CHAPTER 3

STRATIGRAPHY AND SEDIMENTOLOGY OF THE UPPER YENEENA GROUP

3.1 INTRODUCTION

The upper Yeneena Group comprises five formations and one informal division, totalling over 5,500 m in thickness. From the base the sequence is as follows, Isdell Formation, Malu Formation, Telfer Formation, Puntapunta Formation, Wilki Quartzite and an un-named unit (Fig. 2.1, Table 3.1). The stratigraphy and sedimentology of this thick sedimentary sequence are described in detail below; brief interpretations of sedimentary processes are also given, but discussions of palaeocurrents, sedimentary environments and basin development are reserved for the following chapter.

Distribution. The main outcrops of the upper Yeneena Group occur in the Paterson Range map sheet (Fig. 2.2) where the five formations were mapped and named by Chin and Hickman (1977). Due to the economic importance of part of this sequence (the Telfer gold deposits occur in the upper Malu and lower Telfer Formations - Fig. 2.1) a 1:50,000 scale geological map, which covers an area of about 1,250 sq km centred on Telfer, has been compiled by the writer (Map 1, summarised by Fig. 3.1). This map is largely the result of the writer's field mapping and air photo interpretations, but is based in part on an earlier map covering a smaller area compiled by Newmont geologists, and also includes a few features which are taken directly from the 1:250,000 scale map of Chin and Hickman (1977). A comparison of Map 1 with these two previous maps is given in Appendix 1. Map 1 facilitates discussion of the stratigraphy and structure (Chapter 5) of the upper Yeneena Group, and also shows some of the palaeocurrent directions measured by the writer.

Outcrops to the north of the area covered by Map 1 have been tentatively correlated with the formations of the upper Yeneena Group by Chin and Hickman (1977), but the writer has not worked in this remote area to attempt verification of these correlations. To the southeast and northwest of Map 1 sand cover effectively conceals all traces of the upper Yeneena Group. The Isdell Formation is the only unit of the upper Yeneena Group found south of the Map 1 area (Fig. 2.2).

Stratigraphy of the "Telfer Sandstone Formation" at Telfer (Tyrwhitt, 1976)	Stratigraphy of the Yeneena Group (Chin and Hickman, 1977; Chin et al. 1980)	Revised stratigraphy of the Yeneena Group		
	un-named unit		un-named unit	
	Wilki Quartzite		Wilki Quartzite	
	Puntapunta Formation		Puntapunta Formation	
Camp Sandstone	Telfer Formation	Camp Sandstone Member	Telfer Formation	upper Yeneena Group
Outer Siltstone Formation		Outer Siltstone Member		
Rim Sandstone		Rim Sandstone Member	upper Malu Formation	
Upper Vale Shale		Median Sandstone Member		
Median Sandstone				
Middle Vale Shale		Middle Vale Siltstone Member		
Footwall Sandstone		Footwall Sandstone Member		
Lower Vale Shale				
Core Sandstone	Malu Quartzite		lower Malu Formation	
	Isdell Formation		Isdell Formation	
	Choorun Formation		Choorun Formation	lower Yeneena Group
	Broadhurst Formation		Broadhurst Formation	
	Coolbro Sandstone		Coolbro Sandstone	

Table 3.1 Stratigraphic nomenclature of the Yeneena Group

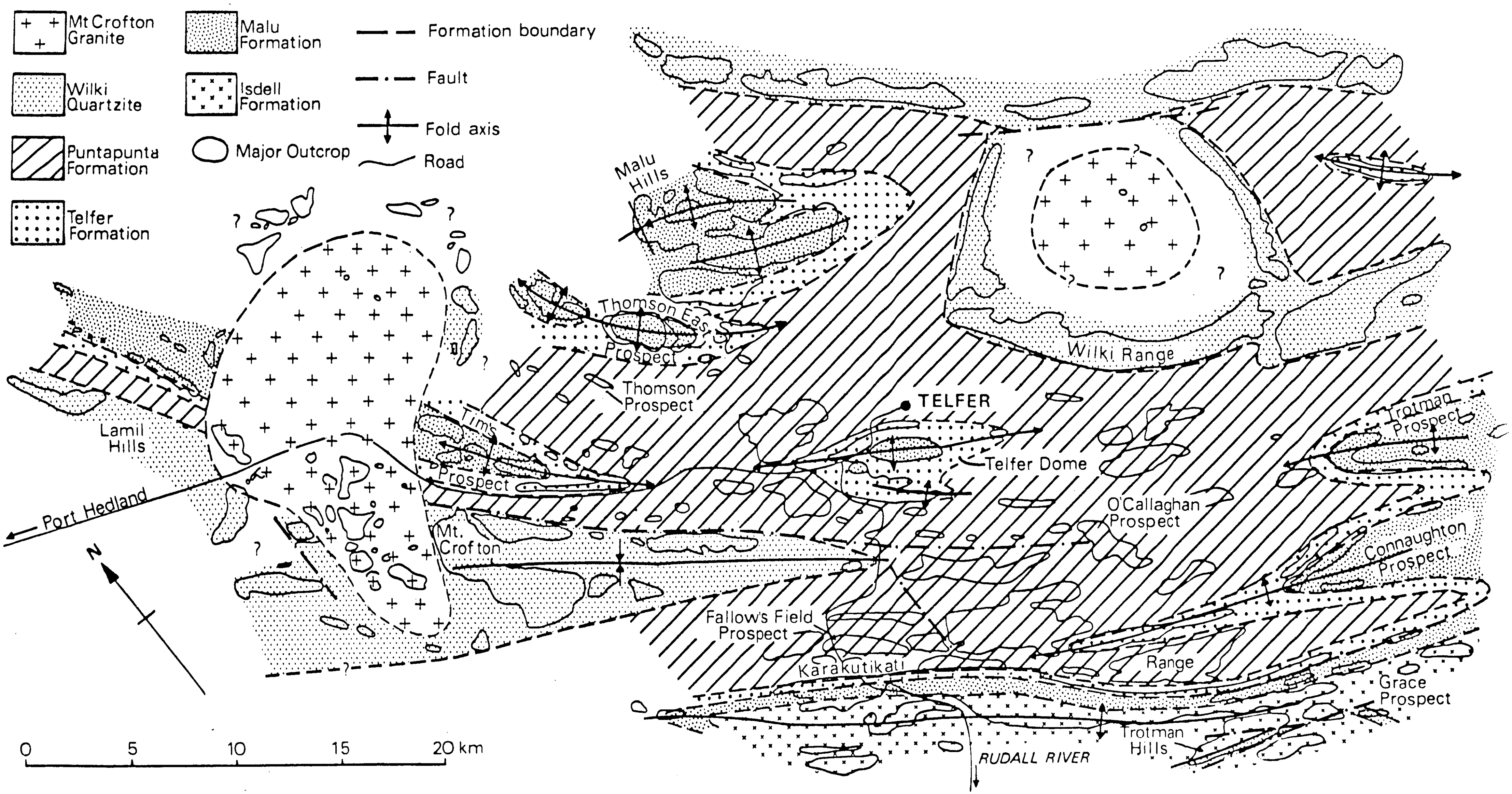

Figure 3.1 - Geological map of the Telfer region. Reduced version of Map 1 (rear pocket).

Facies. Several formations consist of more than one sedimentary facies (as defined for example by Reading, 1978, p.4). These facies are distinguished on lithological characteristics such as composition, texture, bed thickness and sedimentary structures. Some facies are common to more than one formation, but each formation is made up of a characteristic assemblage of facies. For convenience, facies are described under formation headings, but facies nomenclatures are appropriate to their gross lithologies. Thus, those facies dominated by carbonates have a prefix C and those dominated by siliclastic detritus have a prefix S. The Isdell and Puntapunta Formations (Fig. 2.1) consist mostly of carbonate facies, the Malu Formation and the Wilki Quartzite are almost entirely composed of siliclastic facies and the Telfer Formation is composed of thick sequences of both facies types.

Correlation. This presents a considerable problem in the mapping of folded non-fossiliferous Proterozoic strata, particularly in desert areas such as the Telfer region, where outcrops are commonly isolated by aeolian sand. Therefore a brief explanation of correlation procedure follows. In the absence of biostratigraphic criteria or basin-wide chronostratigraphic units such as tuffs, the mapped units are lithostratigraphic, and it is therefore possible and even probable, that formation boundaries are diachronous.

In practice, correlations were made by recognising similar lithological sequences, rather than relying on the recognition of distinct individual rock units. Facies changes occur within some of the stratigraphic units throughout the area, but others (such as the Camp Sandstone and Rim Sandstone Members - Table 3.1) vary little lithologically, and so form reliable reference (marker) horizons. Therefore, for example, the sequence from the Puntapunta Formation down to the medium grained Rim Sandstone Member at Telfer (Table 3.1) can be recognised at the Karakutikati Range despite one of the units (the Outer Siltstone Member) containing more carbonates in the latter area than at Telfer (see section 3.3.2).

3.2 STRATIGRAPHY

3.2.1 ISDELL FORMATION

The type locality of the Isdell Formation is near Mount Isdell (Fig. 2.2) in the northern part of the Rudall map area, where dolomite is the dominant rock type and where the formation "appears to overlie the Broadhurst Formation" (Chin et al., 1980, p.13), the actual contact not being exposed. Chin and Hickman (1977) correlated dolomite just south of the Karakutikati Range (Fig. 3.1) with similar rocks in the upper part of the Isdell Formation at its type locality ten kilometres farther south. This wide intervening area consists of sand plain and flat-lying Permian strata of the Paterson Formation (Chapter 5), which must make this correlation tenuous, but in the absence of evidence to the contrary the writer agrees that the correlation is likely. To the south of the Karakutikati Range the Isdell Formation is overlain with slight unconformity by siliclastic rocks of the Malu Formation (section 3.3.1).

The Isdell Formation must be very thick, despite folding which repeats part of the sequence just south of the Karakutikati Range and which probably also occurs beneath the unexposed area farther south. Chin et al. (1980) suggested a thickness in excess of 1,000 m for the formation in the Mount Isdell area. From Map 1 the formation south of the Karakutikati Range can be measured as over 700 m thick, therefore the total thickness could exceed 1,700 m. A more accurate estimate of the thickness is unfortunately not possible.

A further area of the Isdell Formation, not visited by the writer, has been mapped by Chin et al. (1980) in the northwest of the Rudall map area, 60 km west of the type locality (Fig. 2.2). The formation here apparently overlies the Choorun Formation not the Broadhurst Formation, although the actual contact is again not exposed. In this western area siliclastic sediments occur as well as dolomite. The writer remains uncertain of this correlation, but if it is in fact correct then a major unconformity beneath the Isdell Formation would seem likely, with the Broadhurst Formation being overlain in the east and the Choorun Formation in the west.

3.2.2 MALU FORMATION

The term Malu Formation is used here in place of Chin and Hickman's (1977) "Malu Quartzite" because much of the formation consists of claystone and siltstone as well as quartz-rich arenite. The Malu Formation overlies the Isdell Formation along the southern flank of the Karakutikati Range (Fig. 3.1 and Plate 3.1), and there is some evidence for erosion of part of the upper Isdell Formation prior to the deposition of the basal Malu Formation (see section 3.3.1). The Telfer Formation conformably overlies the Malu Formation, both at the Karakutikati Range and elsewhere. Chin and Hickman (1977) mapped the entire Karakutikati Range as Telfer Formation, but correlation with the stratigraphy at Telfer (Table 3.2) clearly shows that this formation constitutes only the uppermost part of the sequence at the Karakutikati Range (Plate 3.1).

At this range the Malu Formation is 750 m thick, but it thickens northwards to greater than 1,500 m in the Malu Hills north of Telfer (Fig. 3.1). Chin and Hickman regarded the Malu Hills as the type locality for their "Malu Quartzite", but the base of the formation is exposed only at the Karakutikati Range, where a complete stratigraphic section has been measured by the writer (at lat. 21°48'30"S, long. 122°10'00"E - Plate 3.1 and location A, Map 1). This locality is used here as the type section of the formation (see Fig. 3.2).

At Telfer, the dominantly clastic sedimentary sequence was divided into a number of named stratigraphic units by Newmont geologists, whose terminology is largely retained here, their units being formalised to Members (Table 3.2). Chin and Hickman (1977) correlated the lowest of these units (the "Core Sandstone") with the "Malu Quartzite". This correlation is accepted here, but the upper boundary of the Malu Formation is raised to include the Footwall Sandstone, Middle Vale Siltstone, Median Sandstone and Rim Sandstone Members (Table 3.2). This allows the grouping of closely related facies in the Malu Formation, some of which differ from the facies of the Telfer Formation, and provides a more easily mappable upper boundary for the Malu Formation (i.e. the top of the Rim Sandstone Member).

FORMATION	MEMBER	CHARACTERISTICS
Telfer	Camp Sandstone	Facies S2. Defined as the stratigraphically highest sandstone unit beneath the Puntapunta Formation. Abruptly overlain and underlain by Facies S1. Type section is PR396/144-217.5 m, where the true thickness is 67 m.
	Outer Siltstone	Dominantly Facies S1 and S2, some units of which are calcareous; also some calcareous and non-calcareous units of Facies S3; and well bedded dolomite of Facies C4 at the Karakutikati Range; the E Reefs occur in the lower part of the member. Defined as the sequence between the more distinctive Rim Sandstone and Camp Sandstone. Type section is PR518/198-776.7 m, where the true thickness is about 540 m.
Malu	Rim Sandstone	Facies S4. Upper limit defined as top of stratigraphically highest thick medium grained sandstone bed that occurs below the Outer Siltstone. Lower limit is sharply defined, where base of lowest medium grained sandstone bed overlies veryfine grained sandstone or mudstone. Type section is PR518/776.7-802.4 m, where the true thickness is 25.7 m.
	Median Sandstone	Facies S2, with a few metres of S1 near the top in places. Upper limit defined by base of Rim Sandstone. Lower limit defined as base of lowest thick massive very fine grained sandstone bed. Type section is PR518/802.4-840.6 m, where the true thickness is 38.2 m.
	Middle Vale Siltstone	Facies S1; the Middle Vale Reef occurs near the base of the member. Upper limit defined by base of Median Sandstone, but sandstone beds in the upper part of the Middle Vale Siltstone can make the positioning of the boundary uncertain. Lower limit defined as top of highest prominent sandstone bed, beneath which thick mudstone units do not occur. Type section is PR449/86.2-96.3 m, where the true thickness is 8.2 m.
	Footwall Sandstone	Facies S3. Upper limit defined by base of Middle Vale Siltstone. Lower boundary uncertain. Minimum thickness 20 m. Type section is PR449/96.3-102.4 m.

Table 3.2 Stratigraphy of the Telfer and Malu Formations at Telfer. The sedimentary facies are described in section 3.3.

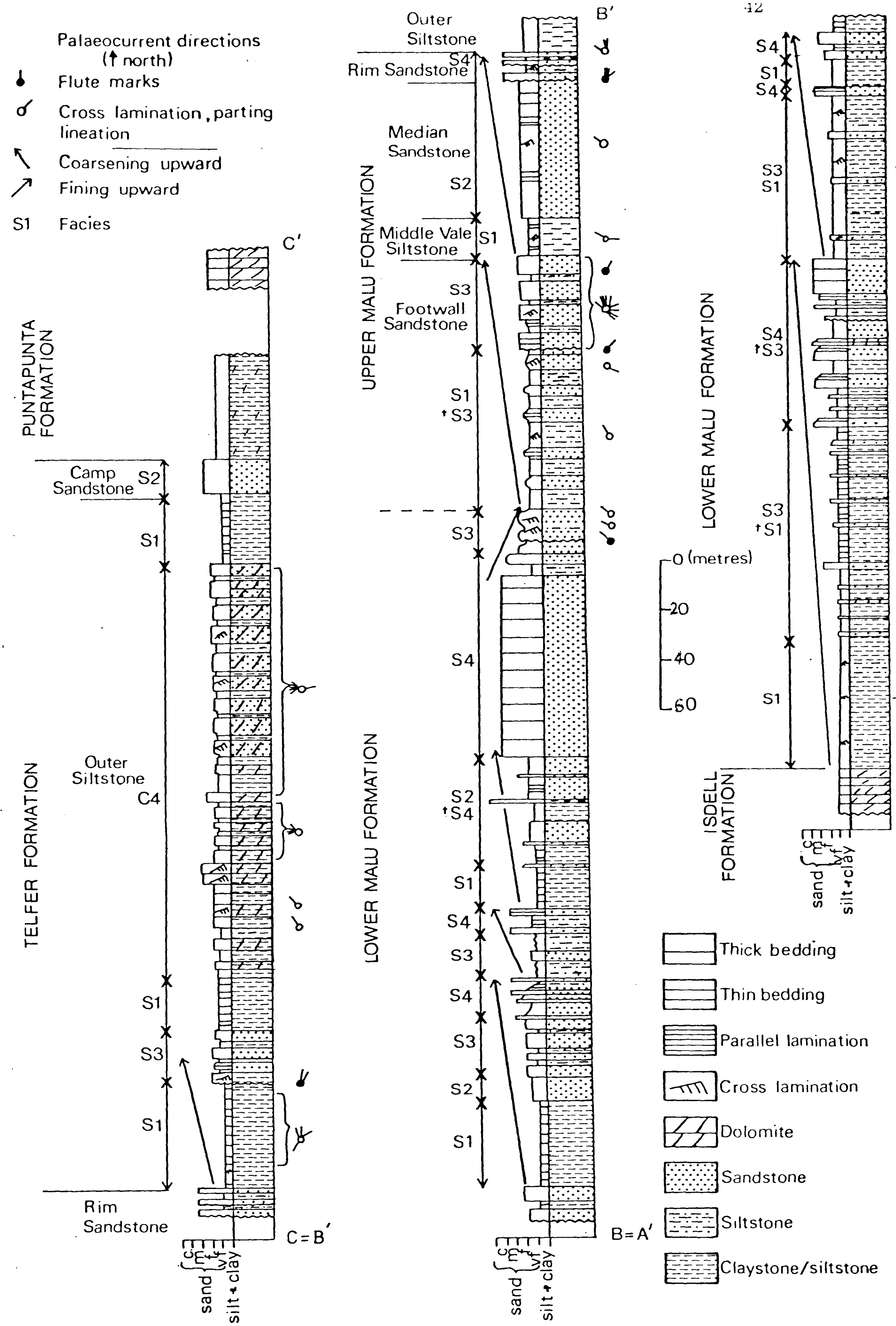

Figure 3.2 - Measured sections through the Malu and Telfer Formations at the Karakutikati Range (Plate 3.1).

The Malu Formation beneath the Footwall Sandstone Member is not formally subdivided here, and is referred to simply as the lower Malu Formation.

3.2.3 TELFER FORMATION

This unit conformably overlies the Malu Formation, and has been recognised throughout the area (Map 1 and Fig. 3.1). Two members are generally distinguishable, correlating with the Outer Siltstone and Camp Sandstone Members at Telfer (Table 3.1). The thickness of the Telfer Formation increases northwards, in common with the Malu Formation, being 400 m thick at the Karakutikati Range, 610 m at Telfer and about 650 m in the Malu Hills area. The type locality of the Telfer Formation is designated here as Telfer itself, where drill cores PR396 and PR518 (see Fig. 3.3) serve as type sections through the Camp Sandstone and Outer Siltstone Members respectively (Table 3.2).

3.2.4 PUNTAPUNTA FORMATION

The Telfer Formation is conformably overlain by the Puntapunta Formation (Plate 3.1), which comprises dolomite, limestone, very fine grained carbonate-rich sandstone and shale. A continuous measured section has not been established, but Chin and Hickman (1977) stated that the type locality occurs 5 km west of Puntapunta Hill, to the north of the Karakutikati Range (Map 1). Although thick lithological units can be distinguished within the Puntapunta Formation, no members have been named and mapped due to the difficulty of tracing units along strike. This is in part due to the fact that faulting is more common in the Puntapunta Formation than in the dominantly siliclastic formations (Chapter 5). The thickness of the Puntapunta Formation is estimated as about 700 m.

3.2.5 WILKI QUARTZITE

This formation consists of a thick sequence (about 1,500 m) of dominantly medium grained quartzite. It is enigmatic in being commonly sheared and recrystallised to a higher degree than other

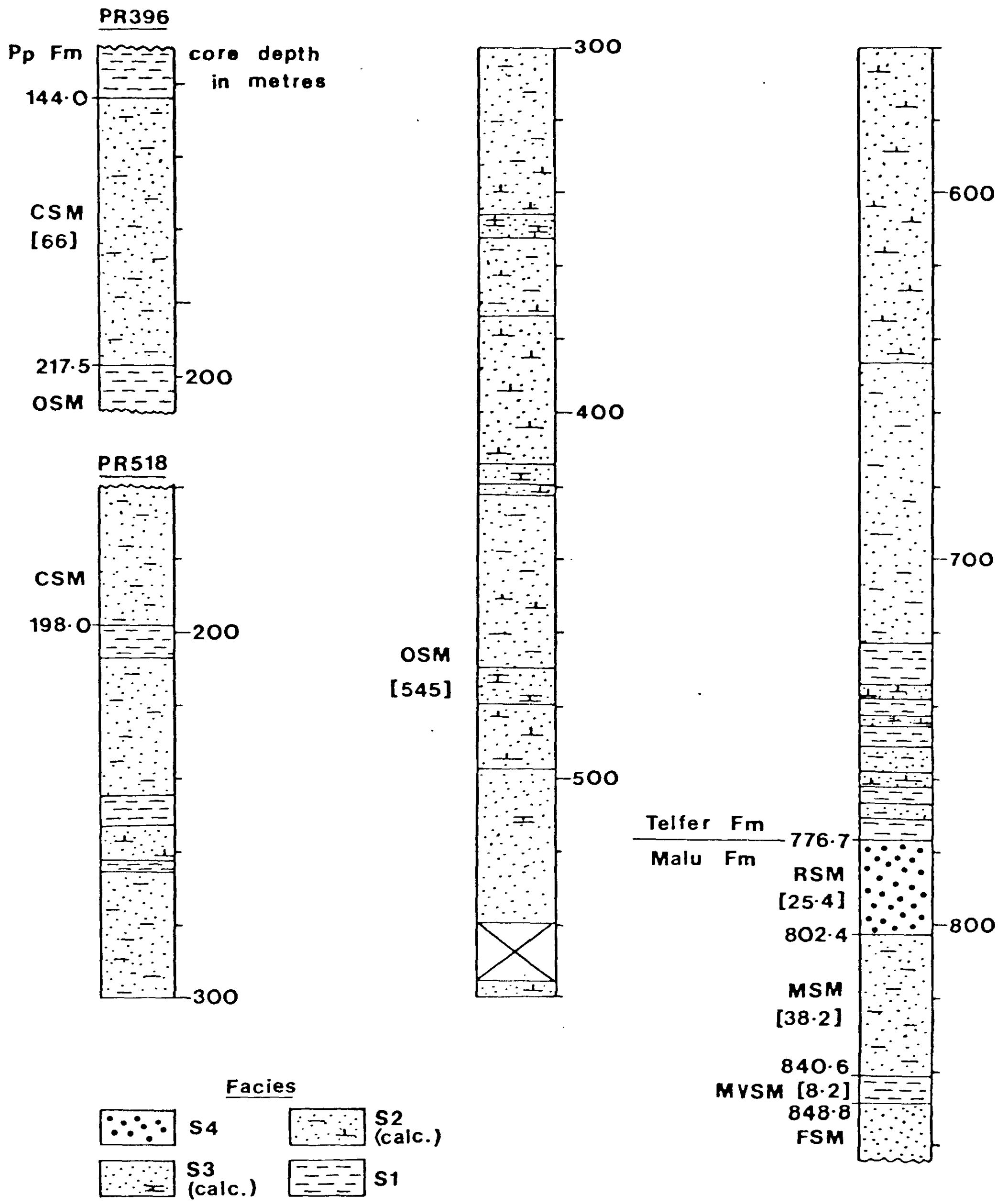

Figure 3.3 - Sedimentary facies of the upper Malu Formation and the Telfer Formation in cores PR518 and PR396 at Telfer (see Fig. 6.1). Pp Fm - Puntapunta Formation; CSM - Camp Sandstone Member; OSM - Outer Siltstone Member; RSM - Rim Sandstone Member; MSM - Median Sandstone Member; MVSM - Middle Vale Siltstone Member; FSM - Footwall Sandstone Member. True thicknesses in brackets.

formations of the upper Yeneena Group. In the early stages of Newmont's mapping in the Telfer region these characteristics led to a debate amongst Newmont geologists concerning the stratigraphic position of the Wilki Quartzite (D.S. Tyrwhitt, personal communication, 1977). The higher metamorphic grade of the quartzite was held by some to indicate that it predated the upper Yeneena Group. Indeed, the sheared, recrystallised and monotonous nature of the Wilki Quartzite suggests comparison with parts of the Coolbro Sandstone of the lower Yeneena Group.

However, the recrystallisation of the quartzite can be attributed mainly to its common proximity to the intrusive Mount Crofton Granite (see Chapter 5). Stratigraphic top indicators in the Puntapunta Formation show that the contiguous Wilki Quartzite does in fact overlie the Puntapunta Formation, although the actual contact is nowhere exposed. There is no evidence to suggest an unconformity between the two formations, and Chin and Hickman (1977) suggested that the Wilki Quartzite conformably overlies the Puntapunta Formation, citing the Wilki Range east of Telfer (Fig. 3.1) as the type locality.

3.2.6 UN-NAMED UNIT

The uppermost unit of the Yeneena Group consists of a very poorly exposed unit of dark grey shale and siltstone which overlies the Wilki Quartzite 17 km east of Telfer (Chin and Hickman, 1977). This unit is suggested here to correlate with similar rocks exposed southwest of the Mount Crofton Granite in the west of the area (Map 1). The small extent of exposures has warranted little study of the unit, which has remained un-named. The top of the unit is not exposed, and a minimum thickness is about 200 m.

3.3 SEDIMENTOLOGY

3.3.1 ISDELL FORMATION

Outcrop characteristics and facies subdivision

The Isdell Formation outcrops to the southwest of the

Karakutikati Range as short strike ridges and as low plateaux. Bedding dips are generally steep or vertical, resulting in locally well exposed cross sections of strata (Plate 3.2A). The formation is dominated by carbonate sediments, and consequently, thin surficial coverings of calcrete are common. Such material also fills joints at most outcrops. Sharp-crested solution flutes with relief of a few millimetres typically occur on exposure surfaces, individual beds and laminae being emphasised by this phenomenon. Larger scale karst features are rare, but in places irregular solution hollows up to 50 cm deep occur.

Three facies of the Isdell Formation are distinguished:-

Facies C1 - Thinly interbedded dololutite and dolarenite
Facies C2 - Cross laminated dolarenite, and dolomitic mudstone
Facis C3 - Thickly bedded dolarenite and calcarenite

During the course of field work the facies were examined at many different localities throughout the area, but time restrictions did not permit accurate mapping of facies boundaries. However, a few generalised comments on facies distribution can be made.

Several across-strike traverses demonstrate that Facies C1 and C2 are the most common, and are interbedded on the scale of a few metres or tens of metres (Fig. 3.4). At the northwestern end of the Karakutikati Range, where the upper Isdell Formation is poorly exposed, dolomitic mudstone of Facies C2 forms a unit about 180 m thick directly beneath the basal terrigenous mudstone of the Malu Formation. Towards the central Karakutikati Range however (location B, Map 1), the same dolomitic mudstone unit is separated from the Malu Formation by a progressively eastward thickening unit (up to at least 100 m) of Facies C1. This suggests either erosion of part of the Facies C1 unit prior to deposition of the Malu Formation, or alternatively a lateral facies change from C1 to C2, both facies being covered by the subsequent influx of terrigenous detritus.

Facies C3 occurs at only one locality in the area mapped as

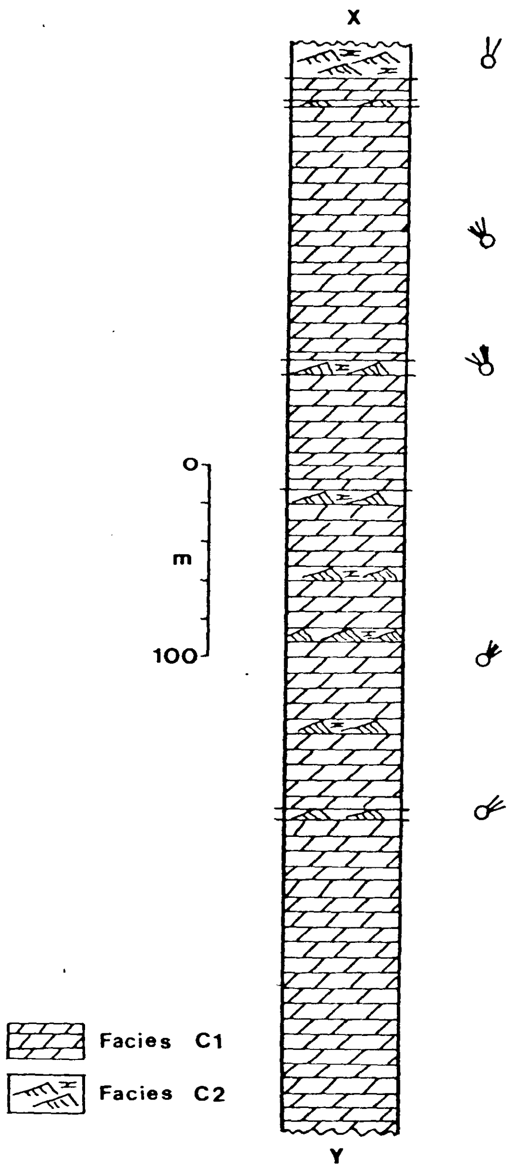

Figure 3.4 - Measured section of the Isdell Formation south of central Karakutikati Range (Map 1). Symbols at right indicate palaeocurrent directions measured from cross lamination; north to top of page.

Isdell Formation, at the northwestern limit of the formation outcrop (location C, Map 1), where it forms a unit at least 50 m thick overlying Facies C1. The stratigraphic position is uncertain however, as it is possible that the anticline south of the Karakutikati Range (Map 1) could have repeated the sequence found to the north of the range. The outcrop of Facies C3 might therefore be part of the Puntapunta Formation, which contains thick sequences similar to this facies. However, in the absence of firm evidence of this possibility, the outcrop of Facies C3 is regarded as part of the Isdell Formation. In the Mount Isdell area farther south, Chin et al. (1980) recorded a lithology similar to Facies C3 in the lowest part of the Isdell Formation, interbedded with quartz sandstone and pebble conglomerate.

Facies C1 - Thinly interbedded dololutite and dolarenite

Lithology. Outcrops of this facies consist of thin beds and thick laminae of reddish brown weathered dolarenite inter-bedded with medium to very thin beds of cream weathered dololutite (Plate 3.2A). On fresh surfaces dololutite is pale brownish grey or pale greenish grey and dolarenite is pale brown. The grain size of the dolarenite is generally in the range of silt to very fine sand, but some beds are fine to medium grained.

Bedding is laterally extensive, and individual beds can be traced across outcrops. Internally, dololutite beds are massive or thickly laminated (Plate 3.2B), but dolarenite beds are more variable. Many dolarenite beds are massive and parallel sided with sharp planar bases and tops, but parallel lamination and cross lamination are also common, in which case the bedding is slightly more wavy (Plate 3.2C). Cross lamination is most commonly in the form of single planar sets about 1 cm thick (Plate 3.2C), but in some cases the dolarenite beds are so thin that isolated lenticular ripples (or starved ripples) occur (Plate 3.2B). Rarely, ripple-drift cross lamination occurs (Plate 3.2D). In this particular example the cross lamination occurs above a zone of parallel lamination at the base of the bed, and stoss side laminae are partially preserved as well as lee side laminae (the transitional stage between Types A and B ripple-drift of Jopling and Walker, 1968). The bed is also graded upward from fine grained sand to silt. Other examples of graded beds are uncommon.

Mineralogy and micropetrography. Thin sections of dololutite (e.g. TEL 424,556,562) are pale brown to pale greenish grey in colour, and are extremely fine grained, with most carbonate grains being less than 20μm across. In some specimens silt-size detrital grains of quartz and sericite are common and are dispersed throughout the dololutite matrix, but in other specimens such detrital material is sparse and the rock is very even-textured. No patches of recrystallised carbonate have been observed. The major mineral constituent of the dololutite is dolomite, which comprises over 80% of the rock (specimens TEL 424,556 - Table 3.3). Minor minerals include quartz, sericite, plagioclase, K-feldspar, chlorite and calcite (Table 3.3). Calcite may be more abundant in some samples as some hand specimens react with cold dilute hydrochloric acid.

Thin sections of dolarenite (e.g. TEL 424,471,562) range from pale grey to pale reddish brown in colour. Although dolomite is usually predominant, quartz, and in some specimens, untwinned feldspar, are also abundant. Chemical analysis of similar dolarenite from a few samples of Facies C2 show high Na_2O contents, indicating that the feldspar is albite (see description of Facies C2 mineralogy). Silt and sand size grains of quartz and albite are set in a crystalline mass of dolomite of similar grain size (Plate 3.2E), which contrasts markedly with the extremely fine grain size of dolomite in the dololutite beds. Polycrystalline aggregates of quartz and albite are common in some layers. Grain boundaries are irregular and angular due to reaction with the crystalline dolomite during metamorphism. Small laths of sericite also occur but generally are not abundant, and in specimen TEL 424 small irregular grains of colourless to pale yellow epidote are common.

Sharp bases of dolarenite beds are visible in thin sections, and in some cases slight erosion of the underlying dololutite is evident. The upper surfaces of dolarenite layers are usually abrupt but commonly show a gradation over one or two millimetres to dololutite. At a few localities brown spherical nodules ranging from

Sample	Facies	Lithology	Quartz	Sericite	Chlorite	Plagioclase	K-feldspar	Dolomite	Calcite
*TEL 424	C1	dololutite	4	7	2	1	1	79	2
TEL 556	C1	dololutite	5	4	1	1	2	84	3
TEL 190	C2	dolarenite/ dololutite	18	-	-	43	1	38	-
TEL 423	C2	dolarenite	22	-	-	36	2	40	-
TEL 563	C2	dolarenite/ dololutite	10	-	-	30	2	58	-
TEL 749	C2	dolarenite	20	-	-	25	1	54	-
PL18/191.1	C2	dol.mudstone	39	24	-	1	1	34	-
**PL18/216.7	C2	dolarenite	35	-	-	38	1	23	-
PL18/279.0	C2	dol.mudstone	29	19	-	2	1	49	-

* contains minor epidote

** contains minor tourmaline

Table 3.3 Approximate mineral compositions of samples from the Isdell Formation, estimated from X-ray diffraction scans and chemical analyses (Appendix 2).

0.5-1.5 mm across occur within the dololutite and very fine grained dolarenite (Plate 3.2D). In thin sections these nodules contain a concentration of quartz and feldspar grains similar to those in the rock matrix (Plate 3.2E), and are rimmed with calcite in some specimens.

Interpretation. Facies C1 resulted from two different sedimentary processes. Slow accumulation of "pelagic" carbonate mud (Chapter 4) was the background sedimentary process, which resulted in massive to thickly laminated even-textured dololutite. The dolarenite beds represent periodic influxes of siliclastic and carbonate sand. These beds have many of the characteristics of contourites (e.g. Stow and Lovell, 1979) although lamination is apparently not ubiquitous and grading is rare. A few of the beds may be turbidites however, such as the graded, laminated and ripple-drift cross laminated dolarenite shown in Plate 3.2D. Any detrital feldspar in the dolarenite beds was probably subsequently altered to albite. The origin of the spherical nodules is uncertain, but they are regarded as diagenetic features rather than primary features, as they cross-cut laminae.

Facies C2 - Cross laminated dolarenite, and dolomitic mudstone

Lithology. Two end members, or subfacies, of this division can be recognised. Their intimate association precludes two distinct facies being defined. Dolarenite, similar to that of Facies C1, but thicker bedded and more extensively cross laminated (Plate 3.2F), forms one end member, while dolomitic, and commonly carbonaceous, siltstone and claystone (Plate 3.2G) forms the other. In places the finer grained subfacies contains dolarenite laminae within the dolomitic carbonaceous mudstone (Plate 3.3A). Both subfacies are grey to dark grey on fresh surfaces, but weather to a dark reddish brown colour, which facilitates their distinction from the Facies C1 in the field.

The dolarenite is fine to very fine grained, and occurs as thin to thick beds which are very commonly cross laminated. Trough cross lamination is abundant (Plate 3.2Fa), with sets up to 1.5 cm thick, some being arranged in ripple drift form (Plate 3.2Fb). Dark carbonaceous mud laminae occur as drapes across some of the ripple forms (Plate 3.2Fb).

The finer grained subfacies is laminated to thinly bedded (Plates 3.2G and 3.3A) and in places is distinctly shaly (e.g. a thick unit near the top of the Isdell Formation). Near the track which crosses the upper Isdell Formation at the northwestern end of the Karakutikati Range, several outcrops of thinly bedded siliceous mudstone occur. This lithology probably belongs to Facies C2 but has suffered surface silicification. Rare exposures of dolomitic mudstone show soft sediment slump folds (Plate 3.3B).

Mineralogy and micropetrography. In thin sections dolarenite is pale grey in colour, fine to very fine grained, moderate to well sorted and commonly laminated (Plate 3.3C). X-ray diffraction scans indicate that the mineralogy is dominated by dolomite (23-58%), quartz (10-35%) and plagioclase (25-43%) (specimens TEL 190,423,563,749 and PL18/216.7 - Table 3.3). Chemical analyses of TEL 190 and PL18/216.7 show 4.92% and 4.47% Na_2O respectively (see Table 9.4), indicating that the plagioclase is albite. However, in thin sections relatively few feldspar grains have multiple twin lamellae. In TEL 190 such feldspar occurs in thin graded laminae with sharp planar bases and more irregular tops. Quartz grains are angular to subrounded in shape, and feldspar grains are angular. Dolomite grains are of similar size to the quartz and feldspar, and form an interlocking mosaic (Plate 3.3C). Brown dololutite (as described below) is interlaminated with dolarenite in some specimens.

The finer grained subfacies is dominated by dolomite, quartz and sericite (specimens PL18/191.1 and PL18/279.0 - Table 3.3). Brown dololutite or dark grey dolomitic carbonaceous claystone is interlayered with dolomitic siltstone or dolarenite, which is similar in thin section to the dolarenite of the coarser subfacies. The brown dololutite is composed of ferroan dolomite or ankerite. This has been tested by treating some specimens with potassium ferricyanide solution, when a blue stain indicates an iron-rich dolomite (e.g. Friedman, 1959). Varying amounts of carbonaceous material occur, in the form of black wavy streaks lying parallel to the bedding (Plate

3.3D). Visual estimates indicate that carbonaceous material forms as much as 10-15% by volume of some mudstone layers.

Interpretation. Facies C2 is closely related spatially to Facies C1, but the processes of deposition were somewhat different. Mudstone of Facies C2 is either iron-rich carbonate or is hemipelagic, with considerable terrigenous detritus, in contrast to the pelagic dolomite of Facies C1 with very little terrigenous detritus. An increase in the supply of detrital material is indicated by the greater thicknesses of dolarenite beds in Facies C2 compared with Facies C1, and more continuous supply of sand by traction currents is suggested by the extensive cross lamination. Unlike the dolarenite beds of Facies C1, it is unlikely that these thicker beds are contourites, and palaeo-current measurements (Chapter 4) suggest that the sands were transported down the palaeoslope.

The carbonaceous material was probably derived from marine algae, and preservation resulted from rapid burial due to the increased supply of detritus (see Chapter 4). The presence of abundant albite in some specimens suggests abnormally high amounts of detrital feldspar, which could be of tuffaceous origin (Chapter 4).

Facies C3 - Thickly bedded dolarenite and calcarenite

Lithology. In the single area where this facies occurs (location C, Map 1), reddish brown weathered dolarenite is the major lithology, with interbedded grey weathered calcarenite being a minor component. Between some of the carbonate sandstone beds are thin beds of cream coloured dololutite. On fresh surfaces the dolarenite is yellowish brown in colour while the calcarenite is grey. Bedding is medium to very thick (Plate 3.3E), with some beds reaching 2-3 m in thickness. Cross bedding is common (Plate 3.3F) with sets up to 10 cm thick. Abundant quartz grains, usually of fine to very fine grain size are evident in hand specimens of both lithologies. Examination of the mineralogy using thin sections and X-ray diffraction scans has not been carried out for this minor facies.

Interpretation. The arrangement of lithologies in this facies is similar to that in Facies C1, but carbonate arenite beds are much thicker and less exclusively dolomitic in Facies C3. Pelagic carbonate deposition was again the background sedimentation, with periodic influxes of carbonate and siliclastic sand leading to deposition of the arenite beds. Facies C3 was deposited proximal to the source of the sand, possibly on a carbonate shelf, while Facies C1 was deposited distally, probably on a carbonate slope (see section 4.2.3). Subsequent partial dolomitisation may account for both dolarenite and calcarenite being present.

3.3.2 MALU AND TELFER FORMATIONS

These two formations are economically the most important units of the Yeneena Group, containing the Telfer gold deposits within the upper Malu and lower Telfer Formations. They are treated together because they are both dominated by siliclastic sediments, and several facies are common to both formations. However, the Telfer Formation is generally finer grained (the coarsest siliclastic facies being absent), and contains more carbonate rocks than the Malu Formation. The formations constitute a northward thickening wedge, their combined thickness varying from 1100 m at the Karakutikati Range to over 2150 m at the Malu Hills.

Outcrop characteristics and facies subdivision

Outcrops of these formations are widespread, comprising the vertical to slightly overturned strata of the Karakutikati Range (Plates 3.1 and 3.4A) and Trotman Hills in the south; the plunging anticlines of Connaughton, Trotman and Tim's Prospects; part of the Lamil Hills in the west; the domes (or periclines) at Telfer, Thomson East Prospect, and to the east of the Wilki Range; and the complexly folded and faulted Malu Hills in the north (Map 1). A series of ridges and valleys, formed by the differential erosion of sandstones and finer grained sediments, is the most common outcrop characteristic, which is best exemplified by the Karakutikati Range (Plate 3.1). Rock exposures are commonly well developed on ridge crests, but slopes are often scree-covered, and aeolian sand and alluvial gravel occur in the valleys.

Four siliclastic facies have been distinguished to facilitate the description and interpretation of the sedimentary sequence. These facies are clearly recognisable at Telfer, where they form the basis of the stratigraphic subdivision, and can also be readily identified elsewhere. Grain size, which rarely exceeds medium grained sand, is the single most important characteristic which distinguishes the facies, but bed thickness and sedimentary structures are also important. Three of the facies have calcareous sub-facies in the Telfer Formation at Telfer, and at the Karakutikati Range a thick dolomitic sequence occurs, also in the Telfer Formation. The dolomitic sequence is composed dominantly of thin to medium bedded dolarenite and dololutite, designated as Facies C4.

The four siliclastic facies are:-

Facies S1 - Pale greenish grey mudstone

Facies S2 - Generally massive very fine grained pale grey sandstone, and pale greenish grey mudstone

Facies S3 - Commonly graded fine grained pale grey sandstone, and pale greenish grey mudstone

Facies S4 - Massive medium grained greyish white sandstone, and pale greenish grey mudstone

The pale greenish grey mudstone, which comprises both siltstone and claystone, is interbedded with the various sandstone types, and is designated as a separate facies only where it is greater than about 3 m thick. In places it is difficult to distinguish Facies S2 from S3, particularly where the exposure is poor, due to a gradation of characteristics between the two facies. However, end members of each facies are distinctive. Little confusion occurs in the identification of Facies S4, as the facies forms discrete stratigraphic units which have sharp contacts with other facies. The stratigraphic relationships between facies at Telfer and the Karakutikati Range are summarised in Figures 3.3 and 3.2, and are discussed in Chapter 4. The major sedimentary features of the siliclastic facies are graphically represented in Figure 3.5 and 3.6. The following descriptions are of the least altered representatives of each facies. Metamorphic effects and alteration due to mineralisation are described in Chapters 5 and 7.

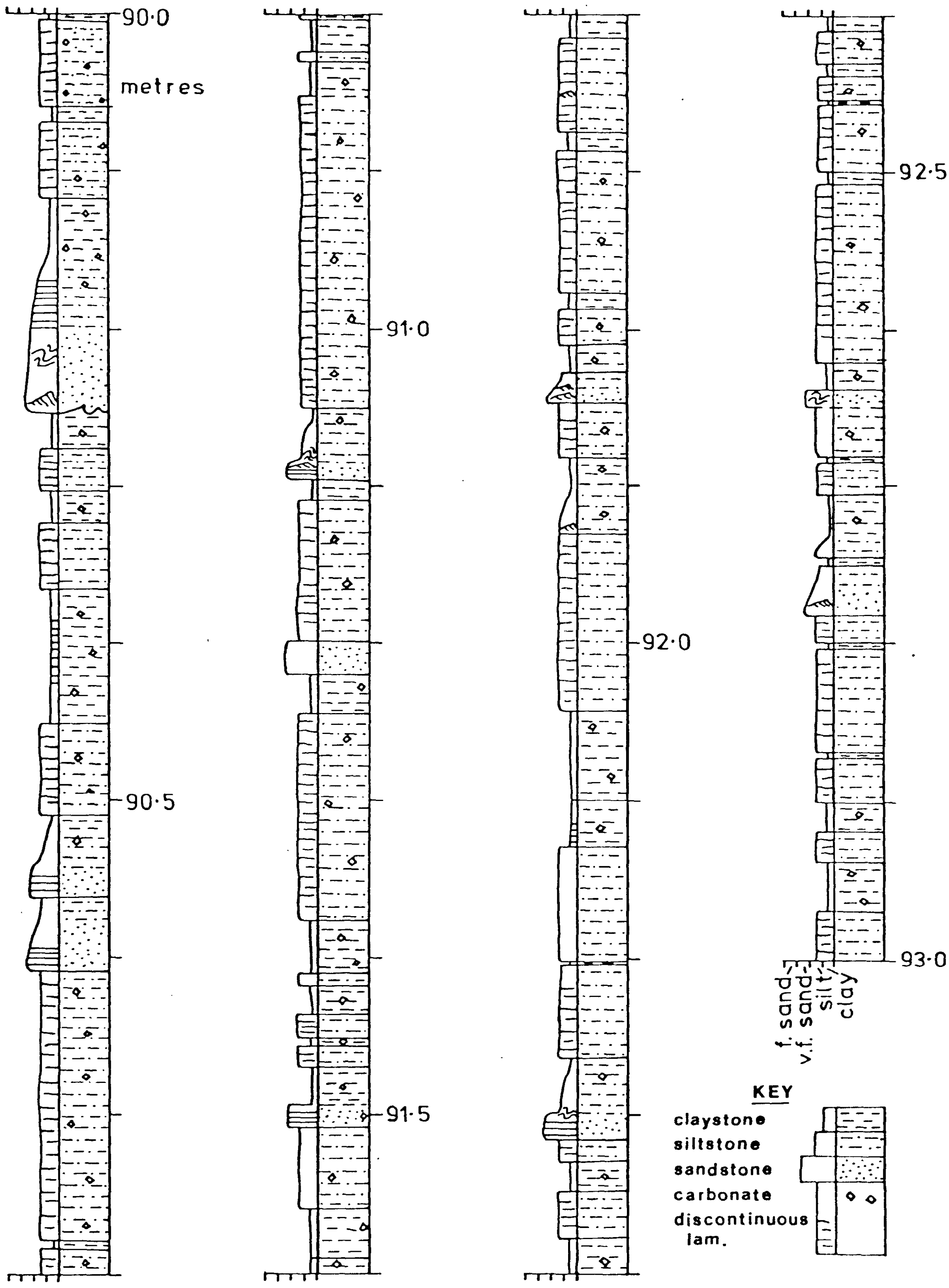

Figure 3.5 - Sedimentary characteristics of Facies S1 in the Middle Vale Siltstone Member of core PR449 (Fig. 5.2) at Telfer. Scale indicates core depth; true thicknesses are 0.75 x this scale. See Figure 3.6 for key to sedimentary structures.

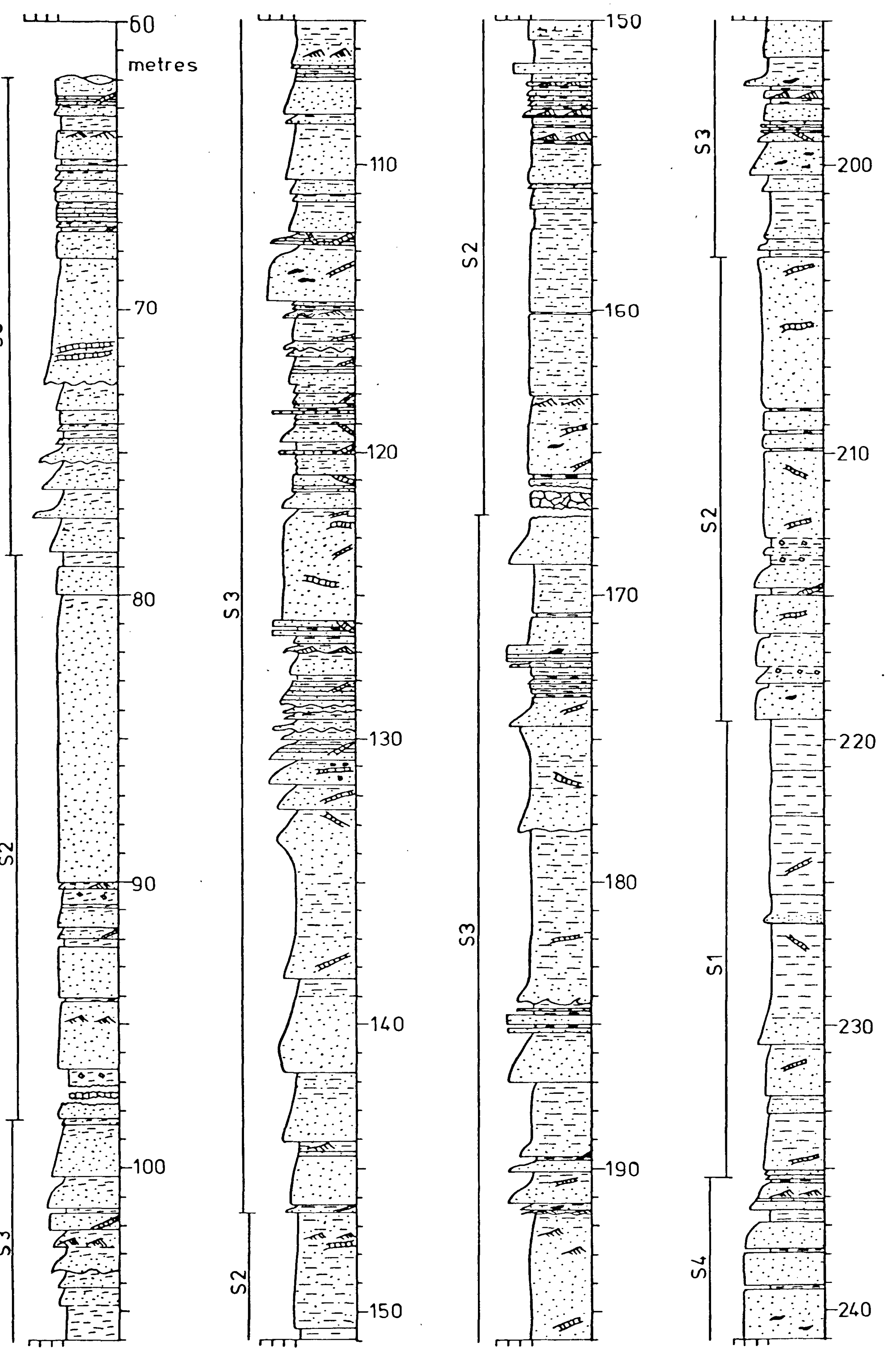

Figure 3.6 - Sedimentary characteristics of Facies S1 - S4 in core PR397 (Fig. 5.2) at Telfer. Scale indicates core depth and also true thickness.

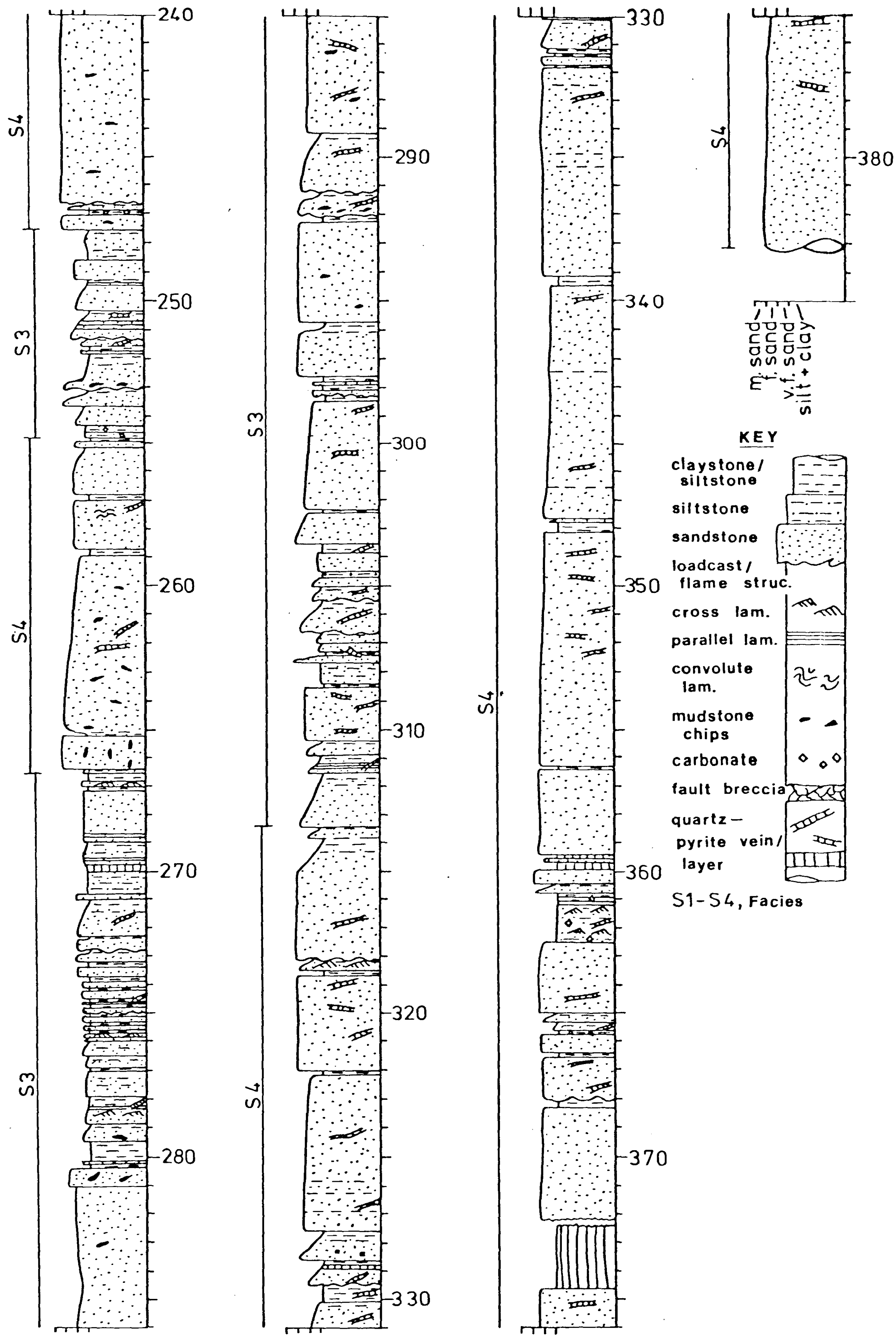

Figure 3.6 - continued.

Facies S1 - Pale greenish grey mudstone

The Middle Vale Siltstone Member (Table 3.2) typifies this facies, and forms the basis for the following lithological description. Numerous unoxidised cores of this member exist at Telfer due to the presence of the Middle Vale Reef near its base (Chapter 7). Other cored units of the facies include parts of the lower Malu Formation (Fig. 3.6), sequences within the Outer Siltstone Member (Fig. 3.3), and in some drill holes, 3-4 m of sediment near the top of the Median Sandstone Member (the Upper Vale Shale of the earlier stratigraphic terminology - Table 3.1). Surface exposures of this facies are generally poorly developed.

Bedding characteristics and sedimentary structures. Interbedded siltstone and claystone dominate the facies, with subordinate fine to very fine grained sandstone beds also occurring in some places. The facies is typically thin to very thin bedded, most beds being between 1 cm and 10 cm thick. For example, over a 3 m interval of the Middle Vale Siltstone Member in core PR449 (Fig. 3.5) eighty beds occur, giving an average true bed thickness of 3.1 cm (the bedding is at 55° to the core axis). Siltstone is the dominant lithology, followed in abundance by claystone and then sandstone. Over the same core interval as above, the sand+silt/clay ratio is 2.66, and the sand/silt+clay ratio is 0.07.

In unoxidised core samples the lithologies are greenish grey in colour, but oxidised exposures in the pits at Telfer are greyish white, and surface outcrops are reddish brown. The claystone is generally massive, but occasionally faint parallel lamination occurs. In many stratigraphic intervals abundant white "spots" of ferroan dolomite and siderite occur within the claystone, and also to a lesser extent in the siltstone. These are generally less than 1 mm across, but the maximum size is about 3 mm. They are rhombic to roughly circular in outline, with diffuse edges. In weathered samples, this carbonate has been oxidised to limonite, and limonite stained hollows are commonly all that remain. Prior to the recovery of unweathered drill cores, the limonite spots were thought to indicate originally pyritic mudstone.

Siltstone beds are usually thicker than the claystone beds, and are slightly lighter in colour. They have sharp planar bases and upper surfaces, and a crude lamination is common (Plate 3.4B). A few beds are visibly graded from coarse silt to clay, and rare cross lamination occurs as isolated sets about 1 cm thick. Rarely, dark grey carbonaceous siltstone beds occur, containing abundant wavy black carbon laminae (see below). In the upper part of the Median Sandstone Member a distinctive unit of eight such beds occurs in many of the drill cores at Telfer (Plate 3.4C), and can be used for correlation around the Telfer Dome.

A few fine and very fine grained, graded sandstone beds also occur within the facies (Fig. 3.5). Parallel lamination, cross lamination, convolute lamination and, rarely, small basal grooves and load casts are all found within these sandstones. When more than one structure occurs, parallel lamination is usually below cross lamination or convolute lamination. Towards the top of the Middle Vale Siltstone Member these sandstone beds are particularly characteristic, and are up to about 50 cm thick.

An important calcareous sub-facies of Facies S1 occurs as thin units within the Outer Siltstone Member and at the base of the Middle Vale Siltstone Member at Telfer (Fig. 3.3). This lithology comprises very thinly interbedded limestone, claystone and siltstone. In the Middle Vale Siltstone Member and near the base of the Outer Siltstone Member this calcareous sub-facies forms the lateral equivalent of the Middle Vale Reef and the E-Reefs, and for this reason a detailed description of the rock type is reserved for Chapter 7, where a full account of the unoxidised ores is given.

Mineralogy and Micropetrography. The two main lithologies of this facies, claystone and siltstone, have similar mineral assemblages. Typical samples are dominated by sericite (27-52%), quartz (28-39%), carbonate (2-27%) and plagioclase (4-19%) (Tables 3.4, 3.5, 3.6). Metamorphic chlorite also occurs in a few samples (see Chapter 5). Detrital tourmaline, zircon and opaque grains (mainly iron oxides) occur in trace amounts (less than 1%), and in some specimens both tourmaline and opaque minerals (usually pyrite)

Sample	Core Interval	Facies	Lithology	Quartz	Sericite	Plagioclase	K-feldspar	Dolomite	Calcite
	LOWER MALU FORMATION								
397-1	74.70-.74	S3	claystone	25	27	45	2	1	-
397-2	123.29-.35	S3	sandstone	72	3	17	1	5	2
397-3	173.14-.19	S3	siltstone	31	17	41	2	9	-
397-4	199.66-.71	S3	sandstone	79	1	11	-	1	8
397-5	209.84-.89	S2	sandstone	50	3	29	-	18	-
397-6	217.69-.74	S2	claystone	28	33	27	1	11	-
397-7	220.60-.69	S1	siltstone/ claystone	39	27	19	1	14	-
397-8	226.42-.48	S1	sandstone	40	3	42	-	15	-
397-9	254.55-.60	S3	siltstone	27	37	29	1	6	-
397-10	263.30-.36	S4	sandstone	85	1	8	-	3	3
397-11	272.79-.87	S3	claystone	15	34	47	1	3	-
397-12	304.65-.70	S3	siltstone	11	23	50	1	15	-
397-13	328.86-.92	S4	claystone	9	31	39	1	20	-
397-14	366.50-.54	S4	sandstone	77	7	10	-	5	1

Table 3.4 Approximate mineral compositions of samples from siliclastic facies in the lower Malu Formation at Telfer (Core PR397 - Fig. 3.6). Estimated from X-ray diffraction scans (Appendix 2).

Sample	Core interval	Facies	Lithology	Quartz	Sericite	Chlorite	Plagioclase	K-feldspar	Dolomite	Calcite	Siderite
	RIM SANDSTONE MEMBER										
548-9	116.28-.35	S4	sandstone	67	7	-	19	1	6	-	-
548-10	125.05-.10	S4	claystone	18	25	-	47	3	7	-	-
548-11	128.95-129.00	S4	siltstone*	31	41	-	9	2	12	-	-
548-12	141.10-.15	S4	sandstone	80	5	-	3	1	11	-	-
	MEDIAN SANDSTONE MEMBER										
548-22	161.84-.88	S2	siltstone*	29	39	-	4	2	21	-	-
548-24	192.00-.04	S2	sandstone	55	1	-	30	-	14	-	-
	MIDDLE VALE SILTSTONE MEMBER										
548-1	199.22-.42	S1	claystone/ siltstone	29	48	5	8	1	2	-	7
548-26	201.43-.49	S1	claystone/ siltstone	31	32	23	8	1	5	-	-
548-2	205.35-.53	S1	claystone/ siltstone	30	52	-	5	2	11	-	-
548-3	206.02-.41	calc.S1	limestone/ claystone	3	21	-	1	1	10	65	-
548-4	206.41-.62	calc.S1	limestone/ claystone	3	17	-	1	-	5	74	-
548-5	206.62-207.38	calc.S1	limestone/ claystone	3	19	-	3	-	5	70	-
548-6	207.38-.89	calc.S1	limestone/ claystone	10	32	-	8	-	10	40	-
548-7	207.89-208.18	S1	siltstone	38	45	-	7	1	9	-	-
	FOOTWALL SANDSTONE MEMBER										
548-8	208.48-.55	S3	claystone/ siltstone	22	69	-	4	1	4	-	-
548-31	209.46-.54	S3	sandstone	78	7	-	6	3	3	3	-
548-32	215.45-.49	S3	sandstone	68	16	-	13	1	2	-	-

* includes ∿5% carbonaceous material

Table 3.5 Approximate mineral compositions of samples from siliclastic and calcareous facies in the upper Malu Formation at Telfer (core PR548 - Fig. 5.2). Estimated from X-ray diffraction, scans (Appendix 2).

Sample	Core Interval	Facies	Lithology	Quartz	Sericite	Chlorite	Kaolinite	Plagioclase	K-feldspar	Dolomite	Calcite
	OUTER SILTSTONE MEMBER										
518-1	358.75-.86	S2	sandstone	49	14	-	2	10	6	7	12
518-2	379.08-.12	calc.S3	claystone	27	41	26	-	4	2	-	-
518-3	458.41-.48	calc.S2	limestone	2	6	-	1	7	7	1	76
518-4	475.03-.06	calc.S3	claystone	36	36	-	3	3	9	12	-
518-5	475.06-.12	calc.S3	calcarenite	26	14	-	2	7	7	5	39
518-5a	513.21-.27	S3	claystone	29	39	-	8	2	10	12	-
518-6	605.16-.26	calc.S1	limestone	1	10	-	-	4	-	2	83
518-7	621.88-.98	calc.S1	limestone	2	9	-	1	12	-	8	68
518-8	634.56-.63	calc.S2	dolomitic sandstone	31	13	-	-	11	8	35	2
518-9	673.90-674.00	S2	siltstone	31	48	-	5	3	1	12	-
518-10	732.23-.30	calc.S1	claystone	28	29	-	-	8	1	34	-
518-11	732.30-.37	calc.S1	limestone	2	8	-	-	6	1	4	79
518-12	744.36-.43	calc.S1	dolomite	2	6	-	-	4	1	86	1
518-13	776.56-.62	S1	claystone	32	35	-	-	5	1	26	1
	RIM SANDSTONE MEMBER										
518-14	788.86-.93	S4	claystone	3	35	-	-	38	4	20	-
518-15	797.35-.41	S4	sandstone	93	2	-	-	3	-	2	-
	MEDIAN SANDSTONE MEMBER										
518-16	837.01-.10	S2	sandstone	62	11	-	-	24	-	3	-
	MIDDLE VALE SILTSTONE MEMBER										
518-17	845.06-.12	S1	siltstone	37	27	23	-	11	-	2	-
518-18	846.80-847.02	calc.S1	dolomite/ siltstone	26	37	-	-	4	-	33	-
518-19	847.02-.47	calc.S1	dolomite/ siltstone	23	31	-	-	10	-	35	1
518-20	847.47-.95	calc.S1	limestone	2	18	-	-	6	-	3	71
518-21	847.95-848.46	calc.S1	dolomite/ siltstone	27	27	-	-	10	-	24	12
518-22	848.46-.80	S1	siltstone	28	48	-	-	4	1	19	-
	FOOTWALL SANDSTONE MEMBER										
518-23	857.12-.19	S3	claystone	3	48	-	-	17	29	3	-

Table 3.6 Approximate mineral compositions of samples from siliclastic and calcareous facies in the Telfer and upper Malu Formations at Telfer (core PR518 - Fig. 5.2). Estimates from X-ray diffraction scans (Appendix 2).

occur as authigenic grains. In weathered samples extensive alteration to kaolinite has occurred (Chapter 6). This alteration is also extensive in the other siliclastic facies, resulting in the friable white rocks which outcrop in the Telfer pits.

In thin sections claystone is massive, but some samples possess a cleavage formed by the alignment of sericite grains (Chapter 5). Siltstone beds, however, are usually faintly laminated, the laminae, commonly less than 0.2 mm thick, comprising silt size grains of quartz, minor feldspar and detrital white mica within a claystone matrix. These laminae are discontinuous, and the structure accounts for the streaky texture seen in cores (Fig. 3.5). In both claystone and siltstone beds a spotted texture is common, due to aggregations of authigenic carbonate grains up to about 1.5 mm across. The aggregations have rounded diffuse outlines and some enclose detrital grains. X-ray diffraction scans show that this carbonate is most commonly dolomite, probably a ferroan variety as limonite forms an alteration product of these spots in weathered samples. In one specimen (548-1, Table 3.6) the carbonate was shown by this method to be siderite.

Both the tops and bases of siltstone beds are usually sharp and parallel in thin sections, and barely perceptible upward grading from coarse to fine silt occurs in some beds. Small scale load casts are rarely developed at the base of siltstone beds (e.g. in specimen 518-21). The texture of the carbonaceous siltstone beds in thin sections is very similar to that of the dolomitic carbonaceous mudstone in the Isdell Formation (Plate 3.3D).

Interpretation. The claystone of Facies S1 accumulated in a quiet, presumably deep marine environment by the slow settling of terrigenous clay from suspension. Siltstone interbeds represent periodic influxes of slightly coarser detritus; the internal lamination suggests slight variations in current strengths during deposition. These siltstone beds are either distal turbidites (representing Bouma D divisions) or contourites (see Chapter 4). The very fine grained sandstone interbeds are interpreted as turbidites due to their commonly graded nature and, in some, the presence of sole markings and partial Bouma sequences (parallel lamination (B), beneath cross lamination (C), beneath diffuse parallel lamination (D)).

Facies S2 - Generally massive very fine grained pale grey sandstone, and pale greenish grey mudstone.

At Telfer the best examples of this facies are the Camp Sandstone Member and the bulk of the Median Sandstone Member. Thick units composed of this facies are also found within the lower Malu Formation and the Outer Siltstone Member (Figs. 3.3 and 3.6). Surface outcrops of this facies weather to a reddish brown colour, in common with the other fine grained siliclastic facies. Only rarely are sedimentary structures seen in outcrops, the typical expression being well jointed massive sandstone in which bedding is very difficult to distinguish from joints. For this reason, drill cores and pit exposures at Telfer form the basis for much of the following description.

Bedding characteristics and sedimentary structures. The diagnostic lithology of this facies is thick to very thick bedded, very well sorted, very fine to fine grained sandstone. Interbedded with this sandstone are thin to very thin beds of mudstone, identical to that found in Facies S1. Sandstone beds often exceed 1 m in thickness, and not uncommonly, core lengths of over 5 m occur where no stratification can be detected (e.g. in the Median Sandstone Member of PR518). The latter figure however may be an overestimation of the maximum bed thickness, as amalgamated sandstone beds with no interbedded mudstone would be difficult to discern in drill core.

Sandstone beds in this facies are typically massive, but parallel lamination and cross lamination occur in places. Grading occasionally occurs over a few centimetres at the tops of sandstone beds, passing from sandstone through siltstone to claystone, but both the bases and the upper surfaces of sandstone beds are usually sharp and flat. The uncommon cross lamination generally occurs near the base or towards the middle of sandstone beds, and only rarely occurs near the top. It comprises isolated sets or stacked sets (cosets) of trough type, each set being less than 5 cm thick.

A calcareous sub-facies of Facies S2 is common in the Outer Siltstone Member (Fig. 3.3), and some of the units in the Malu Formation are calcareous to varying degrees. In the Outer Siltstone Member there are all gradations from pale grey calcarenite which reacts strongly with dilute hydrochloric acid, to darker coloured almost entirely siliclastic sandstone. However, the bedding characteristics and sedimentary structures of both end members are similar.

In the Outer Siltstone Member at Thomson East Prospect (Fig. 3.1) massive fine grained sandstone of this facies contains large scale low angle cross-stratification at a few localities. This uncommon stratification occurs as planar foresets which truncate each other at angles up to 15°, a single truncation surface usually being the only manifestation of the structure. Associated with this structure at two localities are small scale features resembling ripple marks (Plate 3.4D). These features occur on the bases of sandstone beds, and have wavelengths less than 8 mm and amplitudes of about 1 mm.

Mineralogy and Micropetrography. In thin sections of sandstones from this facies the generally well sorted fine to very fine grained texture is apparent (Plate 3.4E), with lamination being visible only rarely. The mineralogy is similar to Facies S1, being dominated by quartz (49-62%), plagioclase (10-30%), sericite (1-14%) and authigenic carbonate (3-19%) in unweathered samples (Tables 3.4, 3.5 and 3.6). In the calcareous sub-facies up to 77% of the rock is composed of carbonate (specimen 518-3, Table 3.6). A few detrital grains of tourmaline, zircon and iron oxides occur in most thin sections. In weathered samples carbonate has been removed, leaving innumerable small voids, and feldspar has been altered to kaolinite.

Grain outlines, particularly of the smaller grains, have been altered by incipient recrystallisation, and a diffuse interlocking mosaic of quartz, feldspar, sericite and minor detrital muscovite is the most common texture. Quartz and feldspar are of similar grain size and shape, and both constituents are thought to be of detrital origin. Sericite, of finer grain size than the muscovite laths, occurs interstitially, being formed from detrital clays during metamorphism. Carbonate occurs as authigenic euhedral rhombs and anhedral grains, which commonly partially replace some of the detrital components. Mudstone interbeds in this facies are similar petrographically to that of Facies S1.

Interpretation. The process of deposition of the thick to very thick bedded, commonly massive, very fine grained sandstone of Facies S2 is not entirely clear. The intimate association of this facies with other siliclastic facies (e.g. Fig. 3.3), some of which have been interpreted as turbidites (see below), suggests a closely related environment, and probably mode, of deposition. For reasons further discussed in Chapter 4, these sandstones are also though to have been deposited from sediment gravity flows (e.g. Middleton and Hampton, 1976). Mudstone interbedded with the sandstone resulted from the same depositional processes as those which deposited Facies S1.

Facies S3 - Commonly graded fine grained pale grey sandstone, and pale greenish grey mudstone

This facies occurs as stratigraphic units generally greater than 10 m thick, in both the Malu and Telfer Formations (Figs. 3.3 and 3.6). At Telfer it is best known from the Footwall Sandstone Member (Table 3.1), the top few metres of which have been extensively cored. At the Karakutikati Range the facies is commonly well exposed (Plate 3.4A), and both bedding plane characteristics and internal sedimentary structures are visible. A calcareous sub-facies occurs in the Outer Siltstone Member at Telfer (Fig. 3.3), and differs from the more abundant siliclastic rocks only in sandstone composition.

Bedding characteristics and sedimentary structures. The facies is typified by thin to thick beds (Table 3.7) of fine to very fine grained sandstone, interbedded with thinner siltstone or claystone beds (Fig. 3.6). Medium grained sandstone is a minor component of some sequences. The sandstone is pale grey to pale greenish grey in colour, and the mudstone interbeds are usually a darker greenish grey, in fresh core samples. Outcrops typically weather to a deep reddish brown colour.

Core No.	Interval (m)	Unit	No. of beds	Average true thickness (cm)	Maximum true thickness (cm)	Percent graded
PR369	139.96-145.8	FSM	15	37	105	73
PR397	68.2 - 78.6	L.Malu Fm	10	104	445	90
PR397	102.2 -132.5	L.Malu Fm	51	59	390	73
PR443	98.1 -107.6	FSM	15	55	177	60
PR445	101.2 -109.1	FSM	20	30	186	10
PR447	119.9 -128.4	FSM	24	25	82	46
PR449	96.2 -101.8	FSM	17	23	71	53
PR518	848.9 -864.0	FSM	33	45	228	45

Table 3.7 Bed thicknesses and graded bedding in Facies S3

Sedimentary structures are more abundant in this facies than in any other facies. Sole marks are occasionally visible, and parallel lamination, cross lamination and graded bedding are all common. On the bases of a few sandstone beds at the Karakutikati Range, well developed flute casts occur (Plates 3.4F and 3.4G), and more rarely, linear groove casts are preserved (Plate 3.4H). At Telfer, similar flute and groove casts were observed on the bases of a few Facies S3 sandstone beds at an exposure of the Outer Siltstone Member in Pit 2 (Fig. 6.2). The structures are probably more widespread in this facies than noted, but exposures seldom permit basal bedding planes to be seen. The flute casts are bulbous (Plate 3.4F) to conical (Plate 3.4G) in shape (using the terminology of Dzulynski and Walton, 1965, p.42) and are up to 1.5 cm deep and 5 cm wide. A spiral structure occurs on the pointed noses of some conical flute casts. Groove casts are less than 2 mm deep and 4 mm wide, but are up to about 20 cm long. These sole marks provide valuable palaeocurrent data (Chapter 4).

No flute casts have been positively identified in cores of this facies, although basal scoured contacts of sandstone on mudstone occasionally occur, with a relief of up to 2 cm. Load casts and accompanying flame structures also occur at the bases of some sandstone beds. The majority of sandstone beds do not possess sole marks however, and have sharp planar bases. Gradational basal contacts are rare. No large scale scours, or channels, occur in the facies.

Grading is common in the sandstone beds (Table 3.7) but is not ubiquitous. Three types of grading occur. Most commonly the entire grain size range decreases gradually upward through the whole bed (the distribution grading of Middleton, 1967). Less commonly there is a rapid grain size reduction in the lowest few centimetres of the bed, with most of the bed being of uniform grain size or imperceptibly graded. Rarely, reverse grading occurs in the lowest one or two centimetres of the bed (e.g. in PR397 at 129.74 m depth). In most graded beds an upward change from sand through silt to clay grade sediment occurs, but in some cases mudstone interbeds (similar to Facies S1) have sharp contacts with underlying sandstone beds.

Several kinds of lamination occur in the sandstone beds, and are usually more readily observed in outcrops rather than in unweathered cores. In individual beds, lamination is commonly restricted to a single type, although sequences of structures do occur in some thick beds (Plate 3.5A). Parallel lamination and cross lamination are both common, and convolute lamination, which is closely associated with cross lamination, is rare. In some beds parallel lamination passes upward into cross lamination, and then rarely into convolute lamination (Plate 3.5A), but in a few beds cross lamination occurs beneath parallel lamination. Repeated sequences of sedimentary structures in successive beds do not occur.

Cross lamination most commonly occurs as single tabular sets from 1 cm to 2 cm thick, but in places cosets comprising two or three sets occur (Plates 3.5B, 3.5C). The maximum set thickness is about 4 cm. Some sets are of trough type, and are well exposed in plan view on a few bedding planes of the Footwall Sandstone Member in pits at Telfer. Individual troughs are about 10 cm across and 2 cm to 3 cm thick. Numerous palaeocurrent measurements have been made on the various types of cross lamination of Facies S3 (Chapter 4).

Mineralogy and micropetrography. The mudstone beds within Facies S3 have similar textures and compositions to the siltstone and claystone beds in the other siliclastic facies. They are composed mainly of sericite, quartz, feldspar and carbonate (Table 3.4, 3.5, 3.6).

The sandstone of this facies is less uniform in texture than sandstones of Facies S2 and S4. The grain size varies from very fine to medium grade, with fine grains being the most abundant. Moderate or poor sorting is characteristic of the sandstone. Numerous specimens have a bimodal texture (Plate 3.5D), with dispersed medium grains of quartz in a fine to very fine grained matrix. The medium grade quartz grains are commonly very well rounded, and are monocrystalline with sharp to slightly undulose extinctions. Feldspar grains are very rare in this coarser fraction. In the fine to very fine grained fraction, grain boundaries are generally less well defined and more irregular in shape due to partial recrystallisation.

Twinned plagioclase is common in the finer fraction, as are sericite and authigenic carbonates. Specimens which do not exhibit bimodality are fine to very fine grained, similar to those of Facies S2. In common with sandstones of the other facies minor detrital tourmaline, zircon and iron oxides occur. Rarely, these heavy minerals are concentrated near the base of a sandstone bed (Plate 3.5D).

The mineralogy of Facies S3 sandstone is dominated by quartz (68-79%), plagioclase (6-17%), sericite (1-16%) and carbonate (2-9%) (Tables 3.4, 3.5). Compared with Facies S2, the sandstone generally contains more quartz, and less feldspar and carbonate. The average feldspar content of four samples analysed by X-ray diffraction is 13% which if the feldspar is entirely of detrital origin allows a classification of sub arkose.

Calcarenite beds occur interbedded with siliclastic mudstone in the Outer Siltstone Member at Telfer (Fig. 3.3), and form a calcareous subfacies of Facies S3. The calcarenite comprises quartz, calcite, sericite, feldspar and minor dolomite (e.g. specimen 518-5, Table 3.6). In thin sections a bimodal texture is typical, with very well rounded medium grains of quartz dispersed in a fine to very fine grained matrix of carbonate, quartz, feldspar and sericite. The carbonate generally has a similar grain size to the quartz and feldspar, and is probably also detrital in origin, although at least partial recrystallisation is likely to have taken place.

Interpretation. The common occurrence of grading in the Facies S3 sandstone beds, and the presence of flute casts and other sedimentary structures, suggests that much of the sand in this facies was deposited from turbidity currents. Some of the more massive sandstone beds resemble the Facies S2 sandstones, and may have been deposited from other types of mass flows such as fluidised sediment flows or grain flows. Localised reworking of the tops of mass flow sands may have taken place, as some cross laminations at the tops of beds are orientated at high angles to the interpreted direction of mass flow movement (see Chapter 4). The thin interbedded mudstone units were deposited in similar fashions to Facies S1 mudstone.

Facies S4 - Massive medium grained greyish white sandstone, and pale greenish grey mudstone

This facies is the most coarse grained found in the Malu and Telfer Formations, and consequently forms the most resistant units. It outcrops as the highest vertical ridges at the Karakutikati Range (Plate 3.4A), and at Telfer, the Rim Sandstone Member, which typifies the facies, forms the outer cuesta around Main Dome and the anticlinal core of West Dome (Plate 5.1, Fig. 5.2).

Bedding characteristics and sedimentary structures. Most sandstone beds in this facies are greyish white, massive, thick to very thick bedded, and are composed dominantly of medium grained quartz. Pale greenish grey claystone and siltstone similar to Facies S1 are interbedded with the sandstone either as thin beds (Fig. 3.6) or thicker units up to 2 m or so thick. In the Telfer pits some of these thick mudstone units can be seen to wedge out between two sandstone beds, over a distance of about 100-200 m.

Typically, both tops and bases of sandstone beds are sharp (Plate 3.5E), and in a few instances at the Karakutikati Range sole marks are exposed beneath vertically dipping beds. These sole marks are generally less pronounced than the well developed flute casts found beneath some sandstone beds in Facies S3, but a few elongate symmetrical flute marks occur, and faint shallow linear groove casts are rather more common (Plate 3.5F). In several cases irregularly undulating sole marks occur, showing no directional fabric (Plate 3.5F); these are probably load casts. The relief on the bases of the sandstone beds is generally less than 1 cm. In one particular locality on the crest of West Dome, linear tool marks occur on a bedding plane exposure of the Rim Sandstone Member (Plate 3.5G). These tool marks are shallow grooves which were caused by the scouring action of angular mudstone clasts (up to about 1 cm across). The imprints of the mudstone clasts can be seen at the downcurrent end of some grooves (Plate 3.5G).

Internally the sandstone beds are most commonly completely massive, but faint parallel lamination occurs in some beds (Plate

3.6A). A single instance of cross stratification has been noted. This occurs at the very top of a 3.4 m thick sandstone bed in the Rim Sandstone Member on the northeast flank of Main Dome, and is a single trough set 10 cm thick. The top few centimetres of some sandstone beds are graded (Fig. 3.6), and a few of the thinner beds are graded throughout their thickness. Angular mudstone clasts less than 1 cm across are common, being randomly dispersed throughout sandstone beds. At one locality in the lower Malu Formation at the Karakutikati Range an intraformational conglomerate of such mudstone clasts occurs. The conglomerate forms the central 30 cm of a 1.5 m thick medium grained quartz sandstone bed, and comprises approximately 50% mudstone clasts.

Medium grained sandstone beds similar to the above occur rarely in isolation within other facies. An important example of this occurs in the upper part of the Footwall Sandstone Member at the Karakutikati Range. Near the measured section at location A (Map 1), towards the northeastern end of the range, a prominent 80 cm thick bed of massive medium grained sandstone occurs within a thick sequence of Facies S3. Southeastwards this bed thickens, and other similar sandstone beds are found in the same stratigraphic unit. This trend continues for a distance of about 12 km southeastwards, where the entire Footwall Sandstone Member (approximately 100 m thick) is composed of Facies S4. The significance of this lateral transition from Facies S3 to S4 is discussed in Chapter 4.

Mineralogy and Micropetrography. The thin mudstone units between the thick sandstone beds are most commonly composed of claystone, with siltstone also occurring in the thicker mudstone units. Three samples of claystone were analysed by X-ray diffraction (Tables 3.4, 3.5, 3.6) and were found to contain particularly high feldspar contents, between 40 and 50%; sericite, carbonate and quartz compose the bulk of the remainder of the claystone.

In thin sections, fresh specimens of Facies S4 sandstones are typically moderately to poorly sorted, with medium grained quartz forming the bulk of the rock and finer grained quartz, feldspar, sericite and carbonate forming a matrix. Some specimens are bimodal, but in most a gradation occurs between the medium grade fraction and the silt to fine grained fraction which forms the matrix. The medium grained fraction is almost exclusively subrounded to well rounded quartz (although partial recrystallisation of the matrix has commonly resulted in slightly serrated grain boundaries). Most medium grade quartz grains are monocrystalline and have sharp to undulose extinctions.

Very angular elongate clasts of siltstone and claystone, up to 1 cm long, are common in the sandstone, many of which are carbonate rich due to preferential alteration during diagenesis or metamorphism. Slightly larger irregular shaped mudstone clasts occur in some sandstone beds just above their sharp basal contact with massive mudstone. Associated flame structures also occur at some of these contacts.

The average major mineral composition of five samples of Facies S4 sandstone is quartz 80%, feldspar 9%, carbonate 6% and sericite 4%. The feldspar, mostly twinned albitic plagioclase, occurs as discrete grains in the matrix of the sandstone, and is probably entirely detrital in origin. The sandstone can therefore be classified as sub arkose. In weathered specimens, carbonate has been leached, and feldspar and sericite have been converted to kaolinite, which has commonly also been removed (Plate 3.6B), resulting in a sandstone of quartz arenite composition. Well rounded detrital grains of zircon, tourmaline and iron oxide are fairly common within the sandstone, and rarely these heavy minerals are concentrated in the lowest grain layer of a sandstone bed (e.g. thin section PR397/263.94m).

The sandstone of this facies is very similar petrographically to the bimodal sandstone of Facies S3, but in Facies S4 there is a much greater proportion of medium grade quartz.

Interpretation. Facies S4 is closely associated spatially with Facies S3, with which it has petrographic similarities, but the assemblages of sedimentary structures and bedding characteristics differs between the two facies. The mode of deposition of Facies S4 sandstone beds is therefore probably related to, but not identical with, the mode of deposition of Facies S3 sandstones. The massive nature, thick bedding, sharp bases with sole marks and sharp tops suggest that the sandstone beds are grain flow deposits (see Chapter 4). The background sedimentation was deposition of terrigenous muds similar to those of the other siliclastic facies.

Facies C4 - Thin to medium bedded dolarenite and dololutite

Within the Outer Siltstone Member at the Karakutikati Range there is a thick (165 m) unit of dolomite (Fig. 3.2). Much of the unit is composed of interbedded dolarenite and dololutite, which is designated as a separate facies, differing from the three facies of the Isdell Formation mainly on bedding characteristics (see below). Dolomitic shales underlie, and are interbedded with, this facies and are regarded as carbonate-rich subfacies of Facies S1 (Fig. 3.2). At Telfer, and elsewhere in the area, a specific dolomite facies has not been recognised in the Outer Siltstone Member, although calcareous subfacies of the siliclastic facies are found in cores at Telfer (Fig. 3.3). The thin to medium bedded dolarenite and dololutite facies is also found within the Puntapunta Formation.

Lithology. The most obvious characteristic of the facies is well developed bedding (Plate 3.6C). Typically, parallel sided thin to medium beds of dolarenite are interbedded with very thin to thin beds of dololutite. Dolarenite consists of finely crystalline dolomite, within which are dispersed very abundant fine to very fine grains of quartz, and dololutite comprises even textured very fine grained dolomite. Dolarenite beds weather to a pale yellowish brown colour and are grey to pale yellowish grey on fresh surfaces, whereas dololutite beds are pale cream coloured on weathered surfaces and pale grey on fresh faces.

Dolarenite beds have sharp bases and tops (Plate 3.6D), and internally are massive or show parallel lamination and/or cross stratification. Both cross lamination and cross bedding occur, the maximum set thickness being about 8 cm. Large scale sets are planar

(Plate 3.6E) with foresets inclined at about 15°, but smaller scale sets are more variable, some being of trough type. In a few beds upward grading from fine to very fine grain size occurs (Plate 3.6D), and in a few of these graded beds parallel lamination is found beneath cross-lamination. The facies resembles Facies C1 of the Isdell Formation, but the dolarenite beds of Facies C4 are thicker and form the dominant lithology of the facies.

Interbedded in a few places with these typical Facies C4 sediments is thick to very thick bedded medium grained reddish brown weathered grey dolarenite, which is similar to Facies C3 of the Isdell Formation. This lithology forms units up to 10 m thick (Fig. 3.2). The bedding is less well defined than in the thin to medium bedded facies, and cross bedding is common, with sets of trough type up to 30 cm thick being present.

Interpretation. Although this facies is dominated by carbonate sediments, the modes of deposition of the two major lithologies of the facies resemble some of those of the siliclastic facies. The dololutite represents background sedimentation in a quiet marine environment due to the slow accumulation of carbonate muds. Periodic influxes of carbonate and siliclastic sand into this quiet environment led to the deposition of the dolarenite beds. The mechanism of deposition of the sands was variable. The typical parallel-sided beds, with occasional grading, parallel lamination and cross lamination (e.g. Plate 3.6D) may be turbidites, but the thicker beds with cross bedding (e.g. Plate 3.6E) represent deposition from more persistent traction currents on relatively large scale bed forms such as sand waves.

3.3.3 PUNTAPUNTA FORMATION

Two major lithological types occur in the Puntapunta Formation, one comprising carbonates and the other carbonate-rich sandstone and siltstone. Individual facies have not been defined, partly due to less systematic study of this formation, and because there are less distinct variations within the two lithological types when compared with the three underlying formations. Carbonates form the bulk of the formation, and most of these resemble either Facies C4 of the Malu and Telfer Formations or Facies C3 of the Isdell Formation.

Carbonates

Most outcrops are composed of dolomite, but in some areas limestone predominates. Dolomite is reddish brown to pale greyish yellow or buff coloured on weathered surfaces, and fresh surfaces are usually yellowish brown or orange. Both fresh and weathered surfaces of limestone are most commonly grey, but rarely pink varieties also occur. Both lithologies are very hard, and commonly outcrop as low ridges. Outcrop surfaces are pitted by chemical weathering, but only rarely are larger scale karst features present, where irregular cavities up to about 1 m deep occur.

Both bedding and sedimentary structures are commonly well developed. Dolomite is typically thin to medium bedded (Plate 3.6F) but thick to very thick beds are not uncommon. Bedding planes range from being parallel to being discontinuous and wavy. Limestone beds tend to be thick to very thick and bedding planes are poorly defined (Plate 3.6G)

The well bedded dolomite comprises two lithologies; dolarenite forms thicker darker beds and dolosiltite or dololutite forms thinner lighter coloured beds (Plate 3.6F). The proportions of these two lithologies varies considerably throughout the area, but dolarenite is almost always predominant , and at many outcrops the finer grained sediment is absent. Limestone units are dominated by calcarenite.

Internally the clastic carbonate beds are either massive, parallel laminated or cross stratified. The dololutite beds are usually parallel laminated. A variety of cross stratification forms occur. The smallest scale form has individual planar cross sets 2-3 cm thick. Low amplitude climbing ripples with both their stoss and lee sides preserved also rarely occur (Type B ripple drift of Jopling and Walker, 1968). More commonly however cross set thickness is in the range of about 5-15 cm. Trough cross bedding occurs in this size range (Plate 3.7A), as does a type of cross stratification analogous to ripple drift cross lamination, where both stoss sides and lee sides are preserved. Oversteepening of the lee side foresets occurs in some of these larger scale "ripple drift" forms. A further type of cross stratification is preserved, representing large scale bed forms, where wavy laminae with amplitudes of 10-20 cm are truncated by similar laminae at both low and high angles (Plate 3.6G). This type of stratification is particularly common in the grey limestone.

A rare type of structure found at a very few outcrops of limestone is an intraformational (or sharpstone) conglomerate (Plate 3.7B). This comprises elongate angular fragments of quartzose limestone identical to that above and below the conglomerate, set in a more quartz rich limestone matrix. Such conglomerate beds do not exceed 50 cm in thickness. At the location of Plate 3.7B the conglomerate is overlain by cross bedded limestone.

In thin sections both the dolomite and limestone consist of extremely fine grained carbonate, with varying amounts of siliclastic detritus, mostly quartz but with minor sericite. Unlike the Isdell Formation, little feldspar occurs in the Puntapunta Formation. The carbonate occurs as silt-size interlocking grains, commonly with long axes twice the length of short axes, and with a preferred elongation direction parallel to the lamination. In a few specimens the carbonate has been recrystallised with more equant interlocking carbonate crystals up to 0.2 mm across (e.g. specimen TEL 189).

Carbonate-rich sandstone and siltstone

During the course of field work relatively little study was given to these siliclastic lithologies of the Puntapunta Formation. However, a brief description of the rocks is given below.

The lithologies form units several tens of metres thick within the more typical carbonates of the formation, and outcrop as low rubble-strewn hills which generally extend for only short distances along strike. Weathered surfaces are reddish brown, but broken faces are greyish white. The rocks are commonly very friable and porous, probably due to the leaching of large quantities of carbonate.

Surface silicification of these lithologies has resulted in extensive areas of silcrete, such as occur on the outcrops immediately north of the northwestern closure of the Telfer dome (Map 1).

Typical grain sizes of these rocks range from silt grade to very fine sand. At many outcrops bedding is difficult to distinguish from jointing, and sedimentary structures are scarce or absent. However, cross lamination, parallel lamination and parting lineation have all been observed. The sandstone units, which are volumetrically more abundant than the siltstone, resemble Facies S2 of the Malu and Telfer Formations. At several localities, such as at the Fallow's Field Prospect southwest of Telfer (Map 1), such sandstones were initially thought by the writer to represent the Camp Sandstone Member of the Telfer Formation (Facies S2), the sandstones eventually being designated as part of the Puntapunta Formation on structural and stratigraphic grounds.

Quartz and clay minerals form the bulk of weathered specimens of these lithologies. The only unweathered samples studied are drill cores from the Thomson Prospect to the northwest of Telfer (Map 1). Here the rocks are of higher metamorphic grade than at Telfer or farther south (see Chapter 5) and are composed dominantly of quartz, calcite, biotite, chlorite and plagioclase.

Interpretation

The bulk of the carbonate of the Puntapunta Formation was deposited from influxes of mixed carbonate and siliclastic sand and silt, into a depositional environment where the background sedimentation was the slow accumulation of pelagic carbonate mud. The transport mechanisms of this sand and silt are not entirely clear.

Some of the well bedded dolarenites resemble those of Facies C4 of the Telfer Formation, which are interpreted as turbidites. However, grading and internal sequences of sedimentary structures have not been observed in the dolarenite beds of the Puntapunta Formation. Some of the sedimentary structures in the carbonates, such as ripple drift cross lamination and the larger scale cross bedding, indicate that persistent traction currents were active at times in the transport and deposition of the sand and silt. The large scale wavy bedding could be the result of storm wave action (Chapter 4). The intraformational conglomerate beds indicate occasional strongly erosional currents. The environment of deposition is further discussed in Chapter 4.

The carbonate-rich sandstone and siltstone units were deposited at times when the supply of siliclastic detritus exceeded that of carbonate sand and silt, but no conclusive evidence of the depositional mechanisms was found during the brief examination of these rocks.

3.3.4 WILKI QUARTZITE

The Wilki Quartzite outcrops as very monotonous sequences of steeply dipping metaquartzite (Plate 3.7C). Individual bedding planes are rarely seen due to extensive shearing parallel to the bedding, but large scale bedding is common in most areas. Laterally extensive units up to about 5 m thick of fine to medium grained quartzite are interbedded with similarly thick units of finer grained clastic sediments (Plate 3.7C). The tops of the coarser grained units are usually more pronounced than the bases, giving the impression of upward coarsening sequences up to about 10 m thick. The stratigraphically lowest 100 m or so of the exposed formation at the Wilki Range east of Telfer is dominated by the finer grained sediments, mostly fine grained silty sandstone.

In most areas no sedimentary structures are recognisable, but at one locality in the wide area of Wilki Quartzite near Mount Crofton (Map 1) cross lamination was observed in a 4 m thick unit of siltstone and shale. The cross lamination consists of unidirectional trough cross sets up to 2 cm thick in whitish grey siltstone.

A few specimens of the Wilki Quartzite retain a sedimentary texture in thin sections (e.g. TEL 460 and 464), being moderately to well sorted medium to fine grained quartz arenite, in which mono- crystalline quartz grains, with sharp to undulose extinction, are sub-angular to well rounded in shape. The matrix comprises finely crystalline quartz and tiny sericite laths (comprising less than 1-2% of the rock). Disseminated haematite and very minor chlorite and tourmaline occur in some specimens. All gradations of recrystallisation exist, up to very coarsely crystalline quartzite, in which angular interlocking quartz grains and minor muscovite occur (see Chapter 5). It is evident that the original Wilki Quartzite sandstone was mineralogically supermature, and this may in part account for its propensity to recrystallisation.

The sheared recrystallised nature of the quartzite, and the lack of sedimentary structures, precludes a detailed interpretation of the formation in terms of depositional processes. However, the sheet-like nature of the interbedded fine to medium grained quartzite and finer grained sediments provides some clues as to the origin of the formation. It is suggested that deposition in a shallow marine environment could have resulted in this configuration of sedimentary units (see Chapter 4).

PLATE 3.1 - KARAKUTIKATI RANGE

Vertical air photograph of central Karakutikati Range (see Map 1), showing vertically bedded Isdell, Malu, Telfer and Puntapunta Formations. Lines $A-A^1$, $B-B^1$, nd $C-C^1$ are measured sections (Fig. 3.2). Photo by Kevron Ltd., Perth.

PLATE 3.2 - ISDELL FORMATION

A. Facies C1 - vertically bedded dololutite (light beds) and dolarenite (dark beds). South of Trotman Hills (Map 1).

B. Facies C1 - laminated dololutite (light beds) with isolated lenticular ripples of dolarenite. Current direction to right. South of central Karakutikati Range (Map 1).

C. Facies C1 - thinly interbedded dololutite (light beds) and cross laminated dolarenite (dark beds). Current direction to right. North of Trotman Hills (Map 1).

D. Facies C1 - ripple-drift cross lamination in dolarenite. Current direction to right. Note abundant small spherical ?diagenetic nodules. Southeast of Trotman Hills (Map 1).

E. Facies C1 - thin section (TEL 471) of very fine grained dolarenite with ?diagenetic nodule. Light minerals are quartz and feldspar, dark matrix is iron-rich dolomite. Plane polarised light. Same locality as Plate 3.2D.

F. Facies C2 - cross laminated dolarenite; a. weathered surface at high angle to current direction; b. polished surface parallel to current direction (to left). South of central Karakutikati Range (Map 1).

G. Facies C2 - laminated dolomitic mudstone. South of central Karakutikati Range (Map 1).

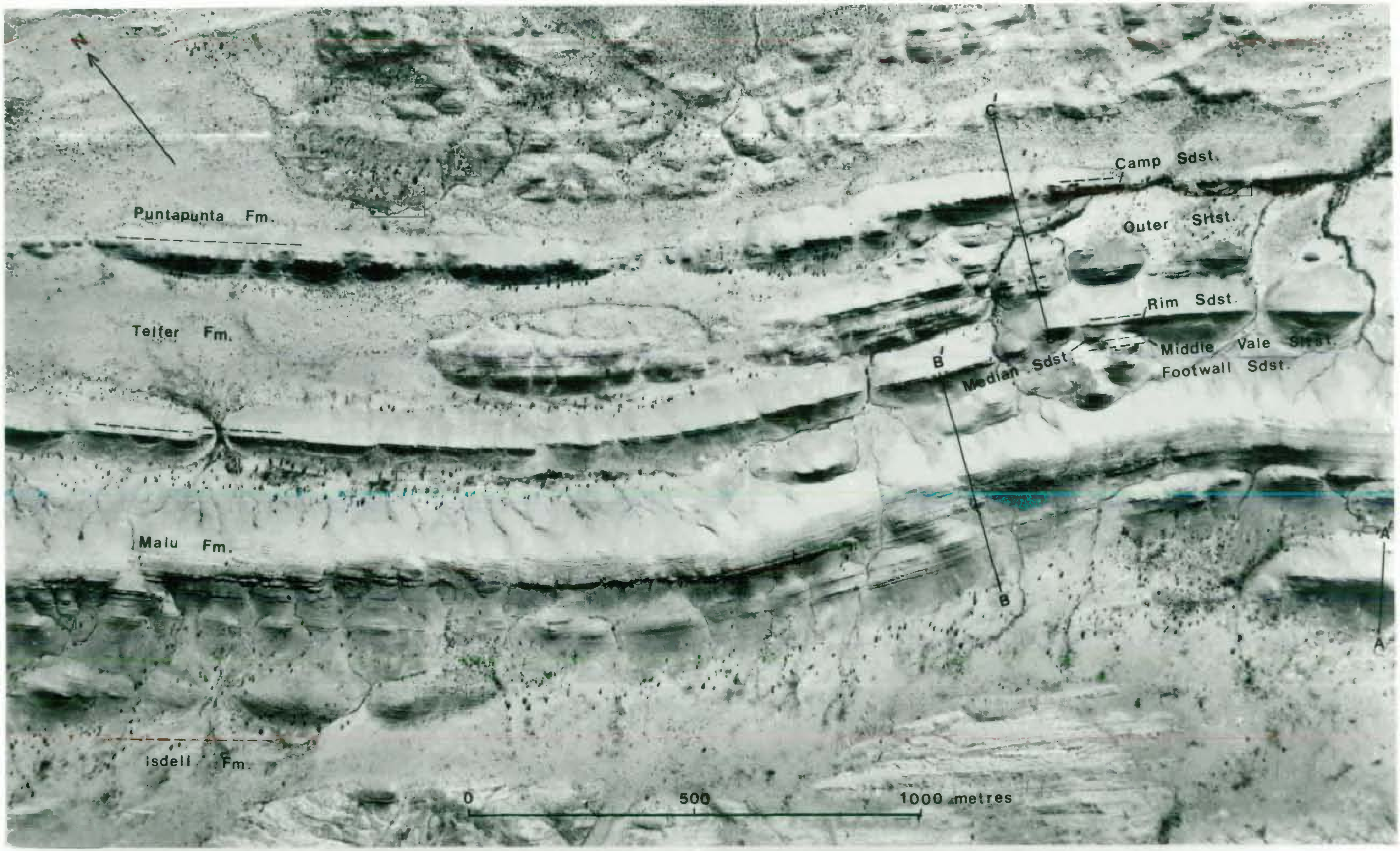
N
Puntapunta Fm.
Telfer Fm.
Malu Fm.
Isdell Fm.
Camp Sdst.
Outer Sltst.
Rim Sdst.
Middle Vale Sltst.
Footwall Sdst.
Median Sdst.
C
C'
B
B'
A
A'
0
500
1000 metres

PLATE 3.1

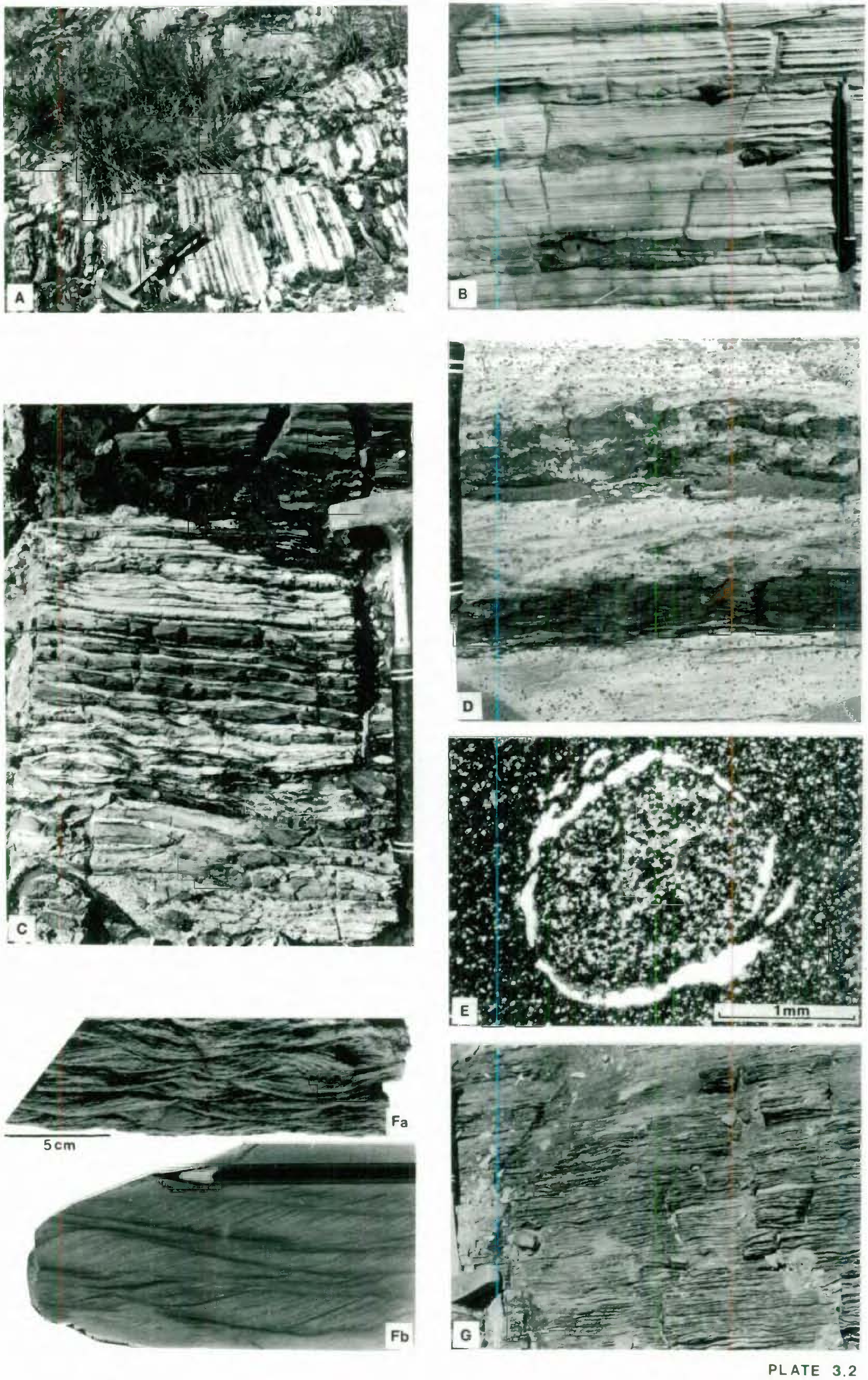

PLATE 3.2

PLATE 3.3 - ISDELL FORMATION

A. Facies C2 - interlaminated very fine grained cross laminated dolarenite (pale grey) and carbonaceous dolomitic mudstone (dark grey). Core PL18 (Map 1), depth 209.85-.96m.

B. Facies C2 - slump folded dolomitic mudstone. South of central Karakutikati Range (Map 1).

C. Facies C2 - thin section of very fine grained laminated dolarenite (TEL 436). Light coloured minerals are feldspar and quartz, dark matrix is iron-rich dolomite. Crossed polars. Same location as Plate 3.2F.

D. Facies C2 - thin section of dolarenite with carbonaceous laminae. Plane polarised light. Core PL18 (Map 1), depth 212.5 m.

E. Facies C3- folded thickly bedded calcarenite (lowest bed) and dolarenite. Locality C, Map 1.

F. Facies C3 - cross bedding in dolarenite. Locality C, Map 1.

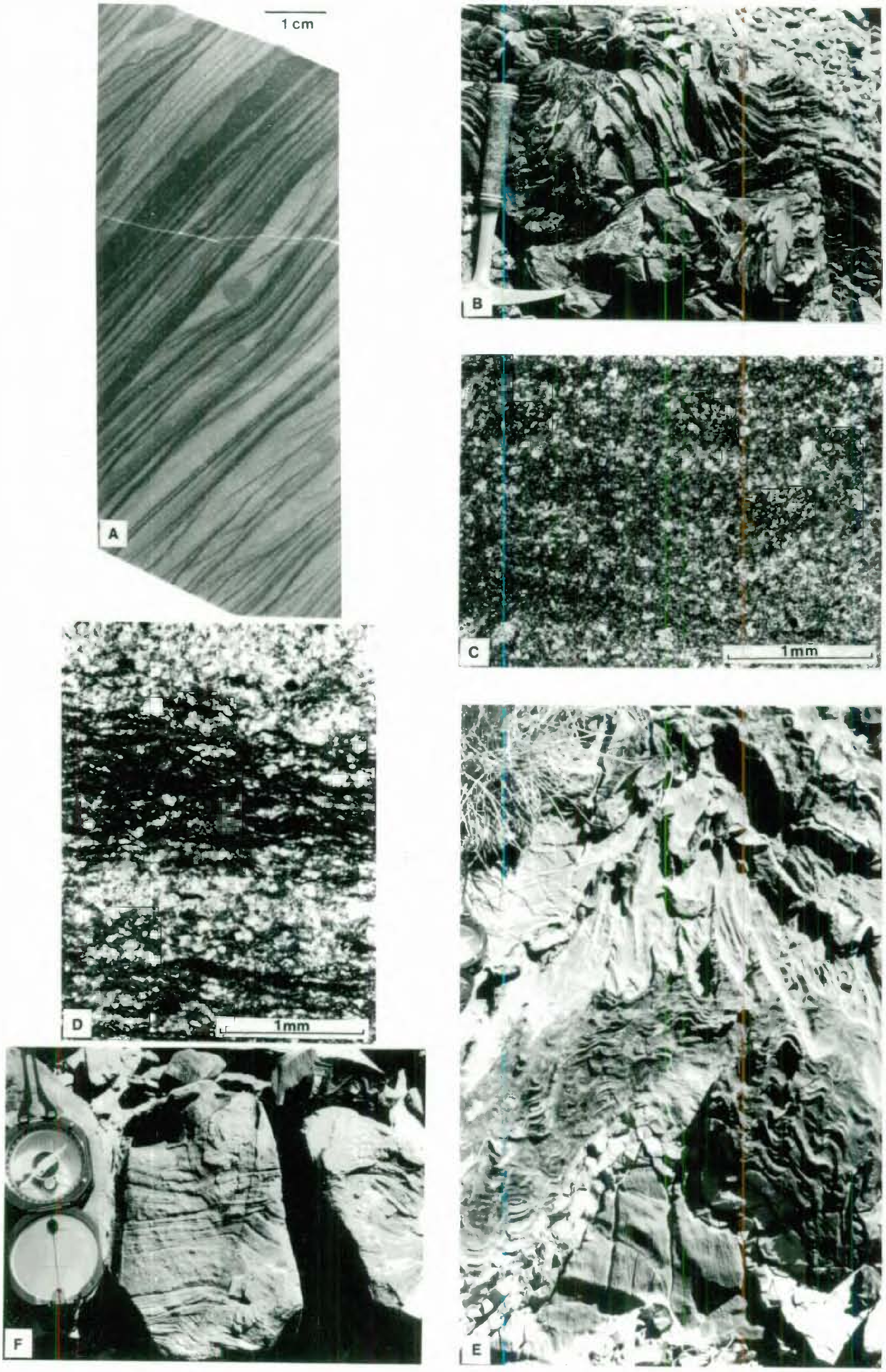

PLATE 3.3

PLATE 3.4 - MALU FORMATION

A. Karakutikati Range - view north from central Malu Formation (just north of A^1, Plate 3.1). Prominent ridge in mid-distance is Rim Sandstone Member. Vehicle track in mid-distance indicates scale.

B. Facies S1, Middle Vale Siltstone Member - interbedded siltstone (with streaky lamination) and claystone (with dark limonite pseudomorphs after siderite). Core PR449, depth 91.22-.41 m (Fig. 3.5).

C. Facies S1, upper Median Sandstone Member - dark grey carbonaceous siltstone beds (with patches of pyrite) in non-carbonaceous claystone and siltstone. a. core PR548 (Fig. 6.1), depth 161.85-162.25 m, b. core WD 29 (Fig. 6.1). Note that scale bar should be 5.5 cm long, not 2 cm.

D. Facies S2, Outer Siltstone Member - small scale ?ripples on base of very fine grained sandstone bed. Thomson East Prospect (Map 1).

E. Facies S2 - thin section of fine grained sandstone, comprising mainly quartz and plagioclase. Crossed polars. Core PR369, depth 93.6 m, Median Sandstone Member.

F. Facies S3 - flute casts on base of fine grained sandstone bed. Lower Malu Formation, central Karakutikati Range (Map 1).

G. Facies S3 - flute casts on base of fine grained sandstone bed. Footwall Sandstone Member, central Karakutikati Range (Map 1).

H. Facies S3 - linear groove casts and small flute casts on base of fine grained sandstone bed. Footwall Sandstone Member, central Karakutikati Range (Map 1).

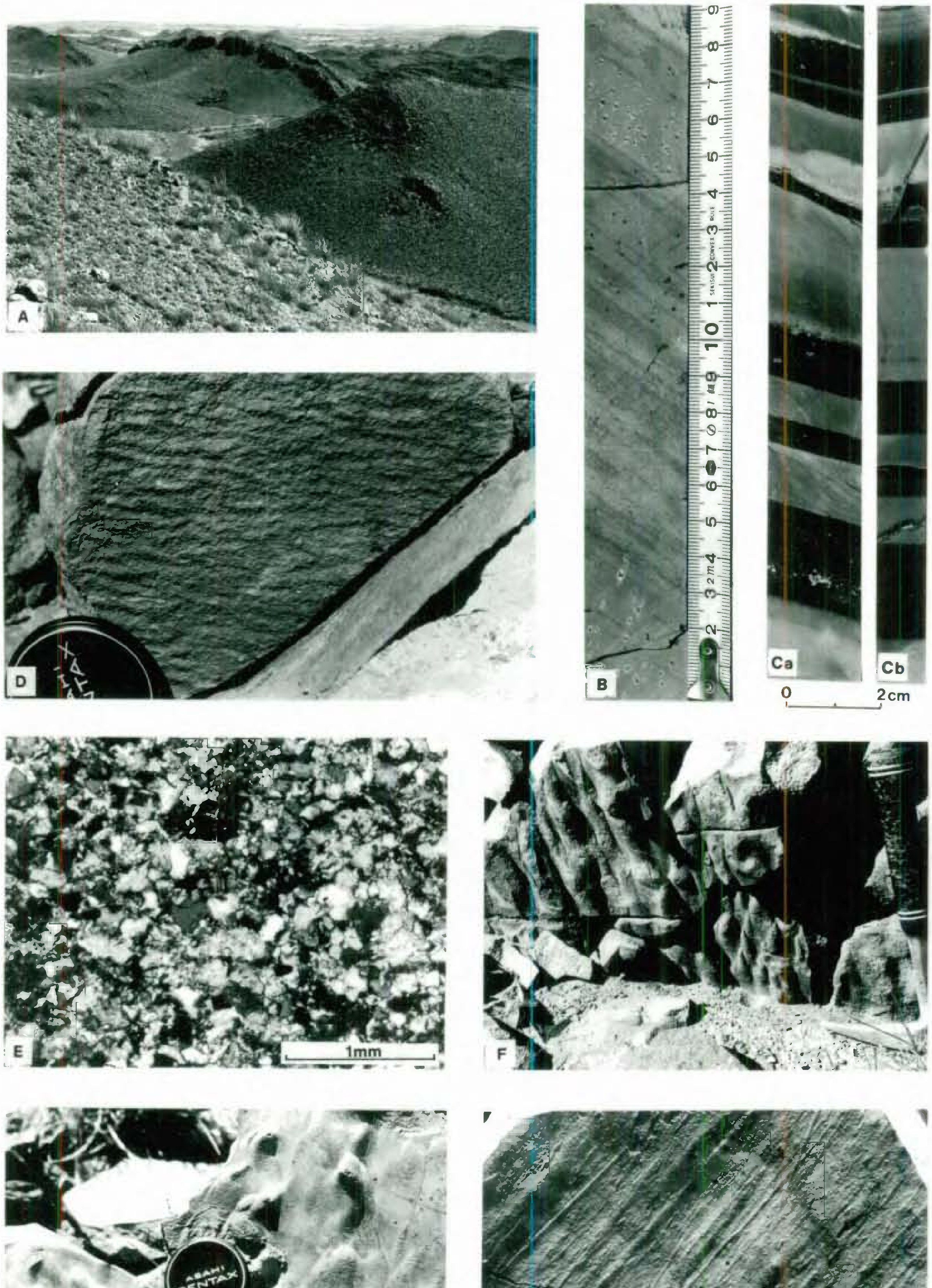

PLATE 3.4

PLATE 3.5 - MALU AND TELFER FORMATIONS

A. Facies S3 - parallel lamination passing upwards into cross lamination in fine grained turbidite, near base of Outer Siltstone Member, central Karakutikati Range (Map 1).

B. Facies S3 - cross lamination in very fine grained sandstone. Median Sandstone Member, central Karakutikati Range (Map 1).

C. Facies S3 - cross lamination in Footwall Sandstone Member at Telfer. Core PR449, depth 100.6-.76 m (Fig. 6.4).

D. Facies S3 - thin section of medium grained sandstone overlying siltstone in Footwall Sandstone Member at Telfer. Well rounded zircon and iron oxide grains occur at base of the sandstone. Plane polarised light. Core PR451, depth 103.45 m (Fig. 6.4).

E. Facies S4 - thin to very thick massive medium grained sandstone beds of the Rim Sandstone Member, overlying very fine grained sandstone (Facies S2) of the Median Sandstone Member. Northern end of Pit 1, Telfer (Fig. 6.2).

F. Facies S4 - irregular load casts and faint linear groove casts beneath vertical medium grained sandstone bed. Malu Formation, central Karakutikati Range (Map 1).

G. Facies S4 - linear tool marks caused by mudstone chips on upper surface of medium grained sandstone bed. Current direction to right (northeast). Rim Sandstone Member, West Dome, Telfer (Map 1).

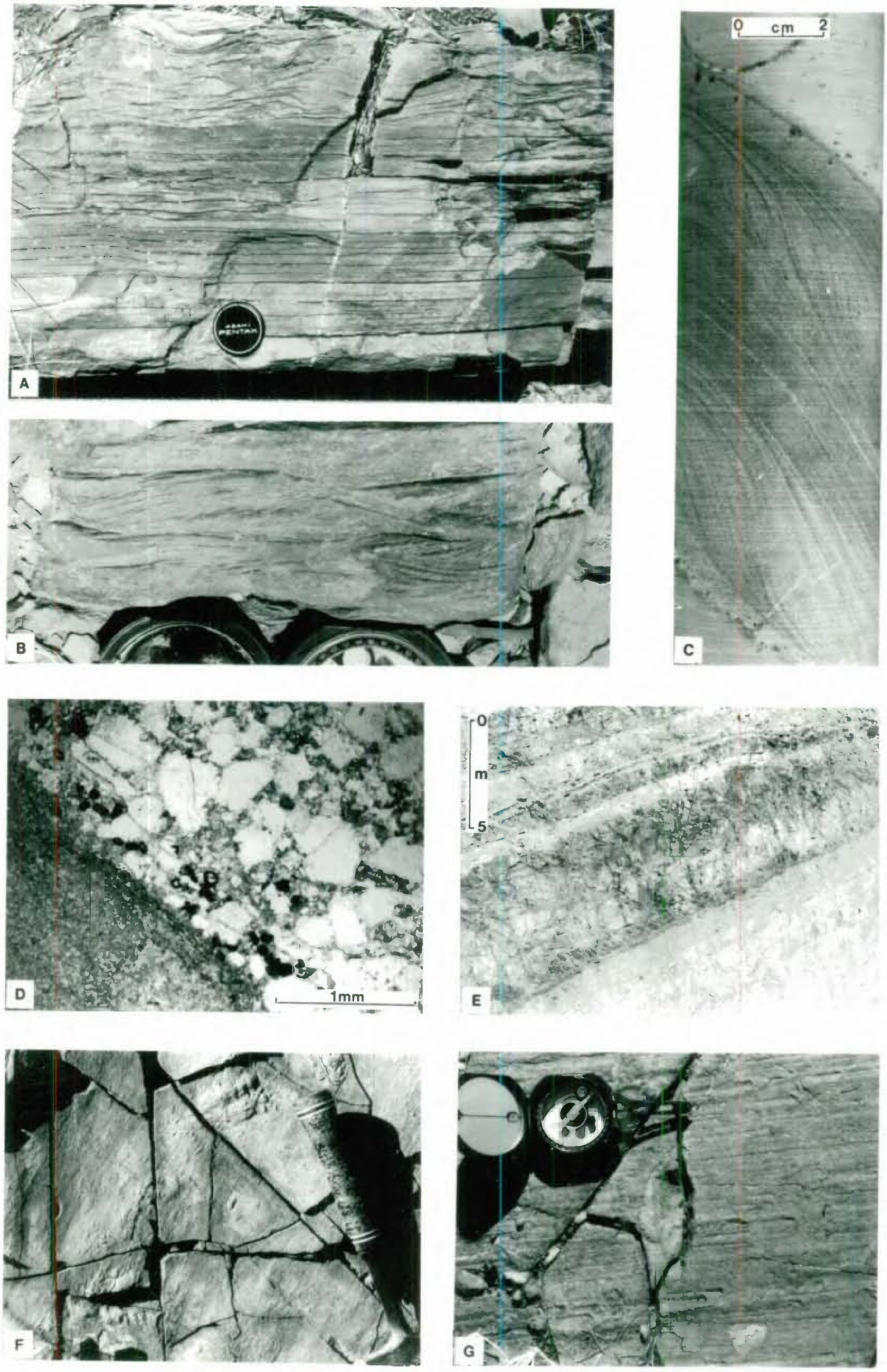

PLATE 3.5

PLATE 3.6 - MALU, TELFER AND PUNTAPUNTA FORMATIONS

A. Facies S4 - single vertical bed of medium grained sandstone, with sharp top (right) and base. Faint parallel lamination beneath hammer. Rim Sandstone Member, central Karakutikati Range (Map 1).

B. Facies S4 - thin section of medium grained quartz arenite (TEL 288) from Rim Sandstone Member at Telfer. Crossed polars.

C. Facies C4 - well bedded dolarenite (dark beds) and dololutite (light beds). Hammer at top of photo for scale. Outer Siltstone Member, central Karakutikati Range (Map 1).

D. Facies C4 - interbedded dolarenite (dark) and dololutite. Dolarenite beds are slightly graded, contain parallel and cross lamination, and have sharp tops and bases. Outer Siltstone Member, central Karakutikati Range (Map 1).

E. Facies C4 - cross bedded dolarenite. Current direction to left. Scale in centimetres. Outer Siltstone Member, central Karakutikati Range (Map 1).

F. Puntapunta Formation - well bedded dolarenite (dark) and dololutite (light). Small patches of white surficial calcrete occur on dolarenite. North of Tim's Prospect (Map 1).

G. Puntapunta Formation - wavy laminae in cross bedded calcarenite. North of Tim's Prospect (Map 1).

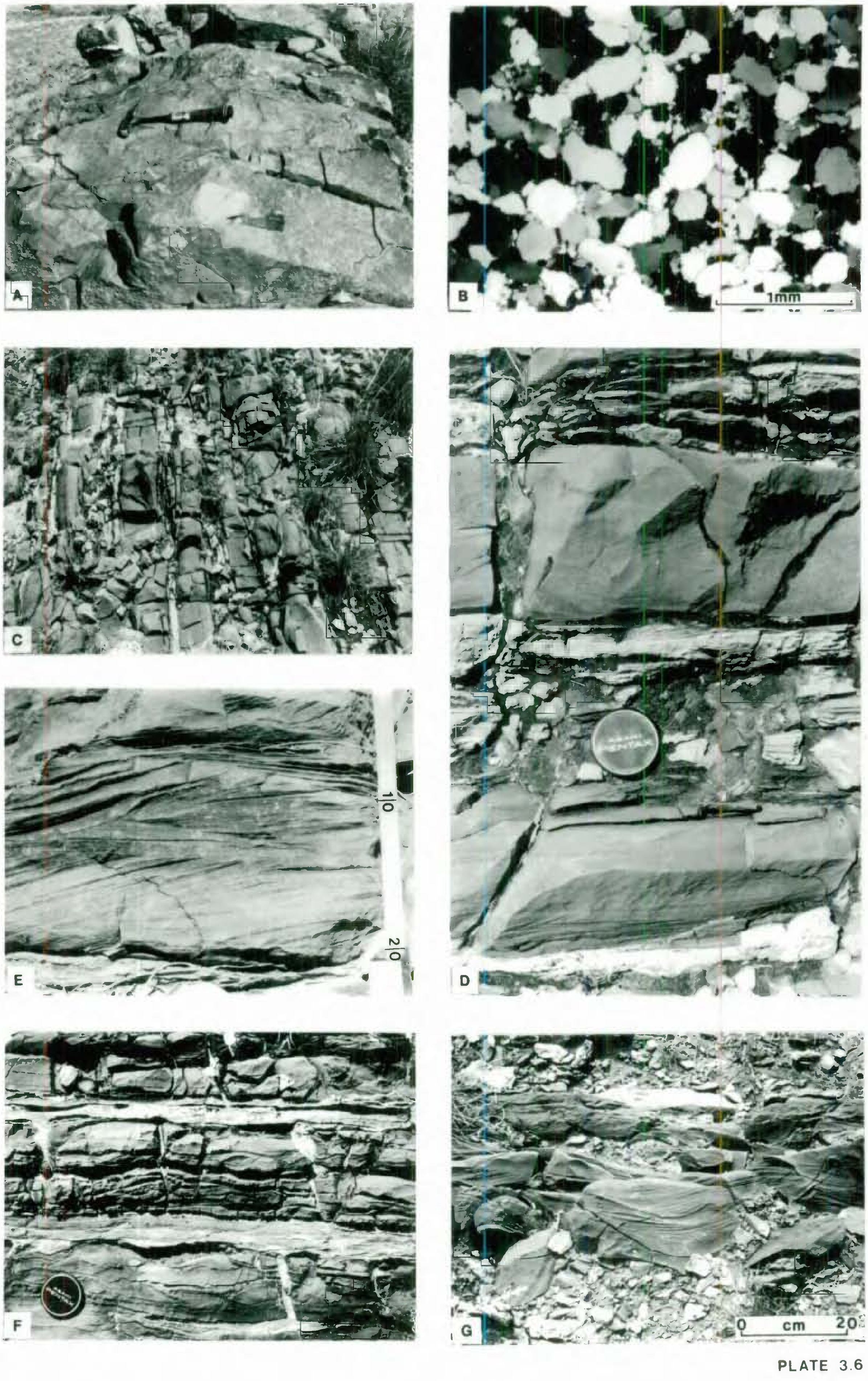

PLATE 3.6

PLATE 3.7 - PUNTAPUNTA FORMATION, WILKI QUARTZITE, STRUCTURAL AND PHANEROZOIC FEATURES

A. Puntapunta Formation - trough cross bedding in dolarenite. South of Tim's Prospect (Map 1).

B. Puntapunta Formation - intraformational breccia in calcarenite. North of Tim's Prospect (Map 1).

C. Wilki Quartzite - parallel-bedded units of quartzose meta-sandstone, dipping steeply to left (northeast). B.C. McKelvey plus hat for scale. Wilki Range (Map 1).

D. Pit 1, Telfer (Fig. 6.2) - dark beds of the Rim Sandstone Member (Facies S4) are downfaulted in graben.

E. Reverse fault (dashed line) in crest of Main Dome, Telfer. Middle Vale Siltstone and Median Sandstone Members in Pit 7 (Fig. 6.2).

F. Permian glacial striations on silicified sandstone of the Wilki Quartzite. South of Tim's Prospect (Map 1).

G. Permian Paterson Formation overlying silcrete developed over carbonate-rich sandstone of the Puntapunta Formation. Hammer marks contact. South of Telfer Dome (Map 1).

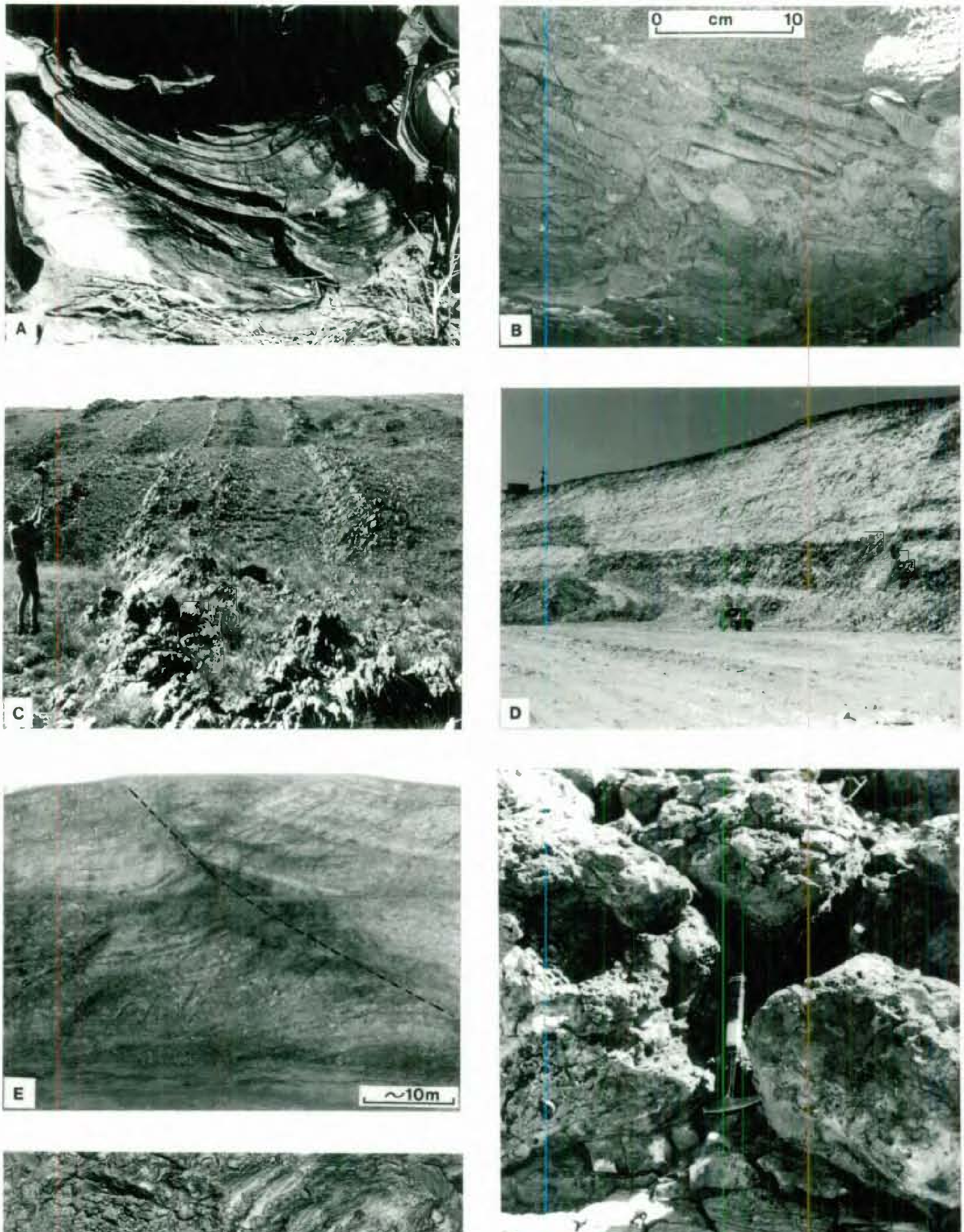

PLATE 3.7