilmenite and traces of oxidized magnetite.

The breccia is now largely cemented by quartz.

Some torbernite appears to have replaced altered mineral grains, some of which could have been apatite.

Sample: P1075/76
TS35545,35608
UEP16 - 237'1"
RS 188

Granitic breccia composed mainly of quartz and microcline with some sericitized plagioclase?. The granitic rock also contains minor magnetite or martite and the feldspar and sericite are locally stained by iron oxide.

late qutz after ochreous haem.

The matrix contains very fine-grained, microspherular and ochreous hematite, some of which is included within late, interstitial quartz. There is no definite evidence to show the origin of the ochreous hematite but in one area some has partly replaced chloritized mica. It certainly crystallized within the breccia late in the history of these rocks.

Sample: P1076/76
PS24613
UEP 17 - 35'8"
RS 189

Brown Hematitic breccia containing some coarse-grained martite (partly dispersed) and coarse-grained, specular hematite, some of which contains small inclusions of pyrite. There is also some finer-grained, specular hematite.

magnetite encrusts martite + haem.

This section is unusual in that it contains portion of a crystalline aggregate of martite and hematite over 5mm long which is bordered by extensively oxidized, zoned magnetite. The interior of this mass is now leached and porous and textures are not very well preserved but it could have contained some martite and tabular hematite which were later encrusted by a rim of zoned magnetite, locally showing re-entrant angles. This section also contains an aggregate or mass over 10 mm in size of intergrown, specular hematite crystals, 2 to 3 mm long. These contain small inclusions of pyrite and very few of chalcopyrite and interstices between the crystals now contain quartz. Some of the specular hematite grades into dispersed martite containing remnants of magnetite but clearly much of this specular hematite is not oxidized magnetite. It is not clear from the polished section whether or not this mass represen[ts a] portion of a large clast.

Much of the finer-grained, specular hematite in interstices between the larger masses of hematite and martite shows subparallel orientati[on] similar to that noted in hematite-bearing siltstones and sandstones. This finer-grained matrix also contains a few small fragments of martite, some clay and ochreous hematite.

In the hand specimen there are some small voids from which pyrite has probably been leached.

Sample: P1077/76
PS24614
UEP17 - 62'8"
RS 190

Hematitic breccia containing abundant zoned martite, some finer-grained specular hematite and some moderately coarse-grained pyrite. Some of the pyrite contains inclusions of non-opaque minerals and very few of magnetite.

The matrix contains clay, ochreous hematite and late, interstitial quartz.

Sample: P1078/76
TS35546
UEP17 - 163'0"
RS 191

Brecciated granitic or gneissic rock which contains a local concentration of zircon with some rutile and opaque oxide. Much of the quartz and some feldspar have been granulated and recrystallized to a finer grain size under conditions of tectonic stress.

Interstices in the breccia contain very fine-grained chlorite or vermiculite and a few very small fragments of specular hematite. There is also some late ochreous iron oxide.

Evidence in the thin section suggests a tectonic breccia.
within apparently in situ crystalline basement See Field Note book 1976

Sample: P1079/76
TS35547
UEP17 - 191'5"
RS192

Granitic breccia showing considerable evidence of tectonic stress. Interstices contain chlorite, some of which is now included within late secondary quartz.

At one end of the sample there is some moderately coarse-grained magnetite (or martite) which appears to have been introduced.

This is very probably a tectonic breccia but the evidence is not absolutely conclusive.
within apparently in situ crystalline basement - See Field note book 1976

Sample: P1080/76
TS35548
UEP18 - 18'0"
RS 193

Breccia containing clasts composed predominantly of quartz with mino microcline and muscovite. The matrix contains more abundant muscovite, minor altered biotite, a trace of hematite or martite and some ochreous hematite and it is cemented by quartz.

This is very probably a tectonic breccia but the evidence is not absolutely conclusive.
within possibly in situ crystalline basement. See Field Note book 1976

Sample: P1081/76
PS24615
UEP18 - 245'6"
RS 194

Hematitic breccia containing abundant clasts of granitic rock, some zoned martite, specular hematite and some moderately coarse-grained pyrite which contains inclusions of non-opaque minerals and some replaced by covellite.

Some granitic clasts contain varying concentrations of fine-grained, partly oxidized magnetite.

The hand specimen contains a trace of molybdenite but this was not included in the section.

The matrix contains chlorite which has also penetrated some granitic clasts.

Sample: P1082/76
TS35549
PS24616
UEP28 - 76'4"
RS 195

Hematite-bearing siltstone and sandstone composed mainly of detrital quartz, feldspar and specular hematite with some small fragments of martite, a few of pyrite, very few of muscovite and traces of apatit monazite and sphene or rutile. Flakes of hematite and elongate fragments of pyrite are subparallel to the bedding.

Sample: P1082/76
Cont'd

The matrix is now mainly clay and ochreous hematite but there are traces of chlorite in some zones.

Sample: P1083/76
PS24617
UEP28 - 102'0"
RS 196

Hematitic breccia with a chloritic matrix. Chlorite has also penetrated some of the granitic clasts.

It contains a few recognisable clasts of porous martite, more abundant specular hematite fragments, many of which are subparallel, possibly to the bedding and a few crystals and fragments of pyrite. The general appearance suggests that all martite, specular hematite and pyrite has been transported or reworked and deposited in this sediment.

Sample: P1084/76
TS35550
PS24618
UEP28 - 290'6"
RS 197

Layered, hematite-bearing siltstone and sandstone with some interbedded hematitic breccia containing larger clasts of granitic rock, specular hematite and minor martite containing remnants of magnetite. In the finer-grained layers much of the hematite is parallel to the bedding. Minor pyrite has been leached and partly replaced by jarosite.

Very few granitic clasts contain some fine-grained, oxidized magneti

The matrix is now mainly ochreous hematite with some clay.

Note: The bedding in this section of core is steeply dipping if the drill hole is vertical. Not vertical

Sample: P1085/76 √
TS35551
UEP28 - 339'0"
RS198

Moderately coarse-grained, feldspathic sandstone or arkose containing some clastic specular hematite and a few fragments of monazite. There are also a few iron oxide grains with external shapes suggesting martite.

angular grains

The grains of quartz, feldspar and granitic rock are angular and hav clearly not been transported any great distance.

The matrix is now ochreous hematite and late interstitial quartz and some ochreous iron oxide has also stained the feldspar and granitic clasts.

Sample: P1086/76
PS24619
UEP28 - 381'7"
RS 199

Hematitic breccia containing martite with remnants of magnetite, some specular hematite and abundant fragments of granitic rock. Very few fragments of granitic rock contain minor, partly oxidized, fine-grained magnetite in partly altered feldspar.

The matrix is now mainly clay and minor, ochreous hematite.

Sample: P1087/76 √
TS35552
PS24620
UEP31 - 16'6"
RS200

Hematitic breccia containing martite (some dispersed), specular hematite and pyrite with traces of monazite and apatite.

The matrix is mainly chlorite and clay with some late, ochreous hematite.

Sample: P1088/76
TS35553
PS24621
MG24 - 183'6" to 183'11"
RS 201

Finely-layered, chloritic and hematitic siltstone and sandstone with some scattered, large clasts of granitic rock 5 to 40 mm in size.

The siltstone and sandstone layers contain quartz, feldspar, specula hematite, muscovite flakes, a few altered biotite flakes, minor

Sample: P1088/76
Cont'd
RS 201 cont

monazite fragments, some recognisable martite fragments and traces of pyrite and molybdenite. Many of the flakes of hematite and elongate fragments of monazite are subparallel to the bedding.

?detrital or hydrothermal

The matrix is mainly chlorite with local concentrations of ochreous hematite, particularly along some layers and this is probably the cause of the variations in colour.

The bedding has been locally disturbed by the presence of the large clasts of granitic rock and one of the sandstone layers is lenticular.

Sample: P1089/76
TS35554, 35555, 35609
PS24666
MG24 - 197'0"
RS202

Non-conformity between hematitic breccia and underlying crystalline basement.

Basement rock.
This is an altered, gneissic rock which is finer-grained than most of the quartz-microcline granitic rocks. It is now composed of quartz and sericitized feldspar with some altered mica, altered ilmenite and at least 10% of partly oxidized magnetite, some of which is intergrown with the altered ilmenite. Most of this magnetite shows only a thin zone of oxidation along grain boundaries. This basement rock has also been invaded by chlorite and, adjacent to the contact, it contains more abundant magnetite, some of which appears to have been introduced. Adjacent to the contact this basement rock has been extensively replaced by calcite.

The contact between basement rock and overlying breccia is irregular, angular and appears locally corroded and along one section, 5 mm long the boundary of the basement rock is apparently encrusted with an aggregate of coarse-grained magnetite or martite. (Plate 5) Smaller masses of iron oxide occur in a few other places along the contact.

monazite crystallised before specular haem.

The overlying breccia contains fragments of quartz, some elongate masses of specular hematite enclosing fragments of monazite, and some coarse-grained magnetite or martite. There is also a zone 4 to 5 mm long, containing an abundance of extensively fractured monazite and towards one end of this zone the monazite fragments are enclosed or partly enclosed by specular hematite.

The matrix is mainly fine-grained chlorite showing some patchy staining and, in a few places there are minor amounts of secondary quartz. Fine-grained, specular hematite is dispersed through parts of the chloritic matrix.

The hand specimen contains some pyrite in the breccia but this was not included in the sections.

Sample: P1090/76
TS35556
MG29A - 96'0"
RS203

Siltstone with small lenses of coarser-grained sediment. It is composed mainly of angular grains of quartz and feldspar with some fine-grained muscovite and chlorite and less than 5% iron oxide. The matrix is mainly very fine-grained sericitic and argillaceous material stained by minor amounts of iron oxide.

angular grains

This appears to be a normal sediment with no special features except that most of the detrital grains are not rounded.

Sample: P1091/76
PS24622
MG29A - 137'0"

Hematitic breccia with a matrix of red, ochreous hematite in contact with a band or layer with a chloritic matrix and some large clasts of granitic rock.

The red hematitic zone contains randomly dispersed and some intergrown and deformed specular hematite, minor recognisable martite and some coarse-grained pyrite. There is also a trace of uraninite and a trace of molybdenite. Monazite occurs as an elongate mass of fractured fragments. Pyrite has been fractured and some has been veined and extensively replaced by chalcocite. Much of the hematite in this zone shows fine overgrowths or fringes of secondary hematite. The composition of the matrix cannot be determined from the polished section but probably it is ochreous hematite and clay with some chlorite and there are also patches of quartz. The overgrowths of secondary, fine-grained hematite and the ochreous hematite are both later than the fragments of specular hematite.

The green, chloritic zone has irregular bands containing specular hematite, martite and pyrite similar to those in the red zone and the pyrite is similarly fractured and veined or partly replaced by copper-bearing sulphides. This band or layer, however, also contains an abundance of fine-grained quartz through which the layers and patches containing hematite, martite and pyrite are distributed.

The contact between the two zones is slightly irregular and fairly sharply defined. The specular hematite, martite and pyrite present in both zones all appear to be clastic fragments, probably of similar age but later movement and fracturing have obscured some relationships.

Sample: P1092/76
TS35557
PS24623
MG29A - 147'3"
RS 205

Steeply dipping contact between hematitic breccia and red, granitic rock.

The granitic rock is composed mainly of microcline and quartz with minor sericite, and fractures contain calcite. It has also been invaded by iron oxide probably mainly magnetite, some of which occurs in poorly defined, vein-like patches and some is dispersed through partly altered microcline. There are also traces of monazite.

Along the contact there is a 2 to 4 mm thick zone which is now composed predominantly of quartz, sericite and chlorite and locally contains groups of magnetite or martite crystals up to 1 mm in size and minor monazite. Some monazite occurring on the contact appears to have crystallized in situ as partly radiating aggregates and this is now included within quartz.

monazite crystallised before quartz

The breccia contains clasts of granitic rock, specular hematite, martite, pyrite and minor monazite in a matrix composed predominantly of chlorite. There is a trace of uraninite, a trace of molybdenite and some porous patches of copper-bearing sulphides which have partly filled some interstices. There is also some late interstitial quartz.

One small mass of pyrite is intergrown with, or partly encrusts some martite and most of the pyrite has been extensively fractured.

Sample: P1093/76
TS35558
PS24624
MG62 - 552'6"
RS208

Silicified breccia containing clasts of partly-chloritized basement rock, specular hematite, coarse martite, pyrite and minor monazite. The matrix has been almost completely replaced by quartz but there are remnants of chlorite included within this quartz and locally there are small patches of fluorite, either intergrown with the quartz or included within quartz.

Sample: P1094/76
TS35559
MG83 - 643'6"
RS208

Red siltstone containing a few fragments of hematite, a few of sericitic rock, flakes of chlorite or chloritized biotite and a few fragments of monazite. It is heavily stained by red, ochreous hematite and has been partly silicified. It is cut by a few quartz veins which contain remnants of chlorite, partly replaced by ochreous hematite.

Sample: P1095/76
PS24625
MG83 - 673'6"
uraninite RS208
aggregate of spec. haem intergrown c qutz - ie like Mt Gee haem aggregates

Hematitic breccia containing specular hematite, martite, minor monazite and a trace of uraninite. Some specular hematite aggregates (not martite) are intergrown with quartz and this appears to be part of a large clast. ?of what

There are traces of finer-grained, later hematite, some occurring as overgrowths or fringes on the larger crystals.

The uraninite appears partly altered and there is also a mass of apparently amorphous limonite which contains a few minute specks of galena?and an included fragment of martite.

The matrix contains abundant ochreous hematite with a few remnant patches of green chlorite and some late interstitial quartz. There are traces of migratory chalcopyrite occurring in some interstices and although some of this appears to be included within quartz some has filled interstices between small quartz crystals. Some chalcopyrite has also invaded uraninite.

late chalcopyrite invaded uraninite

Sample: P1096/76
TS35560, 35614
MG73 - 398'6"
RS209

Reddish-brown sandstone within hematitic breccia.

The lower contact between this sandstone and underlying breccia is not a sedimentary contact.

The sandstone differs from sediments associated with many of these breccias in that it contains some rounded quartz grains and some rounded lithic grains composed of fine-grained sericitic material and quartz. It also contains a few large grains and pebbles of varying composition. Although no evidence of layering was found in the sandstone, many elongate grains show a preferred orientation which is very probably the direction of bedding and this is now at a high angle to the lower contact with hematitic breccia. This contact also apparently cuts through one of the large grains or smal pebbles in the sandstone. A border zone up to 1 mm thick in the sandstone against the lower contact with breccia appears bleached in that it does not contain the very fine iron oxide staining present i the remainder of the sandstone. Near this contact the breccia contains a clast 2 mm in diameter, composed of similar sandstone and showing a similar zone of bleaching along its boundary. (Plate 10d)

Sample: P1096/76
Cont'd

It is therefore concluded that this reddish sandstone occurs as clasts within the hematitic breccia.

Sample: P1097/76
TS35561
MG73 - 434'6"

Breccia containing quartz crystals, specular hematite, moderately abundant pyrite, some chloritized mica flakes, minor fractured monazite and a trace of sphene in an abundant matrix of chlorite which shows patchy brown staining. A few patches of chlorite show relict textures outlined by very fine-grained hematite but these cannot be identified. It is possible that any feldspar present in this breccia has been replaced by chlorite.

Some pyrite has been extensively fractured and chlorite is now present within these fractures. Some chlorite is also present in an inclusion or embayment in pyrite.

authigenic chlorite has crystallized after clasts in breccia

Conclusion: The matrix is of authigenic chlorite showing patchy brown staining and some relict textures. This has crystallized after fracturing of the pyrite and also after martite, specular hematite and monazite.

Sample: P1098/76
TS35562
PS24626, 24627
MG73 - 501'0"
RS 211

Contact between hematitic breccia and a large clast of foliated basement rock.

The foliated basement rock has a similar texture and grain size to basement rock in Sample P1089/76 but in this sample (P1098/76) all silicate has been replaced by fine-grained sericite and chlorite and the rock is now composed only of quartz, greenish sericitic material and chlorite, altered ilmenite or leucoxene, and some opaque iron ox There is a trace of apatite. Adjacent to the contact with the brec there is an increasing amount of iron oxide, some occurring as coars martite and some as finer-grained, specular hematite and the surface of the gneissic rock in contact with the breccia is encrusted by fin to medium-grained iron oxide, much of which is specular hematite. Secondary quartz occurs in the breccia and has also penetrated the altered clast of basement rock.

Basement rock c̄ ilmenite & magnetite

A polished section of the basement rock shows altered ilmenite and partly oxidized magnetite, very similar to those in Sample P1089/76 (see Plate 5) and there is also some much finer-grained hematite along grain boundaries. There is a trace of pyrite.

The breccia contains hematite, martite, pyrite and a trace of monazi

Sample: P1099/76
TS35563
MG73 - 527'0"
RS 212

A porous, vughy rock in which most of the numerous voids are lined with small quartz crystals and this quartz cements the rock.

It is a poorly sorted, detrital sediment, containing some clasts of chloritized feldspar, numerous flakes of chloritized mica, angular fragments of monazite, minor iron oxide and some clasts of basement rock containing altered ilmenite. There are also a few irregular patches of chlorite similar to that forming the matrix in some brecc but it is not clear whether these are remnants of matrix chlorite in this sediment or whether they are clasts from earlier rocks or porti of chloritized basement.

Sample: P1099/76
Cont'd

The rock contains traces of fluorite and it has been extensively replaced by quartz, some of which now forms small crystals projecting into leached voids. Some of the fluorite is included within quartz.

Although the rock does not show any evidence of bedding, many of the chloritized mica flakes are subparallel and almost horizontal, assuming the drill hole is vertical, and this probably represents the direction of bedding. The hand specimen contains some pyrite not noted in the section.

Conclusion: This is a poorly sorted sediment or breccia containing moderately abundant fragments of chloritized basement rock and chloritized mica. It also has some pyrite and some iron oxide and may have had a chloritic matrix but this has been almost completely replaced by quartz, some of which contains a little fluorite.

Sample: P1100/76
TS35564
PS24628 RS213
MG73 - 572'0"
aggregates spec. haem c̄ qutz + clay
uraninite crystallised after monazite
no clasts

Hematitic breccia characterised by the presence of numerous aggregate of specular hematite crystals which are intergrown with random orientation and which are associated with interstitial quartz and minor interstitial clay. Some of these aggregates also contain monazite. They vary in size up to 1.5 cm and could represent clasts derived from hematite-quartz veins or from some other source. The breccia also contains some dispersed specular hematite, some martite and minor monazite. It is of interest in that it contains a patch o uraninite 2 to 3 mm in size which encloses some fragments of monazite and fills interstices between fractured and dispersed monazite fragme (Plate 11a). This uraninite contains some swarms of minute inclusio or remnants of hematite (Plate 11b) the composition of which was confirmed by the electron probe.

Chlorite matrix replaced by red ochre.

The matrix is now predominantly ochreous hematite with some small patches or remnants of chlorite and some patches of secondary quartz. There are also traces of migratory bornite. The red, ochreous hematite has probably replaced chlorite and some of this ochreous hematit and traces of chlorite are included within the late quartz.

Conclusion: It has not been possible to definitely establish the origin of the hematite-quartz aggregates in this breccia but the gener appearance of the rock suggests that they are clasts and therefore th may have been derived either from hematite-quartz veins or represent reworked material from earlier sediments or breccias.

Sample: P1101/76
PS24629
MG91 - 621'6"
RS214
no clasts
late specular haem.

Hematitic breccia with a chlorite matrix. It contains some coarse martite, abundant specular hematite, coarse pyrite, some unoxidized magnetite, a few monazite fragments and traces of molybdenite and uraninite. The rock is of interest in that it contains dispersed fragments of specular hematite and martite as well as some fragments of magnetite showing little or no evidence of oxidation. Both specular hematite fragments and magnetite show overgrowths or fringes of secondary, fine-grained specular hematite.

uraninite encloses specular haem.
molybdenite

It is also of interest in that the section contains one irregular patch of uraninite which apparently encloses a fragment of specular hematite (Plate 11c). The molybdenite flakes are isolated and defor and show no evidence of relative age except that some are partly en-cluded within late quartz.

Sample: P1101/76 Cont'd
chlorite replaced by ochreous haem.

This breccia also contains a few relatively large clasts composed of fine-grained chlorite stained and partly replaced by ochreous hematite.

Some pyrite has been fractured and veined by bornite and chalcocite.

Sample: P1102/76
PS24630
MG91 - 626'5"
RS 215

Breccia containing irregular patches of intergrown specular hematite and quartz with minor pyrite in an abundant matrix now composed predominantly of red, ochreous hematite but with irregular patches which are probably remnants of dull green chlorite. There is also a trace of molybdenite associated with some chlorite and specular hematite. In general, the chlorite is better preserved adjacent to the hematite-quartz aggregates.

This specular hematite contains small inclusions of pyrite and very few of chalcopyrite and, although it does not show any textural evidence suggesting replacement of magnetite, some crystals do conta small inclusions or remnants of magnetite. The problem of its orig is similar to that of hematite in Sample P1100/76.

Sample: P1103/76
TS35565
MG93 - 687'10"
Hematitic s.st. & siltst.
RS 216

Hematitic sandstone and siltstone with fine laminations dipping at approximately 45° if the drill hole is vertical. This sediment is overlain by hematitic breccia but the contact is irregular and does not follow a bedding plane. However, less than 2 cm of this contac is exposed.

The sediment contains quartz, fine-grained hematite, fine-grained muscovite and traces of heavy minerals including monazite, apatite, zircon and sphene. The shape of a few hematite grains suggests tha they may represent martite but this could not be confirmed from the thin section.

The sediment has been silicified.

Sample: P1104/76
TS35566 *RS217*
MG66 - 154'6" to 155'8"
matrix greenish sericite and minor chlorite
Red matrix tillite is stained by iron oxide

Green 'tillite'

A poorly-sorted sediment containing abundant, sand-sized quartz grain (some rounded) and a few feldspar grains together with numerous larg fragments composed of a variety of rock types including granitic rocl acid gneiss, a few of fine-grained metasediment and fragments compos mainly of sericite and one pebble of a poorly-sorted sediment contai ing up to 5% iron oxide. The cementing matrix is mainly greenish sericite with minor chlorite.

It is very similar to Sample ~~P1833/76~~ *P1533/75* except that the matrix does no contain, or is not stained by very fine-grained iron oxide.

Note: The rock occurring as large and small clasts? in hematitic breccia in Sample P1096/76 shows some similarities to this 'tillite'.

Sample: P1105/76
PS24631
MG66 - 214'6" to 215'0"
RS 218

A very small sample of hematitic breccia containing some clasts of sericitized and chloritized granitic rock which appear corroded, in a matrix containing abundant specular hematite, some of which occurs a intergrowths of crystals showing apparently random orientation. One of these intergrowths of hematite contains a fragment of monazite (Plate 10b) and some hematite contains small inclusions of bornite.

Sample: P1105/76 Cont'd
RS 2[illegible]

The breccia also has some coarse martite with inclusions of pyrite. There is a trace of molybdenite and one of these flakes appears to partly enclose the end of a crystal of specular hematite, however, because of the obvious deformation of the molybdenite, this relationship is uncertain and it could well be that the small plate of hematit has been forced against and into the soft molybdenite.

Some of the hematite in this sample shows small overgrowths or fringe of very fine-grained, specular hematite.

Coarse-grained pyrite in this sample has been extensively fractured, some has been corroded (possibly by carbonate) and some is now veined by chalcocite and bornite. The sample also contains a trace of uraninite.

uraninite

The matrix is mainly clay, possibly with some chlorite and some patch of late quartz.

Sample: P1106/76
TS35567
MG66 - 214'6" to 215'0"
(same depth as Sample P1105/76)
Sandstone in haem. breccia
RS 219

This is a hematitic sandstone reported to be interbedded with the breccia P1105/76.

This is a poorly-sorted sandstone containing quartz grains (some rounded), some sericitic lithic grains, a few flakes of mica and chlorite, relatively minor hematite, a few angular fragments of monaz and very few rounded grains of zircon. The interstitial matrix is mainly very fine-grained sericitic material associated with, or staine by fine-grained iron oxide.

This differs from many of the hematitic siltstones and sandstones interbedded with the breccias in that it contains a proportion of rounded quartz grains and little or no detrital feldspar.

Sample: P1107/76
PS24632
MG66 - 220'6" to 221'4"
RS220
fracturing of components after formation ? due to sedimentary movement from elsewhere
no clasts [illegible] fractures

Hematitic breccia reported to be at the base of the hematitic breccia sequence overlying crystalline basement.

Hematitic breccia containing closely packed fragments of specular hematite, some coarse martite, extensively fractured, coarse pyrite, a few deformed flakes of molybdenite and some extensively fractured monazite. In some zones, elongate plates of hematite and flakes of molybdenite are subparallel but whether or not this represents a direction of bedding is not clear. There certainly appears to have been considerable fracturing or crushing of material within this breccia after its formation and therefore the reason for the subparallel orientation of many elongate fragments cannot be determined.

Interstices now appear to be filled mainly by quartz crystals, (22nd generation qtz) intergrown with carbonate and carbonate has penetrated and possibly partly replaced some extensively fractured crystals of pyrite. Traces of copper-bearing sulphides have also invaded fractures in pyrite.

Sample: P1108/76
TS35568
PS24633 RS221
MG66 - 220'6" to 221'4"
(in contact with P1107/76)

Silicified breccia containing clasts of sericitized granitic rock, hematite which has been extensively replaced by quartz (Plate 3d), extensively fractured pyrite and minor molybdenite and monazite. There are also traces of uraninite, some late pitchblende occurring as colloform masses against molybdenite (Plate 12c) and some late, migratory copper-bearing sulphides including chalcopyrite and chalcoc

uraninite and pitchblende

?1st generation

Sample: P1108/76 Cont'd

some of which occurs in interstices between the late quartz crystals
? crystals suggest that it is first generation quartz
The secondary quartz which has replaced much of the rock forms a porous mass of intergrown crystals, most of them less than 1 mm long and some of this quartz contains included remnants of hematite. Th relationship between uraninite and quartz is not clear but the collo form pitchblende appears to have been deposited after crystallizatio of the quartz as does the migratory copper-bearing sulphide. Some late, very fine-grained, microspherular hematite has also been deposited in interstices between the quartz crystals.

Note: Samples P1107 and P1108/76 are both breccias and the pyrite and molybdenite occurring within them are very similar. Most of th pyrite crystals have been extensively fractured and in P1107 they ha been invaded and partly replaced by carbonate and quartz and in P110 they have been partly replaced by quartz. The molybdenite occurs a separate flakes which have been deformed and, except for those which have been invaded by late quartz and pitchblende in P1108/76 there is no evidence of age relationship.

Sample: P1109/76
TS35569 ·RS222
MG66 - 273'6" to 274'0"

Breccia composed of clasts derived from granitic rock which has now been extensively replaced by sericite and minor carbonate. Interstices contain mainly sericitic material. Alteration has obscured or obliterated any evidence of origin of this breccia.

Sample: P1110/76
PS24634
AG8 - 69'8" ·RS223

Hematitic breccia containing coarse-grained martite, dispersed specu hematite, oxidized pyrite (now goethite), quartz crystals and a trac of monazite. There are few clasts of granitic rock.

Haematite is transported

This is of interest in that some of the coarse-grained pyrite (now oxidized) encloses small patches of matrix material containing fragments of specular hematite (Plate 8c, d). This pyrite appears to h crystallized within the breccia and does not show evidence of fractu ing and transport or dispersion shown by the iron oxides.

The matrix appears to be mainly chloritic material and some ochreous hematite.

Sample: P1111/76
TS35570 AG8
PS24635 ·RS 224
Plate 14a, b
authigenic vermiculite
later fluorite
later quartz
93' 10"

Granitic breccia containing relatively minor, coarse martite, specula hematite and oxidized pyrite similar to those in P1110/76.

The 'khaki matrix' was identified by X-ray diffraction as a vermicul like mineral or, less likely, a montmorillonite. It is of authigenic origin and is associated with some very fine-grained microspherular to ochreous iron oxide which locally appears to be stainin the vermiculite. A few interstices lined by this vermiculite conta later fluorite and both fluorite and vermiculite are included within some late quartz.

Sample: P1112/76
PS24636 ·RS225
AG8 - 135'10"
no clasts

Hematitic breccia cemented by a dark green mineral identified by X-ray diffraction as hexagonal chlorite.
clasts of granite & gneissic rock
The breccia contains coarse-grained, zoned martite, specular hematit coarse-grained pyrite and traces of molybdenite, uraninite and monaz Minor late or migratory chalcopyrite is locally associated with a tr of sphalerite.
later chalcopyrite & sphalerite

unoxidised magnetite mixed c spec. haem

Sample: P1112/76 Cont'd

Some zoned martite contains moderately abundant, unoxidized magnetite and, in this sample, there are a few angular fragments of unoxidized magnetite mixed with abundant specular hematite and completely oxidi[zed] magnetite.

late galena chalcopyrite

A trace of galena is associated with chalcopyrite in one fracture in coarse-grained pyrite.

Sample: P1113/76
TS35571, 35572
PS24637
AG8 - 150'8"
RS226

A 5 cm band of granitic rock in hematitic breccia.

The granitic rock is composed of quartz and mircocline but in the interior of the band most of the microcline has been replaced by chlorite locally associated with a little fluorite. Some microcline contains scattered small crystals of magnetite (or martite) locally associated with chlorite and clay and, although the origin of this magnetite has not yet been determined it is similar to that noted in a few microcline-bearing clasts in breccias. Some of this microcline shows evidence of partial granulation and recrystallization and most of it is now stained by very fine-grained iron oxide. A few crystalline aggregates of monazite are also present in the partly altered granitic rock and, some inter-related textures suggest that this crystallized before the introduced chlorite, which in turn was followed by fluorite. (Plate 10a)

[illegible] accounts for red [illegible] around contact

monazite then chlorite then fluorite

magnetite → martite c specular haem. then pyrite

The hematitic breccia contains coarse, zoned martite, specular hematite and some coarse-grained pyrite and it is of interest in that the coarse-grained pyrite in this specimen has clearly crystallized after the martite and specular hematite (Plate 7c, d). Examination under low magnification suggests that this breccia contains a large clast over 5 mm in size composed of coarse martite intergrown with, and partly surrounded by aggregates of specular hematite and the boundary of this clast is partly encrusted by the coarse-grained pyrite which also penetrates along some grain boundaries.

Plate 7c shows chalcocite veining fractured 2nd genⁿ pyrite

The matrix of the breccia is now mainly ochreous hematite but contains minor chlorite.

Hand spec - haem. breccia khaki coloured.

Sample: P1114/76
TS35573 RS227
AG13 - 132'0"
khaki matrix is vermiculite

Granitic breccia containing relatively minor, coarse martite, specula[r] hematite, oxidized pyrite and a trace of monazite. The 'khaki matr[ix'] is authigenic, vermiculite-like mineral, stained and possibly partly replaced by ochreous iron oxide. vermiculite appears to be matrix where granite clasts dominate (ie granite breccia) while chlorite is matrix of haem. breccia.

Sample: P1115/76
TS35574 RS228
AG28 - 123'0"
granitic rock c veins chlorite - compare c P196/76 from BFD1

Brecciated and metasomatically altered granitic rock which has been invaded by dark chlorite locally associated with fluorite which has crystallized after the chlorite. Quartz and microcline show eviden[ce] of granulation and recrystallization under conditions of tectonic stress and the rock now contains at least 5% magnetite or martite, some along veins but much of it dispersed through recrystallized and altered microcline. Recrystallized titanium oxide is also moderately abundant and is concentrated along numerous small planes or lines which possibly represent fractures now completely healed by the recrystallized rock. This migration of titanium oxide is unusual but the pattern certainly suggests numerous small veins.

Possible crystalline basement. See Field Note book 1975

Sample: P1115/76
Cont'd

Most of the magnetite or martite in this altered, granitic rock is fine-grained (up to 0.5 mm) but there are a few larger crystals 2 to 4 mm in size.

Sample: P1116/76
TS35575
PS24687
AG28 - 127'4"
RS229

Fractured and altered, granitic rock now composed of quartz and turbid, iron-oxide stained microcline partly replaced by chlorite. There are scattered aggregates and discontinuous, small veins of fine-grained, recrystallized titanium oxide and traces of fine-grained iron oxide (less than in P1115/76).

metasomatic chlorite c̄ titanium oxide, iron oxide, fluorite & ?uraniferous ilmenite counter to P BFD!

The rock is cut by irregular and discontinuous veins of fluorite with patchy, purple staining, and in one area there is a colourless mineral which was identified by X-ray diffraction as bastnaesite ($CeCO_3F$). This has crystallized across the earlier fabric and contains inclusions of quartz and iron oxide.

Radioactivity in this rock is due to the presence of small patches of a uranium oxide mineral (analysed by the electron probe) some of which is associated with recrystallized titanium oxide. ? formerly uraniferous ilmenite. Possible crystalline basement see Field Note Book, 1975

Sample: P1117/76
PS24638
AG31 - 127'10"
RS230

Hematitic breccia with a matrix containing chlorite, some fluorite and abundant, ochreous hematite. Locally there is some kaolin.

molybdenite then magnetite then spec. haem.

The breccia contains coarse-grained martite, aggregates of specular hematite, some coarse-grained pyrite and traces of molybdenite and late covellite. It is of interest in that the section contains one aggregate of molybdenite flakes partly enclosed by coarse-grained martite (Plate 9a, b). This suggests that the molybdenite was already in existence when this coarse-grained magnetite (now martite) crystallized. It is the only example found in these sections in which the molybdenite is intergrown with other early minerals.

Some coarse-grained pyrite contains inclusions of non-opaque minerals and also a few inclusions of martite (Plate 8b) and a very small inclusion of magnetite.

Traces of covellite occur in a few interstices.

Sample: P1118/76
TS35576
SR1 - 85'9"
RS23?

Chlorite? replacing pyrite
84'7"-85'2" – no clasts
25.7 - 25.9 m
to Mark Fanning ANU to extract monazite to see if suitable for U/Pb date
9 Dec 93
Supply Req.
9 02556

Hematitic breccia with a chloritic matrix.

It contains clasts of chloritized granitic rock, hematite, quartz, fragments composed of very fine-grained chlorite, some porous, coarse-grained pyrite and minor but persistent monazite. Some of the coarsely crystalline pyrite is unusual in that it contains abundant negative crystals and/or embayments which contain chlorite similar to that found in the matrix (Plate 12b).

Monazite is slightly more abundant and coarser-grained than usual and the section includes one aggregate of crystals with parallel growth 3 mm in size. Both monazite and specular hematite have been fractured and invaded by the chloritic matrix and some specular hematite appears to have been corroded and partly replaced by the chloritic matrix (Plate 12a).

Traces of fluorite fill or partly fill a few small voids lined by colloform chlorite but in some of these there is a zone of clay between the chlorite and the later fluorite (Plate 14c).

Much of the colloform chlorite in this rock shows textures very similar to those shown by vermiculite in more altered specimens.

Sample: P1119/76
PS24639
SR2 - 118'8"
RS232

Hematitic breccia with a chloritic matrix.
Has fluorite in hand spec.
It contains martite with some remnants of magnetite, dispersed hematite and some coarse-grained pyrite. There is some secondary quartz and some migratory chalcopyrite.

spec. haem. c qtz.

Some specular hematite intergrown with quartz may be portion of a large clast and some of this is invaded by and partly encrusted by coarse-grained pyrite as in Sample P1113/76.

Sample: P1120/76
TS35577
SR2 - 157'6"
RS233

Extensively sericitized and chloritized granitic rock. It contains a trace of magnetite which may have been introduced but this is uncertain.

Sample: P1121/76
TS35578
SR9 - 94'0" to 94'6"
RS 234

Granitic rock which at 94'6" is composed of quartz and microcline but with decreasing depth there is a progressive replacement of microcline by chlorite and at 94' the rock is composed predominantly of quartz and chlorite with only very few remnants of microcline and traces of fine-grained muscovite. Apatite is associated with some chlorite.

Sample: P1122/76
TS35579
SR9 - 97'0"
RS235

Granitic breccia, probably of tectonic origin (Plate 13c, d). The clasts contain some sericitized feldspar? but much of the microcline is unaltered.
Field book 1975 says pink leucogranite c spec. haem. matrix. Overlain + underlain by haem. + q. breccia
Chlorite has penetrated all fractures and is locally associated with minor iron oxide, probably magnetite.

Sample: P1123/76
PS24640
SR9 - 128'5"
RS 236

Hematitic breccia with a chloritic matrix. It contains moderately abundant clasts of granitic rock, porous, zoned martite with some zones of unoxidized magnetite, finer-grained specular hematite and some coarse-grained pyrite. One small crystal of pyrite contains inclusions of magnetite and is intergrown with a trace of galena.

Sample: P1123/76 Cont'd

Much of the pyrite has curved faces. against chlorite (Plate 8a)

Sample: P1124/76
TS35580 RS237
SR11 - 137'2"

Chloritized granitic breccia with a matrix of chlorite. It contains sporadically distributed coarse-grained martite, specular hematite, pyrite and a trace of monazite. Chlorite has extensively replaced some microcline and has also invaded and possibly partly replaced some hematite and martite.

Sample: P1125/76
PS24641 RS238
SR11- 148'4"

Hematitic breccia with a matrix of dark chlorite. It conains clasts of chloritized granitic rock, martite and dispersed hematite, moderately abundant, coarse-grained pyrite with curved crystal faces and a trace of late, migratory chalcopyrite occurring along a thin, irregular vein. A trace of fluorite is visible in the hand specimen

Sample: P1126/76
TS35581
MH3 - 50'5"
RS239
tourmaline in basement

Granitic breccia, probably of tectonic origin but the evidence is not absolutely conclusive. It contains minor hematite (or martite) and a trace of oxidized pyrite along some fractures. There is also some recrystallized titaniferous material and some introduced tourmaline. torbernite in hand sp. - has this come from uraniferous ilmen[ite]
within crystalline basement. See Field Note book 1975

Sample: P1127/76
TS35582
MH3 - 76'10"
RS240

Crushed and possibly sheared granitic rock composed of quartz, microcline, muscovite and sericite and traces of rutile (recrystallized) and zircon. The silicates are stained by extremely fine-grained and microspherular hematite. Some of the muscovite and sericite occur in elongate and apparently sheared aggregates up to to 1.5 cm long and other parts of the rock appear extensively crushed and partly recrystallized to a finer grain size.
within crystalline basement. See Field Note book 1975

Sample: P1128/76
TS35583
MH3 - 92'0"
RS 241
tourmaline in basement.

Granitic breccia probably of tectonic origin which has been cemented and partly replaced by abundant, secondary quartz. The matrix replaced by secondary quartz contains minor amounts of hematite but one fracture contains a higher concentration of opaque iron oxide associated with a trace of tourmaline. Fine-grained ochreous and microspherular hematite has stained silicates and accumulated along some grain boundaries and some of this is included within the late cementing quartz.

A late joint through the breccia is encrusted with torbernite.

On the scale of the thin section it is not possible to definitely determine the origin of the breccia, particularly as there is such an abundance of secondary quartz.
within crystalline basement See Field Note book, 1975.

Sample: P1129/76
TS35584
JDH119C - 329'0"
RS 242

Granitic breccia with a small amount of matrix containing small chips of quartz, a few of microcline and a few small flakes of muscovite cemented by very fine-grained, argillaceous material stained by reddish iron oxide. Some of the granitic clasts contain scattered crystals of iron oxide and some altered ilmenite and there are very few crystals of opaque oxide in the matrix material.
Handspec. + drill hole suggest this is granitic breccia in cryst. basement. See Field N[ote] Book, 1975.

tourmaline has been introduced into basement but not R.R. Beds

Sample: P1129/76
Cont'd

A crystalline aggregate of monazite is present at the boundary of one small granitic clast and a trace of extensively fractured monazite was found in the matrix.

There is some moderately coarse-grained secondary quartz and parts of the matrix have been replaced by microcrystalline quartz.

Conclusive evidence was not found in the hand specimen or in the thin section to show whether this is a tectonic or sedimentary breccia. Most of the quartz and microcline in the granitic clasts are moderately coarse-grained and do not show evidence of granulation and recrystallization as shown by quartz and some microcline in tectonic breccias and much of the quartz in the granitic clasts shows very little evidence of strain or undulose extinction between crossed nicols. The matrix contains numerous small, angular chips of quartz and microcline which does not appear to be consistent with the lack of evidence of tectonic stress in the granitic clasts. However, all granitic clasts are of similar composition and texture. There is, therefore, no conclusive evidence as to the origin of this breccia.

5. SUGGESTIONS FOR FURTHER WORK

1. Electron probe microanalysis to determine:-

   (i) The trace element content of magnetite in the hematitic breccias and magnetite occurring in basement rock (P1089, 1092/76) and in some microcline clasts.

   (ii) The trace element content of the coarse-grained pyrite with particular emphasis on its possible uranium content.

   (iii) If possible determine the cause of the patchy dark staining in some of the matrix chlorite.

2. Fluid inclusion studies on monazite which was clearly an early mineral and possibly related to magnetite and hematite in time and place of crystallization.

3. More detailed investigation of the chloritic matrix and if possible the nature of the dark staining in some of it.

4. Additional petrology and mineragraphy which may be suggested by field investigation and drilling now in progress.

REFERENCES

WHITTEN, G.F. (1970). The investigation and Exploration of the Razorback Ridge Iron Deposit. S. Aust. Dept. of Mines Report of Investigation No. 33.

- Do fluid inclusion work on monazite

Plate 1

a. Sample P1081/76 PS24615
UEP18 at ~~245'6"~~ 73·65

A partly oxidized crystal of magnetite showing evidence of zoning. Many zones are now composed of hematite (white) and some contain remnants of magnetite (grey). The crystal has been fractured and partly leached.

b. Sample P1074/76 PS24612
UEP12 at 136'3" 41.87m

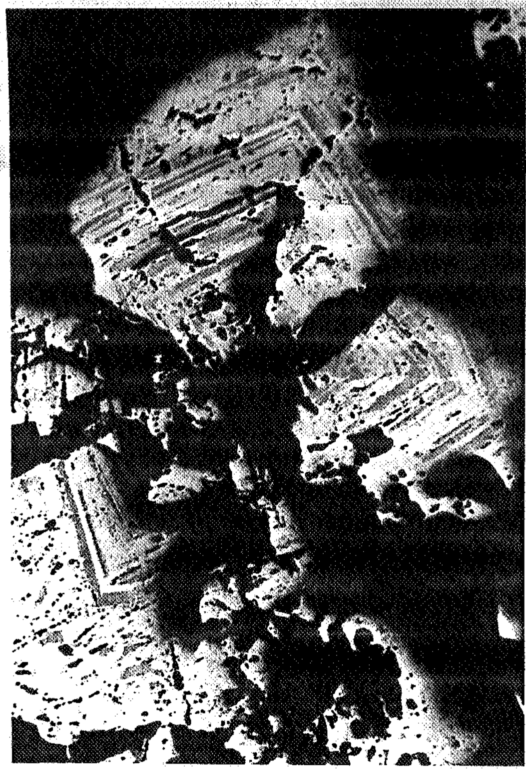
Porous, partly leached, zoned martite (oxidized magnetite) associated with dispersed specular hematite.

c. Sample P1112/76 PS24636
AG8 at 135'10"

Partly oxidized, zoned magnetite. It has been fractured and partly leached.

d. Sample P1071/76
UEP10 at 91'3"

A clast of coarse-grained, zoned martite containing a few small remnants of magnetite (grey)



a. 0·1mm

b. 1mm

PLATE 1

c. 1mm

d. 0·1mm

Plate 2

a. Sample P1074/76 PS24612
UEP12 at 136'3"

Coarse-grained martite showing evidence of an octahedral pattern inherited from the magnetite. It grades into dispersed specular hematite (top)

b. Sample P1074/76 PS24612
UEP12 at 136'3"

Coarse-grained and finer-grained martite now porous and partly leached. The smaller clasts? near centre show some evidence of internal structure inherited from magnetite and the larger clast? shows evidence of zoning. They are associated with dispersed, specular hematite.

c. Sample P1074/76 PS24612
UEP12 at 136'3"

Dispersed specular hematite now showing no recognisable pattern. The hematite contains a few small inclusions of magnetite.

d. Sample P1068/76 PS24608
UEP8 at 19'0"

Coarse-grained martite containing remnants of magnetite (grey) is associated with specular hematite showing preferred orientation and some pyrite (white).

a. 1mm

b. 1mm

PLATE 2

c. 1mm

d. 0·1mm

Plate 3

a. Sample P1101/76 PS24629
MG91 at 621'6"

Specular hematite (white) and a fragment of slightly oxidized magnetite (pale grey) in breccia with a chloritic matrix. Overgrowths of fine-grained, specular hematite are present on both hematite and magnetite.

b. Sample P1102/76 PS24630
MG91 at 625'5"
187·63

Specular hematite crystals intergrown with apparently random orientation contain a few minute inclusions of pyrite (small, white inclusions) and very few of chalcopyrite. Interstices between the hematite crystals contain quartz. ? 1st generation qutz

This hematite did not pseudomorphously replace magnetite.

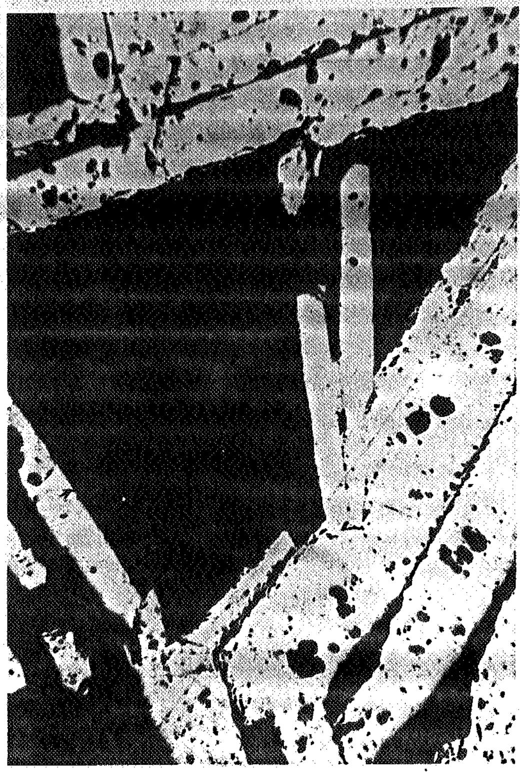
c. Sample P1069/76 TS35541 Crossed nicols.
UEP8 at 129'0"

Breccia containing a skeletal intergrowth of specular hematite (black) which probably replaced magnetite. Interstices now contain fine-grained late? quartz. The breccia also contains clasts of granitic rock, quartz and microcline.

d. Sample P1108/76 TS35568 crossed nicols
MG66 at 221'0"

Specular hematite has been extensively replaced by quartz ? 2nd generation qutz in a silicified breccia.

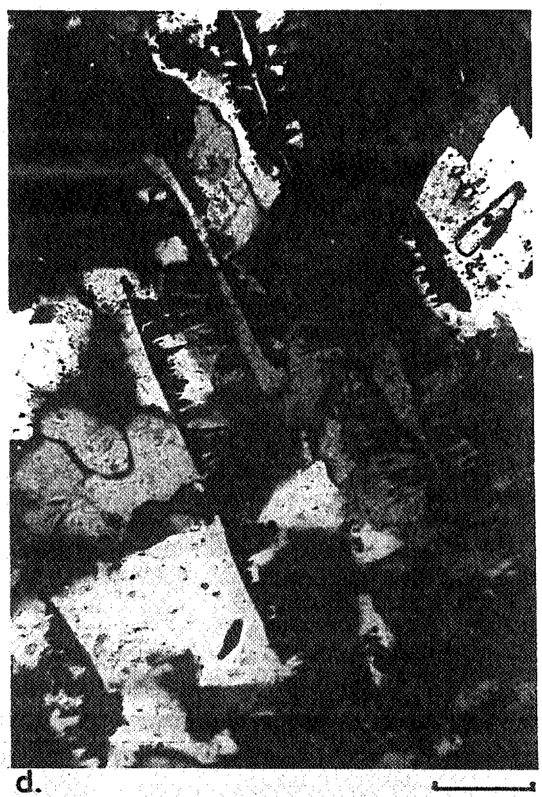
a. 0·1mm



b. 1mm

PLATE 3

c. 1mm



d. 0·1mm

late 4

. Sample P1082/76 TS35549
UEP28 at 76'4"

Laminated, hematitic sandstone composed mainly of grains of quartz and feldspar with flakes of hematite (black). The bedding has been disturbed.

. Sample P1082/76 PS24616
UEP28 at 76'4"

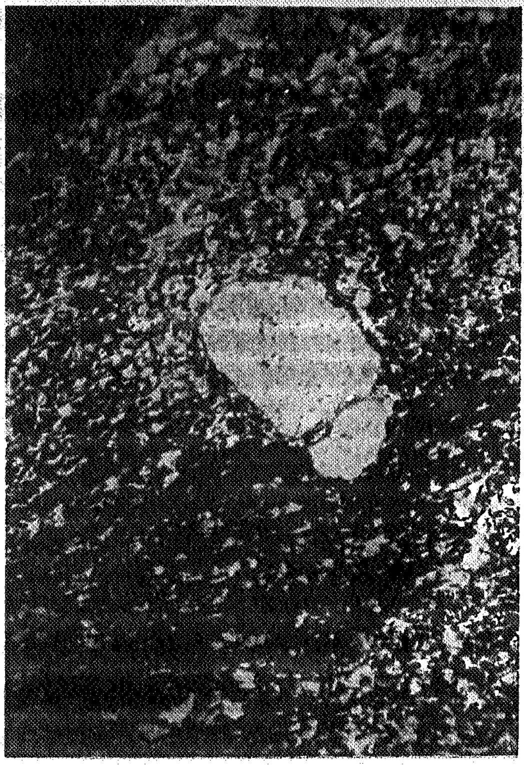
Polished section of a coarser-grained layer in the laminated sandstone of (a). This shows fragments of specular hematite, one of partly oxidized, probably zoned magnetite/martite and one fragment of pyrite (white). The magnetite was oxidized before it was fractured and the fragments incorporated in this sediment.

. Sample P1072/76 PS24611
UEP12 at 14'9"

Specular hematite and zoned martite in hematitic breccia which has been partly cemented by quartz. The zoned martite contains remnants of magnetite.

. Sample P1084/76 TS35550
UEP28 at 290'6" 87-15m

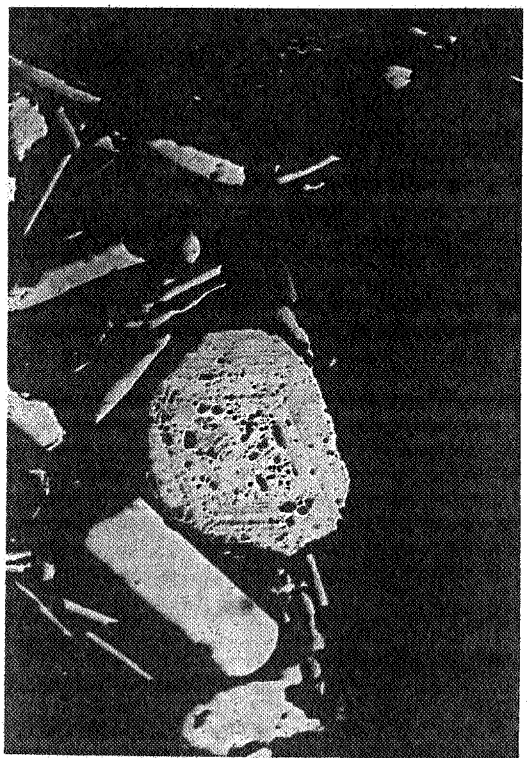
Interbedded coarser and finer-grained layers in hematitic siltstone, sandstone and breccia. It is composed mainly of quartz, feldspar and specular hematite with some clasts of granitic rock.



a. 1mm

b. 0·1mm

PLATE 4



c. 0·1mm

d. 1mm

Crystalline basement Sample P1089/76
MG24 at 197'0"

TS35555
This shows an aggregate of magnetite (or martite) (black) apparently encrusting the surface of the altered basement rock in contact with overlying hematitic breccia. The breccia has a chloritic matrix.

TS35555
Basement rock near the contact with overlying hematitic breccia. It has been extensively replaced by calcite, chlorite and iron oxide (black)

TS35609
Basement rock 3 to 5 cm from the contact with overlying hematitic breccia. All feldspar has been replaced by chlorite and sericite (turbid grey) but most of the quartz (white) remains unaltered. Opaque minerals (black) are magnetite and altered ilmenite (see d).

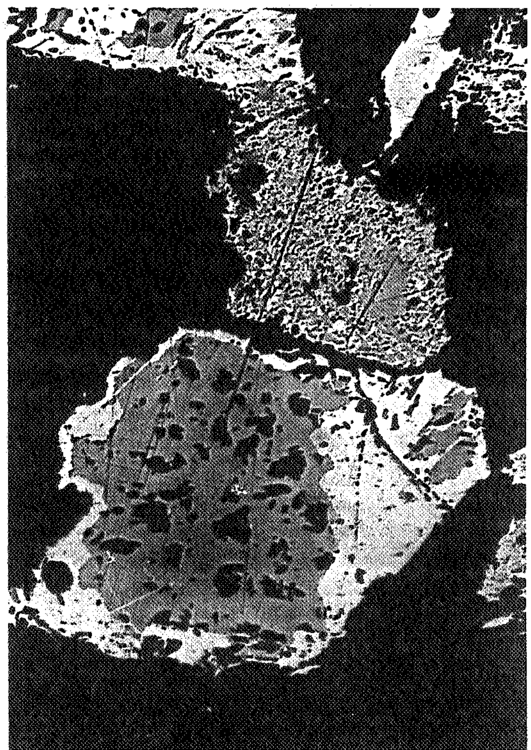
PS24666
Opaques minerals in basement gneiss . Those shown are partly oxidized magnetite and altered ilmenite now fine-grained hematite and rutile.

a. 1mm

b. 1mm

PLATE 5

c. 1mm



d. 0·1mm

ate 6

b Sample P1092/76 TS35557
MG29A at 147'3"

a. Contact between basement granitic rock and overlying hematitic breccia.

The basement rock is composed of quartz and microcline but, near the contact, it has been invaded by fine-grained iron oxide (black) and some chlorite. There is also some monazite (M) in a patch of rock partly replaced by chlorite and magnetite (or martite). Traces of calcite are associated with some chlorite.

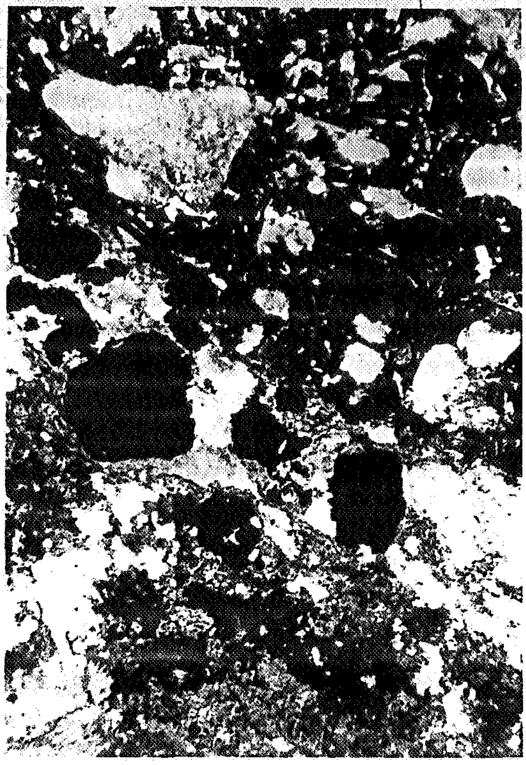
The overlying breccia contains clasts of granitic rock, quartz, hematite and some pyrite in a matrix of chlorite (dark grey). Coarse-grained iron oxide occurs in the contact zone.

b. Another area of the basement rock, showing a vein-like aggregate of fine-grained magnetite which has invaded and partly replaced some microcline in partly-altered granitic rock. There are also irregular veins of quartz (white).

d Sample P1069/76 TS35541 PS24609
UEP8 at 129'0"

c. A microcline clast in hematite-bearing breccia contains dispersed, fine-grained magnetite (black).

d. Polished section showing crystals of partly oxidized magnetite in another clast of microcline in the breccia.



a. 1mm

b. 1mm

PLATE 6

c. 1mm

d. 0·1mm

Plate 7

a-b Sample P1068/76 PS24608 (b shows higher magnification)
UEP8 at 19'0"

Hematitic breccia containing some coarse-grained martite with remnants of magnetite (grey), some specular hematite and some coarse-grained pyrite (white) which contains a few inclusions of non-opaque mineral grains. Much of the specular hematite appears deformed. Pyrite in this breccia has probably crystallized after the iron oxides.

c-d Sample P1113/76 PS24637
AG8 at 150'8"
45.2m

Hematitic breccia in which some coarse-grained pyrite (white) has enclosed porous, leached martite and has also penetrated some interstices between specular hematite crystals. The pyrite contains a few inclusions of quartz? Some fractures in pyrite contain chalcocite.? left side of c grey material

In (c) the specular hematite aggregate encloses a group of porous martite crystals or fragments.


a.

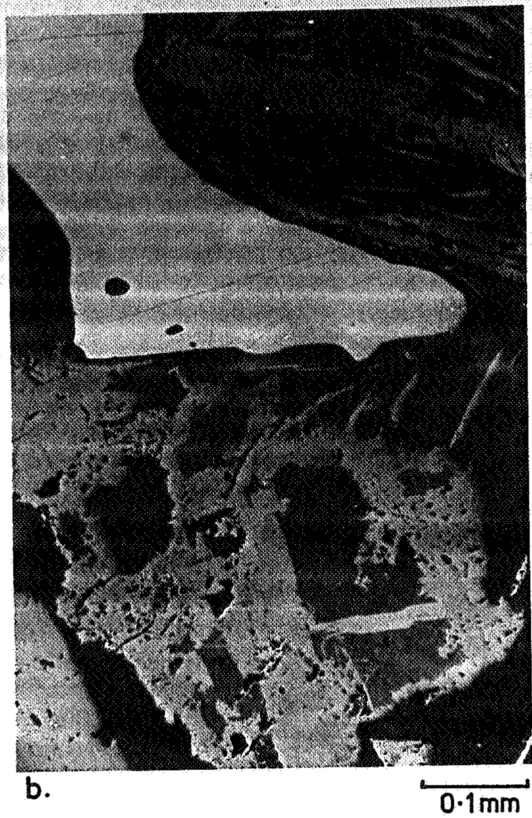

b.

PLATE 7


c.


d.

Plate 8

a. Sample P1123/76 PS24640
SR9 at 128'5"
38·53 m

Pyrite (P) in hematitic breccia. This crystal shows the curved faces common in much of coarse-grained pyrite in these breccias where it has crystallized against matrix chlorite. It contains an inclusion of a non-opaque mineral with high refractive index and also angular inclusions of magnetite (pale grey). This pyrite is intergrown with galena (G) against which it shows a straight crystal face.

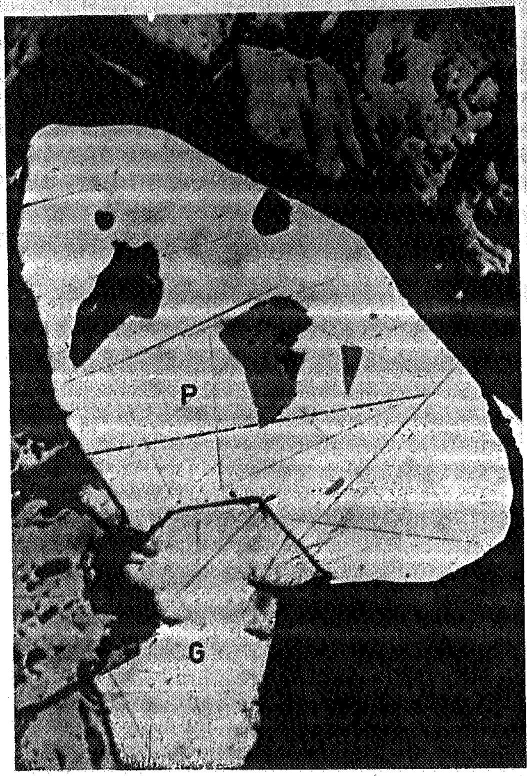
b. Sample P1117/76 PS24638
AG31 at 127'10"

Pyrite (white) in hematitic breccia. This crystal contains an inclusion of porous martite (near centre) and a very small inclusion of magnetite

c-d Sample P1110/76 PS24634
AG8 at 69'8"

Pyrite (now replaced by goethite) enclosed small patches of matrix which contained some small fragments of hematite associated with non-opaque material possibly chlorite.

(d) shows one of these inclusions at higher magnification and also some relict textures within the oxidized pyrite.



a. 0·1 mm

b. 1 mm

PLATE 8

c. 1 mm

d. 0·1mm

Plate 9

a-b Sample P1117/76 PS24638
AG8 at 69'8"

An aggregate of molybdenite flakes is partly enclosed by porous hematite which shows some textures suggesting that it has replaced coarse-grained magnetite. (b) shows the molybdenite aggregate at higher magnification.

c-d Sample P1107/76 PS24632
MG66 at 220'6" - 221'4"
66.15 - 66.42 m

Deformed flakes of molybdenite (Mo), plates of specular hematite, and minor pyrite (P) in hematitic breccia. These show a preferred orientation which may be a direction of bedding but elsewhere much of the pyrite is extensively fractured and there is evidence of tectonic deformation. There is a fractured mass of monazite (c - lower right) and fractured martite (d - lower right).

The matrix contains intergrown quartz crystals and some carbonate.

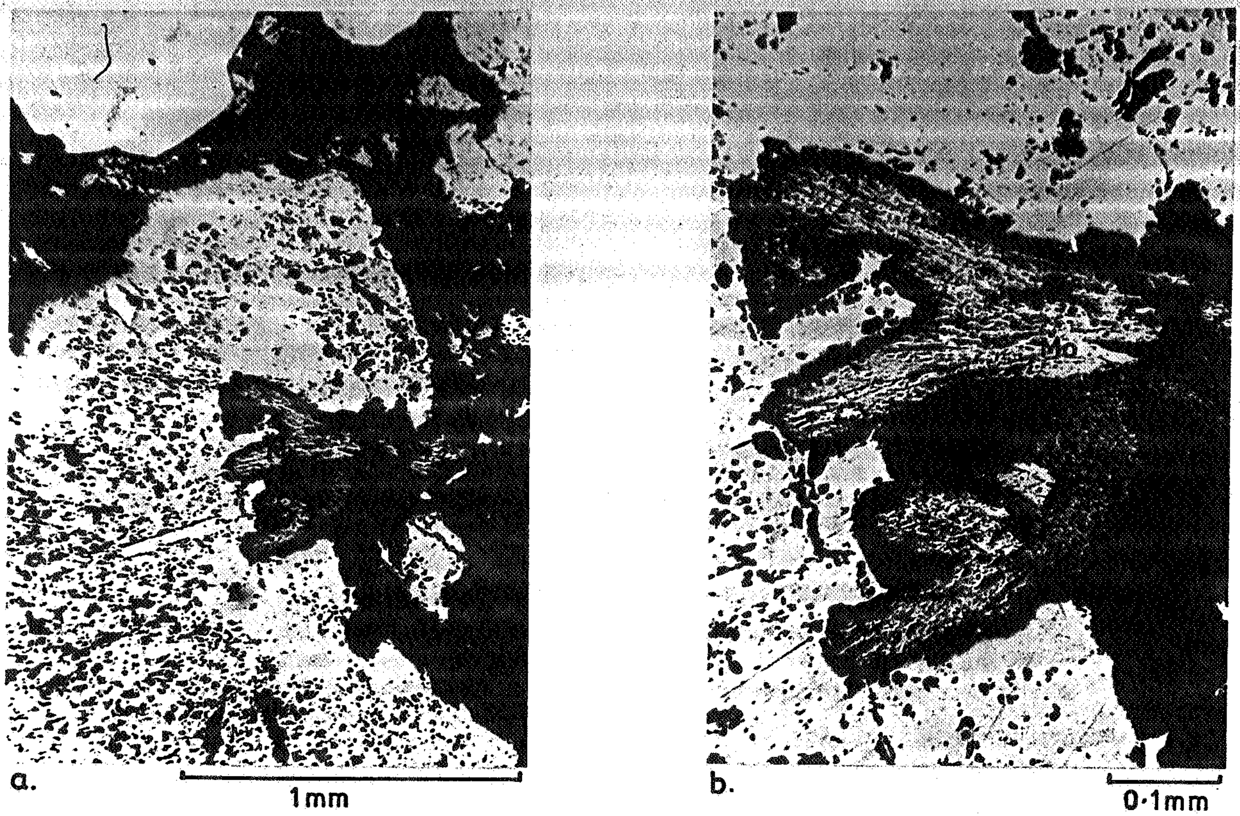


PLATE 9

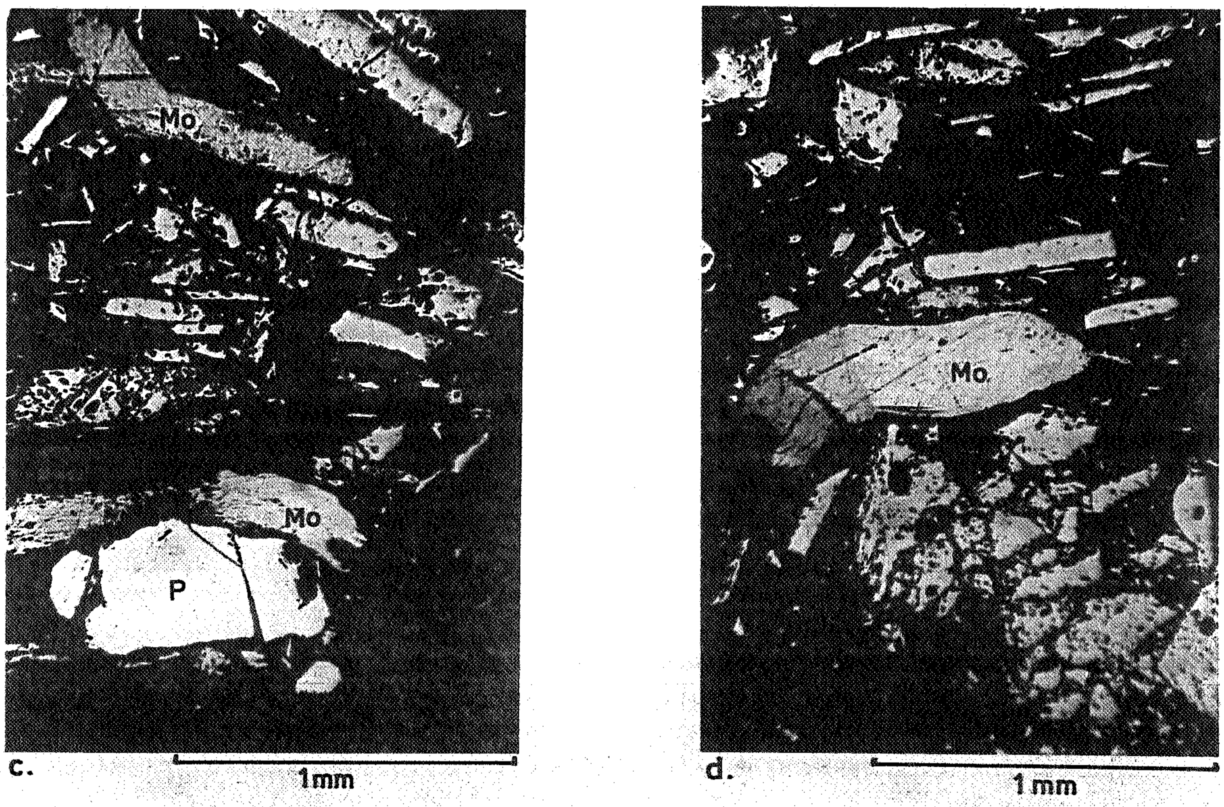


Plate 10

a. Sample P1113/76 TS35571
AG8 at 150'8"

Monazite (Mo) has crystallized in a fracture in granitic rock (or granitic clast) near contact with hematitic breccia. The fracture also contains chlorite and clay which have crystallized after the monazite.

b. Sample P1105/76 PS24631
MG66 at 214'6" - 215'.

Monazite fragment (grey) is enclosed by an aggregate of specular hematite in hematitic breccia. Some of the hematite shows overgrowths of finer-grained hematite.

c. Sample P1092/76 TS35557
MG29A at 147'3"

Monazite crystals (turbid dark grey), some iron oxide (black) and chlorite have invaded basement granitic rock near contact with overlying hematitic breccia.

d. Sample P1096/76 TS35614
MG73 at 398'6"

Lower contact of a 'band' of sandstone with underlying hematitic breccia. A small 'pebble' of similar sandstone is present in the underlying hematitic breccia and both the small pebble and larger 'band' of sandstone show a thin zone of bleaching adjacent to the hematitic breccia. The surface of the sandstone also appears corroded.

This is not a sedimentary contact and the evidence suggests that the sandstone may occur as clasts within the hematitic breccia.

a. 0·1mm

b. 1mm

PLATE 10

c. 1mm

d. 1mm

Plate 11

a-b Sample P1100/76 PS24628
MG73 at 572'0"
171·6m

a. Uraninite (mottled pale grey) has enclosed some fragments of monazite and filled some interstices between other fractured monazite crystals (grey). This uraninite has crystallized in the breccia after fracturing of the monazite.

b. Higher magnification of some of the uraninite in (a) showing swarms of very small inclusions of hematite.

The compositions of monazite and also of hematite were confirmed by the electron probe.

c-d Sample P1101/76 PS24629
MG91 at 621'6"
186·45 m

c. An irregular mass of uraninite (U) encloses or partly encloses a fragment of specular hematite (almost white). Similar hematite in later generatio the breccia shows overgrowths (or small fringes) of fine-grained, small hematite but the fragment enclosed by uraninite does not show this overgrowth. The matrix contains chlorite and quartz.

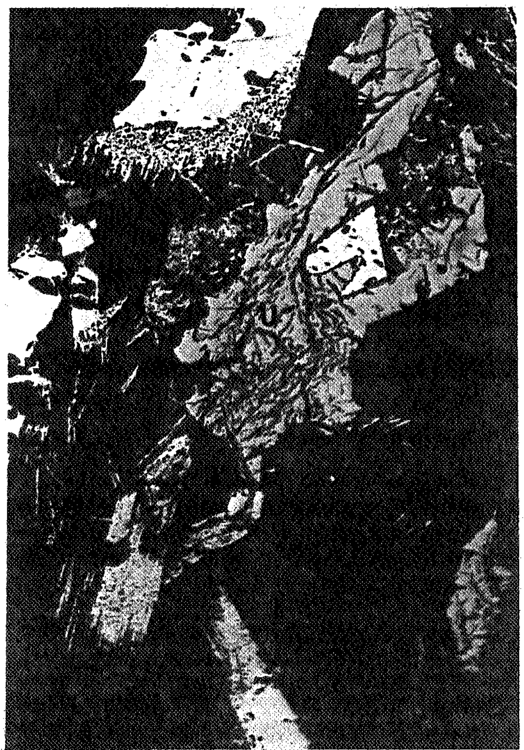
d. A porous, zoned crystal of uraninite surrounded by fine-grained (overgrowth) hematite which has crystallized after the uraninite.

The uraninitic crystal contains two polygonal, dark zones and a third similarly shaped zone which shows fine-grained hematite. When this crystal was analysed by the electron probe, the zoned areas were found to be uraninite but the three, included, polygonal zones were found to contain only iron oxide. No evidence could be found to suggest the origin or significance of these included zones of iron oxide within the uraninite crystal. They do not contain silicate or phosphate but it is possible that an earlier mineral was leached.

a. 1mm

b. 0·1mm

PLATE 11



c. 0·1mm

d. 0·1mm

Plate 12

a-b Sample P1118/76 TS35576
SR1 at 85'9"

a. Specular hematite (black) with a chloritic matrix. In this area some hematite has been corroded and is now replaced by chlorite which locally shows colloform and microspherular textures. Some small voids lined with colloform chlorite now contain clay and others contain late quartz.

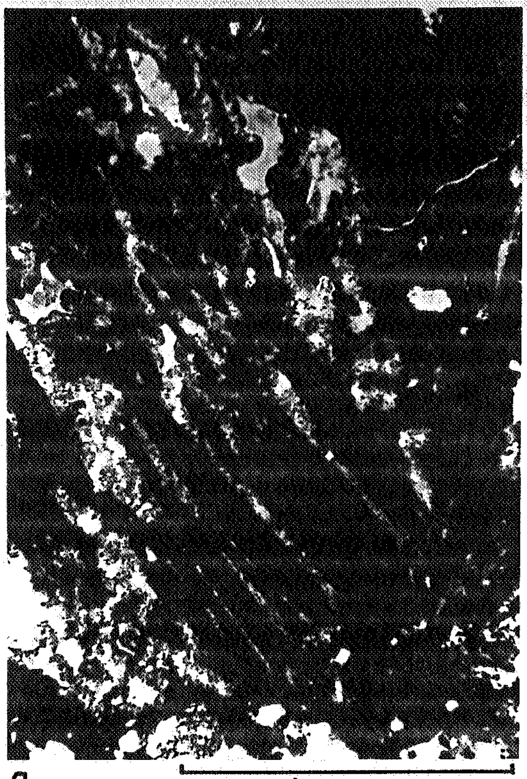
b. An irregularly shaped crystal or crystalline aggregate of pyrite (black) which has enclosed or partly enclosed some areas of matrix. These now contain colloform chlorite similar to that present in the matrix. It is possible, however, that the apparent inclusions (seen in the two-dimension section) are actually embayments.

c. Sample P1108/76 PS24633
MG66 at 220/6" - 221'4" (Silicified breccia)

Colloform pitchblende (grey) has accumulated against a deformed flake of molybdenite and has also penetrated along some cleavage planes in the molybdenite.

d. Sample P1068/76 PS24608
UEP8 at 19'0"
5.7m

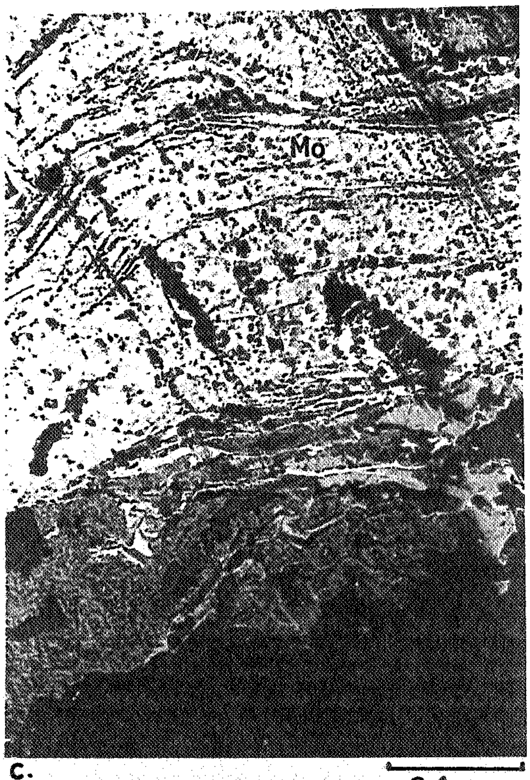
A crystal of partly altered uraninite (dark grey) is partly surrounded by specular hematite.



a.

b.

PLATE 12



c.

d.

Plate 13

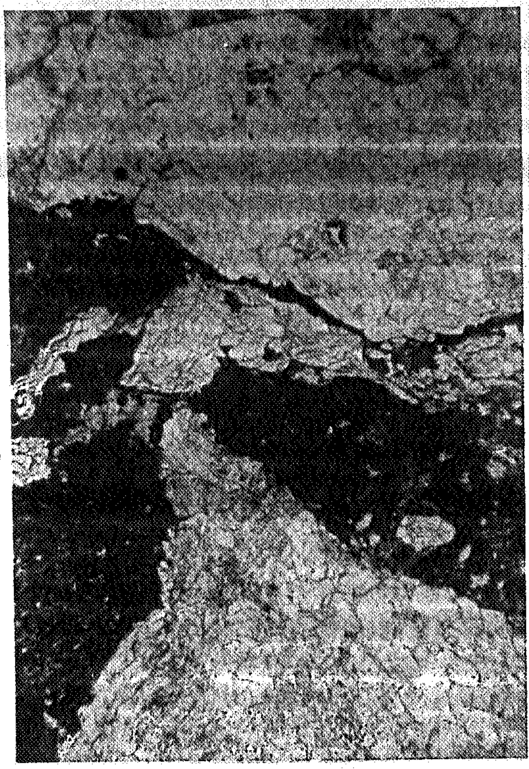
a-b Sample P1078/76 TS35546 Crossed nicols on right.
UEP17 at 163'

Brecciated granitic rock (tectonic breccia) in which some quartz has been granulated and recrystallized to a finer grain size.

The breccia has been invaded by chloritic material (grey) containing small fragments of hematite.

c-d Sample P1122/76 TS35579 Crossed nicols on right.
SR9 at 97'

Brecciated granitic rock invaded by chlorite and some iron oxide (black)



a. 1mm b.

PLATE 13

c. 1mm d.

Plate 14

a-b Sample P1111/76 TS35570 (a) has half crossed nicols.
AG8 at 93'10"

The matrix of this breccia is now composed mainly of very fine-grained vermiculite much of which occurs as thin layers of small crystals showing textures very similar to those of matrix chlorite in other samples (compare Plate 12) Much of this vermiculite is associated with very fine-grained (ochreous) iron oxide, some of which shows microspherular structures. Some vermiculite appears stained and partly replaced by ochreous iron oxide.

In (b) there is some late interstitial fluorite (F) in which purple staining shows cloudy dark patches.

The vermiculite in this specimen was identified by X-ray diffraction.

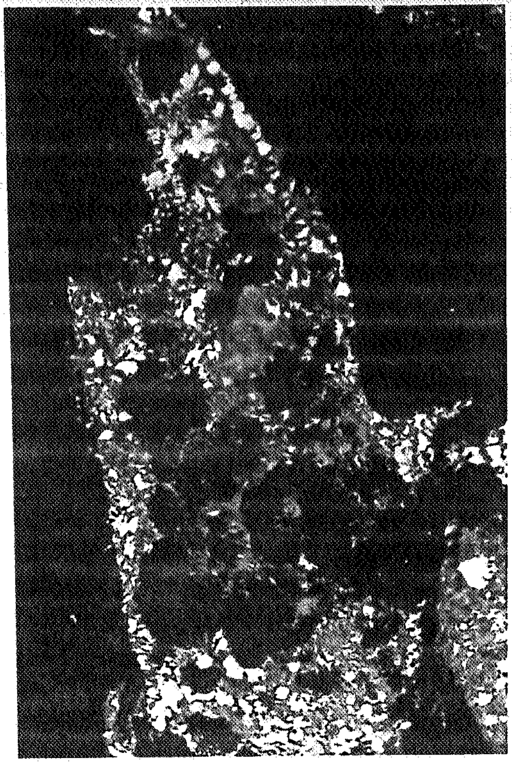
c. Sample P1118/76 TS~~35576~~ 35576
SR1 at 85'9"
25.73m

Chloritic matrix in breccia containing fragments of hematite (dark) and one of monazite (M).

A void lined by chlorite contains clay (almost white) and some later fluorite (darker outline)

d. Sample P1068/76 PS24608
UEP8 at 19'0"
5.7m

Some interstices in hematitic breccia contain irregular, porous masses of copper-bearing sulphides mainly chalcocite and covellite (mottled grey and white areas).

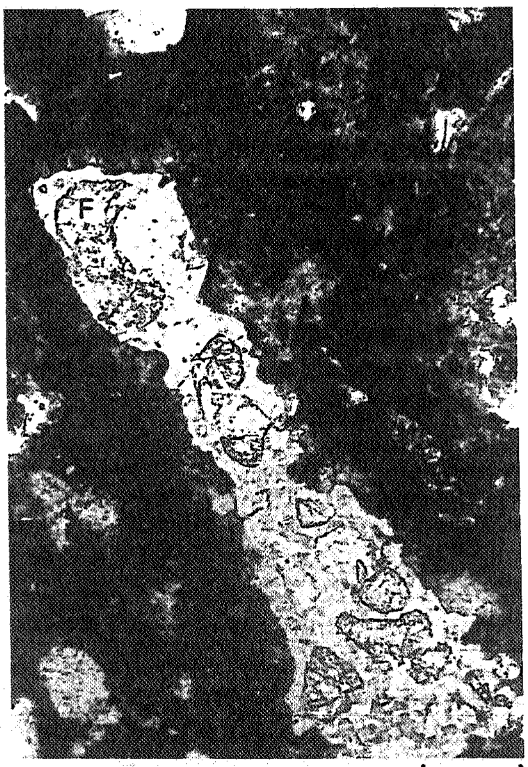


a.

b.

0·1mm

PLATE 14



c.

0·1mm

d.

0·1mm