CHAPTER 7

SULPHIDE MINERALISATION AT TELFER AND THE LATERAL STRATIGRAPHIC EQUIVALENTS OF THE CONCORDANT MINERALISATION

7.1 INTRODUCTION

Beneath the zone of weathering at Telfer the unoxidised protore of the MVR consists of an auriferous highly pyritic and commonly quartz-rich interval of siltstone. On the northeast flank of Main Dome several cores have been recovered from such mineralised units. The textures of these cores are critical to the understanding of the relationship between the mineralisation and the host sedimentary rocks, and are described in detail below.

In addition to gold-rich pyritic siltstone, the MVR horizon consists of other lithologies in some areas (section 6.2.1). For example, the pyritic but essentially non-auriferous interval in this stratigraphic position in borehole PR21 at West Dome (Fig. 6.3) is described below (section 7.3.1), as are the carbonate and "chert" plus carbonate intersections on either side of Main Dome (sections 7.3.2 and 7.3.3).

Other mineralisation at Telfer discussed below includes the massive pyritic intersection directly beneath the Rim Sandstone Member in borehole PR548 (section 7.4), and the various types of veins that occur throughout the upper Malu and Telfer Formations (section 7.5). The occurrence and morphology of gold is described under a separate heading (section 7.6), and the chapter concludes with a brief account of the possible origin of the ores. A more detailed discussion of the genesis of the mineralisation is given in Chapter 10, following an account of the geochemistry of the ores and host sediments (Chapter 9).

7.2 SULPHIDE MINERALISATION IN THE MIDDLE VALE REEF AT MAIN DOME

Gold-rich pyritic intersections of the MVR have been discovered only on the northeast flank of Main Dome, at depths between 91 m (PR450) and 227 m (PR268A) (Figs. 6.1 and 6.4). The thickest and best preserved intersections are from boreholes PR449, PR450, PR451, PR671 and PR673 (Fig. 6.1). Other intersections, such as PR268A consist of only sparsely pyritic siltstone. The MVR in PR449 and PR451 is illustrated in Plates 7.1 and 7.2. These two cores have been studied in detail geochemically (Chapter 9) as well as texturally and mineralogically.

7.2.1 MINERALOGY

The compositions of pyritic intersections of the MVR have been studied using thin sections, polished slabs and polished thin sections. In addition, the MVR in PR449 and PR451 have been divided into a number of lithological units (Plates 7.1 and 7.2), from which continuous samples have been taken for mineralogicial and chemical analysis. All of these samples have been scanned by X-ray diffraction (XRD) to give estimations of the modal compositions by the measurement of peak heights on the XRD traces. The X-ray method used is described in Appendix 2. Amounts of the main mineral constituents of the MVR in PR449 determined by this method are shown in Table 7.1.

Silicates

Quartz and kaolinite are the chief constituents of the least mineralised intervals in the MVR, with pyrite being the major component in the most highly mineralised intervals. Sericite is also abundant in some samples of mudstone (Table 7.1). Opaline silica has been detected by XRD scans in many of the intervals, including samples of the hangingwall siltstone. Feldspar occurs in small amounts in most samples, with plagioclase being more abundant than potash feldspar. In some samples of mudstone from beneath the MVR plagioclase is abundant (e.g. 10% in PR449-12, Table 7.1). These samples also have high Na_2O contents (Chapter 9), suggesting that the plagioclase is albite. Minor amounts of tourmaline (less than 1% in all samples) occur throughout the MVR. In thin sections the tourmaline is pleochroic from olive green to greenish blue, and is therefore the iron variety schorl.

Sample	Unit	Facies/ min. type	Quartz	Opal	Sericite	Kaolinite	Plagioclase	K-feldspar	Pyrite
449-1	MVS	S1	18	8	19	55	-	-	-
-2		S1	19	2	10	65	3	1	-
-3		A	42	-	Tr	4	2	-	52
-4		C	73	-	3	-	2	-	22
-5	MVR	D	58	2	14	12	Tr	Tr	14
-6		D	42	2	25	18	2	Tr	11
-7		C	87	1	Tr	4	3	-	5
-8		D	60	5	1	30	2	1	1
-9		D	51	5	2	38	2	1	1
-10	MVS	S1	66	11	1	16	4	2	-
-11		D	48	5	1	35	6	1	4
-12		D	56	4	1	26	10	1	2

Table 7.1. Approximate mineral compositions of the lower Middle Vale Siltstone (MVS) and Middle Vale Reef (MVR) in core PR449 (see Plate 7.1 and Table 9.3A). Other minerals each constitute less than 1% of the samples (see text).

Sulphides and Oxides

Pyrite is by far the most abundant sulphide mineral at Telfer, other sulphides comprising only about 1-2% of the total sulphide. Supergene chalcocite is common in slightly altered ore, commonly rimming pyrite, and chalcopyrite occurs as small inclusions in many pyrite grains. Rarely, bornite also occurs as small inclusions in pyrite. Partial oxidation of pyritic MVR intersections has commonly resulted in rims of goethite around pyrite grains. Oxides other than those of iron have not been recorded from the MVR, and there is no indication of primary oxide minerals, apart from a few very fine grains of detrital iron oxides in the host sediments.

Other minerals

Small crystals of carbonate occur locally in the pyritic MVR (section 7.2.2), but form a very minor component of the ore. Minor monazite has been reported by Whittle (1977) in a sample of the pyritic MVR in PR451 at a depth of 98.9 m, but the presence of this mineral has not been confirmed during the present study.

7.2.2 TEXTURES

In common with outcrops and oxidised cores of the MVR, the pyritic MVR has a very pronounced top which follows a bedding plane (e.g. Plates 7.1, 7.2 and 7.3D). The overlying siltstone is unmineralised, apart from sparsely disseminated sulphide grains and a few very thin veinlets (about 1 mm thick) of quartz and minor sulphide. The mudstone within the MVR is generally grey or bluish grey in colour, which contrasts with the lighter coloured sediments above and below the ore (e.g. Plate 7.1). This is a distinctive feature of the MVR, and assists in the identification of the unit in the more sparsely mineralised intersections (e.g. PR268A, Fig. 6.5). The lower boundary of the MVR is generally less pronounced than the top, and is taken as the base of the lowest highly mineralised layer. Patchy mineralisation and veins commonly occur beneath the MVR.

Several distinctive types of mineralisation occur within and beneath the MVR, which are classified as follows.

Type A - massive to crudely laminated granular* pyrite with intergranular quartz and kaolinitic mudstone

Type B - laminated granular pyritic mudstone with minor authigenic quartz

Type C - massive coarsely crystalline quartz with irregular patches of sulphide

Type D - veins of variable composition, and irregular patches and disseminations of sulphide

Gradations occur between these types of mineralisation, particularly between A and C, but typical examples are distinctive and represent different modes of ore formation. In all of these mineralisation types gold occurs dominantly within pyrite, microscopic inclusions of gold within the sulphide being common but not abundant (section 7.6). For this reason emphasis is placed on the occurrence and morphology of pyrite in the following discussions.

The upper part of the MVR generally consists of either type A or type B mineralisation, with type C being confined to the central or lower parts of the ore layer. The more irregular type D mineralisation occurs within the lower part of the MVR and as footwall mineralisation in the lowest part of the Middle Vale Siltstone and the upper Footwall Sandstone.

Type A mineralisation

Examples of this type of mineralisation include the top of the MVR in PR449 (interval 3, Plate 7.1), PR450 between 92.05 m and 92.30 m depth, and PR451 between 100.25 m and 100.30 m (the central part of interval 16, Plate 7.2). Oxidation of this type of mineralisation has produced the widespread massive iron oxide - quartz ore described in section 6.3 (e.g. Plates 6.1C and 6.1E). The lithology is dominated by granular pyrite, together with minor quartz, set in a matrix of

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*The term granular is used to distinguish accumulations of discrete anhedral pyrite grains from both discrete euhedral pyrite crystals, and larger areas of massive pyrite.

kaolinitic mudstone. A crude lamination occurs in places (Plate 7.1), with the pyrite grain size varying between layers (Plate 7.3A).

Most of the pyrite occurs as discrete or coalesced grains less than 1 mm in diameter, but some grains up to 2.5 mm across also occur. The grains have irrgular anhedral to subhedral outlines. They are often crudely rounded, and commonly have embayments and cracks infilled with the matrix material. Small irregularly shaped inclusions of non-sulphide minerals are common in the pyrite grains, and in some samples these are very abundant. These inclusions are up to about 0.6 mm across, and comprise quartz, kaolinitic mudstone and, more rarely, tourmaline. Other inclusions in pyrite consist of irregularly shaped blebs of chalcopyrite and very rarely bornite. Gold has not been detected optically by the writer in this type of pyrite, despite high assay values for both the whole rock and separated pyrite (see section 7.6 and Chapter 9).

Some patches of more massive pyrite occur as layers 1 cm or so thick. A cataclastic texture is present in some of these layers, with microfractures roughly parallel to the layering (Plate 7.3A). Similar but less pronounced deformation features occur in other layers of the MVR, with pyrite in places being cracked and infilled with quartz.

Quartz occurs in several forms in this type of mineralisation. It ranges from finely divided authigenic crystals (which are possibly recrystallised detrital quartz) in the kaolinitic mudstone patches, through crystalline interstitial quartz between pyrite grains, to patches up to about 1 cm across of coarsely crystalline quartz which contain very little sulphide (Plate 7.3B). Much of the quartz, particularly the more coarsely crystalline variety, is grey or milky white in hand specimens, and in thin sections is cloudy with numerous fluid inclusions (as in type C mineralisation below). Individual quartz crystals are roughly equidimensional, and the larger areas comprise interlocking anhedral crystals which generally have undulose extinction, probably due to straining during deformation. Some of the intergranular quartz occurs as short prismatic crystals, which are generally clear with few fluid inclusions, and have sharp to slightly undulose extinctions. In places this type of quartz occurs in pressure fringes adjacent to pyrite grains (as in type B mineralisation below).

The amount of included sedimentary material in this ore type is variable. In interval 3 of the MVR in PR449 (Plate 7.1) less than 10% of the rock is altered sediment, but in interval 16 of PR451 (Plate 7.2) this value is about 20%. Most of the sediment occurs as irregular grey patches a few millimetres across, and consists of finely divided authigenic quartz set in an apparently non-crystalline to extremely fine grained mass of almost isotropic clay mineral, which X-ray diffraction scans indicate is kaolinite. This is similar to the grey mudstone beds in the less mineralised lower parts of the MVR. Vermicular kaolinite is also present, occurring in colourless intergranular areas between pyrite grains.

Authigenic tourmaline (schorl) is common in small amounts in this pyritic ore, occurring mainly in the kaolinitic mudstone, but also being present in patches of quartz and as small inclusions in pyrite. In some patches of mudstone a few millimetres across small crystals of tourmaline are concentrated to form about 20% of the lithology (e.g. in PR450 at a depth of 92.25 m). The tourmaline occurs as randomly orientated subhedral prismatic crystals, generally 0.05 mm - 0.3 mm long. Other minor minerals include laths of white mica up to about 0.15 mm long, and a few crystals of grey carbonate up to about 1.5 mm long.

Type B mineralisation

The most distinctive feature of this type of mineralisation is the occurrence of granular pyrite in thin laminae within kaolinitic, and in places carbonaceous, mudstone. The upper part of the MVR in PR451 is an example of this type (intervals 4, 5 and 6, Plate 7.2), as is the top unit of the ore in PR671 (Plate 7.3D). An example of the oxidised equivalent of this laminated ore is the upper ore bed shown in Plate 6.2A.

The laminae of this ore type are of sedimentary origin, and as discussed in Chapter 10 most pyrite grains within the laminae are thought to be original constituents of the sediment. The tops of layers containing pyritic laminae are mostly very sharp (e.g. the top of the MVR in PR671 - Plate 7.3D), as are the bases in many instances (e.g. PR451 at 99.02 m - Plate 7.2). Cross lamination occurs in this ore type in PR671 (Plate 7.3D), with pyrite grains again being concentrated in particular cross-laminae.

Pyrite grains occurring in the planar- and cross-laminae mostly range from about 0.01 mm - 0.5 mm in diameter (Plates 7.3E and 7.3F), but a few anomalously large grains up to 2 mm across also occur. In laminae with particularly high concentrations of pyrite the grains are in contact, but more commonly individual grains are separated by the kaolinitic sediment. Most grains have rather rounded outlines with ragged edges (e.g. Plate 7.3F), but a few are subhedral. Fewer inclusions of the host sediment occur in pyrite from type B mineralisation than in type A, but small inclusions of chalcopyrite are common, and blebs of gold occur in a few pyrite grains (see Plates 7.7C and 7.8A). Not all of the opaque grains in the laminae are pyrite, some of the smaller grains being iron oxides. This may be due to incipient oxidation of this ore type, especially as some of the larger pyrite grains are rimmed with iron oxide.

The matrix of the pyritic laminae is similar to the unmineralised interbedded sediment, comprising dominantly kaolinite and very fine grained quartz. Sericite is locally abundant in some layers, and small patches and wisps of opaque carbonaceous material occur in many pyritic laminae. When present, sericite laths are foliated parallel to the bedding. Authigenic quartz is only a very minor component of this type of mineralisation, occurring as coarsely crystalline nodular patches up to about 1 cm across, and as small acicular crystals in pressure fringes around pyrite (Plate 7.3E). White haloes also surround some pyrite grains, and are composed of vermicular kaolinite, which also occurs as small irregular patches in the sediment matrix.

Small authigenic tourmaline crystals commonly occur dispersed throughout the laminated pyritic ore. These crystals are similar to those in the massive pyritic ore, but are generally of smaller size and are less abundant. A few colourless to grey rhombs and subhedral crystals of carbonate, up to 0.4 mm across, occur in some thin sections of the ore. For example, in the basal 1 mm of the laminated pyritic ore layer at a depth of 98.90 m in PR451 (Plate 7.2), patchy concentrations of such carbonate crystals occur, in which the carbonate comprises up to about 30% of the lamina.

In several thin sections of this ore type small scale geopetal structures occur, which may be the result of differential compaction during burial. In PR671 structures resembling load casts and a small flame structure occur beneath a lamina of siltstone which contains small (up to 2 mm) patches of authigenic quartz. The underlying pyritic lamina has apparently been squeezed upward into the flame structure (Plate 7.3D and Fig. 7.1). A somewhat similar structure occurs in PR451 (Plate 7.3E) where a pyritic lamina is bent over a nodular accumulation of quartz. In both cases the structures suggest that the pyritic laminae and the nodular patches of quartz formed part of the sediment prior to compaction.

Type C mineralisation

The massive quartz that dominates this type of mineralisation is commonly restricted to the lower part of the MVR (e.g. intervals 4 and 7 in PR449 - Plate 7.1; in the adit at the south end of Pit 1 - Fig. 6.7; and cores PR667, PR671 and PR673 - Figs. 6.1 and 6.5). In hand specimens it is milky white to pale grey in colour, and in thin sections it is dusty or cloudy due to the presence of abundant minute fluid inclusions and numerous discontinuous shear lamellae. The fluid inclusions are mostly between about 5 μm and 10 μm across. They commonly contain vapour bubbles, and some also include tiny transparent cubic crystals. The grain size of the quartz is variable, but is commonly very coarse, with individual grains reaching 1.5 cm in diameter (e.g. in PR450 at 91.93 m depth). The quartz grains are anhedral, with irregular interlocking outlines, and most have pronounced undulose extinction in thin sections.

Variable amounts of sulphide (or iron oxides in the weathered zone) are associated with the quartz. Some core intervals, such as

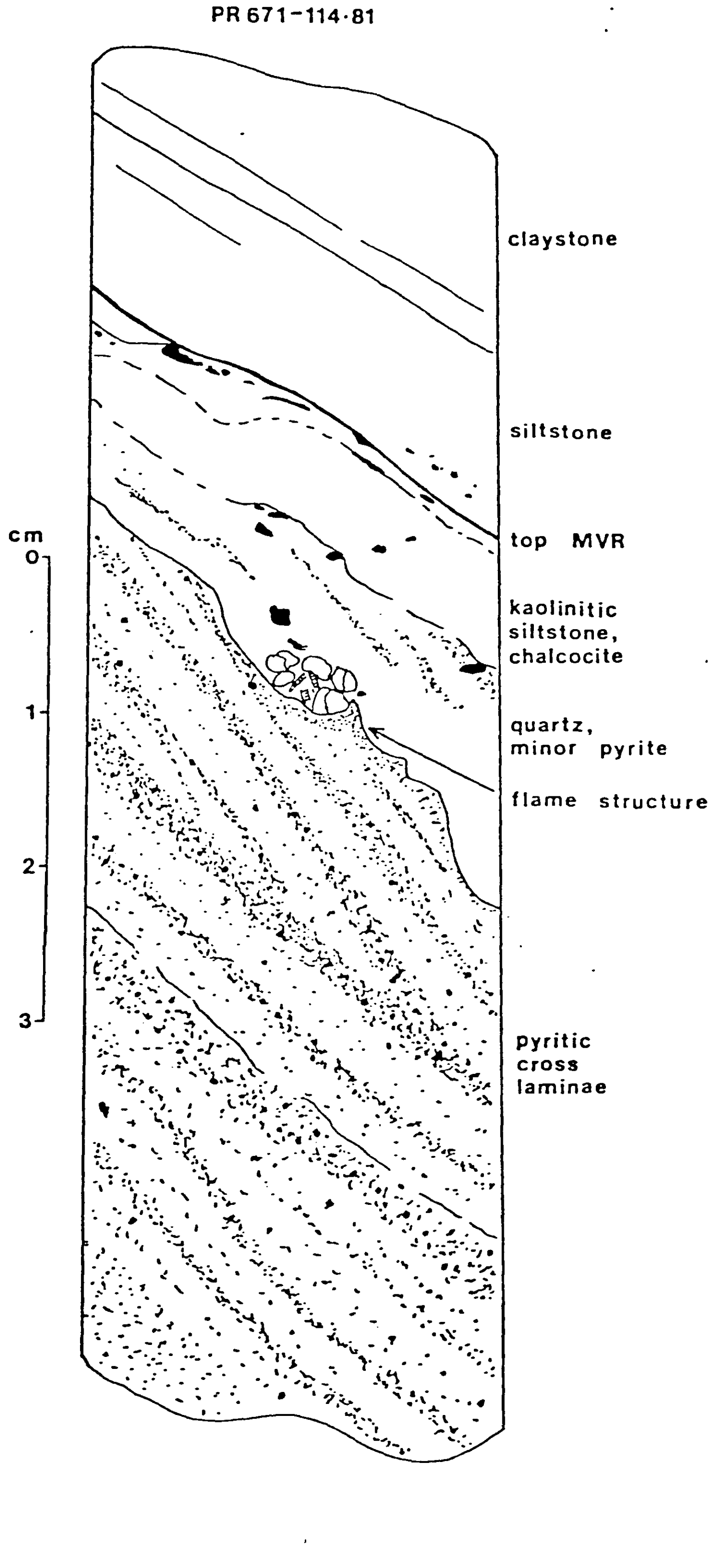


Figure 7.1 - Sketch of thin section projection of top of MVR in core PR 671 (see Fig. 6.5 and Plate 7.3D). Black specks represent pyrite grains (larger black areas at top of ore represent supergene chacocite), which occur in cross laminae. The top of the MVR is a pronounced bedding plane, overlain by unmineralised siltstone and claystone.

between 125.3 m and 126.0 m depth in PR667 and between 115.4 m and 115.65 m in PR671, are virtually 100% quartz, but in general irregular patches of pyrite and minor chalcocite form 10 - 20% of quartz-rich intervals (Plate 7.3C). The pyrite in this ore type differs from that in types A and B by being massive and non-granular. Very few crystal faces occur and pyrite - quartz boundaries tend to be irregular and ragged.

Quartz completely surrounds individual pyrite grains and the larger patches of pyrite, suggesting that the quartz formed at a slightly later stage than the pyrite. Chalcocite, and also iron oxides, occur mainly as very narrow (often less than 0.1 mm) stringers between the large quartz grains; these minerals are of supergene origin. Patches of white coarsely crystalline and highly strained carbonate occur between the large quartz grains in some thin sections (e.g. PR450 at 91.93 m depth).

The larger patches of pyrite (of the order of 1 - 2 cm across) are commonly very fractured, with the cracks invaded by a second generation of quartz. This type of quartz is the same as that occurring as acicular crystals in pressure fringes in types A and B mineralisation. In the type C mineralisation this quartz is generally fine grained, although some crystals up to 4 mm across locally occur. The quartz is very clear and generally has sharp extinction. It is quite distinct from the earlier formed large cloudy quartz crystals, and probably formed in voids during folding, when the earlier quartz was extensively strained and the pyrite was fractured.

Some of the massive coarse grained quartz has been highly fractured and partially recrystallised. For example, in core PR449 at a depth of 94.68 m a cataclastic texture is evidence in thin section, with highly strained and fractured coarse grained quartz cut by irregular shear zones a few millimetres wide, which are infilled with cryptocrystalline to fine grained quartz.

Where massive quartz is in contact with the kaolinitic sediment small inclusions of sediment in the quartz commonly occur. In places the grain size of the quartz decreases close to the contact, but more commonly very coarse grains of quartz protrude into the sediment, the contacts being sharp and jagged (e.g. the top of interval 7, Plate 7.1). Some layers a few centimetres thick are an intimate mixture of authigenic fine grained quartz and kaolinitic mudstone.

Type D mineralisation

This type of mineralisation is more variable texturally than the above three types, comprising veins and disseminated sulphides, but the unifying feature is the clearly secondary or epigenetic nature of the mineralisation. It most commonly occurs in the lower part of the MVR and in the footwall sediments (e.g. intervals 5,6,8,9,11 and 12 in PR449 - Plate 7.1).

In the cores examined, veins are commonly between 2 mm and 1 cm thick, but in pit outcrops of the Footwall Sandstone (Plate 6.1F) veins up to 40 cm thick occur. Many of the veins lie parallel to the bedding, but others cross-cut the strata at high angles (Plate 7.1). Most have sharply defined margins, and range from being parallel-sided to being more irregularly bulbous and discontinuous. The most abundant constituents are quartz, pyrite, vermicular kaolinite and amorphous pale brown opaline silica (e.g. in PR449 at a depth of 95.25 m, Plate 7.1). The latter constituent occurs along the margins of veins and as irregular patches intergrown with the other minerals. Minor tourmaline also occurs in some veins, as both small inclusions in pyrite and as larger crystals within quartz. Minor chalcocite commonly accompanies pyrite, and very minor chalcopyrite also occurs in places surrounded by chalcocite, or as small inclusions in pyrite. The chalcocite is probably a replacement product of chalcopyrite. The amounts of each constituent vary greatly between veins, some veins being virtually 100% pyrite, quartz or kaolinite, but other veins having an intimate mixture of several different minerals.

Many of the veins cut unmineralised kaolinitic sediment, but around some veins there are haloes of disseminated pyrite, and in places sparse irregular chalcocite blebs up to 2 mm across occur (e.g. in PR449 at a depth of 94.78 m - Plate 7.1). Disseminated euhedral to subhedral pyrite crystals up to 2 mm across, and smaller sparse irregular blebs of chalcocite, also occur within the MVR and footwall sediments in some intervals which are devoid of veins.

The sediments of the lowest part of the Middle Vale Siltstone Member, which are within intervals of this type of mineralisation, are extensively altered. The finest grained layers (claystone and fine siltstone) are pale grey, and in thin sections they consist of very fine grained quartz set in a matrix of extremely fine grained virtually isotropic kaolinite, with minor opaline silica and very minor sericite and feldspar (e.g. sample 449-10, Plate 7.1 and Table 7.1). The vermicular form of kaolinite does not occur in the matrix of the host sediments, being confined to veins and other small recrystallised patches.

In the upper Footwall Sandstone Member, beneath the sulphide/ quartz MVR, alteration of the sediment is less pronounced. Interstitial sericite occurs in places between detrital quartz grains, but authigenic carbonate, which is abundant in deeper cores of this member, has commonly been replaced by extremely fine grained clay mineral (e.g. in specimen PR449/97.05 m rhombic pseudomorphs, about 0.1 mm across, of ?kaolinite after carbonate occur). In some specimens of sandstone from this stratigraphic position little interstitial sericite or clay mineral occurs, the matrix of the detrital quartz grains being very fine grained quartz. This suggests partial silicification of the sandstones, possibly associated with the mineralisation (e.g. specimen PR449/97.40 m).

7.3 LATERAL STRATIGRAPHIC EQUIVALENTS OF THE MIDDLE VALE REEF AND THE E REEFS

As outlined in section 6.2.1 the stratigraphic position equivalent to the MVR, in areas other than the crestal part of Main Dome, includes several different lithologies. At West Dome a pyritic, but essentially non-auriferous, interval occurs in PR21; a carbonate unit occurs in boreholes WD29, PR548, PR549, PR518 and PR517A; and a "chert" plus carbonate interval occurs in PR263 and PR563A (Fig. 6.5). In the lower Outer Siltstone Member, carbonate units occur in the stratigraphic positions of the E Reefs in borehholes PR517A and PR518.

7.3.1 THE PYRITIC MVR IN PR21 (TYPE E MINERALISATION)

The pyritic unit 1.2 m thick which was cored at a depth of about 126 m in PR21 (Fig. 6.5) has been shown to occur in exactly the same stratigraphic position as the auriferous MVR at Main Dome (Fig. 6.3). The mineralisation in this interval is termed type E to distinguish it from the auriferous sulphide mineralisation. The unit (Plate 7.5) has the following characteristics in common with the pyritic MVR at Main Dome.

1. The hangingwall siltstone and claystone is only very sparsely mineralised with a few disseminated pyrite crystals.
2. The top of the pyritic unit is pronounced, being a conformable bedding plane.
3. The mineralisation is layered, with some beds of massive pyrite and other units of disseminated pyrite in the very fine grained sediment (Plate 7.4C).
4. The base of the unit is less sharply defined than the top, with common disseminations of pyrite and a few veins in the sediments beneath the main mineralisation.

However, several features of the MVR in PR21 differ significantly from the MVR at Main Dome. These can be listed as follows.

A. Whole rock assays and analyses of separated pyrite grains show very low gold values for the PR21 mineralisation (Fig. 6.3 and Chaper 9).
B. Very little authigenic quartz is associated with the pyrite, and no units of massive quartz occur.
C. Most pyrite grains have a well developed crystal form, many occurring as pyritohedra (Plate 7.4C).
D. No laminated mineralisation with granular pyrite occurs in PR21.
E. The sediments above, within and directly below the PR21 mineralisation are sericitic, there being only minor associated kaolinite or other clay minerals (Table 7.2).

Sample	Unit	Facies/ min. type	Quartz	Sericite	Kaolinite	Chlorite	Plagioclase	K-feldspar	Dolomite	Pyrite
21-1	MVS	S1	49	36	15	-	-	-	-	-
21-2		S1	47	45	7	-	-	-	-	1
21-3		E	42	36	2	-	-	-	-	20
21-4		E	26	9	1	5	-	-	-	59
21-5		E	34	14	6	-	-	-	-	46
21-6	MVR	E	30	16	2	6	-	-	-	46
21-7		E	44	23	7	-	-	-	-	26
21-8		E	42	45	4	-	1	-	-	8
21-9		E	25	18	-	6	1	-	-	50
21-10		S1	55	39	2	-	-	1	-	3
21-11	MVS	S1	44	39	-	-	-	-	16	1
21-12		S1	43	56	-	-	-	1	-	-

Table 7.2. Approximate mineral compositions of the Middle Vale Siltstone (MVS) and MVR equivalent unit in core PR21 (see Plate 7.5 and Table 9.3B).

The Middle Vale Siltstone directly overlying the MVR (unit 2 in Plate 7.5) comprises interbedded siltstone and claystone layers of Facies Sl (see Chapter 3). In thin sections these lithologies are seen to be dominated by detrital quartz and sericite (Table 7.2), but authigenic carbonate was originally also present, which has been leached during incipient weathering to leave numerous small voids, some of which have rhombic outlines. Authigenic quartz is also found in the sediments just above the pyritic interval, as rare crystalline patches up to about 1 mm across.

Within the MVR the sediment grain size is commonly equivalent to very fine grained sandstone, which may be the result of partial recrystallisation, as quartz grains commonly have interlocking boundaries. In addition to quartz and sericite, minor plagioclase and very minor authigenic tourmaline also occur.

In beds of disseminated pyrite, both within and beneath the MVR, the pyrite grains are commonly euhedral, although diffuse anhedral patches also occur. Most pyrite grains are less than 1 mm in diameter, but a few are as large as 4 mm. The pyrite occurs in two forms. Much is "spongy" with numerous small inclusions of the host sediment, but other grains are homgeneous and devoid of inclusions. Some of the larger pyrite grains are distinctly zoned, with cores of homogenous pyrite surrounded by spongy pyrite. In some spongy pyrite crystals the inclusions are discrete grains, mostly of quartz, but with minor sericite, plagioclase and rarely tourmaline. However, in other pyrite crystals the inclusions occur as irregular polycrystalline patches.

In layers of more massive pyrite the crystal size is generally larger than that of the disseminated grains (Plate 7.4C), being commonly between 1 mm and 6 mm. The pyrite crystals are generally euhedral to subhedral and form an interlocking mosaic with only small patches of included sediment. The individual crystals commonly contain numerous small inclusions of the host sediment similar to those described above. Small blebs of chalcopyrite rarely occur in pyrite from PR21, but no gold inclusions have been found.

Small patches, up to about 1 cm across, of coarsely crystalline authigenic quartz occur in the MVR, and finer grained authigenic quartz is common as acicular crystals, which radiate outwards from discrete euhedral pyrite crystals. These quartz crystals often occur as pressure fringes orientated parallel to cleavage in this host sediment (Plate 7.4D). In a few of these fringes sericite, and very rarely authigenic tourmaline, also occur. The associated cleavage is bent around euhedral pyrite crystals in some instances (Plate 7.4D).

Beneath the highly pyritic MVR the lowest Middle Vale Siltstone and the upper Footwall Sandstone also commonly contain euhedral disseminated pyrite crystals. These seldom exceed 1 mm in diameter and are mostly homogeneous. At a core depth of 130.32 m a 6 mm wide vein of quartz, pyrite, white mica and minor tourmaline occurs (Plate 7.4B). The quartz is coarse grained and clear, with sharp extinction. Pyrite and white mica tend to occur near the borders of the vein, and pyrite is also abundant as disseminations in siltstone on either side of the vein. Tourmaline occurs as subhedral laths up to 0.5 mm long in the quartz and as small inclusions in the pyrite.

7.3.2 THE CARBONATE EQUIVALENT OF THE MVR

The five thickest intersections of the carbonate that occurs in the same stratigraphic position as the MVR (WD29, PR548, PR549, PR517A and PR518 - Fig. 6.5) are all texturally similar, consisting of grey and dark grey limestone interbedded with greenish grey mudstone and very fine grained sandstone (Fig. 7.2 and Plate 7.4E). The true thicknesses of the carbonate intervals in the area between Main Dome and West Dome are 1.5 m in WD29, 1.9 m in PR549 and 2.1 m in PR548. In PR548 carbonate-rich layers occur in the top of the Footwall Sandstone in addition to the lower Middle Vale Siltstone, whereas carbonate is confined to the latter member in WD29 and PR549 (Fig. 6.5). On the northeast side of Main Dome the major carbonate unit is approximately 90 cm thick in both PR517A and PR518, but thin carbonate layers also occur above this unit in the former core (Fig. 6.5). Four of the cores (the exception being WD29) have been studied chemically (Chapter 9), and two of these (PR548 and PR518) have also been studied in thin section and by X-ray diffraction.

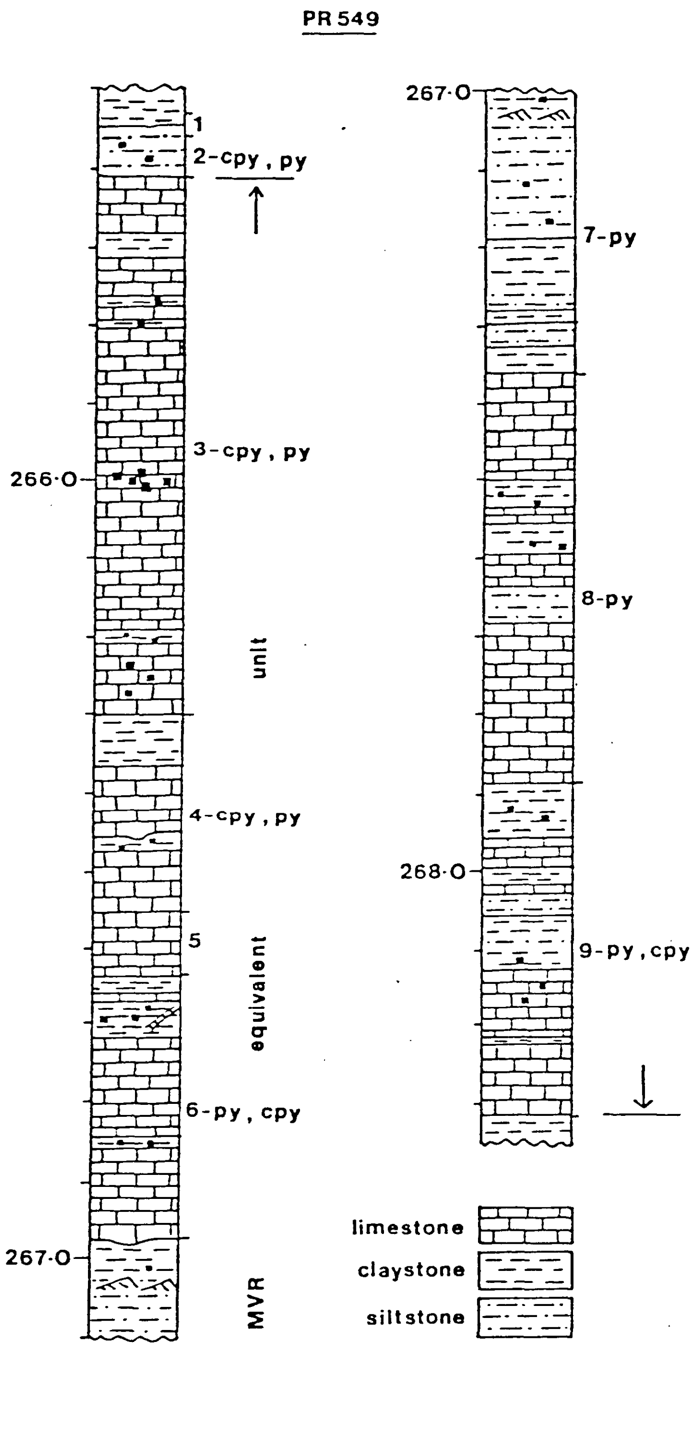


Figure 7.2 - The carbonate equivalent unit of the MVR in core PR549 (Fig. 6.5). Numbers at right represent analysed intervals (Chapter 9). Black squares represent disseminated mineralisation (py - pyrite; cpy - chalcopyrite) which is commonly aligned along faint cleavage. True thickness of the carbonate unit is 1.9 m.

Most of the carbonate beds within these intervals are sharply defined, with planar tops and bases, and range in thickness from about 2 cm to 35 cm. Internally the carbonate beds are commonly colour banded, with sharply discontinuous dark and lighter grey layers (Plate 7.4E). In the five thickest intersections (above) the carbonate beds react strongly with cold dilute hydrochloric acid, and are therefore composed of calcite. However, in core PR369 the carbonate does not react with this type of acid, and is probably dolomite. The intervening siltstone and claystone beds are similar to those of the Facies S1 lithologies, but also tend to have relatively high carbonate contents (e.g. sample 518-22, Table 3.6).

In thin sections most carbonate beds are strongly foliated due to the alignment of elongate calcite crystals, which are typically between about 0.1 mm and 0.3 mm long (Plate 7.6A). Very fine detrital grains of quartz are scattered throughout the carbonate beds, and sericite laths also occur (e.g. samples 548-3,4,5 and 6 - Table 3.5; and 518-20 and 21 - Table 3.6). Veinlets 1 mm - 2 mm wide of coarsely crystalline carbonate and very minor quartz occur in places. The vein margins are not sharply defined, and are composed of identical carbonate to the main lithology.

The paler grey carbonate bands (Plate 7.4E) are composed of uniform calcite crystals and minor quartz, but the darker grey bands include abundant grey carbonate crystals as well as the dominant colourless calcite. The darker carbonate crystals include tiny diffuse opaque patches, which also occur adjacent to sericite laths in these layers. The composition of these opaque patches is uncertain. However, their irregular diffuse nature suggests that they are carbonaceous material, similar to that occurring in distinct thin beds elsewhere in Facies S1 (see Chapter 3) and in some layers of the pyritic MVR. The manganese content of this dark grey carbonate is relatively high (Chapter 9), and this may also contribute to the dark colour.

Sparsely disseminated pyrite grains, generally less than 0.5 mm across, occur in some carbonate beds, and larger patches of pyrite a few millimetres across are also locally present. In PR549 minor chalcopyrite is also present. Disseminated sulphide grains are also common, although not abundant, in the less calcareous sediments beneath the carbonate-rich layers. Some of this pyrite is associated with small patches of coarsely crystalline authigenic quartz.

7.3.3 "CHERT" AND CARBONATE IN THE MVR STRATIGRAPHIC POSITION

Two drill cores from the lower Middle Vale Siltstone contain thin layers of extremely fine grained quartz (Plate 7.6B), interbedded with carbonate similar to that described above (Fig. 6.5). The grain size of the quartz (below) is greater than that of true chert (which is microcrystalline - e.g. Pettijohn, 1975, p.394). However, the quartz may well have formed by the recrystallisation of true chert, and it is therefore, termed "chert" to distinguish it from other forms of silica in the MVR stratigraphic position. Drill core PR563A, from the northeast side of Main Dome, intersected such a lithology at a depth of about 388 m (Fig. 6.5 and Plate 7.4F), and PR263 from the southwest side of the dome contains poorly preserved chert-like layers between 72 m and 73 m. Core logging indicates that these units are in the same stratigraphic position as the MVR (Fig. 6.5). No other units of "chert" have been recorded from sediments of the Malu and Telfer Formations.

<u>The MVR equivalent unit in PR563A</u>

The interval containing "chert" layers in PR563A occurs in the upper 20 cm of a sparsely mineralised unit 70 cm thick, the top of which is a sharply defined bedding plane (Plate 7.4F). Sericitic siltstone and claystone layers abruptly overlie this interval, which comprised dolomite and plagioclase-rich layers as well as laminae of the extremely fine grained "chert".

The top 5 cm of the unit (Plate 7.4F) is pale brownish grey and is thinly laminated, with even textured "chert" laminae 0.5 - 5 mm thick, and thicker coarser grained laminae of dolomite, quartz, plagioclase and very minor sericite. The "chert" consists dominantly of interlocking quartz and plagioclase crystals, which are mostly 0.01 - 0.05 mm across. Some layers are delicately laminated, due to the presence of tiny (<0.02 mm) colourless to green needle-like impurities, which are probably clay minerals. A few irregular tiny opaque patches also occur, which may be carbonaceous material. The grain size of the dolomite-rich laminae is variable, but most grains of carbonate, quartz and plagioclase fall in the range 0.05 - 0.1 mm. Extensive patches of relatively coarse grained authigenic carbonate occur in some of the "chert" layers, and discontinuous veins of very coarse grained carbonate and minor quartz cut both lithologies . Veins dominated by quartz tend to be restricted to the "chert" layers, whereas carbonate veins are thickest in the carbonate-rich layers, indicating a metamorphic origin for the veins.

The uppermost layer of the unit is underlain by a 4 cm thick layer of darker grey "chert" (Plate 7.4F). This is thinly laminated in a similar manner to that of the upper layer, but contains little carbonate. However, quartz and minor plagioclase veins occur, and the layer is cut by a 1 cm thick vein of very coarsely crystalline white dolomite.

Beneath this dark "chert" layer is a pale grey layer of intergrown quartz, dolomite and plagioclase crystals, which are mostly between 0.2 mm and 0.6 mm in diameter. Larger crystals of quartz and dolomite also occur however, and short veinlets of these minerals are present. The layer has irregular boundaries (Plate 7.4F) and may be essentially a replacement product of the original sediment. Another 6 cm thick layer of interlaminated "chert" and carbonate occurs beneath the plagioclase-rich layer, and the base of the "chert" unit is marked by a sharp bedding plane (Plate 7.4F). A few subhedral crystals of pyrite, up to 1 mm across, occur throughout the "chert" unit, and also in the sediment beneath.

7.3.4 THE CARBONATE EQUIVALENT OF THE E REEFS

Cores through the lower Outer Siltstone Member, beneath the limit of weathering, have been obtained from boreholes PR517A and PR518 on the northeast side of Main Dome, and from PR530 on the southwest side of the structure. In the first two cores carbonate units are found in approximately the same stratigraphic positions as the E Reefs.

In PR517A three intervals of the Outer Siltstone Member contain carbonate beds, which are probably equivalent to the E0, E1 and E2 reefs (section 6.2.2) farther up dip (Fig. 5.2). The tops of these intervals occur at 17.6 m, 34.5 m and 43.8 m above the top of the Rim Sandstone Member, and the units are 1.13 m, 2.88 m and 3.58 m thick respectively (Fig. 7.3). In PR518 the carbonate intervals are slightly thicker (2.83 m, 4.03 m and 4.48 m) and the tops of the units are at 19.2 m, 35.5 m and 44.7 m above the top of the Rim Sandstone Member. In all of these intervals carbonate beds up to about 80 cm thick are interbedded with non-calcareous to calcareous claystone, siltstone and minor fine grained sandstone beds, in a similar manner to the carbonate in the MVR stratigraphic equivalent position (section 7.3.2).

In thin sections the pure carbonate beds are texturally identical to the MVR carbonate (see Plate 7.6A), comprising foliated masses of interlocking carbonate crystals, mostly between 0.1 mm and 0.3 mm long, which form about 85% of the rock. Minor scattered detrital quartz and feldspar grains, and authigenic sericite, quartz and very minor sulphide also occur. Some of the beds are composed dominantly of calcite, and in other intervals dolomite is dominant (e.g. in Table 3.6, specimen 518-11 is a limestone from the E2 equivalent position, and specimen 518-12 is a dolomite from the E1 equivalent position). However, not all of the carbonate beds contain as much carbonate mineral, and beds with about 50% carbonate and 50% combined quartz, feldspar and sericite are also found. In the E1 equivalent position in PR517A several of the relatively non-calcareous interbeds between the carbonate layers contain very thin discontinuous wispy laminae of black carbonaceous material.

Sulphide minerals within the carbonate intervals consist mostly of sparsely disseminated subhedral to euhedral pyrite crystals. However, pyrite also occurs in small irregular patches and rare very thin discontinuous quartz and carbonate veins. Very minor chalcopyrite and sphalerite also occur locally in tiny veinlets and as disseminations (e.g. in specimen 518-12, see Chapter 9).

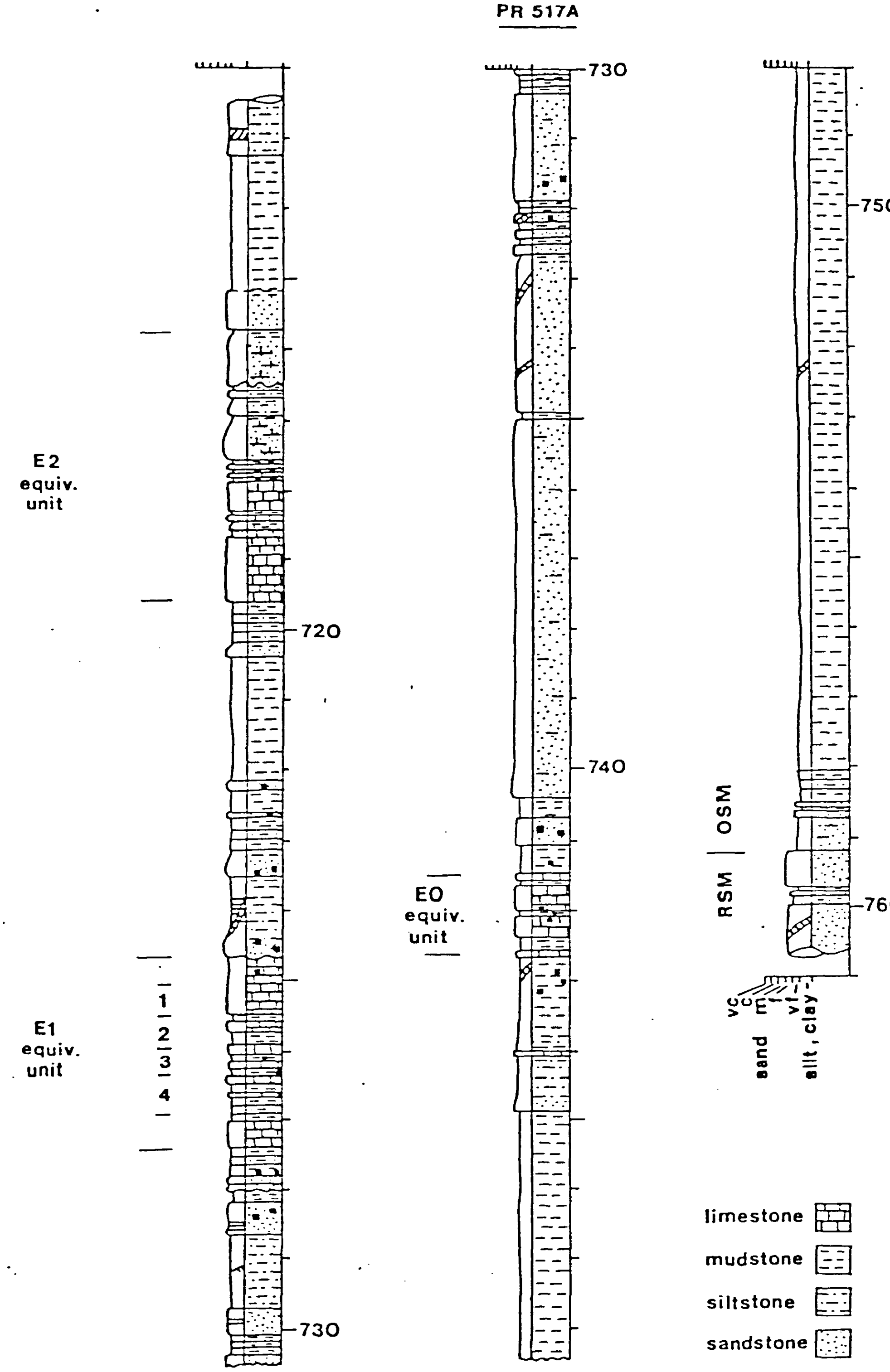


Figure 7.3 - Lower Outer Siltstone Member (OSM) in core PR517A (Fig. 6.1), showing position of calcareous units possibly equivalent to the E0, E1 and E2 reefs. Trace element analyses of samples 1 - 4 shown in Table 9.11. Symbols as on Figure 6.4.

In core from borehole PR530 (Fig. 6.1) no such carbonate beds occur, the sequence equivalent to the E Reefs comprising interbedded claystone, siltstone and very fine grained sandstone. This has important genetic implications, as it would appear that the carbonate units, like the concordant mineralised intervals, are of limited areal extent (see Chapter 10).

7.4 MINERALISATION DIRECTLY BENEATH THE RIM SANDSTONE MEMBER

7.4.1 THE PYRITIC UNIT IN PR548

The most highly mineralised interval directly below the Rim Sandstone Member is in borehole PR548 (Fig. 6.1) at a depth of about 145 m. Here, a 1.2 m thick unit of interbedded pyrite layers and subordinate thin beds and irregular patches of mudstone and sandstone occur (Fig. 7.4).

The top of the pyrite unit is sharply defined against medium grained sandstone of the Rim Sandstone Member, but a distinct bedding plane does not occur at the boundary. The contact is irregular in detail, and in thin section detrital quartz grains at the base of the sandstone bed have been partially replaced by pyrite. A few disseminated pyrite crystals occur in the sandstone above the boundary. The contact of these pyrite crystals with the detrital quartz grains is similar to that of the top of the pyrite unit with the overlying sandstone, with the quartz grains being terminated against the crystal facies of the pyrite.

The thin sediment layers included in the pyrite unit (Fig. 7.4) commonly contain disseminated pyrite, and bedding surfaces are cross cut by the more massive pyrite layers in several places. The base of the unit is as sharp as the top, and minor disseminated pyrite occurs in the sediment beneath the unit. However, no veins are found in the underlying lithologies.

Pyrite in individual pyritic layers ranges in texture from closely spaced discrete grains, mostly about 1 mm across, to virtually solid pyrite. Most commonly the pyrite forms a mesh of crystals which

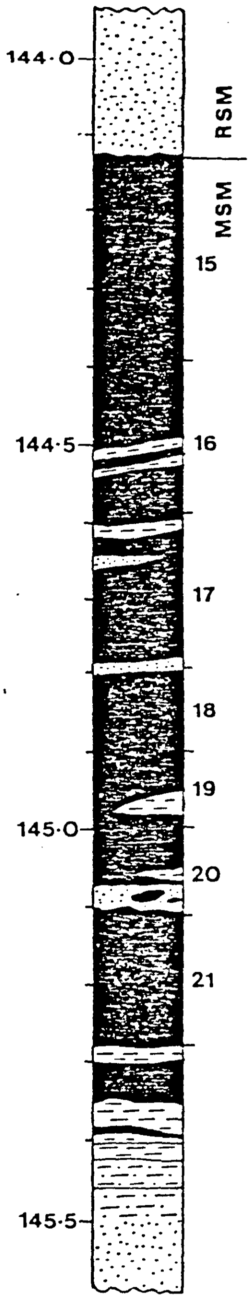


Figure 7.4 - The pyritic unit in the Median Sandstone Member (MSM) directly beneath the Rim Sandstone Member (RSM) in core PR548 (Fig.6.1). Core depths (left) are in metres; sample intervals (Chapter 9) on right. Black - massive pyrite; dashed - claystone; dash-dot - siltstone; stippled - sandstone).

are intergrown with a mosaic of clear authigenic quartz, acicular white mica, twinned plagioclase, extremely fine grained kaolinite and rare tourmaline (Plate 7.6C). Crude layering is present in some pyritic layers (Plate 7.4G) with individual pyrite crystals reaching 1 cm in diameter. Pyrite forms at least 80% of individual pyritic layers and is very pure, no inclusions of other sulphides or gold being seen microscopically in polished sections (see also Chapter 9 for chemical analyses of separated pyrite). Much of the pyrite is very "spongy", with abundant inclusions of quartz and plagioclase grains.

Some of the sediment interbeds, particularly near the base of the pyritic unit, are rich in small plagioclase crystals, which are intergrown with quartz to form an even-textured granular mass.

The included quartz and sericite within the pyritic layers are probably the result of recrystallisation of original sedimentary constituents, but the abundant plagioclase may be the result of metasomatic alteration of the sediments. There are no patches of coarsely crystalline authigenic quartz, as there are in the massive auriferous pyrite of the MVR type A mineralisation. The mineralisation in PR548 closely resembles the pyritic, but non-auriferous, intersection of the MVR in PR21, and can thus be classified as type E mineralisation. However, the crystal form of the pyrite is generally less well developed in PR548 than in PR21.

7.4.2 VEIN TYPE MINERALISATION BENEATH THE RIM SANDSTONE ON THE NORTHEAST SIDE OF MAIN DOME

Several of the deeper boreholes on the northeast side of Main Dome intersected carbonate-rich sediments of the Median Sandstone Member directly beneath the Rim Sandstone, in which irregular patches and veins of quartz, carbonate and sulphides occur (e.g. PR562, PR563A, PR564A and PR578 - Fig. 6.1). Some of the pyrite in these mineralised intervals contain inclusions of gold.

Such carbonate-rich units include siltstone (some of which is carbonaceous) and very fine grained sandstone, which is gradational to finely crystalline limestone. The intervals range in thickness from about 40 cm to 1.5 m. The irregularly shaped mineralised patches and veins are up to 10 cm across, and comprise coarse grained calcite or dolomite, quartz, minor plagioclase, white mica, pyrite and chalcopyrite. The sulphide minerals occur both as anhedral patches up to 1 cm or so across, and as fine grained disseminations in the sediments. Chalcopyrite is usually separate from pyrite, but some small inclusions of the former in the latter also occur. Gold blebs up to 0.25 mm across are present in some patches of pyrite (section 7.6).

In PR517A and PR518 (Fig. 6.1) similar carbonate-rich sediments occur in the same stratigraphic position. However, mineralisation in these intervals is slight, with patches of coarse grained carbonate, small nodular patches of quartz and sparse disseminated pyrite grains up to about 0.5 mm across.

7.5 VEINS IN THE MALU AND TELFER FORMATIONS

Veins associated with the MVR have been described already in section 7.2.2, and those occurring directly beneath the Rim Sandstone Member have been described in section 7.4.2. However, numerous other mineralised veins occur throughout the cored sequences of the Malu and Telfer Formations. Many veins found in the Telfer cores are composed solely of quartz, but sulphide and carbonate minerals are also common, and plagioclase is present in some veins. Most veins range in thickness from a few millimetres to about 2 cm, but a few are up to 10 cm thick.

The distribution of veins through the sedimentary sequence at Telfer is best seen in the long cores from boreholes PR397 in the centre of Main Dome, and PR517A and PR518 farther northeast (see Fig. 5.2). The intensity of veining is greater in PR397 than in the cores from the northeast side of the dome, the average spacing of sulphide-bearing veins in PR397 being about 5 m, whereas the average spacing of such veins in PR518 is about 25 m.

Pyrite is by far the most common sulphide mineral, and is ubiquitous in sulphide-bearing veins. However, other sulphides also occur, and there is a marked difference in composition between some of the veins found in the deeper cores on the northeast side of Main Dome, and those occurring in cores closer to the anticlinal crest and on the southwest side of the fold. In PR517A and PR518 chalcopyrite, galena (Plate 7.7A) and sphalerite are in places associated with pyrite, but elsewhere galena and sphalerite are absent, and chalcopyrite is only a minor component. In some carbonate-bearing veins the carbonate mineral is calcite, but in others it is ferroan dolomite or ankerite.

On textural grounds two main types of vein can be distinguished, one type being probably of pre-folding origin, and the other type probably being of post-folding origin, related to thermal metamorphism of the sediments (see Chapter 5, and below). Quartz and sulphides are the dominant minerals of the first type of veins, whereas carbonate and commonly plagioclase are prominent in addition to quartz and sulphides in the second vein type.

Two types of quartz are generally present in the first type of vein, as in the concordant mineralisation. Much of the quartz is very coarse grained, cloudy and commonly highly strained, but a second generation of quartz also occurs, which is generally finer grained, less cloudy and has sharp or only slightly undulose extinction. The strained quartz is in places associated with deformed sulphide minerals. For example, in core PR562A at a depth of 345.80 - .85m, medium grained sandstone of the Rim Sandstone Member is cut by an 8-10 mm thick vein of pyrite and quartz. The pyrite has a cataclastic texture, being broken into innumerable angular grains up to 2 mm across. Finely crystalline quartz occurs in the gaps between the pyrite fragments, and coarsely crystalline highly strained cloudy quartz occurs in larger patches. Pyrite bordering the vein commonly invades and partially replaces well rounded detrital quartz grains in the sandstone (in a similar manner to the top of the pyritic layer in PR548 - section 7.4.1). Microscopic inclusions of gold and chalcopyrite occur in some of the pyrite grains (section 7.6).

In the second type of veins abundant well twinned plagioclase crystals occur (e.g. in PR397 at 205.45 m depth). However, the veins are dominated by carbonate, with subordinate sulphides and generally very minor clear quartz. Muscovite is also present in a few of these veins. Plagioclase tends to rim the veins, and occurs as unstrained crystals up to 3 mm long which are commonly orientated at high angles to the vein margins. The centres of the veins comprise coarsely crystalline carbonate and irregular patches of sulphide, which enclose small areas of carbonate. Some of these veins lie parallel to the cleavage in claystone beds (e.g. PR397/189.4 m). Such veins are interpreted as being of post-tectonic metamorphic origin, probably related to the thermal metamorphic event which caused the formation of biotite to the northeast of Main Dome (Chapter 5). A metamorphic origin is supported by the lack of deformation of these veins, and also by the following observations.

In core PR397 at a depth of 246.60 m a medium grained feldspathic and carbonate-bearing sandstone bed overlies fine siltstone with a similar composition. Load casting has resulted in flame structures at the contact of the lithologies and the inclusion of a small patch of siltstone in the sandstone. Two veinlets 0.1 mm wide, comprising quartz, plagioclase and carbonate, cut the siltstone inclusion, but do not extend into the sandstone. These veins are interpreted as being due to in situ recrystallisation of the three main components of the sediments, and probably represent an incipient stage in the development of carbonate/plagioclase-rich veins. In core PR518 at a depth of about 345 m coarse grained aggregates of euhedral pyrite (up to 3 mm across), clear quartz, carbonate and thermal metamorphic biotite occur. This further suggests a genetic link between some of the mineralisation and thermal metamorphism.

The veins containing galena, sphalerite, chalcopyrite and pyrite are not common, only six being noted in over 500 m of core from PR518. Sphalerite is always accompanied by galena, but galena occurs in some veins without sphalerite. Most of the veins are of the carbonate-sulphide-quartz-plagioclase type (less plagioclase occurs in veins from the northeast side of the dome than in PR397), and are therefore suggested to be of metamorphic origin. However, in one example (PR518 at a depth of 520.05 m) galena and pyrite occur in a quartz vein devoid of carbonate and plagioclase, and some of the quartz is moderately strained. In this vein the galena occurs as discrete patches up to 2 mm across and as small inclusions in euhedral pyrite crystals. In other veins galena is also closely associated with pyrite, occurring as inclusions in some instances. However, spalerite forms irregularly shaped patches which commonly enclose the other three sulphide types (e.g. PR517A at a depth of 666.55 m). No gold has been found in any of the veins which contain spalerite and/or galena.

7.6 THE OCCURRENCE AND MORPHOLOGY OF GOLD AT TELFER

The average gold content of the mineable concordant mineralisation at Telfer is slightly less than 10 ppm (section 1.1). Assay values of individual samples are very variable, and values in excess of 100 ppm are common (e.g. Fig. 6.7) in the best developed sections of the ore. On average, however, the distribution of gold is remarkably constant compared with the patchy distribution of gold associated with many gold deposits. Figures 6.2 and 6.6 show that gold in both the MVR and the E Reefs is concentrated in particular areas and dies out laterally in a gradual manner. For both the MVR and the E Reefs the main concentration of gold occurs on the northeast side of Main Dome (Fig. 6.2). However, gold in the E Reefs is also concentrated in the West Reefs area and at the southern and northern ends of West Dome (Fig. 6.6).

The oxidised ores

The occurrence of gold in oxidised ore samples (i.e. iron oxide/quartz mineralisation) has been examined in some detail by Newmont, with particular regard to the practicalities of gold extraction. Slightly less than half of the gold from the oxidised ore is extracted by crushing and gravity settling processes, the remainder being recovered by cyanide leaching followed by precipitation of the gold (Tyrwhitt, 1979). Gold most commonly occurs in the ores as discrete particles associated with iron oxide boxworks after pyrite (Plate 7.7B). The particles rarely exceed 1 mm in dimension, and many are only visible microscopically, being as small as one or two microns in diameter.

Odekirk (1973) studied samples of surface gossans from both the MVR and the E Reefs, and deduced that visible gold was of supergene origin. The gold occurred in the following manners, 1) as filaments in cellular cavities of boxworks, 2) associated with goethite in ferruginised siltstone fragments, 3) associated with goethite in coarse grained quartz, 4) as tiny veinlets in late fractures that cut goethitic boxwork cell walls and quartz veins, and 5) as spherical gold particles ranging from 7 μm to 40 μm in diameter associated with limonite in siltstone (in a sample from the exposure shown in Plate 6.1B). Gold has also been observed by the writer in surface samples as discrete particles in massive quartz. In a single sample of gossan from the MVR Goode (1974) also reported small gold grains (between 3 μm and 10 μm in diameter) confined to areas of iron oxide boxworks.

In subsurface samples of oxidised ore, less variation in the nature of the gold has been reported, but this may be the result of less detailed study. Most gold still occurs as small particles associated with iron oxide boxworks. The degree to which gold has been mobilised in the oxidised zone is uncertain, but the nature of the gold in this zone suggests that much has undergone some solution and redeposition. In unoxidised mineralisation from the deeper levels at Telfer the gold occurs as small inclusions in pyrite (see below). Oxidation of such pyrite with no remobilisation of the gold would result in gold occurring <u>within</u> the cavities of iron oxide boxworks (as in the first type of gold recognised by Odekirk, above). However, gold occurrences at the rims of box structures may indicate transport and redeposition of gold along the margins of original pyrite grains. Other types of gold, such as the veinlets reported by Odekirk (op. cit.) are clearly of late supergene origin.

Some of the gold examined by Odekirk had a pronounced yellow colour, which suggested a high fineness (i.e. low silver content). In other gold deposits such a phenomenon has been attributed to leaching of silver from the gold during weathering (e.g. Chisholm, 1979, p. 67). However, Chisholm (op. cit.) reported a relatively high silver content of a gold sample from the oxidised zone at Telfer (11.58%), compared with a low silver content in a sample from the unoxidised zone (1.73%).

The degree of actual supergene enrichment of gold in the oxidised zone is also uncertain, but in the writer's opinion there is no evidence for extensive enrichment in this zone. Gold was doubtless originally present in both the MVR and the E Reefs over the crest of Main Dome prior to erosion, and as weathering and erosion proceeded some of the gold was very probably carried down dip within the pyritic layers. However, the detrital gold found in streams draining the MVR gossan (section 6.3.1) indicates that much gold was also mechanically removed from the original gold-bearing layers. The amount of such detrital gold was not examined in detail before mining began, and there are no data to indicate the amount of gold that may have been eroded. In addition, gold assays from pyritic ore, where the gold is locked in pyrite (see below), are of the same order of magnitude as assays from oxidised ore, suggesting little supergene enrichment. For example, similar gold values are found in the pyritic MVR of cores PR449, PR450 and PR451 as in the oxidised cores from the same level (Fig. 6.4).

The pyritic mineralisation

In the above descriptions of unoxidised mineralisation it has been noted several times that visible gold most commonly occurs as microscopic inclusions in pyrite. This has been pointed out in reports by Hausen (1974 and 1979) and has been confirmed during the present study. However, an exhaustive examination of the mode of occurrence of gold has not been attempted during this study, and occurrences described below are those noted from the examination of numerous polished sections of all types of unoxidised mineralisation.

In type B pyritic mineralisation from the MVR several pyritic grains have been found with inclusions of gold (e.g. Plates 7.7C, 7.8A and 7.8B). These inclusions are commonly accompanied by inclusions of chalcopyrite, which are more numerous and generally slightly larger than the gold inclusions. Both gold and chalcopyrite inclusions are irregularly shaped, ranging from roughly equidimensional blebs which have embayments filled with the enclosing pyrite (Plate 7.8B), to more smoothly sided elongate inclusions (Plate 7.8A). Gold blebs rarely exceed about 50 μm in diameter. In most cases the gold inclusions are surrounded by homogeneous pyrite, but in a few grains narrow cracks follow elongate inclusions. The formation of all the gold inclusions is thought to be coeval with the formation of pyrite, there being no evidence that gold has been emplaced into pyrite at a late stage along cracks.

Gold occurs in similar habits in pyrite from vein type mineralisation in the footwall of the MVR, in a few of the veins beneath the centre of Main Dome (in PR397), in veins beneath the Rim Sandstone (e.g. Plates 7.8C and 7.9A), and in other veins such as the deformed pyrite/quartz vein in the Rim Sandstone of PR562A (section 7.5 and Plate 7.9B). Larger gold blebs are found in some of these instances than in pyrite from the MVR; the largest gold inclusion noted is shown in Plate 7.9A and is approximately 0.21 mm long. A single instance of a gold inclusion in chalcopyrite has been noted by the writer, in a vein from the Rim Sandstone in PR517A at a depth of 760.55 m (Plate 7.9C). However, Hausen (1979) also recorded gold inclusions in chalcopyrite.

Despite its striking appearance gold is not commonly seen in polished sections, and in several sections from the massive pyrite of type A mineralisation no gold was seen despite careful microscopic examination. However, assays of separated pyrite from such intervals (Chapter 9) indicate that gold is present in quite high concentrations, suggesting that the gold occurs as submicroscopic particles, or in solid solution, in the pyrite.

There have been numerous investigations of the nature of gold in pyrite in other gold deposits (e.g. see Boyle, 1979, p.31), and both of the above mechanisms have been suggested to accommodate gold in pyrite. In Boyle's view the second mechanism is the most likely. For example, McPheat et al. (1969) demonstrated that 0.02 - 0.03 oz/ton (0.6 - 0.9 ppm) gold was in solid solution in pyrite from the Mt Morgan (Queensland) copper-gold deposit.

7.7 BRIEF INTERPRETATION OF THE TELFER GOLD DEPOSITS

There are a number of hypothetical origins for the Telfer stratiform gold deposit that can be suggested from the stratigraphical, sedimentological, structural and textural criteria described in the preceding chapters. Each of the hypotheses listed below is consistent with certain features of the mineralisation, but the most acceptable hypothesis is that which satisfactorily explains the most features of the ores.

Establishing the timing of mineralisation is of paramount importance to the deduction of the controls of mineralisation, and it is therefore important to identify the earliest recognisable features of the ores. In the list below, three epigenetic and three syngenetic possibilites are considered. If the ores were syngenetic with the sediments, then they will have suffered similar deformation and metamorphism to the Malu and Telfer Formations, and some of their primary features may well have been destroyed or modified. At the other extreme, if the ores were formed epigenetically late in the history of the fold belt (i.e. hypothesis 1) then they would probably have a more straightforward set of characteristics, having suffered little subsequent modification apart from weathering.

The hypothetical origins considered for the Telfer ores are -

1. The ores may have been formed by the epigenetic <u>replacement</u> of particular sedimentary beds in the folded sequence by ore solutions emanating from intruding granite.
2. The mineralisation might represent <u>saddle reefs</u> emplaced in anticlinal crests during or after the main period of deformation. A somewhat similar possibility is that the ores were emplaced along bedding plane shears.
3. <u>Replacement</u> of receptive beds may have taken place prior to or during early folding, the ore solutions being ascending hydrothermal fluids, perhaps associated with a deep-seated igneous source.
4. The stratiform pyritic layers might be <u>placer deposits</u>.
5. The ores might be syngenetic <u>chemical sediments</u>, i.e. sulphide iron formations, with gold being either a primary feature or a later addition.

6. The ores could represent essentially syngenetic deposits of submarine hydrothermal spring origin, with various modifications occurring during the later geological history.

All of these hypotheses are discussed in Chapter 10, where it is concluded that the evidence marginally favours a modified submarine hydrothermal spring origin. However, due to the presence of limestone beds down-dip from the stratiform ores, replacement of these beds prior to or in the early stages of folding cannot be entirely discounted. Further research and exploration drilling may be able to resolve this uncertainty (see Chapter 10). The remaining four possibilities can be rejected for a variety of reasons (Chapter 10).

PLATE 7.1 - MVR IN PR449

Core intersection of the pyritic MVR, within the Middle Vale Siltstone Member (MVSM). Note the sharp top of the ore, the crudely laminated granular pyritic mineralisation (type A - interval 3), the massive coarse grained quartz (type C mineralisation - intervals 4 and 7), and veins and disseminated mineralisation (type D) within and below the MVR. True thicknesses of intervals are about 0.75 x the vertical scale.

PR 449

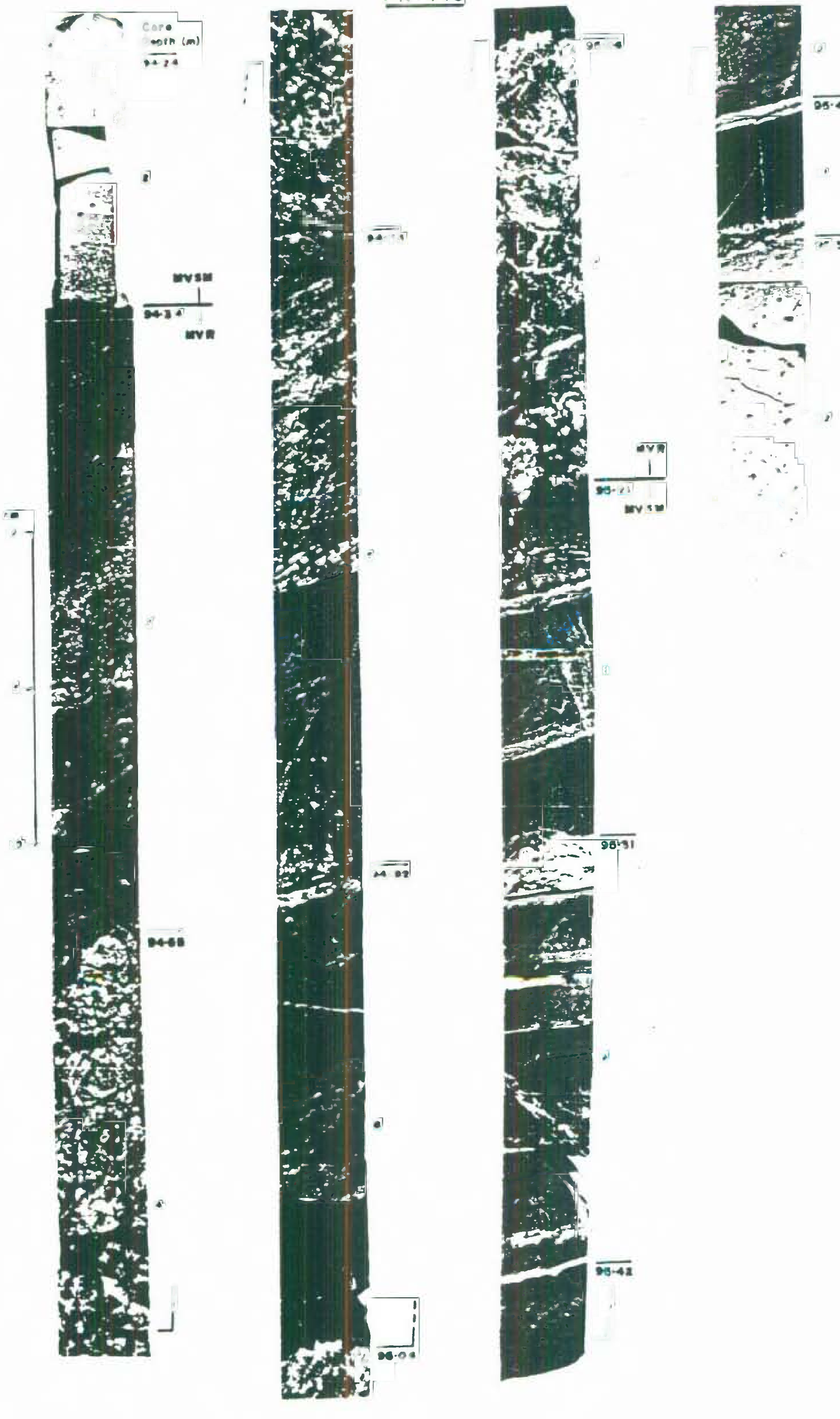
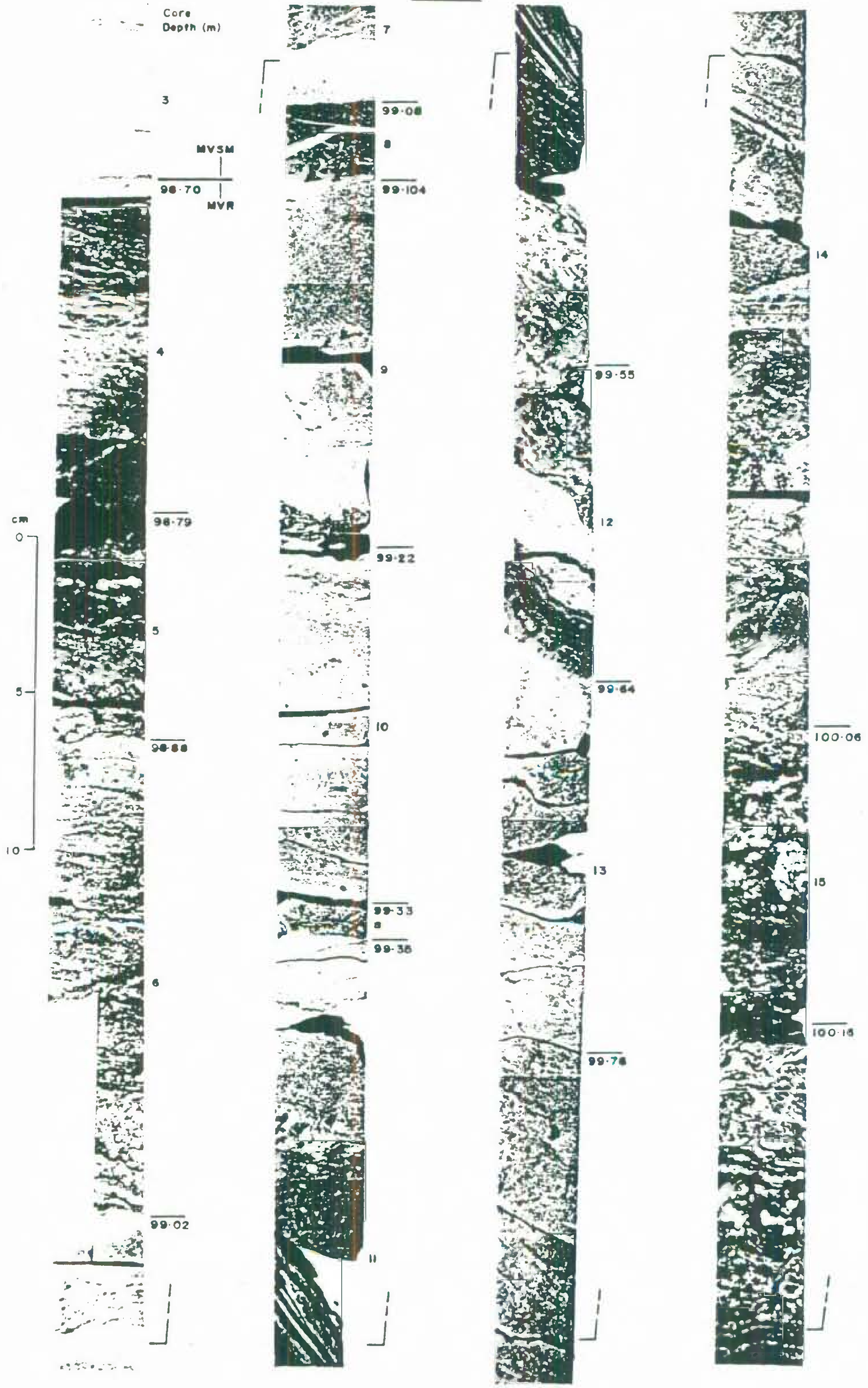


PLATE 7.2 - MVR IN PR451

Core intersection of relatively weakly mineralised pyritic MVR, overlain by unmineralised Middle Vale Siltstone Member (MVSM), and underlain by mineralised Footwall Sandstone Member (the top of which is the pale grey cross laminated sandstone bed in interval 17). Type A mineralisation is represented only by the central part of interval 16; intervals 4, 5, 6, 11 and 12 represent type B mineralisation; interval 15 is type C mineralisation; and disseminated mineralisation (pyritic plus minor chalcocite) in some other units is type D. The two thin beds termed interval 8 consist of slightly carbonaceous siltstone. Small faults in interval 17 are probably due to soft sediment deformation, as is the isolated mudstone clast in the upper part of interval 18. True thicknesses of intervals are about 0.7 x the vertical scale.

PR 451



Core
Depth (m)
3
MVSM
98·70
MVR
4
98·79
cm
0
5
10
5
98·88
6
99·02
7
99·08
8
99·104
9
99·22
10
99·33
8
99·38
11
99·55
12
99·64
13
99·76
14
100·06
15
100·16

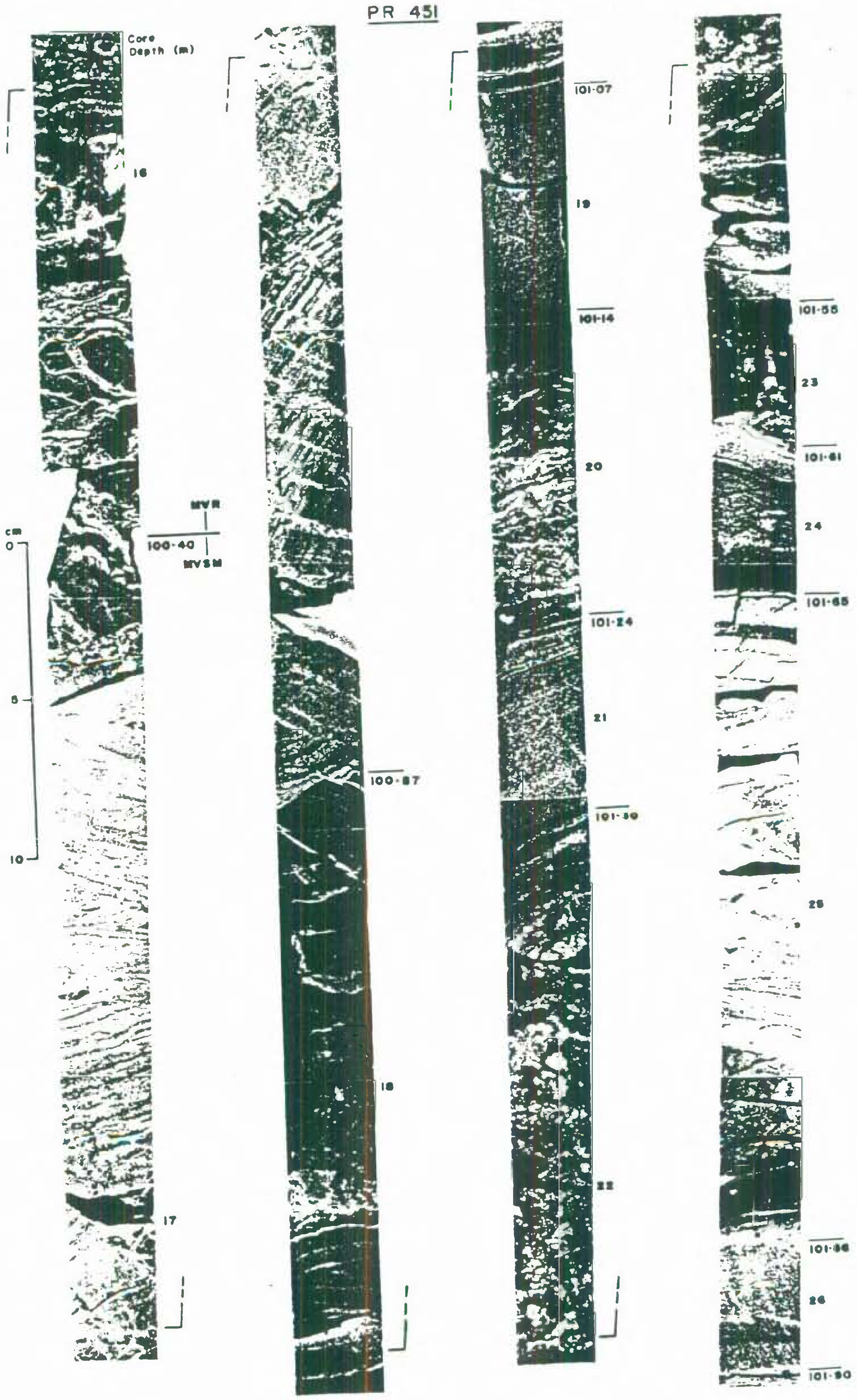

PR 451
Core Depth (m)
16
cm
0
5
10
MVR
100·40
MVSM
17
100·87
18
101·07
19
101·14
20
101·24
21
22
101·55
23
101·61
24
101·65
25
26

PLATE 7.3 - TEXTURAL FEATURES OF THE MVR

A. Type A mineralisation - polished slab of massive and granular pyrite (white) with small nodules of quartz (light grey). Note cataclastic texture of lowest pyrite layer. Interval 3, PR449, depth 94.47 - .52 m.

B. Type A mineralisation - thin section of granular pyrite (black) and intergranular quartz (white). Plane polarised light. Interval 3, PR449, depth 94.44 m.

C. Type C mineralisation - polished slab showing two mineralised layers separated by kaolinitic siltstone. Pyrite (bright grains) occur within milky white to grey quartz. Interval 15, PR451, depth 100.07 - .16 m.

D. Type B mineralisation - unpolished slab of pyritic MVR, showing sharp top of the ore, with overlying unmineralised siltstone, and finely granular pyrite and minor chalcocite in well developed laminae. Top 3 cm cross laminated. Small flame structure (arrowed) beneath quartzose layer (Fig. 7.1). PR671, depth 114.80 - .93.

E. Type B mineralisation - thin section of laminated pyritic MVR. Black grains are pyrite, grey areas are kaolinitic and sericitic siltstone, and white patches are quartz. Note pressure fringes parallel to bedding around pyrite grains, and differential compaction over nodular quartz. Plane polarised light. PR451, depth 99.50 m.

F. Type B mineralisation - same thin section as 7.3E. Note ragged rounded pyrite grains with adjacent pressure fringe. Top to left.

G. Type C mineralisation - polished slab showing patches of pyrite (white) within massive coarse grained grey quartz. Interval 4, PR449, depth 94.65 - .73.

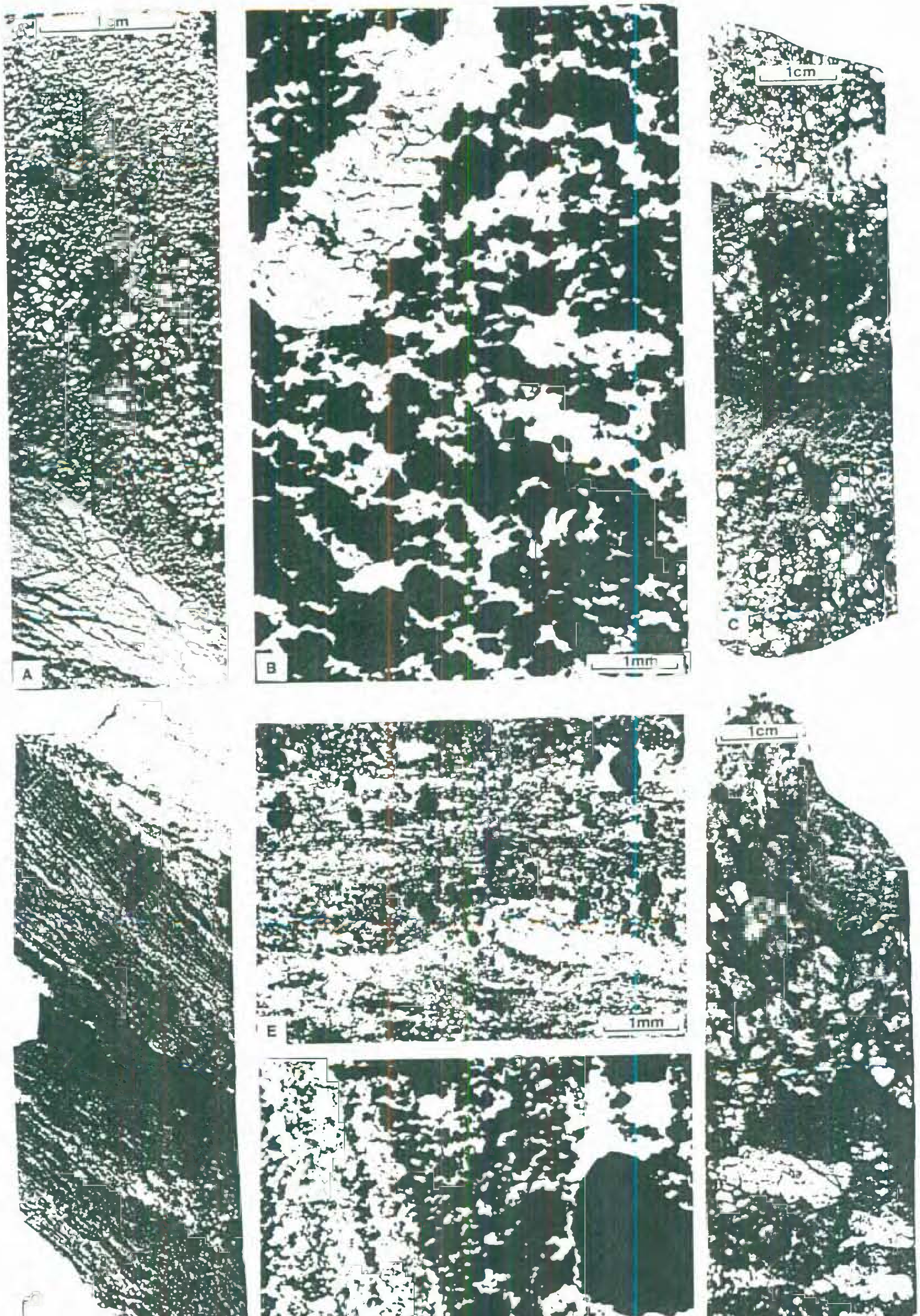

1cm
1mm
1cm
A
B
C
1cm
1mm
E
D
0·5 mm
G

PLATE 7.4 - MVR AND EQUIVALENT LITHOLOGIES,
AND SUB-RIM SANDSTONE PYRITIC LAYER

A. Type D mineralisation - thin section showing anhedral pyrite (black), enclosed in, and including, kaolinitic siltstone (grey). Plane polarised light. Interval 5, PR449, depth 94.78 m.

B. Thin section of euhedral pyrite (black), coarse grained quartz (white) and tourmaline (grey) in vein from Footwall Sandstone. Plane polarised light. PR21, West Dome, depth 130.32 m.

C. Type E mineralisation - polished slab showing pyrite (white) as large euhedral crystals and as fine disseminated grains in sericitic claystone (black). Interval 9, PR21, depth 126.27 - .39 m.

D. Type E mineralisation - thin section showing euhedral pyrite (black) in sericitic siltstone (upper half) and claystone (lower half) Note cleavage at low angle to bedding, and quartz (white) in pressure fringes around pyrite. Plane polarised light. PR21, depth 127.52 m.

E. Unpolished core through carbonate-rich MVR equivalent unit in PR548 (Fig. 6.5). Dark grey layers in intervals 3 to 6 are limestone; lighter grey areas are siltstone and claystone. Core depths in metres.

F. Unpolished split core through "chert"-rich MVR equivalent unit. Arrow marks top of unit; base is flat bedding plane 4 cm above bottom of photo. PR563A (Fig. 6.5), depth 388.32 - .55 m.

G. Unpolished core of massive pyritic mineralisation beneath Rim Sandstone Member. PR548, depth 144.47 - .58 m (Fig. 7.4).

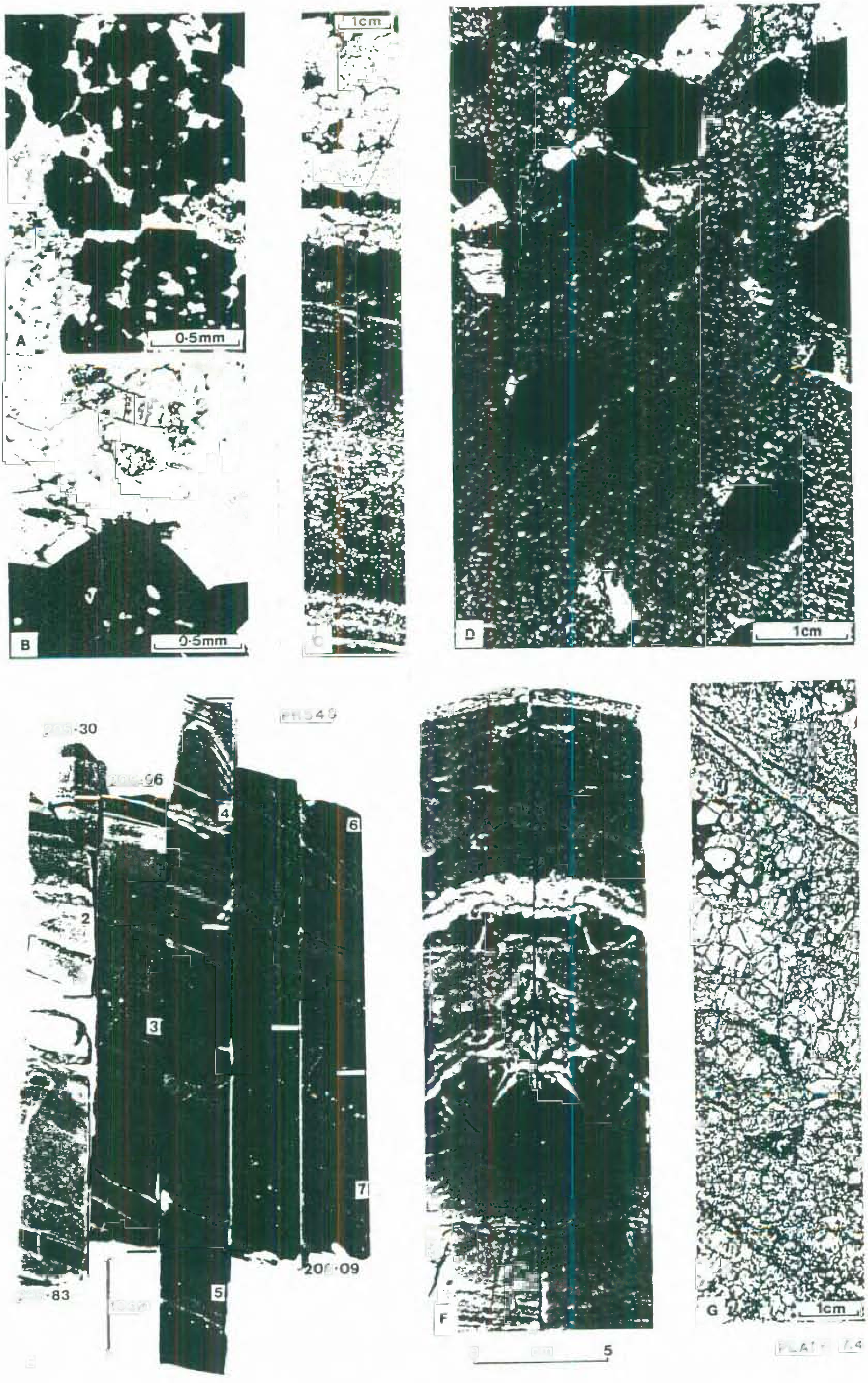


PLATE 7.4

PLATE 7.5 - MVR IN PR21

Core through pyritic interval in MVR stratigraphic position in PR21 from West Dome. Interval 2 is unmineralised Middle Vale Siltstone Member (MVSM); intervals 3 to 9 are the MVR - intervals 4, 5, 6 and 9 being the most pyritic; underlain by MVSM and Footwall Sandstone Member (FSM) with patches of disseminated pyrite. Core depths are same as actual depths.

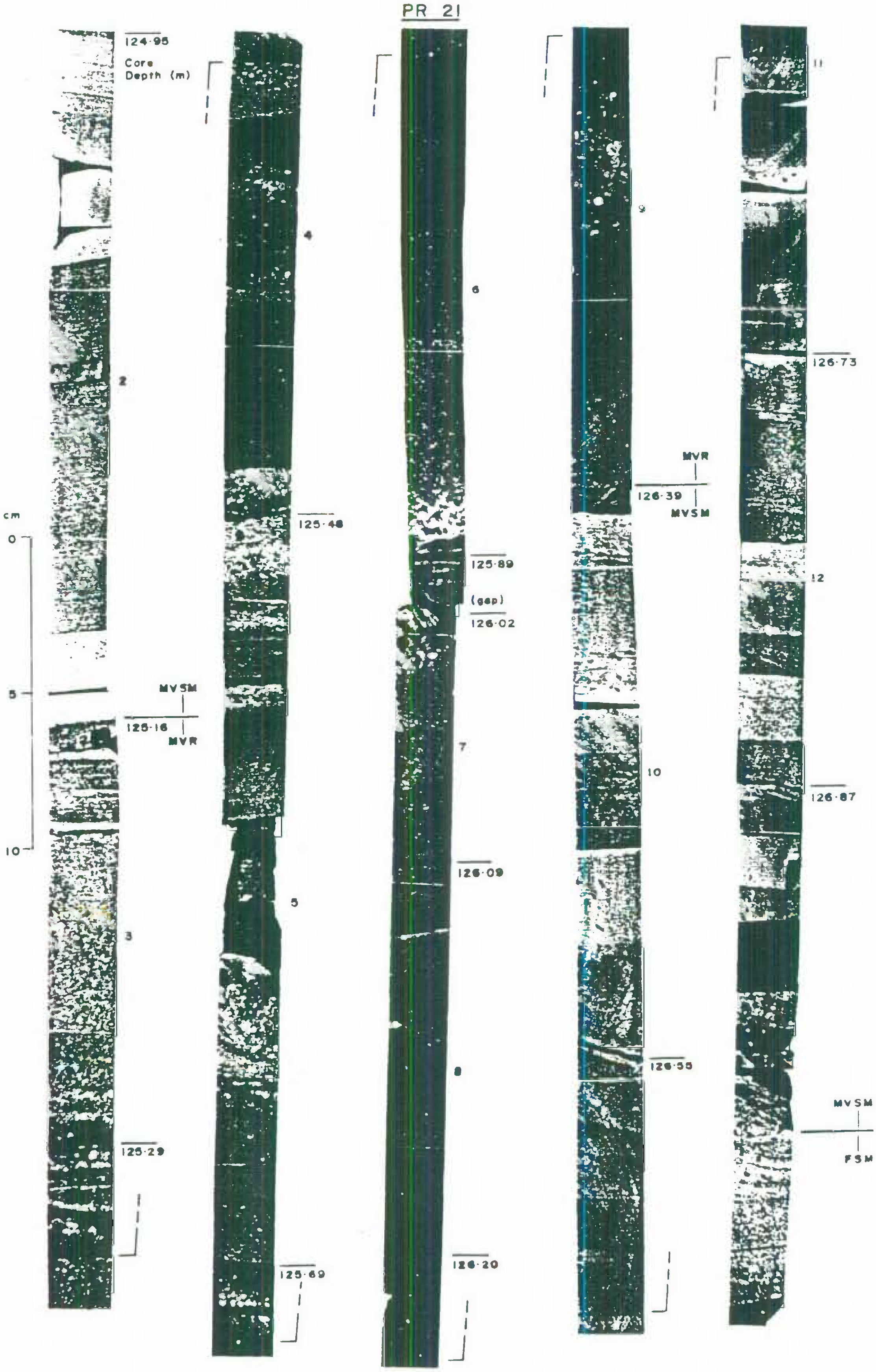

PR 21
124·95
Core Depth (m)
cm
0
5
10
2
MVSM
125·16
MVR
3
125·29
4
125·48
5
125·69
6
125·89
(gap)
126·02
7
126·09
8
126·20
9
MVR
126·39
MVSM
10
126·55
11
126·73
12
126·87
MVSM
FSM

PLATE 7.6 - COLOUR PHOTOMICROGRAPHS OF MVR EQUIVALENT UNIT AND SUB-RIM SANDSTONE MEMBER PYRITIC UNIT

A. Thin section of limestone in the MVR stratigraphic position. Isolated quartz grains (white) and small pyrite grains (black) in mass of aligned calcite crystals. Crossed polars. Field of view 0.9 mm. PR548 (Fig. 6.5), depth 206.59 m.

B. Thin section of "chert" (upper) and metamorphic quartz vein (lower) in the MVR stratigraphic unit, PR563A (Fig. 6.5), depth 388.1 m. Crossed polars. Field of view 0.9 mm.

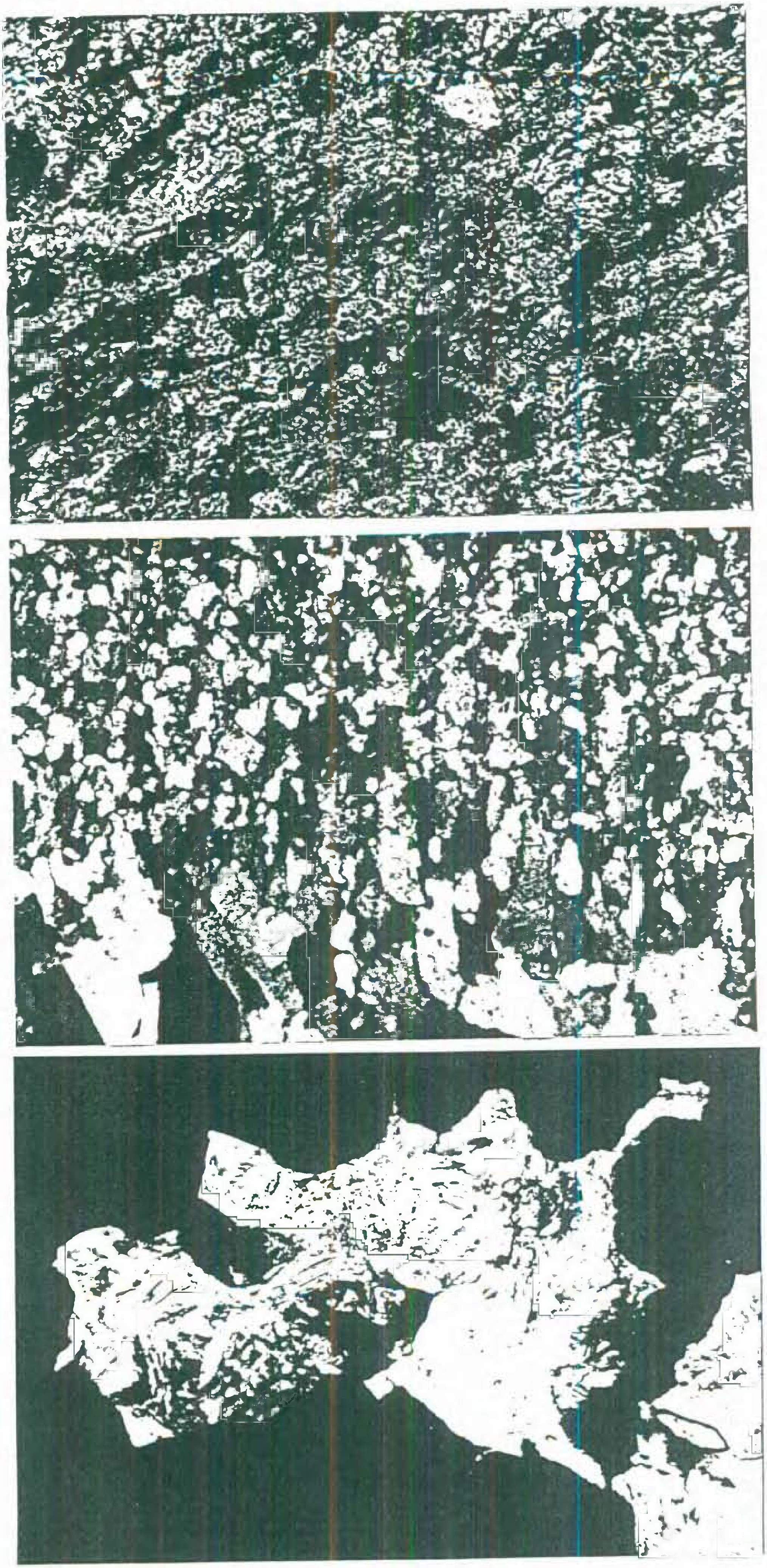
C. Thin section of pyrite (black) enclosing muscovite and quartz (recrystallised siltstone) in pyritic interval beneath Rim Sandstone Member from PR548, depth 144.15 m. Crossed polars. Field of view 0.9 mm.

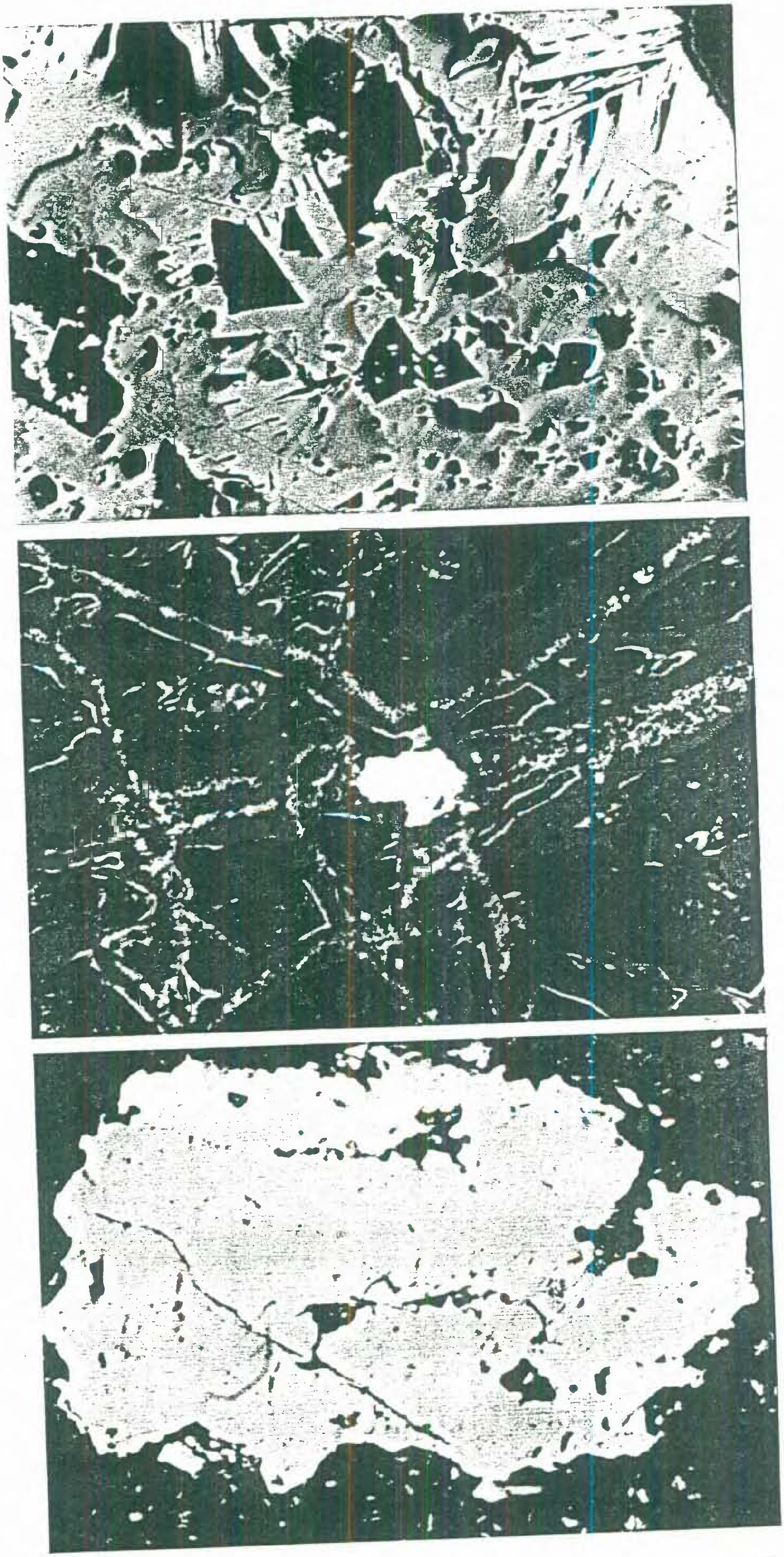
PLATE 7.7 - COLOUR PHOTOMICROGRAPHS OF VEIN MINERALISATION AND GOLD OCCURRENCES

A. Polished section of galena (light grey) intergrown with chalcopyrite (yellow) and quartz (dark grey) in vein from Median Sandstone Member, PR517A, depth 805.28 m. Field of view 0.9 mm.

B. Polished section of oxidised ore. Gold (yellow) in boxwork of iron oxides. PR598, depth 54.35 m (E2 Reef). Field of view 0.35 mm.

C. Polished section of pyrite from type B mineralisation in the MVR. Small irregularly shaped bright yellow inclusions to right and left of centre are gold. PR451, depth 99.5 m. Field of view 0.35 mm.





A

B

C

PLATE 7.8 - COLOUR PHOTOMICROGRAPHS OF GOLD OCCURRENCES

A. Polished section of pyrite grain from type B mineralisation in MVR. Irregularly shaped darker yellow inclusions are chalcopyrite, and small bright yellow inclusion just below centre is gold. PR671 (Fig. 6.5), depth 114.8 m. Field of view 0.35 mm.

B. Polished section of part of pyrite grain from type B mineralisation in MVR. Gold occurs as bright yellow inclusion in centre. PR667 (Fig.6.1), depth 125.15 m. Field of view 0.28 mm.

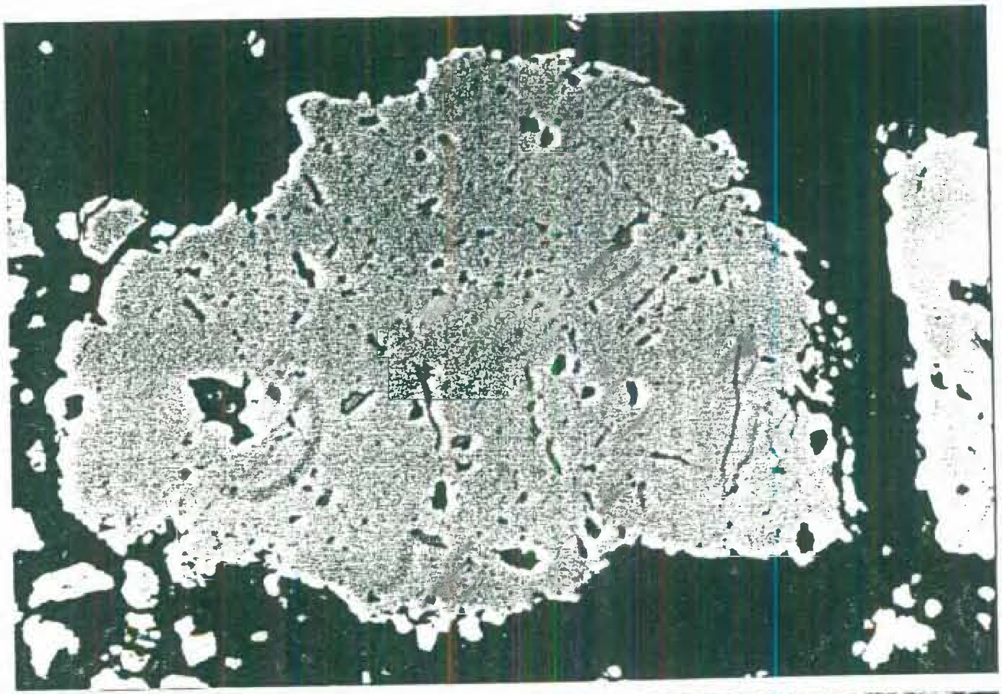
C. Polished section of pyrite (yellow) and quartz (grey) in vein from upper Median Sandstone Member. PR578 (Fig.6.1), depth 172.28 m. Field of view 0.9 mm.

PLATE 7.9 - COLOUR PHOTOMICROGRAPHS OF GOLD OCCURRENCES

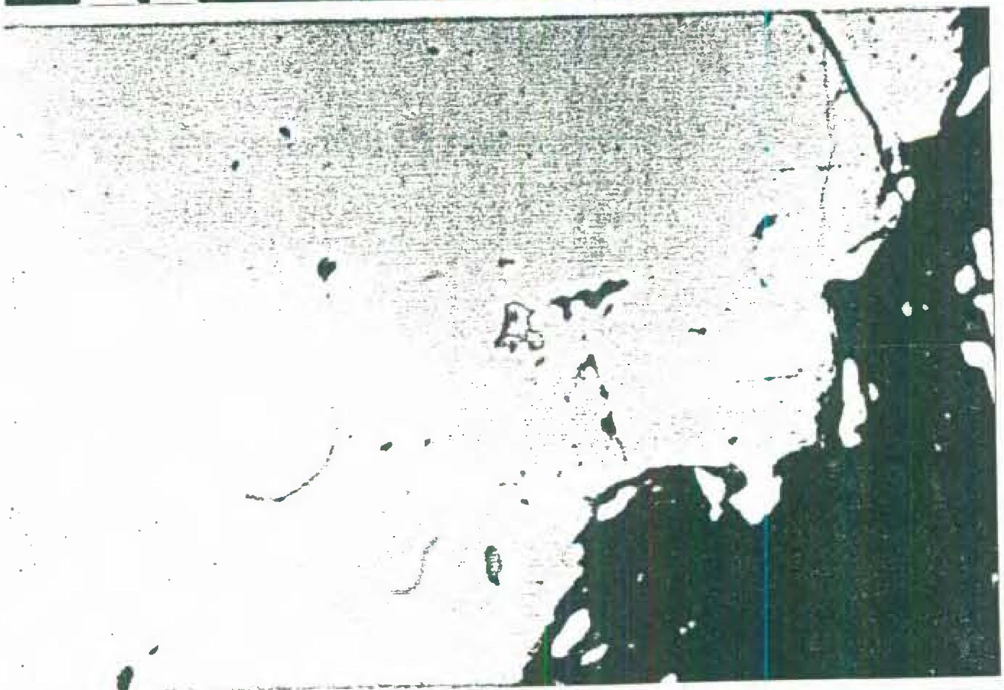
A. Polished section of pyrite (yellow), gold (bright yellow inclusions), chalcopyrite (dark yellow - top) and quartz (grey) in vein from upper Median Sandstone Member. PR578, depth 172.28 m. Field of view 0.9 mm.

B. Polished section of pyrite with bright yellow gold inclusions. PR562A (Fig.6.1), depth 345.5 m. Field of view 0.35 mm.

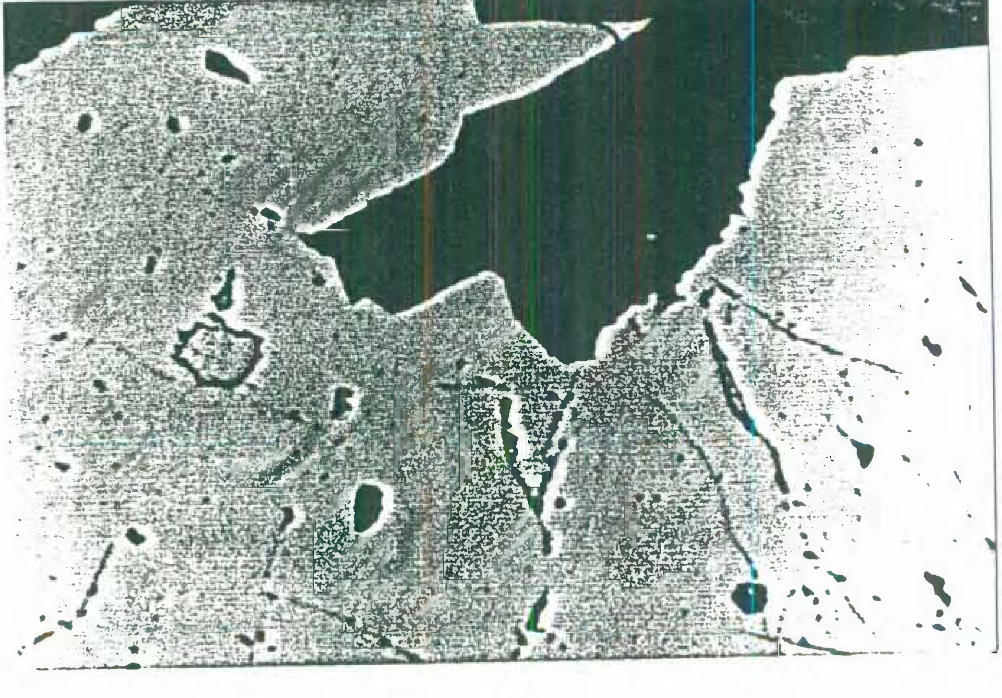
C. Polished section of pyrite, with dark yellow chalcopyrite inclusion, which encloses bright yellow gold (small patch in centre), in vein within Rim Sandstone Member. PR517A , depth 760.55 m. Field of view 0.57 mm.



A

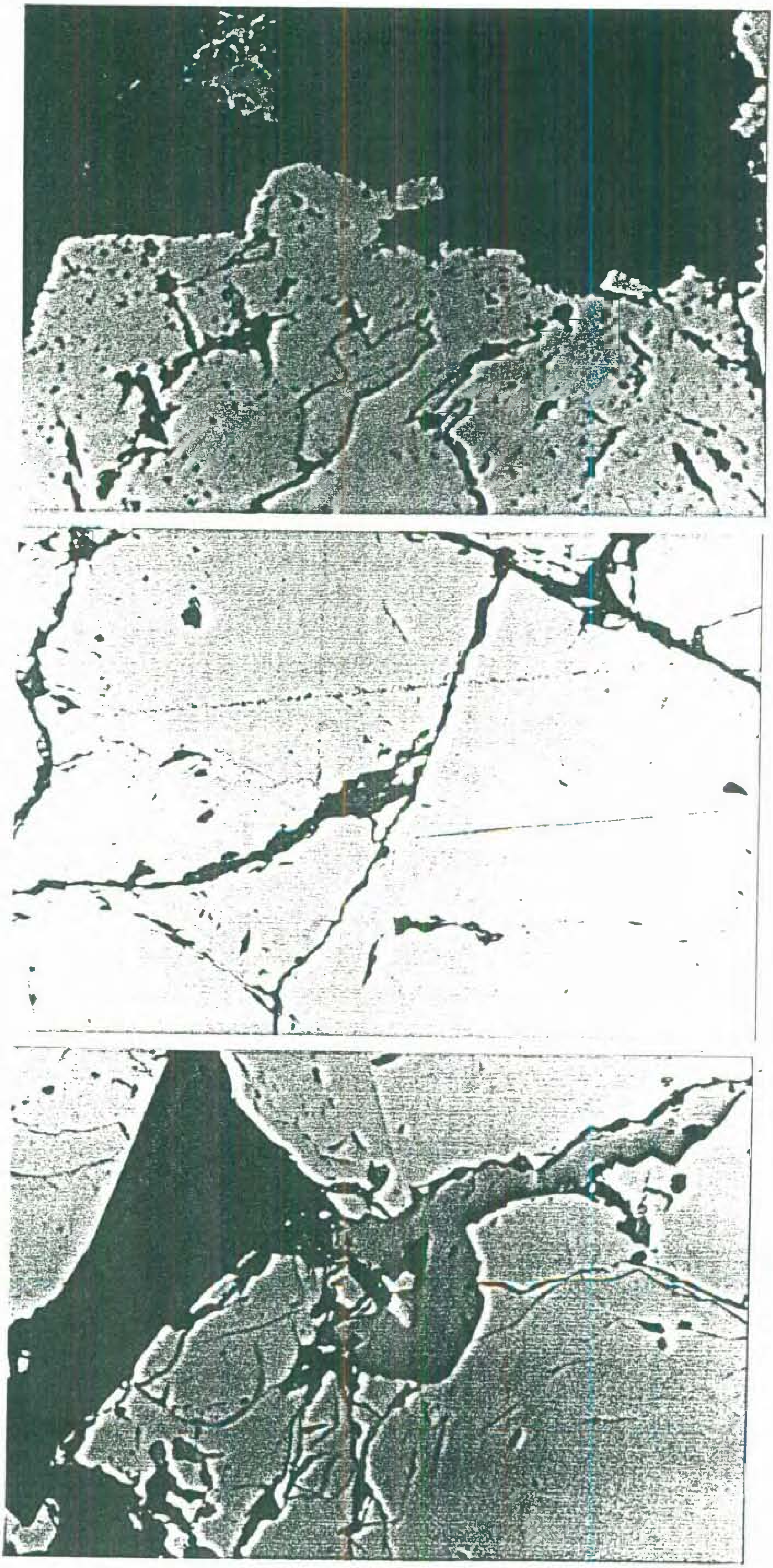


B



C

PLATE 7.8



A

B

C

PLATE 7.9

CHAPTER 8
MINERALISATION IN THE YENEENA GROUP BEYOND THE LIMITS OF THE TELFER MINERALISATION

8.1 INTRODUCTION

The Telfer gold ores are the only economic mineral deposits presently known in the Yeneena Group. However, at several other localities in the Isdell, Malu, Telfer and Puntapunta Formations in the Telfer region (Map 1), surface mineralisation in the form of gossan or massive quartz occurs. In some areas such mineralisation contains traces of gold. These mineral prospects are described briefly below to give a more complete picture of mineralisation in the Yeneena Group. The origins of the mineralisation are discussed in Chapter 10. These mineralised areas have been given informal names by Newmont, and have been explored for subsurface mineralisation by this company and by other companies.

In addition to mineral explorations in the Telfer region, other companies have explored the more northern outcrops of the Yeneena Group and also the Broadhurst Range area south of Telfer (Fig. 2.2). The first of these areas has not been visited by the writer, and details of any mineral occurrences are unknown. However, limited field work was carried out in the Broadhurst Range, and several occurrences of concordant iron formation were noted near the base of the Broadhurst Formation (section 2.3.2), which may have mineralisation potential. Surface samples of this iron formation, collected by the writer and N. Norris of Newmont, showed slight enrichment of Au, Cu, Zn, Pb and As compared with data from the enclosing shales (see Chapter 9), but no significantly high metal values were found. Any other mineral occurrences in this area, and also the results of company exploration here, are unknown to the writer.

The following descriptions of mineralisation in the Telfer region are based on observations made by the writer during field work, together with limited Newmont data. Core samples from some of the mineral prospects have also been examined, and a few of these have been partially chemically analysed for comparison with the Telfer geochemical data (Chapter 9).

8.2 MINERALISATION IN THE ISDELL FORMATION

8.2.1 COPPER AND PYRITE MINERALISATION

In the Isdell Formation to the south of the Karakutikati Range (Fig. 3.1) there are several localities of surface copper mineralisation (Map 1). At each of these localities the mineralisation consists of areas of dark brown to black ferruginous, and in places, copper-rich, gossan, together with patches of green malachite. Unlike much of the gossan at Telfer these copper-bearing gossans are generally not conformable with the bedding, and occur as fracture fillings and irregular patches between fragments in dolomitic breccias (Plate 8.1A).

The largest gossan extends for a distance of about 250 m along the hinge zone of a major isoclinal anticline (locality Cu 1, Map 1), and is up to 10 m wide (Sargeant, 1973). Other patches of gossan are more irregular in outline, and occur over areas about 50 m in diameter, individual patches being of the order of 2 m by 0.5 m across. Two of these areas are also close to the hinge zone of the anticline, and another (Cu 2, Map 1) lies adjacent to a northeast - southwest trending fault zone.

The gossans consist of iron oxides (goethite pseudomorphs after pyrite being common), copper oxides, malachite and minor copper sulphides, which are commonly associated with coarsely crystalline dolomite or calcite and finely crystalline quartz. At locality Cu 2 small amounts of relict chalcopyrite and covellite were found in surface samples by Hausen (1973), who suggested that chalcopyrite was the dominant primary copper mineral at this locality. Copper values of up to 30% were recorded from these gossan samples by Hausen, but other samples from the same locality had an average value of less than 1% (Sargeant, op. cit.).

Trace gold values (less than 1 ppm) occur in some gossan samples from these areas, and Sargeant recorded gold contents of up to 15.6 ppm in gossan from locality Cu 1. Pyritic mineralisation in drill core from this locality is described below.

Drill core PL18

This borehole was drilled at locality Cu 1 (Map 1) at an angle of 45° beneath the surface gossan (Fig. 8.1). It reached a drilled depth of 280 m (total vertical depth of 225 m), and intersected the axial plane of the isoclinal anticline, which dips steeply to the northeast. Pyritic mineralisation, accompanied by minor arsenopyrite, occurs in two main intervals, between about 199 m and 216 m, and between 246 m and 248m, on either side of the postulated axis of the anticline (Fig. 8.1).

In the lower mineralised zone minor chalcopyrite occurs in addition to pyrite and very minor arsenopyrite. Copper values of about 2% were assayed by Newmont over an 80 cm core interval in this zone. Gold values were low in all samples assayed by the company, the highest value being 0.2 ppm in a 37 cm interval, also in the lower mineralised zone. The compositions of separated sulphide samples from these mineralised zones are shown in Chapter 9.

The mineralisation is of two types - disseminated and commonly banded pyrite (Plate 8.1B), and veins of carbonate and quartz with minor plagioclase and sulphides (Plate 8.1C). In the first type of mineralisation fine grained disseminated euhedral to anhedral pyrite is concentrated in particular laminae in thinly banded tourmalinised dolomitic sediment of Facies C2. The unmineralised host sediment is similar to that shown in Plate 3.3A. The degree of mineralisation varies greatly, with sulphides forming less than 5% of the sediment at the margins of the mineralised zones, but up to about 50% in highly mineralised intervals. The mineralisation is not sharply confined to conformable bedded units as at Telfer. However, individual mineralised bands are conformable with the bedding (Plate 8.1B), and range from less than 1 mm to about 1 cm thick.

The grain size of the banded pyrite commonly varies between layers. In some bands pyrite grains average about 0.1 mm in diameter, but in adjacent bands pyrite crystals 0.5 - 0.8 mm in diameter are most common (Fig. 8.2A and B). In the most highly mineralised intervals crystalline quartz, tourmaline, plagioclase and carbonate

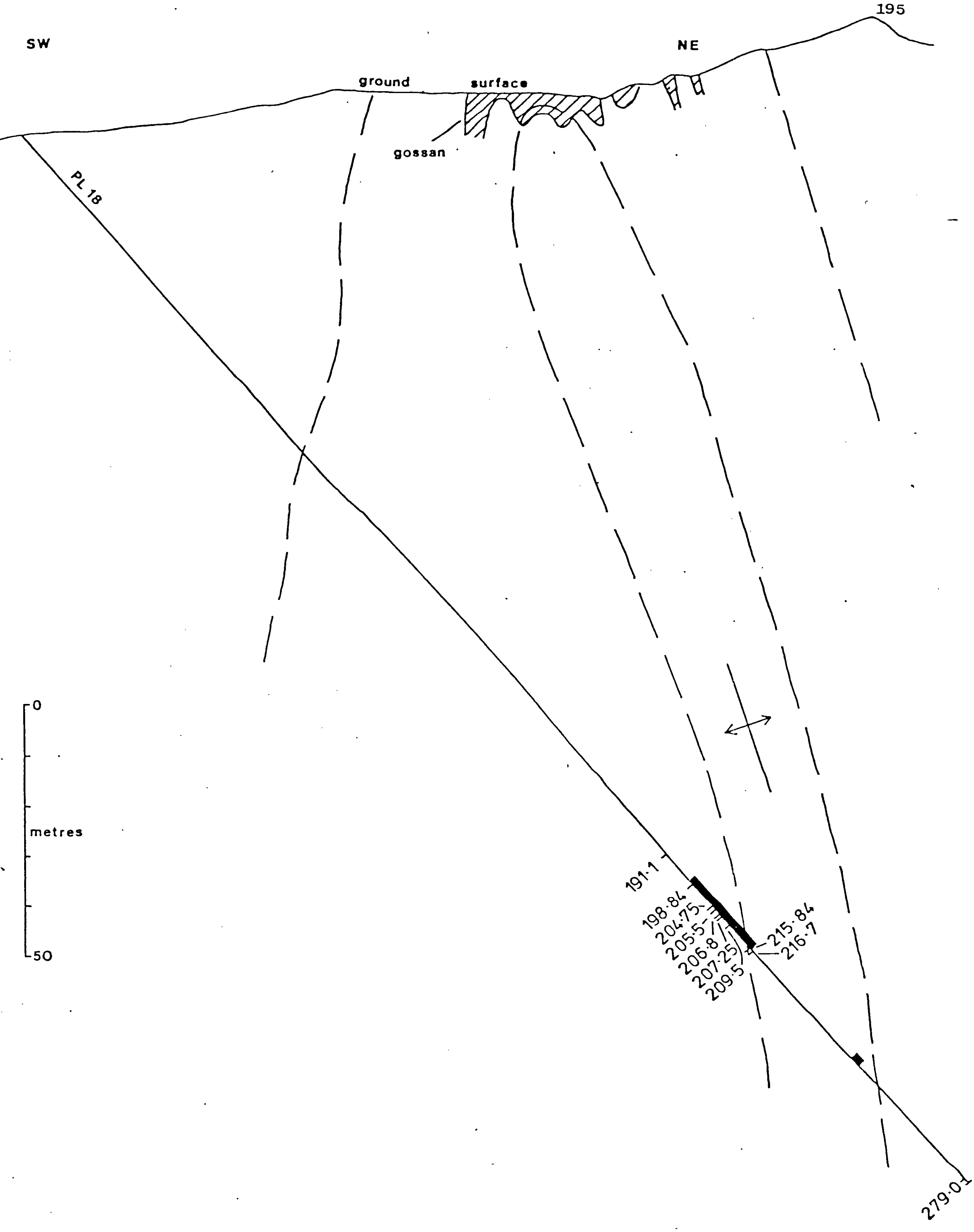


Figure 8.1 - Orientation of bore hole PL18 in the Isdell Formation (Map 1), position of the main intervals of pyritic mineralisation (black) and sample locations. The structure at depth is conjectural. Modified from a 1974 Newmont Pty. Ltd. report.

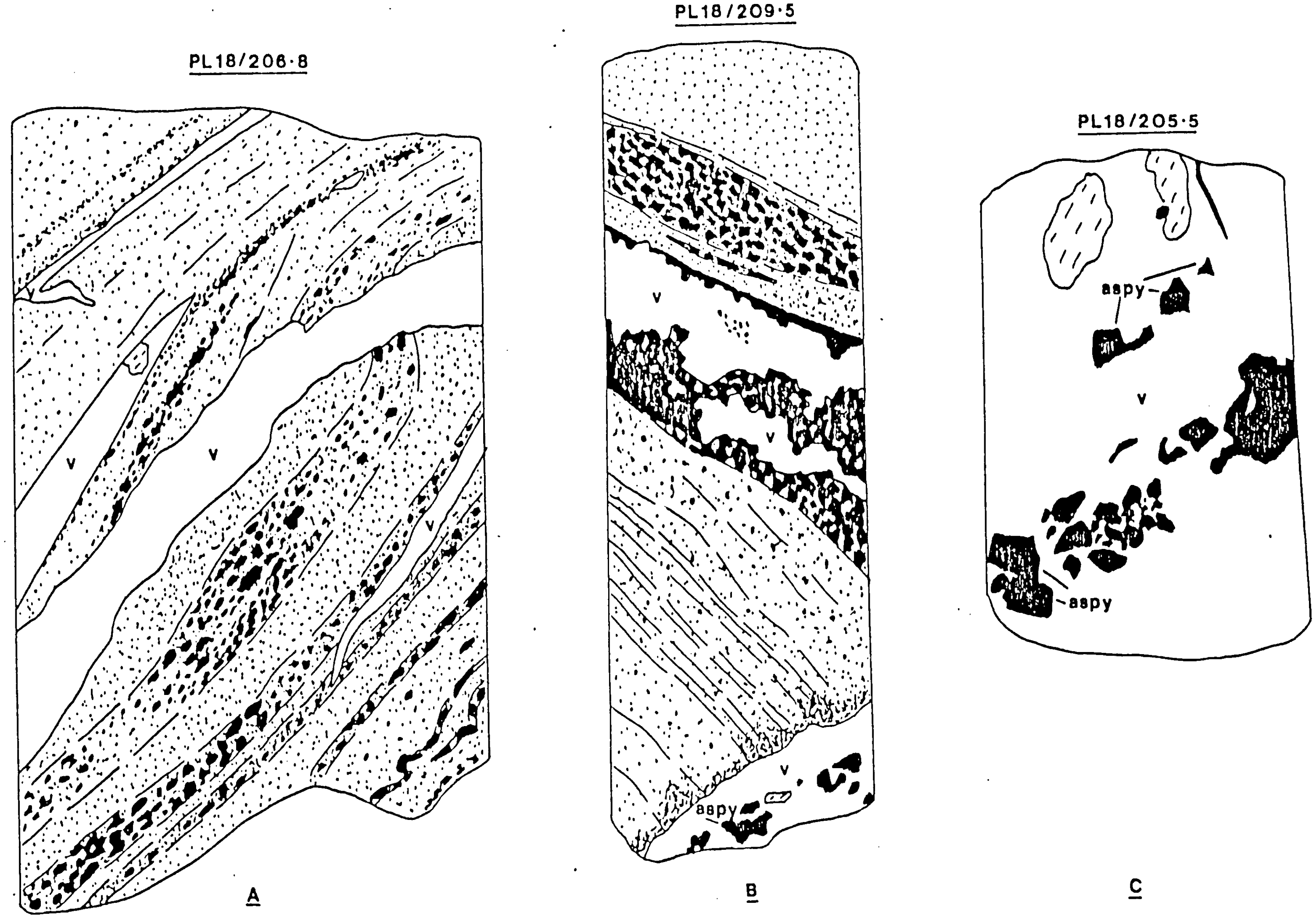


Figure 8.2 - Characteristics of mineralisation in thin sections from bore hore hole PL18 in the Isdell Formation. Black areas and dots represent pyrite, apart from those labelled aspy - arsenopyrite. Veins (v) cut pyritic layers, and are composed of quartz and carbonate (clear) and plagioclase (dashed). Long dashed lines are bedding surfaces.

accompany the pyrite (Plate 8.1D), and vary in grain size between layers in a similar fashion to the pyrite. The tourmaline is colourless to pale brown in thin sections, and is slightly pleochroic. It is estimated to form 15 - 20% of the finer grained layers, but less than 5% of the coarser layers, where quartz is more abundant. Plagioclase is intergrown with the other minerals in both fine and coarser grained layers, forming an estimated 5 - 8% of the lithology.

In a sample from a depth of 207.25 m a few patches of arsenopyrite occur in an interval containing abundant finely disseminated pyrite. These patches are up to 4 mm across, and enclose numerous fine pyrite grains. Arsenopyrite also occurs as the dominant mineral in a 3 mm thick vein which cuts the same sample. Clearly the formation of this sulphide post-dated the formation of pyrite.

In the second type of mineralisation veins ranging in thickness from a few millimetres to about 10 cm cut the intervals of disseminated mineralisation. Some veins are parallel to the bedding, but others cross-cut the strata. Coarsely crystalline carbonate is the dominant mineral in most veins, and staining with potassium ferricyanide solution indicates that this is ankerite. Coarse grained quartz is also abundant, and has slightly to strongly undulose extinction, indicating straining. Plagioclase crystals up to about 2 mm long also occur in many veins, and these are commonly slightly deformed, being bent or cracked and infilled with a second generation of finely crystalline quartz. Pyrite occurs in some veins as anhedral crystals up to 5 mm across, and arsenopyrite crystals of similar size more rarely also occur (e.g. at a depth of 205.5 m - Fig. 8.2C).

The vein mineralisation in PL18 post-dates the formation of the disseminated pyrite. This is evident from the cross-cutting relationship of veins with the pyritic layers, and slight displacement of some pyrite layers on either side of veins (Fig. 8.2A). The veins are suggested to be of metamorphic origin, due to the mobilisation of the various constituents in the zones of disseminated mineralisation during deformation.

8.2.2 GOLD MINERALISATION AT GRACE PROSPECT

In the southeast of the Telfer region several outcrops of sparse surface gold mineralisation occur, which have been collectively termed the Grace Prospect by Newmont (Map 1). The major indication of mineralisation here is a quartz "blow" which forms a low ridge approximately 5 m high, 15 m wide and 200 m long (locality GP on Map 1). The quartz is very coarse grained, milky white in colour and includes numerous patches of finely crystalline yellowish brown silicified dolomite. It is within the silicified dolomite that rare very small specks of visible gold occur.

This quartz outcrop is aligned along a major southeast - northwest trending fault, which cuts the Isdell Formation and truncates the Malu Formation at the southeastern end of the Trotman Hills (Map 1). The quartz is deduced to have been emplaced in the fault zone during deformation, when fragments of dolomite from the Isdell Formation were also included. Gold was mobile in this zone at the time of faulting, and was apparently precipitated preferentially in the carbonate inclusions.

Other mineralisation at this prospect consists of sparse auriferous quartz veins up to 5 cm thick, which cut outcrops of the Isdell Formation (N. Norris, personal communication, 1980). One such vein, at a locality 5 km east-southeast of locality GP (Map 1), had an assayed gold content of 80 ppm (1975 Newmont report on Grace Prospect). This locality is in line with the eastwards extension of the major fault, to which the vein may be genetically related.

8.3 GOLD PROSPECTS IN THE MALU AND TELFER FORMATIONS

The location of high grade concordant gold mineralisation at Telfer in particular members of the Malu and Telfer Formations, suggests that these stratigraphic units may be the most favourable for the discovery of similar mineralisation elsewhere in the Telfer region. One of the major aims of the writer's field work was to correlate subdivisions of the Malu and Telfer Formations throughout the area of Map 1, in order to pinpoint the same members that host the

Telfer concordant ores. Particular note was taken of any surface mineralisation in these members during the field work. Several of these localities have been prospected in detail by Newmont, and also by Geopeko Ltd., and some of the former company's data are included in the following descriptions.

The Karakutikati Range and Connaughton Prospect

The longest continuous exposures of the Malu and Telfer Formations occur at the Karakutikati Range south of Telfer, where the two members of the Telfer Formation, and locally the members of the upper Malu Formation, can be recognised (Map 1 and Plate 3.1). This range of hills was prospected by Newmont soon after the discovery of the Telfer gold deposits, but to the writer's knowledge no gold, or other significant mineralisation, was found. There are no concordant gossans, and although thin quartz veins, probably of metamorphic origin, are not uncommon, very few of these contain iron oxides (or pyrite). At Telfer, ferruginous quartz veins are much more likely to be auriferous than pure quartz veins, and the lack of such ferruginous veins in the Karakutikati Range suggests that near surface gold deposits are unlikely to be found in this area.

Sparse outcrops of sandstone and siltstone at Connaughton Prospect to the north of the Karakutikati Range have been correlated with the succession at Telfer, as shown on Map 1. In common with the Karakutikati Range there are very few veins cutting the sediments, and no indications of gold mineralisation have been found.

Trotman Prospect

This area of exposed Malu and Telfer Formations occurs as a northwestwards plunging anticline, to the northeast of Connaughton Prospect (Map 1). The area now mapped as Malu Formation was originally mapped as both Telfer and Malu Formations by Newmont, but individual members of the Telfer and upper Malu Formations can be recognised as shown on the map.

Little surface mineralisation occurs at the prospect, and no gossans corresponding to concordant mineralised layers have been found. However, a few ferruginous quartz veins occur in sandstones correlated with the Footwall Sandstone Member at Telfer. At locality TP (Map 1) these veins are less than 5 cm thick, and commonly lie along joint planes. A few of these veins have been found analytically to contain very low contents of gold, but one vein sample collected by the writer contained a visible speck of gold about 0.5 mm across. The identification of this gold was confirmed optically on a polished slab, the mineral being enclosed in coarse grained quartz.

Tim's Prospect

Tim's Prospect, to the northeast of Telfer (Map 1), is a southwestwards plunging anticline of the Malu and Telfer Formations. The stratigraphic units from the Footwall Sandstone Member through to the Camp Sandstone Member can be mapped, and are lithologically very similar to the same units at Telfer.

Mineralisation was discovered by Newmont within the Footwall Sandstone Member in the core of the anticline, as discontinuous zones of gossan aligned parallel to the axial plane of the fold. The largest gossan is 30 m long and up to 4.2 m wide (Royal, 1976). The gossans consist of massive iron oxides with cellular boxworks after pyrite and quartz, similar to the gossans at Telfer. However, unlike the Telfer gossans, the gold contents of gossan samples at Tim's Prospect are low, the highest recorded by Royal (op. cit.) being 1.16 ppm.

No concordant zones of mineralisation have been found at the surface at this prospect, but two angled boreholes were drilled by Newmont on opposite sides of the anticline, to test for possible concordant mineralisation at depth. No such mineralisation was encountered in the boreholes. However, a 60 cm thick zone of very fine grained sandstone, cut by a few quartz - iron oxide veins, occurred in the borehole on the southwest side of the anticline, and had a gold content of 2.06 ppm (Royal, op. cit.). Royal suggested that this zone of veining was in the "Lower Vale Shale" (i.e. part of the Footwall Sandstone Member - Table 3.1), but examination of the core by the writer indicates that the interval is in the stratigraphically higher Median Sandstone Member.

Thomson East Prospect, McKay Prospect and the Malu Hills

These large areas of the Malu and Telfer Formations to the north of Telfer (Map 1) are less well known to the writer than the areas described above. However, from several traverses made during field work the two members of the Telfer Formation can be mapped as shown (Map 1). Subdivisions of the Malu Formation are less distinct as the sequence contains more medium grained sandstone than elsewhere, which hampers recognition of the usually distinctive Rim Sandstone Member.

The Thomson East Prospect is an elongate dome, around which small quartz veins with minor iron oxides after pyrite occur at several localities. No gossans as large as those at Tim's Prospect or the concordant gossans at Telfer have been found around the structure. There is a concentration of veins in the strata equivalent to the Median Sandstone and Middle Vale Siltstone Members, beneath the Rim Sandstone Member at the northwestern end of the fold. The highest gold value found by Newmont in a surface vein sample from the area was 2.0 ppm (1974 Newmont Pty. Ltd. Map of Thomson East Prospect). In the Outer Siltstone Member at the southeast end of the structure sparse veins also occur, one of which was reported to contain visible gold (1974 Newmont map, op. cit.). Drilling at the prospect by Newmont proved additional veins with trace gold values, but no concordant mineralisation or highly mineralised veins were encountered.

No mineralisation is known to the writer in the poorly exposed sandstone outcrops of the Malu Formation at the McKay Prospect. However, several areas of surface mineralisation in the Malu Hills area were noted during field work. Results of company explorations in this area are unknown to the writer, and mineralisation is probably more widespread than described below. At locality MH1 (Map 1) an iron oxide - quartz gossan about 5 m long and up to 50 cm wide occurs in the lower part of the Outer Siltstone Member. This is aligned parallel to the bedding, and is in the same approximate stratigraphic position as the E Reefs at Telfer. At locality MH2 (Map 1) a massive quartz "blow" occurs in a narrow northeast - southwest orientated shear zone, and at MH3 another massive ferruginous quartz "blow" occurs, possible related to a north - south orientated shear zone. It is unknown whether or not these outcrops contain gold.

8.4 MINERALISATION IN THE PUNTAPUNTA FORMATION

Significant surface mineralisation in the Puntapunta Formation occurs at Thomson Prospect, between Thomson and McKay Prospects, at Fallow's Field Prospect and at O'Callaghan Prospect (Map 1).

Thomson Prospect and Thomson - McKay Prospect

Thomson Prospect is an isolated prominent ridge, on which apparently concordant gossan occurs. The ridge was regarded by Newmont as the crest of a tightly folded anticline of the Telfer Formation, but the writer's field mapping indicates that the sandstone dips uniformly to the southwest at an angle of about 60°, and is part of the Puntapunta Formation (Fig. 8.3).

Apparently conformable gossan occurs along part of the southwest flank of the outcrop, and other gossan outcrops occur in a small graben at the southeast end of the ridge (Fig. 8.3). The gossan in the graben area consists of very massive iron oxides (Plate 8.1E), while along the southwest side of the ridge the mineralisation is represented by ferruginous fine grained sandstone, with iron oxide cubes after pyrite being common. Coarse grained quartz is scarce in these gossans. Shallow drilling (to depths of less than 20 m) has revealed low gold values (up to 6.9 ppm) in subsurface extensions of the concordant gossan (1974 Newmont Pty. Ltd. map of Thomson Prospect). A deeper borehole (T26, Fig. 8.3) intersected a pyritic interval between a drilled depth of 458.8 m and 466.25 m (about 380 m vertical depth), which may be the deep extension of this mineralised unit.

The pyritic interval in T26 has an average gold content of 0.3 ppm (Sargeant' 1976). Samples studied by the writer from this

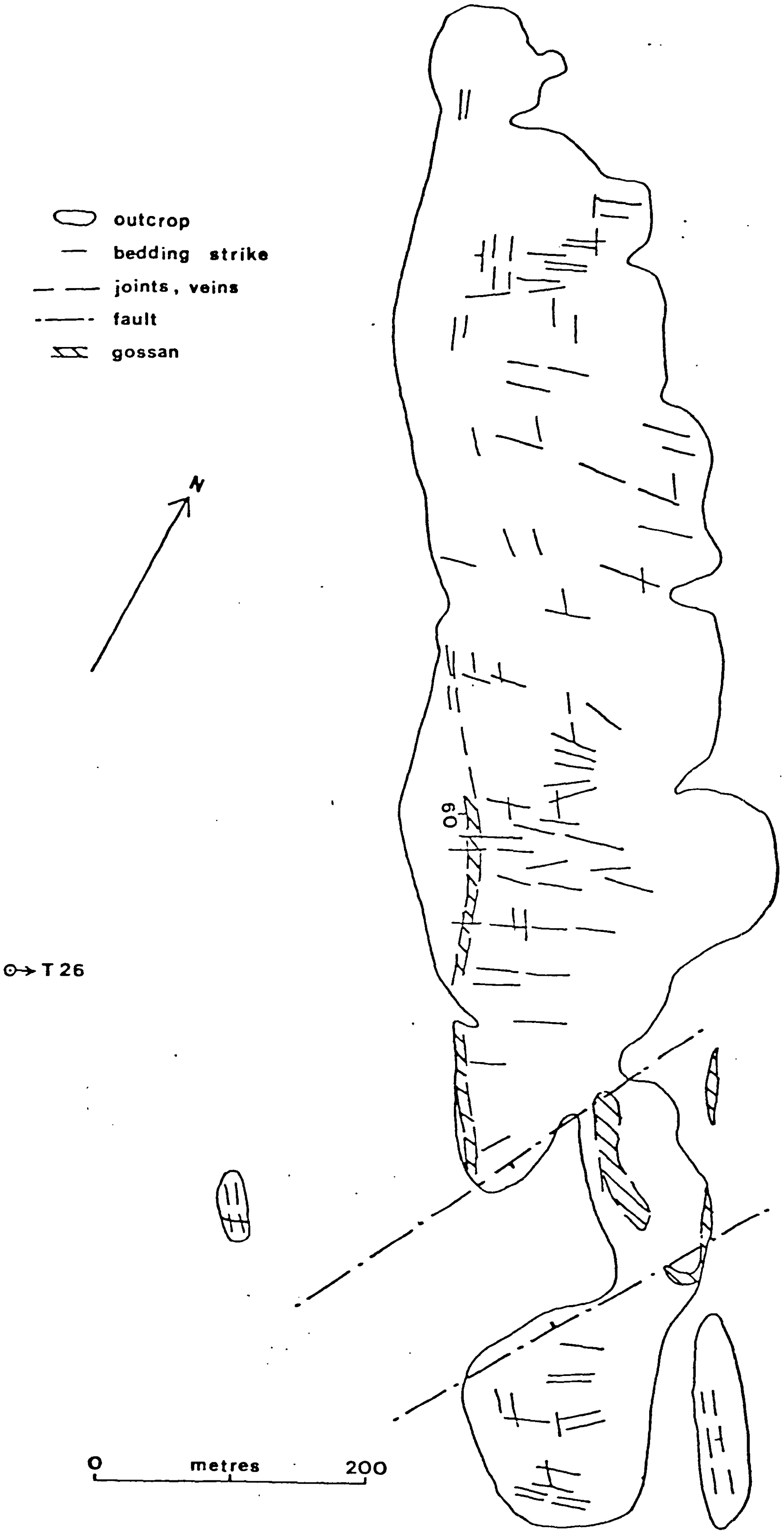


Figure 8.3 - Simplified geological map of Thomson Prospect (Map 1) in the Puntapunta Formation. Sketched from vertical air photograph, and based on map by Sargeant (1976).

mineralised unit are of two types. Isolated euhedral pyrite cubes up to 1 cm across occur in slightly recrystallised fine grained sandstone, and fractured massive pyrite occurs in more highly recrystallised sandstone. In the first textural type, finely crystalline quartz occurs in pressure fringes on opposite sides of some pyrite cubes, the quartz crystals being aligned parallel to faint cleavage in the sandstone. A similar texture is found at Telfer (e.g. Plate 7.4D), and suggests that the pyrite pre-dates the metamorphism and deformation which formed the cleavage. In the second type of mineralisation, the fractures in the massive pyrite are infilled with strained crystalline quartz.

Both textural types of pyrite in T26 contain numerous small inclusions of quartz and sericite from the host sandstone. Chemical analyses of pyrite samples from this interval are given in Chapter 9. The pyrite is clearly epigenetic, having grown in situ in the sandstone as discrete crystals or as larger massive patches. It was probably formed prior to deformation and metamorphism. The presence of euhedral and massive pyrite in an apparently conformable layer, the scarcity of associated coarse grained quartz, and the low trace element contents of the pyrite (Chapter 9), suggest comparison of the Thomson Prospect mineralisation with that found in the MVR horizon in drill core PR21 from West Dome.

Midway between Thomson Prospect and McKay Prospect are small outcrops of massive white quartz, whose structural relationship to the surrounding Puntapunta Formation is uncertain due to the lack of exposure. However, within one outcrop, about 10 m across, are irregular patches of yellowish brown recrystallised and silicified dolomite and dark brown to black iron oxides. Visible gold flakes up to 1 mm across are common in samples from this locality, and assayed gold values are very high, several samples containing over 50 ppm gold (1974 Newmont assay data). Most gold occurs in the massive quartz, adjacent to patches of iron oxides. The nature of the outcrop, particularly with silicified dolomite inclusions in the quartz, suggests comparison with outcrops at Grace Prospect. It is considered by the writer that the highly auriferous quartz outcrop probably lies along a fracture zone of uncertain orientation. There is no evidence of a link between this outcrop and the ferruginous sandstone mineralisation at Thomson Prospect.

Fallow's Field Prospect

This area to the south of Telfer is structurally complex, but is essentially a faulted antiform (Map 1). Very fine grained sandstone and dolomite are the major lithologies, which field mapping indicate belong to the Puntapunta Formation. Sparse outcrops of ferruginous breccia occur along the northeastern fault shown on the maps, close to the track traversing the prospect. In addition, two bands of gossan about 30 cm thick, with strike lengths of about 150 m, lie parallel to the bedding near the core of a small fold within the antiform, about 500 m east of the track. Four samples from these latter gossans were found by Newmont to contain between 2.8 and 4.0 ppm gold (1975 Newmont Pty. Ltd. map and assay data). Adjacent to these gossan bands occur patches of yellowish brown silicifed dolomite, similar to that found within quartz at Grace Prospect and between Thomson and McKay Prospects.

The mineralisation at Fallow's Field Prospect is considered by the writer to be structurally controlled. The auriferous gossan bands lie parallel to the axial planes of the folds in this area, and other indications of mineralisation occur along a fault zone.

O'Callaghan Prospect

At the area known as O'Callaghan Prospect, southeast of Telfer (Map 1), en echelon outcrops of massive white quartz occur on a low ridge (Plate 8.1F), which from air photographs appears to be crossed by several small faults. Possible strike-slip movement along these faults may have caused large scale tension gashes which were filled with quartz. There is little ferruginous material associated with the quartz, however, and no gold has been reported from the prospect. However, one malachite stained quartz vein was reported to contain 0.9% Cu and 29 ppm Ag (1975 Newmont report on O'Callaghan Prospect).

PLATE 8.1 - MINERALISATION AT OTHER PROSPECTS IN THE TELFER REGION

A. Outcrop of malachite-rich gossan (enclosed by dashed line) within dolarenite of the Isdell Formation. Locality Cu2 (Map1).

B. Pyritic Facies C2, Isdell Formation - polished slab showing disseminated pyrite grains (light grey) in dolomitic laminae. Core PL18 (Map 1), depth 206.8 m.

C. Vein-type mineralisation in Facies C2, Isdell Formation. Quartz, carbonate and albite veins (white), probably of metamorphic origin, cut folded laminated dolomitic siltstone. Core PL18, depth 204.55 - 213.3 m.

D. Thin section of mineralised Isdell Formation. Pyrite (black) and tourmaline (dark grey laths) occur in quartz - feldspar matrix (white). Quartz - pyrite vein in lower left. PL18, depth 206.8 m.

E. Outcrops of massive iron oxide gossan at Thomson Prospect (Map 1).

F. Massive quartz blow at O'Callaghan Prospect (Map 1).

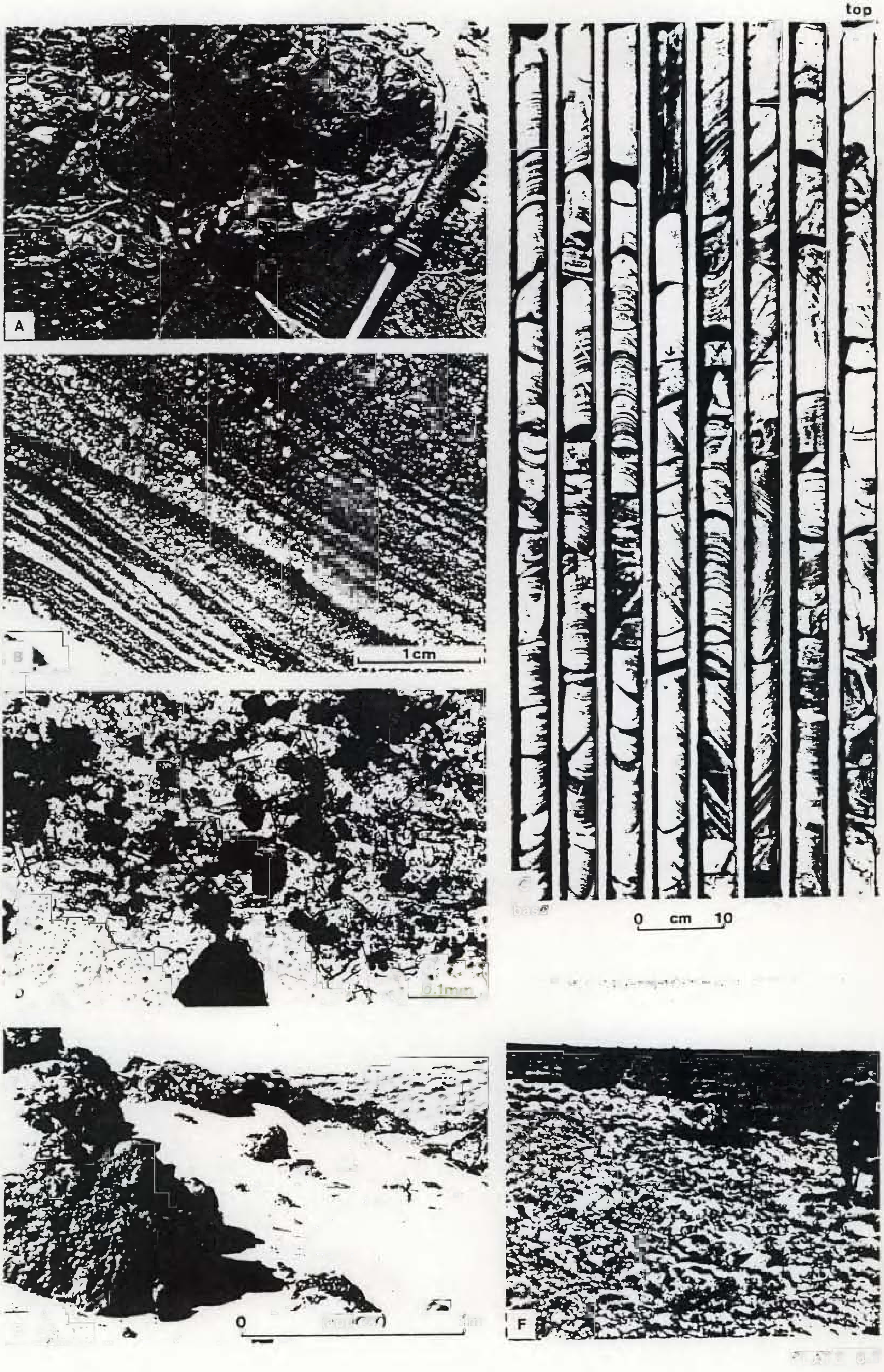


PLATE 8.1