

STRATIGRAPHY AND SEDIMENTOLOGY OF THE RENISON MINE SEQUENCE

by

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SUMMARY

- 1) The stratigraphy and sedimentology of the Renison mine sequence has been described from detailed core logs, hand specimen observation, and petrography and chemical analyses of the carbonate rocks.
- 2) The Renison mine sequence is interpreted to be of Upper Proterozoic age and a facies equivalent of the Smithton Dolomite.
- 3) The subdivisions of the mine sequence can be generally correlated in the Renison-Mount Lindsay area. There are two major facies variants of the mine sequence. Between the mine and Owen Meredith areas there is normal mine sequence whereas between Dunkley Tram and Mount Lindsay the dolomite units are stromatolitic, oolitic and partly silicified.
- 4) Within the mine area the distribution of subunits of the Dalcoath, Renison Bell and Red Rock Members is lenticular. Consequently correlation in the mine area is largely based on the distribution of the more uniform carbonate units.
- 5) The typical mine sequence is interpreted as two regressive and a partial transgressive cycles of subtidal-intertidal -supratidal and fluival units. The lower regressive cycle is the units below the Renison Bell Member. The upper regressive cycle is the units up to the middle of the Red Rock Member and the partial transgressive cycle is the units above the middle of the Red Rock Member. The stromatolitic-oolitic facies is a more extensive supratidal platform continuous with the Smithton Dolomite.
- 6) Although the original depositional texture is locally recognisable in the dolomites, it has largely been destroyed by early diagenetic burial recrystallisation, late diagenetic karstic brecciation, contact metamorphic reactions with silicate minerals and hydrothermal overprint. The distribution of hydrothermal alteration and mineralisation is not significantly affected by the nature

of pre-existing alteration in the dolomites.

7) The thickness of the carbonate horizons influences the distribution of ore away from major fluid channelways and the composition of the clastic rocks underlying the dolomite horizons modifies the fluid composition thus influencing the transport and deposition of tin. The No. 1 Dolomite is barren because the underlying Red Rock Member effectively traps the tin in the No. 2 Dolomite.

8) The development of a structural model for the mine area and a study of the role of major structures as fluid conduits is the next necessary step in understanding the genesis of Renison ore.

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1. INTRODUCTION

This report describes the stratigraphy and sedimentology of the Renison mine sequence with particular emphasis on the nature of the carbonate rocks and their role in ore localisation. The study is part of an ongoing project investigating the replacement process and ore formation at the Renison tin mine.

The Renison replacement project was initiated by L.A. Newnham (Renison Limited) in collaboration with R.G. Taylor (James Cook University) and T.A.P. Kwak (La Trobe University). Brett Davies (James Cook University) is currently working on the replacement process and its relation to ore deposition. A.V. Brown (Tasmania Department of Mines) introduced me to the mine sequence along the Pieman Dam Road. The staff of the Geology Department, Renison Limited helped me understand the mine geology and find my way around the core shed. P. Jackson (La Trobe University) performed the carbonate analyses under the supervision of D. Sewell (University of Melbourne) and G. Holm (La Trobe University) prepared the polished and thin sections. I am most grateful to all these people for their help with the project.

There is previous work on the stratigraphy but not the sedimentology of the Renison mine sequence. The distribution of the mine sequence outside the mine area has been mapped recently by A.V. Brown of the Tasmania Department of Mines and the stratigraphy of the mine sequence in the Renison-Mount Lindsay area has been described by Newnham (1975). A detailed stratigraphy of the mine sequence on the mine lease is provided by Bond (1979) and Lees (1973). There are numerous general descriptions of the mine stratigraphy (e.g. Patterson *et al.*, 1981), a detailed stratigraphy and sedimentology of the Red Rock Member (Djakic, 1981) and limited chemical and isotopic data on the carbonate rocks (Patterson, 1979; Collins, 1972).

A total of ten weeks were spent at the mine in detailed logging of representative drill cores through the mine sequence, fill-in mapping in areas of sparse drill-hole data and compilation of maps showing thickness variations in ore-bearing horizons. Six months were spent at La Trobe University studying sedimentary

structures in polished slabs, doing petrography of representative samples and interpreting chemical analyses of the carbonate minerals. The report was completed at James Cook University.

2. STRATIGRAPHY

2.1 Regional Stratigraphy

The Renison deposit is at the margin of the dominantly Cambrian Dundas Trough which is bound to the west by the Rocky Cape Precambrian block and to the east by the Tyennan Precambrian block (Fig. 1). The lowest stratigraphic unit in the Renison Bell area (Table 1) is the Precambrian Oonah Formation which is at least 700m of interbedded siltstone, sandstone and mudstone. It is overlain with inferred angular unconformity by the Upper Proterozoic? Success Creek Group (Taylor, 1954) which is 820m of quartz sandstone, siltstone, shale and dolomite. The Success Creek Group is overlain conformably by the Lower Cambrian? Crimson Creek Formation (Taylor, 1954; Blissett, 1962) which is at least 1000m of purple and green mudstone and wacke. The Crimson Creek Formation is conformably overlain by the Middle to Late Cambrian Dundas Group (Elliston, 1954; Blissett, 1962) which is approximately 3800m of mudstone, acid volcanic rocks, wacke and conglomerate. Ultramafic and mafic complexes occur within the Crimson Creek Formation and at the contact with the overlying Dundas Group (Williams, 1978). Granitoids spatially associated with the mineral occurrences at Renison and Mount Lindsay (Figs. 1, 2) are similar to other Late Devonian granitoids in western Tasmania (Williams, 1978).

The Success Creek Group, which hosts the Renison deposits, is correlated on stratigraphic grounds with the dolomite-bearing sequences at Smithton and Mount Bischoff (Williams, 1978; Fig. 1). Possibly similar dolomite-bearing sequences also occur at King Island, near Savage River, at Birthday Bay and in the Jane River and Adamsfield areas (Fig. 1; Williams, 1976, 1978; Spry, 1957). The dolomite-bearing sequences are within or marginal to the Precambrian blocks rather than restricted to the Dundas Trough (Fig. 1).

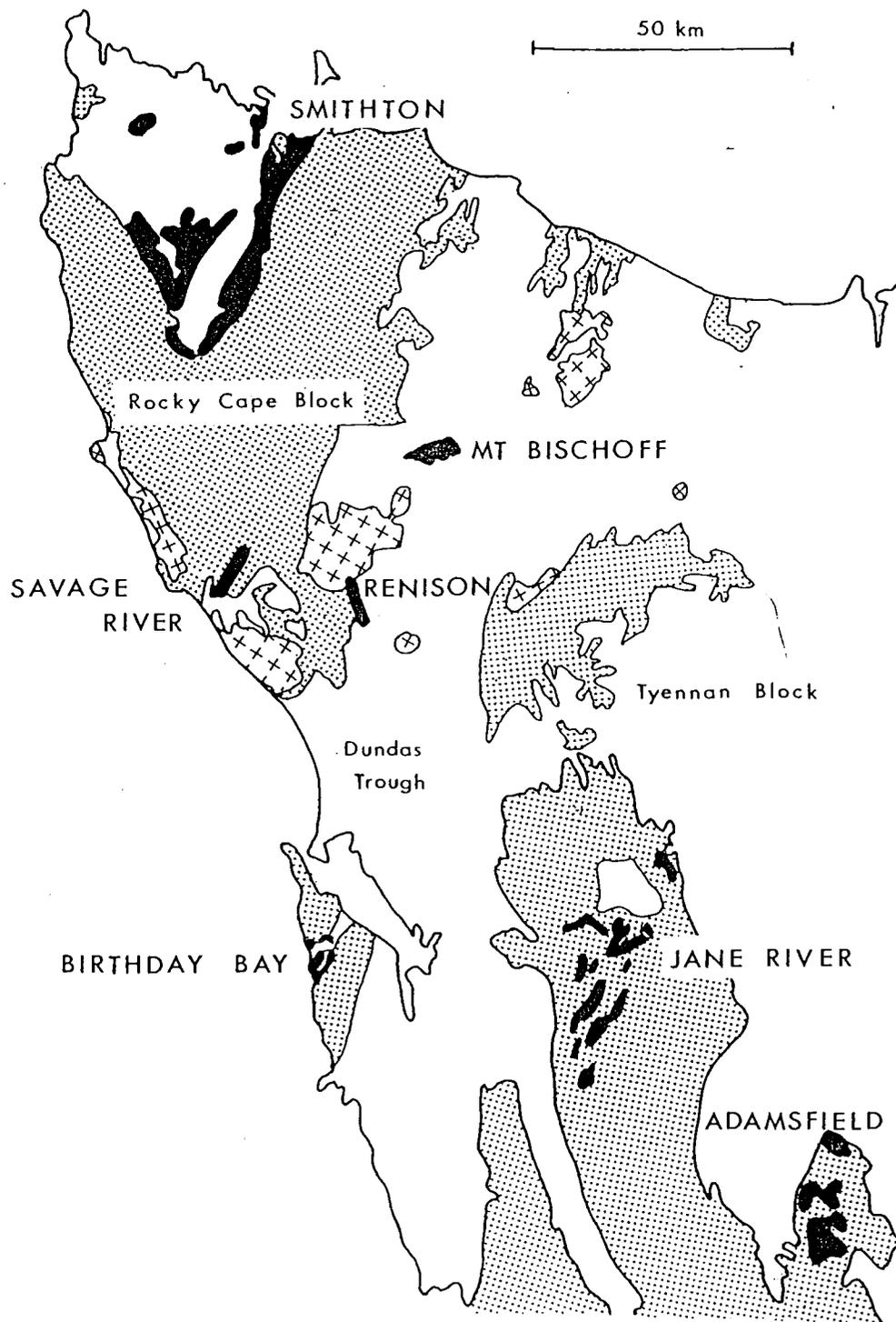


Figure 1 : Distribution of Upper Proterozoic? dolomite-bearing sequences (black) in northwest Tasmania. Areas of older Precambrian rocks (dots) and Devonian granitoids (crosses) also shown. Note association of dolomites with Precambrian rather than Cambrian sequences. Modified after Williams (1978) and Spry (1957).

Table 1 : Comparison of stratigraphic subdivisions of units in the Renison Bell area

REGIONAL
Blissett, 1962; Taylor, 1954

TYPICAL MINE
Patterson et al., 1981

MAPPING
Brown, 1960

EXTENDED MINE
this paper; Bond, 1979

DUNDAS GROUP Middle Cambrian 3800m unconformable	RR sequence	No. 1 Dolomite 15m				No. 1 Dolomite	
		Red Rook 20m				Red Rook Member	
	CRIMSON CREEK FORMATION Lower Cambrian? 1000m+ unconformable	SUCCESS CREEK GROUP	No. 2 Dolomite 15m		Ochert-Bearing Unit		No. 2 Dolomite
			Renison Bell Shale 60m				Renison Bell upper R.B. 2.2 dolomite
			No. 3 Dolomite 5m		Sillioeous Siltstone		Renison Bell middle Renison Bell lower R.B. pebble beds
			Dalooath Quartzite 800m+				Renison Bell lower No. 3 Dolomite Dalooath upper
	SUCCESS CREEK GROUP		Deformation Zone	Dalooath carbonao. and non-carbonao.			
	Upper Proterozoic? 820m+ unconformable		Quartz Sandstone	Dalooath concorded			
	MOONAH FORMATION Precambrian 700m+		Mixtite	Dalooath undivided			

Their stratigraphy and sedimentology, in particular, the presence of partly silicified, stromatolitic and oolitic dolomites is comparable to Late Proterozoic (Adelaidean) sequences elsewhere in Australia (c.f. Preiss & Forbes, 1981). However there is no direct evidence of the age of the Success Creek Group or the other dolomite-bearing sequences.

The oldest known macrofossils in the Renison area are early-Middle Cambrian trilobites near the base of the Dundas Group (Williams, 1978). The Crimson Creek Formation and Success Creek Group are generally considered older than early-Middle Cambrian (approx. 530m.y.) but younger than the Penguin orogeny (720m.y., J.R. Richards in Solomon & Griffiths, 1974) which is inferred to have deformed the underlying Oonah Formation (Williams, 1978).

Acritarchs (acid resistant, organic walled, normally spherical algal cysts 10-3000 μ m in diameter) identified by Dr G. Vidal and reported by K.D. Corbett (1976; unpublished letter to L.A. Newnham) suggest the Crimson Creek Formation and Success Creek Group are of Vendian (Late Proterozoic) age. In the North Atlantic region the Vendian is 707 to 570m.y. (Vidal, 1981). If a similar age applies in the Renison area, then it is not inconsistent with the 720-530m.y. age suggested by the other data. Stromatolites and carbonaceous microfossils collected by the author from Renison diamond drill hole S705, from float on the track to the old Misty Valley campsite and from the Pieman Dam Road have been sent to Dr. W.V. Preiss of the South Australia Department of Mines for identification. They may provide further evidence of the age of the Success Creek Group.

The Success Creek Group is generally considered as the sequence of quartz sandstone, siltstone, mudstone and dolomite unconformably overlying the Oonah Formation but below the distinctive hematitic sandstone, siltstone, conglomerate and chert referred to as the Red Rock. The Red Rock has been included in the Crimson Creek Formation (Blissett, 1962) and thought to represent the onset of volcanism in the Dundas Trough (Solomon, 1964). However, volcanic rocks only occur as fragments in fluvial sedimentary rocks of the Red Rock and their composition is more comparable to volcanic rocks in the upper

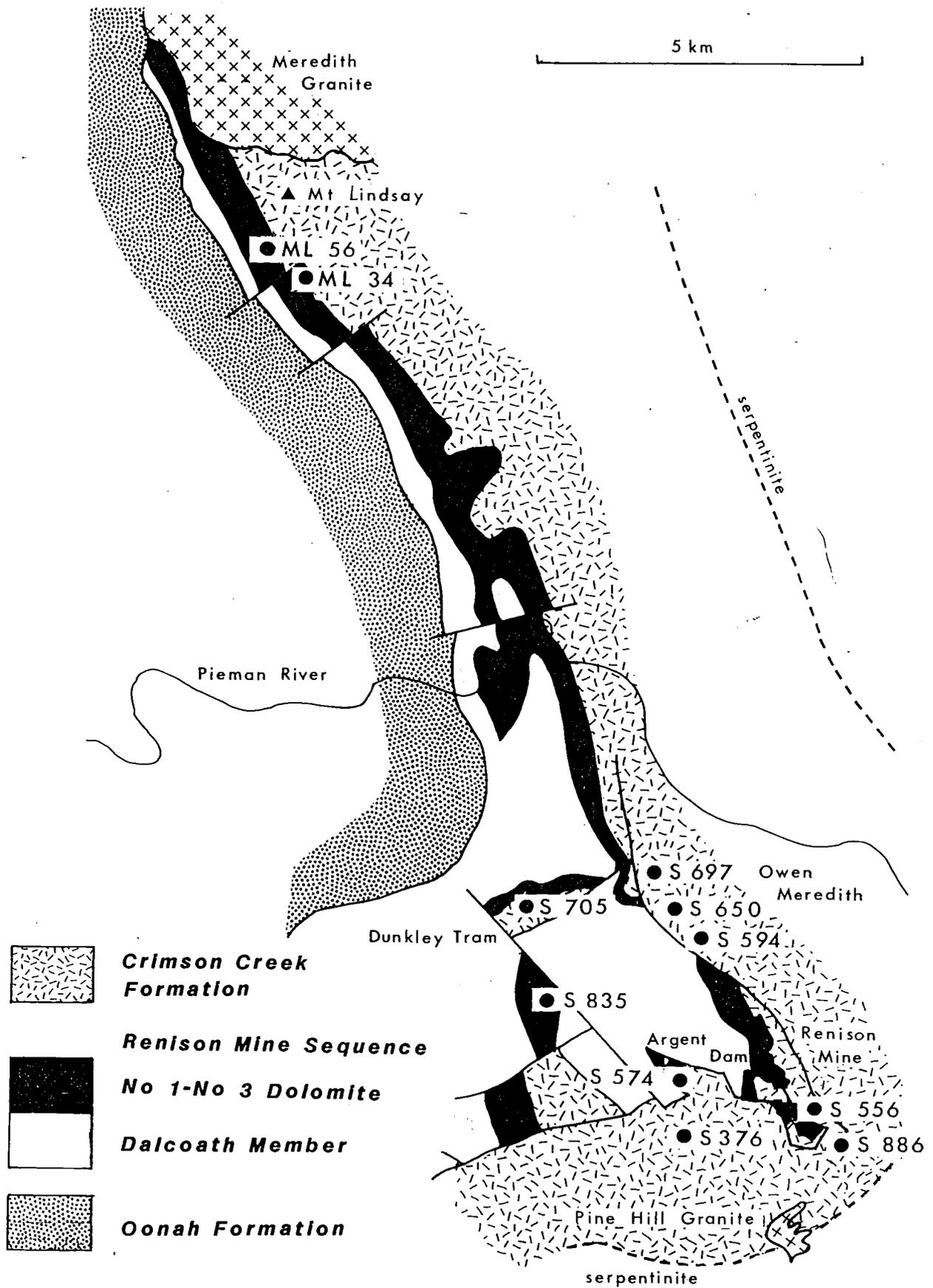


Figure 2 : Simplified geologic map of the Renison mine - Mount Lindsay area showing the distribution of major unit and the location of drill holes used in correlation (Fig. 3). Compiled from maps by Renison Limited and A.V. Brown (Tasmania Department of Mines, unpublished).

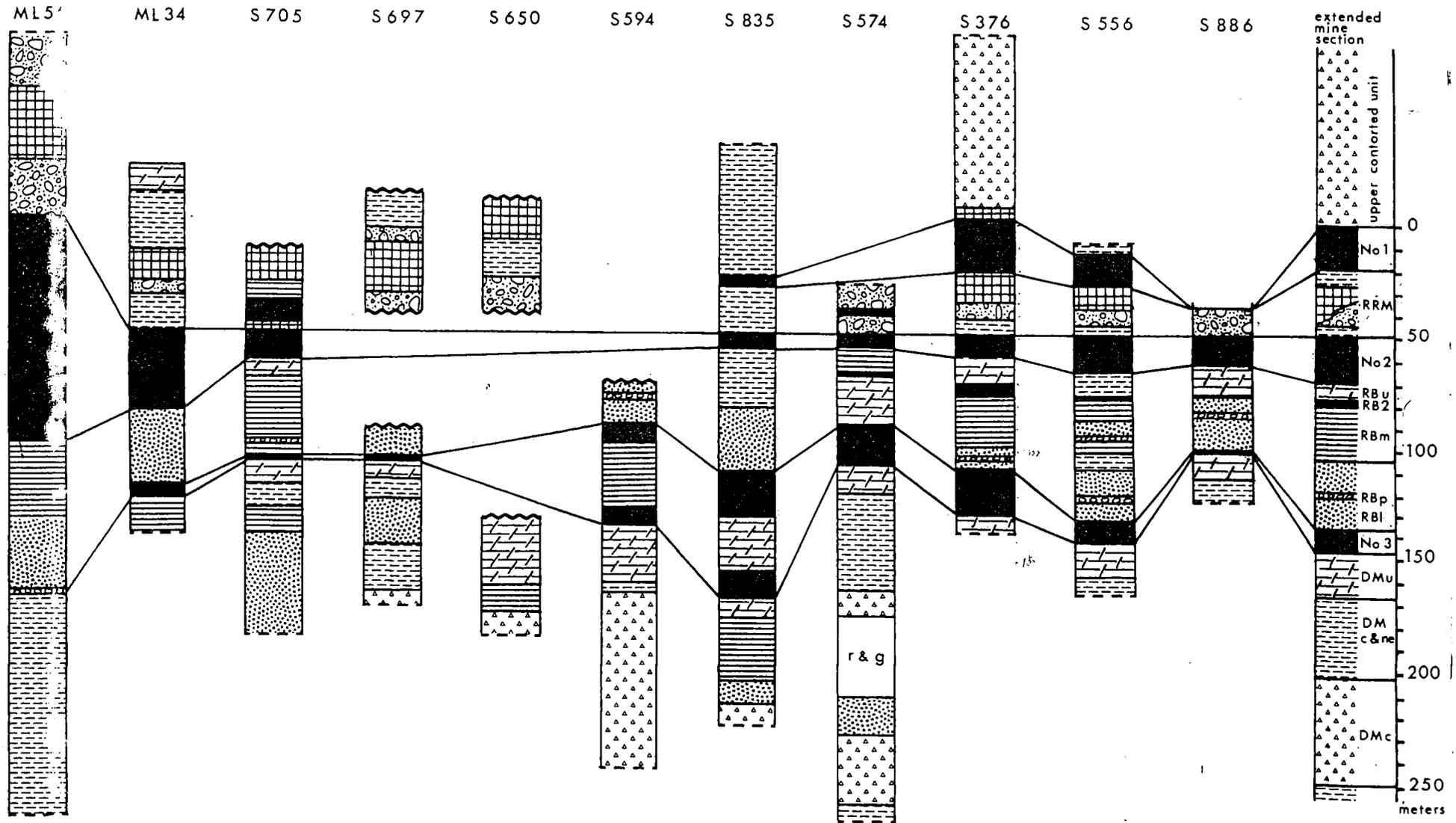


Figure 3 : Representative stratigraphic sections based on drill holes in the Mount Lindsay-Renison mine area (see Fig. 2 for locations). A tentative correlation of the major units is possible but there are important facies variations. ML56 is a compilation of mapping and drilling plotted at a scale of 1:5000 compared with 1:2500 for the other sections.

The lowermost regional mapping unit, the mixtite rests with inferred landscape unconformity on the Oonah Formation. It is approximately 50m of pebble to cobble conglomerate consisting of clasts of carbonate, mudstone, quartzite and chert in a matrix of silt, sand and carbonate. It has not been encountered in drilling by Renison Limited.

The second unit, quartz sandstone, is the characteristic lithology of the Dalcoath Quartzite mapped in the mine area (Gilfillan, 1965; Patterson et al., 1981). The unit consists of thick bedded, clean quartz sandstone and is up to 800m thick. It is rarely drilled to any depth in the mine area (Fig. 3).

The third unit, the deformation zone, consists of mudstone with interbedded siltstone, sandstone and conglomerate and is characterised by extensive intraformational slumping and brecciation. It is comparable to the Dalcoath contorted unit which has been encountered in all deep holes in the Owen-Meredith and Argent Dam areas (Table 1, Fig. 3). It has not been seen in the Mount Lindsay area nor is it encountered in normal drilling in the mine proper.

The fourth unit, the siliceous siltstone consists of thin bedded siliceous siltstone with mudstone partings and minor sandstone and carbonate-bearing siltstone. Although it is considered the walkable continuation of the Renison Bell Member of the normal mine sequence (Brown, 1980), it probably also includes the lithologically similar Dalcoath carbonaceous and non-carbonaceous unit, Dalcoath upper unit and No. 3 Dolomite of the extended mine sequence (Table 1).

The fifth, or chert-bearing unit consists of interbedded, laminated siliceous siltstone, black or pink mudstone, dolomite, black oolitic chert and chert breccias. Near Mount Lindsay the unit is approximately 60m thick and underlies the Red Rock. The chert beds are walkable replacements of stromatolitic and oolitic dolomites which occur in the area from Mount Lindsay to Dunkley Tram but are not found in the mine area. The sequence siltstone and black mudstone-oolitic chert-black and pink mudstone-dolomite beneath the Red Rock on the Pleasant Dam road is correlated with the upper part of the Renison Bell middle, the Renison Bell 2.2 Dolomite, the Renison Bell upper and the No. 2 Dolomite respectively (Table 1).

The Red Rock is a distinctive red to maroon sequence consisting of conglomerate, sandstone, siltstone, grit, chert iron formation and dolomite. It is traceable from Mount Lindsay to the Renison mine (Newnham, 1975) but is faulted out of the Pieman River type section of Brown (1980) and Taylor (1954).

The No. 1 Dolomite has not been encountered in drilling outside the Renison Mine-Argent Dam area, but a silicified or impure equivalent may be present in the Mount Lindsay area (Fig. 3; Newnham, 1975).

The main units recognised in the mine can be tentatively correlated between Renison and Mount Lindsay (Fig. 3; Newnham, 1975). However, the area can be separated in two on the basis of rock types. In diamond drill holes ML56, ML34 and S705 and in numerous outcrops between Mount Lindsay and Dunkley Tram the No. 2 Dolomite is partly silicified and contains stromatolites, large oolites, ovoid carbonaceous bodies that may be fossils, and textures suggesting that some of the dolomites replace evaporites (Plate 3). In this area also the No. 1 and No. 3 Dolomites are locally silicified and oolitic; Red Rock-like siltstones both overlie and underlie the No. 1 Dolomite; and the upper units of the Dalcoath Member consist of grey-green-sandstones and siltstones rather than the carbonaceous shales and siltstones typical of the Argent Dam-Renison mine area. These differences suggest a change in depositional environments between the two areas.

There are other stratigraphic changes within the Mount Lindsay-Renison mine area (Fig. 3). In the Mount Lindsay-Dunkley Tram area there is one thin No. 3 Dolomite, whereas between Dunkley Tram and Argent Dam, there are two No. 3 Dolomites separated by shale and siltstone and in the Renison mine area one No. 3 Dolomite that thins to nothing going southeast (Fig. 3). In S574 there is a distinctive red and green sandstone and siltstone unit above the contorted unit in the Dalcoath Member. This unit has also been observed in mapping to the northwest, and drilling to the southeast of Argent Dam (P. Stephenson, pers. comm., 1982). A similar red and green unit is in the Red Rock of hole S705 at Dunkley Tram associated with stromatolitic and oolitic dolomite. These stratigraphic changes are considered products of local sedimentological variation rather than major facies variation.

In hole S376 south of Argent Dam a contorted unit, similar to that in the Dalcoath Member, conformably overlies a fairly typical mine sequence (Fig. 3) and underlies the Crimson Creek Formation. A similar unit is present in the upper part of S495 (northwest of Argent Dam) and in recent drilling southeast of Argent Dam. In this area the unit has been interpreted as a faulted section of Dalcoath Member in contact with the Crimson Creek Formation. However, if the stratigraphy in S376 is representative, this is a completely separate unit that is lithologically similar to the Dalcoath Member but stratigraphically much younger.

The faulted contact between the Crimson Creek Formation and ophiolitic serpentinite bodies is roughly parallel to stratigraphic contacts between the Crimson Creek, Success Creek and Oonah Formations (Fig. 2). This fault boundary probably represents the transition from the thick continental crust of the Rocky Cape block to thinner oceanic crust of the Dundas Trough. This boundary is probably also an approximate limit to the continent-related sedimentary rocks of the Success Creek Group. That is, the Success Creek Group does not extend out into the Dundas Trough beyond the limit of the faulted serpentinites.

In summary, the Renison mine sequence occurs in the area between Mount Lindsay and the Renison mine, is limited to the north and west by exposures of the Oonah Formation and to the south and east by fault blocks of serpentinite. Although units recognised in the mine can be correlated throughout the area, there are three main facies subdivisions. In the Mount Lindsay-Dunkley Tram area partly silicified stromatolitic and oolitic dolomites are characteristic; in the Renison mine area, normal mine sequence is characteristic; and in the area south of Argent Dam a contorted unit occurs between the Crimson Creek Formation and normal mine sequence.

2.3 Detailed Stratigraphy of the Renison Mine Sequence in the Immediate Mine Area

Although the distribution of units is complicated by folding and faulting (Fig. 4), a stratigraphy of the mine area has been developed by the mine geologist (Bond, 1979; Lees, 1973) and

extended for the Argent Dam area (Table 2). A more detailed stratigraphy is provided here by comparing true thickness plots of eighteen representative drill holes from the area around Dreadnought Hill, Renison Bell Hill and Stebbins Hill (Fig. 5). The area has been subdivided into three subareas centred about each of the hills to identify local facies variations (Figs. 6, 7, 8) and a comparison has been made between representative sections from each subarea to evaluate overall variations in the mine area (Fig. 5).

The major variations within the mine area (Fig. 5) include:

- 1) An overall thinning of the mineralised part of the section (No. 1 to No. 3 Dolomites) towards the southwest or Renison Bell Hill.
- 2) The presence of a Red Rock-like unit above the No. 1 Dolomite around Renison Bell Hill.
- 3) Much less conglomerate within the Red Rock Member around Renison Bell Hill.
- 4) A very thick (30m plus) Renison Bell middle unit around Dreadnought Hill which locally includes additional, mineralised carbonate units (2.5 horizon).
- 5) The absence of a sandy portion of the Renison Bell lower unit above the pebble beds around Dreadnought Hill.
- 6) The pebble beds are thicker and coarser grained at Dreadnought Hill, locally absent at Stebbins Hill and near the base of the Renison Bell lower unit at Renison Bell Hill.
- 7) The No. 3 Dolomite thins to nothing southward. That is from Dreadnought Hill to the south side of Renison Bell Hill and Stebbins Hill.

The most important feature is that the mineralised section (No. 1 to No. 3 Dolomites) of the mine sequence is thinner and finer grained towards the south and southwest. This is reinforced by recent drilling south of the mine area (Fig. 3, S886) where the section has thinned to approximately 70m compared with 90m at Renison Bell Hill and 150m at Dreadnought Hill. The implication is that the mineralised section thins to nothing in this direction and is probably replaced by Crimson Creek Formation which lies directly on the lower part of the Dalcoath Member.

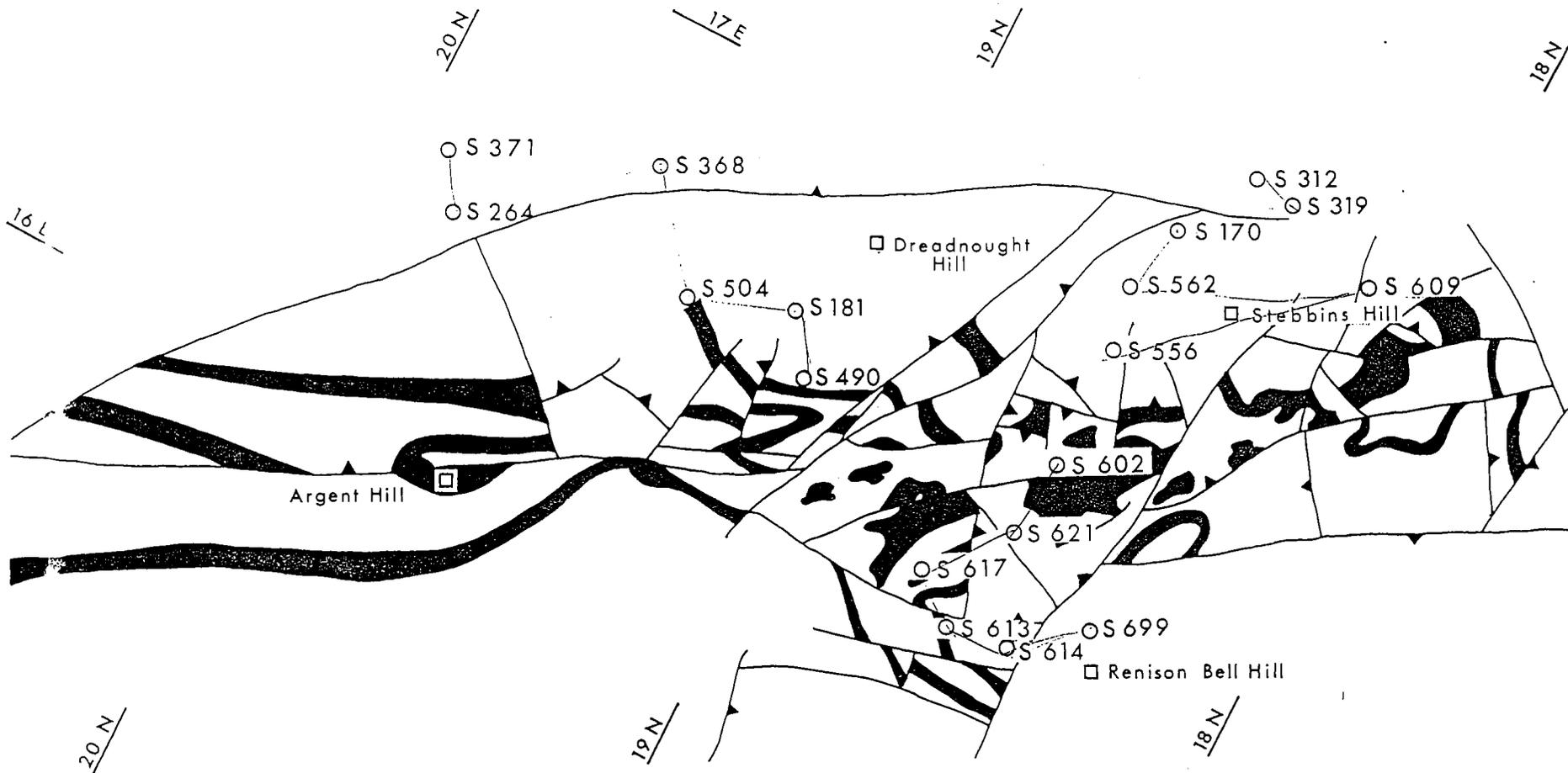
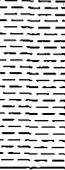


Figure 4 : Surface distribution of carbonate beds (black) and faults in the Renison mine area. The drill holes used in the stratigraphic analysis (circles) have been divided into three groups centred on Dreadnought Hill, Stebbins Hill and Renison Bell Hill respectively. Compiled from mapping by Renison Limited.

TABLE 2 : STRATIGRAPHY OF THE EXTENDED MINE SEQUENCE

Modified from Bond (1979).

		Dreadnought Hill Member : green and red-brown siltstone and greywacke, minor basalt, tuff.
	UCU	Upper Contorted Unit (0-45m) : red siltstone, chert, lapilli tuff, locally contorted black shale, siltstone, sandstone.
	No1	No. 1 Dolomite (8-25m) : grey stylolitic, laminated dolomite, impure margins, locally sandy.
	RRM	Red Rock Member (25-35m) : interbedded red white and grey sandstone, conglomerate, siltstone, chert, jasper and iron formation, local volcanic fragment.
	No2	No. 2 Dolomite (5-30m) : grey stylolitic dolomite locally laminated, pelletal or with red-lined cavities.
	RBu	Renison Bell upper (5-10m) : grey-green dolomitic siltstone.
	RB2	Renison Bell 2.2 (1-3m) : nodular dolomite, siltstone.
	RBm	Renison Bell middle (10-30m) : black shale, minor sandstone, siltstone, conglomerate.
	RBp	Renison Bell lower (20-40m) : quartz sandstone, shale partings, pebble beds to 10m, local basal intraclast conglomerate.
	RBl	
	No3	No. 3 Dolomite (to 15m) : grey stylolitic dolomite, locally laminated, pelletal; locally divided in two by shale.
	DMu	Dalcoath upper (10-15m) : grey-green dolomitic siltstone and shale with nodular dolomite, tuff beds.
	DM c&nc	Dalcoath carbonaceous and non-carbonaceous siltstone (8-2 1/2 m) : grey and black laminated siltstone, locally colour mottled slump folded, broken. Minor sandstone, shale beds.
	r&g	Dalcoath red and green (to 54m) : siltstone, sandstone, shale.
	DMc	Dalcoath contorted (to 80m) : black to grey shale and siltstone with broken beds of sandstone.
		Dalcoath undivided (to 800m) : massive quartz sandstone, shale and siltstone in upper part.

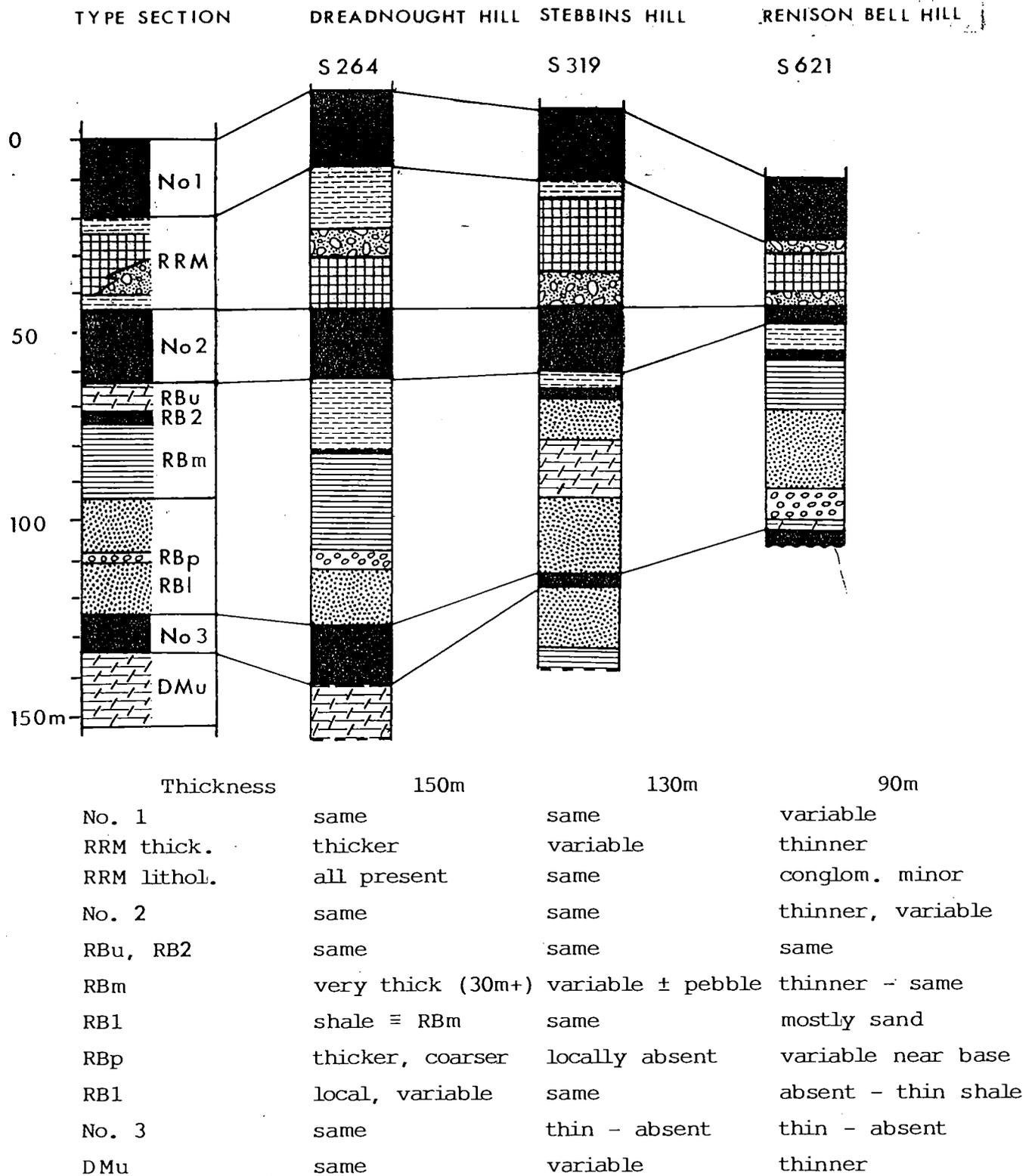


Figure 5: Comparison of representative stratigraphic sections from each sub-area with the type section for the mine (Bond, 1979) illustrating stratigraphic variations in the mine area.

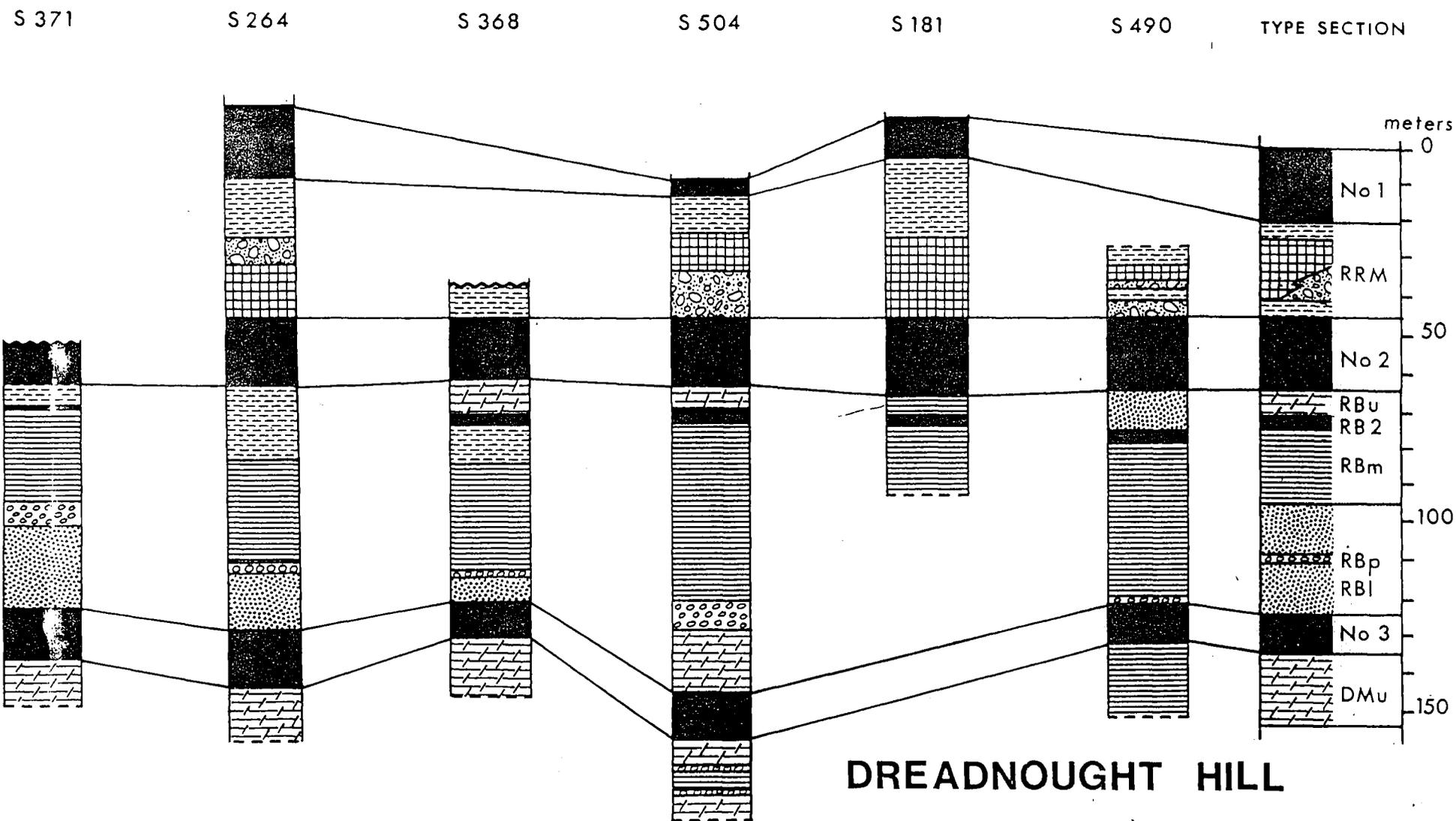
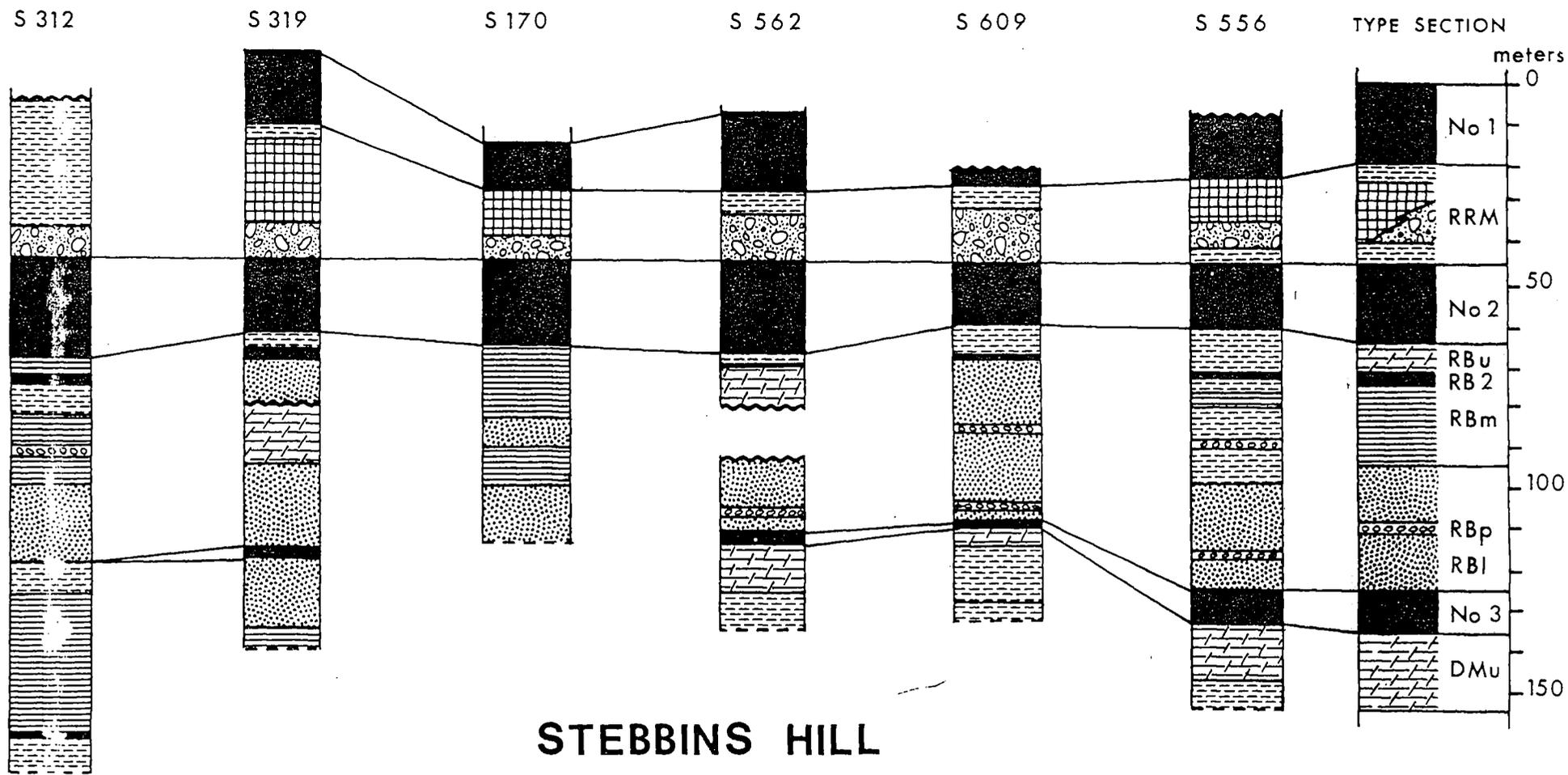


Figure 6 : Stratigraphic sections for drill holes in the Dreadnought Hill area (see Fig. 4 for locations). Correlation of the carbonate units is regular but for subunits within the clastic units distribution is irregular.



STEBBINS HILL

Figure 7 : Stratigraphic sections for drill holes in the Stebbins Hill area (see Fig. 4 for locations). Correlation of the No. 2 Dolomite is regular, but all other units are irregular or lensoid.

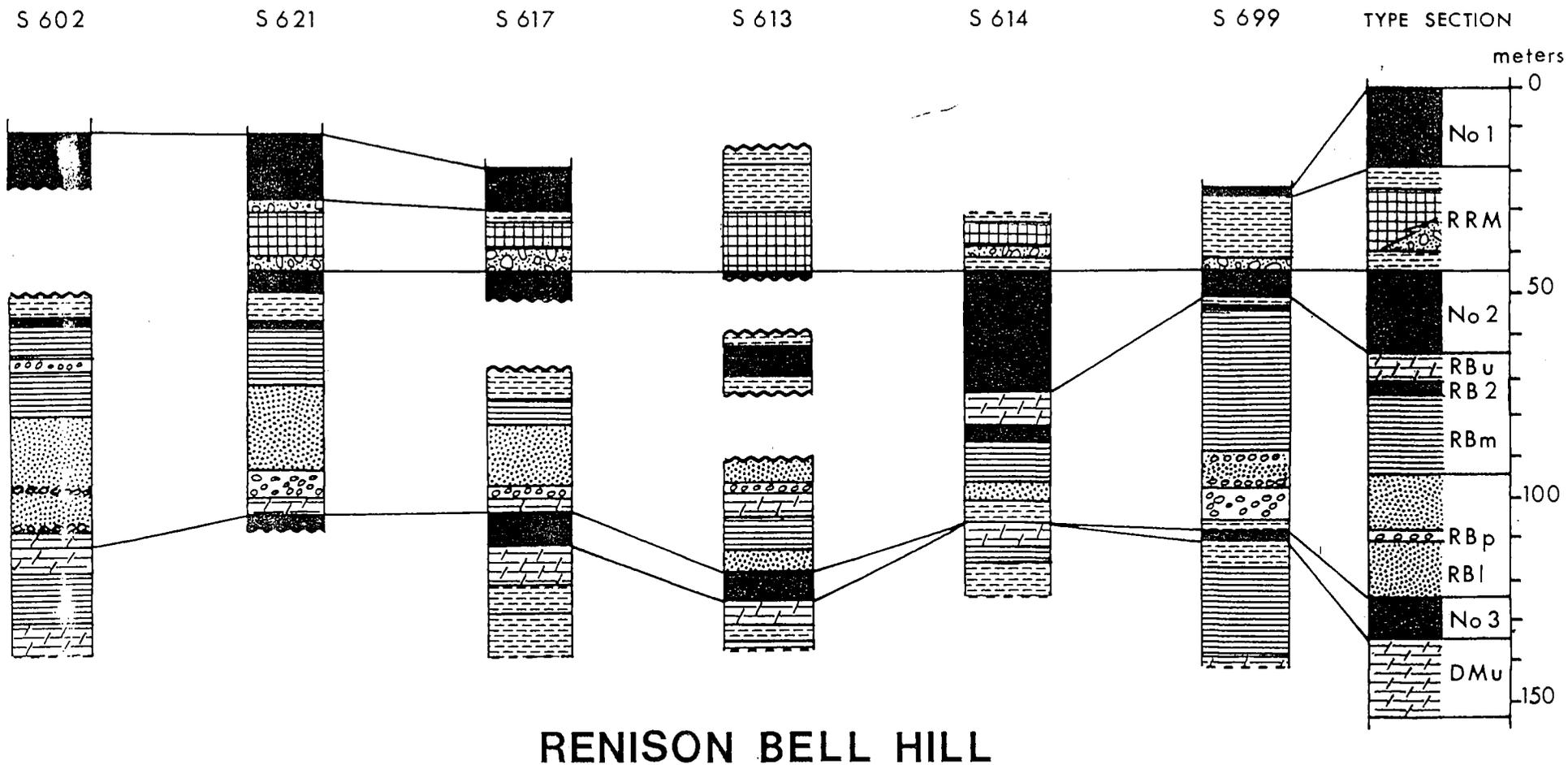


Figure 8 : Stratigraphic sections for drill holes in the Renison Bell Hill area (see Fig. 4 for locations).
 All units are irregular in distribution or are faulted out.

Within each subarea there is a reasonable consistency of thickness of the major units, but considerable variation in the distribution of subunits of the Red Rock, Renison Bell and Dalcoath Members (Figs. 6, 7, 8). The Dreadnought Hill area (Fig. 6) is characterised by: uniform thickness of major units, particularly the Dolomites, a thick Red Rock Member dominated by chert and siltstones, a thick shale-rich Renison Bell middle unit; and a thin, sand-poor Renison Bell lower unit. The Stebbins Hill area (Fig. 7) is characterised by: uniform thickness of major units; a thin and irregular sequence of Renison Bell upper, 2.2 Dolomite and middle units; a thin to absent No. 3 Dolomite; and an irregular Dalcoath upper unit. The Renison Bell Hill area (Fig. 8) is characterised by: correlatable but thin and variable major units; the presence of pebble beds near the base of the Renison Bell lower unit; a distinct dolomitic sequence at the base of the Renison Bell lower unit; and a thin dolomitic Dalcoath upper unit. Considering all three subareas, the major units are correlatable because of the uniformity of the carbonate units, whereas there is considerable facies variation within the clastic units. However, there is a generalised sequence of rock types within each of the clastic units and some characteristics for each of the subunits that allow them to be distinguished.

3. SEDIMENTOLOGY

3.1 Description of Units

3.1.1 Dalcoath Contorted

The Dalcoath contorted unit is present in long holes drilled in the Owen Meredith and Argent Dam areas, is reported from the main decline area in the mine (P.R. Stephenson, log of S574) but is not present in the Mount Lindsay-Dunkley Tram area or in the eastern part of the mine. In one hole (S574, Fig. 3) the unit is underlain by massive siltstone to very fine sandstone. The upper contact is gradational into lithologically similar but uncontorted, siltstone, sandstone and shale of the carbonaceous and non-carbonaceous siltstone unit. The total thickness of the unit is generally not

defined but appears quite variable. Thicker sections, for example more than 80m in S594 (Fig. 3), appear to be associated with thinner sections of the overlying carbonaceous and non-carbonaceous siltstone. These relationships suggest these two units are textural variants of the same sandstone-siltstone-shale sequence.

The Dalcoath contorted unit consists of finely laminated black shale and grey siltstone locally with laminae to thin beds of fine sandstone. Where sandstone is present the beds are commonly broken into angular fragments up to a few centimetres long which float in a matrix of black shale with slump-folded, contorted and locally fragmented siltstone laminae (Plate 1, P, Q). A complete gradation is evident from irregularly interbedded sandstone, siltstone and shale to partly broken sandstone beds associated with contorted siltstone-shale to isolated sandstone fragments in a wispy highly contorted siltstone-shale matrix. Fragments of finely laminated pyrite or aggregates of framboidal pyrite grains are also present locally. Many partly broken fragments and segments of the matrix have gash veins with quartz, calcite and euhedral pyrite (Plate 1, Q).

The rock types in the Dalcoath contorted are similar to those elsewhere within the Dalcoath Member and in the Renison Bell Member. However, the contorted texture is a distinct feature that allows correlation but which cannot be directly compared with sedimentary structures described from the literature. The presence of swirl and bleach textures in the adjacent Dalcoath carbonaceous and non-carbonaceous siltstone, the local presence of red and green sandstone-siltstone sequences (fluvial origin?) and limited petrographic evidence that the broken sandstone beds are cemented by carbonate, suggest the contorted texture is a product of slumping and compaction of unconsolidated siltstone and shale within which already cemented, brittle sandstone laminae became broken fragments. The association with fluvial rocks and the partial cementation suggest irregular exposure to air whereas the carbon-rich nature of the fine sediments suggest submarine conditions. The most likely environment which fulfills these conditions, is an intertidal flat with tidal channels along which slumping and brecciation took place.

3.1.2 Dalcoath Red and Green Siltstone

The distinctive red and green siltstone unit in hole S574 and elsewhere between Argent Dam and the mine portal occurs between the Dalcoath contorted unit and the Dalcoath carbonaceous and non-carbonaceous unit. In S574 it is 53m thick with an entirely green lower half and a green and red upper half. Subunits 0.2 to 5m thick are normal graded sequences of green grit and sandstone, green siltstone, red siltstone, green siltstone, and green cherty mudstone or yellow carbonate caliche. The cherty mudstone typically has dessication cracks and occurs as intraclasts or edgewise conglomerate in the overlying grit or sandstone (Plate 1, N). The sandstone is cross-bedded and rippled and there are dykes and sand volcanoes up into the overlying green siltstone. The green siltstone is variably laminated, colour mottled or massive whereas the red siltstone is massive with patches and veins of green alteration. The cherty mudstone is laminated to massive with the textures noted above whereas the caliche is massive and nodular with fractures and stylolites filled with green siltstone (Plate 1, M).

The colour, colour mottling, sequence and sedimentary structures of this unit are typical of the meandering fluvial model of Walker (1976). In this model, the intraclasts represent channel scour, the graded sequence progressive fill of the channel, and the caliche stabilisation of the filled channel. The colour mottling is due to periodic exposure to the air.

3.1.3 Dalcoath Carbonaceous and Non-Carbonaceous Siltstone

Most holes drilled in the mine area terminate in non-dolomitic, grey and black laminated siltstone (Figs 6, 7, 8) that has here been designated the Dalcoath carbonaceous and non-carbonaceous siltstone. In regional drilling (Fig. 3) the unit occurs between the dolomite-bearing Dalcoath upper and the Dalcoath contorted. Contact with the Dalcoath upper is a gradational increase in the proportion of dolomitic beds but the contact proper is defined by a sharp contact with a particular dolomitic horizon. The unit is typically 35m thick but ranges from 8 to 54m in studied drill holes (Fig. 3).

The lower portion of the Dalcoath carbonaceous and non-carbonaceous is typically colour mottled grey to black siltstone and shale separated from laminated siltstone, shale, sandstone and dolomite of the upper portion by a few metres of evenly laminated shale and siltstone. Colour mottling is present locally throughout the whole unit and rarely within the Dalcoath contorted and Dalcoath upper as well. However, it is always in highly contorted and broken siltstones and shales with few if any sandstone interbeds (Plate 1, O). The colour mottled portion may be in sharp or gradational contact with either brecciated or regularly laminated shale and siltstone. In the more regularly laminated rocks the siltstone laminae are still wavy, lenticular and locally slump-folded or broken. The mottled texture is best developed in rocks where there is more siltstone than shale and the shale laminae have been completely disjointed so that they appear to float in a siltstone matrix. Where the disjointing of the shale is extreme, it is difficult to tell if the colour mottling is entirely due to disjointing or if there is also some bleaching of shale possibly related to exposure to air or diagenesis. The association of mottling with folded and disjointed beds and the absence of plant or animal borings suggest the mottling is related to slumping rather than to bioturbation (c.f. Coneybeare & Crook, 1968, p. 52).

The upper portion of the unit is in many ways similar to the Renison Bell Member. It consists of finely laminated grey and black siltstone with sandstone laminae concentrated toward the base and shale or dolomite laminae concentrated toward the top. Light grey rocks consist of fine irregular laminae of ⁺siltstone and very fine sandstone. The siltstone laminae are homogeneous and parallel-sided with fine partings of carbonaceous siltstone or shale whereas the very fine sandstone laminae have bulbous margins and wisps of carbonaceous siltstone. Typically there is a gradational increase in the number of wisps outward from the sandstone toward a sharp contact with the adjacent siltstone laminae. This defines units approximately 1.5cm thick (Plate I, K). Elsewhere there are irregular lenses up to 2cm thick of cross-bedded, very fine sandstone with shale wisps. In thicker sandstone beds toward the base of the unit, fine or medium-grained massive to cross-bedded sandstone also has thin, irregular wispy partings of carbonaceous shale (Plate I, L). This is the Fraser bedding of Renison Bell

& Singh (1975, p. 98). Where shale is interbedded with the siltstone, fine, more regular lamination is common and discrete laminae of pyrite are present. Sandstone layers are lenticular and cross-bedded and the siltstone locally also forms lenticular layers up to 2cm thick in finely laminated shale and siltstone. Slump folds, wrinkle folds and convolute bedding are also present in thicker siltstone or pyritic layers associated with finely laminated shale and siltstone. These structures are also common in the Renison Bell middle (Plate 1, B-F).

The consistent laminated texture of the shale-siltstone-sandstone and particularly the lenticular cross-bedded nature of the sandstone (flaser bedding) are characteristic of tidal flats where the sandstone represents ripples formed and moved by the waxing tide and the shale represents the high stand of the tide (Reineck & Singh, 1980). The deformation textures typically relate to slumping around scoured channels during tidal wane.

3.1.4 Dalcoath Upper

The Dalcoath upper is present throughout the Dunkley Tram-Owen Meredith-Renison mine area even where the overlying No. 3 Dolomite is absent (for example S614, Fig. 8). It is in sharp regular to irregular contact with the No. 3 Dolomite, is 10-15m thick and is characterised by the presence of dolomite interbeds in laminated siltstone and shale. Overall the unit is similar to the Renison Bell upper and the laminated siltstone and shale is similar to the finer portions of the Dalcoath carbonaceous and non-carbonaceous siltstone.

Dolomite in the Dalcoath upper is regular to nodular laminae, or beds to 2cm thick with slump folds, nodular texture and pull apart texture. These textures are also typical of the Renison Bell 2.2 dolomite and the dolomite beds in the Renison Bell upper. The siltstone and shale are irregularly laminated with the laminae locally split apart by thin lenses of fibrous carbonate in which the fibres are oriented perpendicular to the bedding (Plate 1, J). This is cone-in-cone structure which is generally considered of diagenetic origin (Coneybeare & Crook, 1968, p. 49). There is a distinctive correlatable unit three to four metres thick in the lower part of the Dalcoath upper that exhibits

this texture. Where fine sandstone is present there are normal graded units approximately 1cm thick with shale wisps in the sandstone. There is also a distinctive green horizon a few centimetres thick grading from grit to very fine sandstone that is reported to consist of K feldspar-rich tuff fragments. There are also beds of fragmental rocks that resemble tuffs. The tuff beds and the cone-in-cone structure laminated horizon are characteristic markers in the Dalcoath upper.

Sedimentary structures in the clastic rocks are similar to those in the Dalcoath carbonaceous and non-carbonaceous siltstone. The nodular texture in dolomite is generally attributed to differential compaction of chemical versus clastic sedimentary strata (McCrossan, 1958) and is a common feature of mixed sequences formed in shallow water.

3.1.5 No. 3 Dolomite

The No. 3 Dolomite is present throughout most of the Mount Lindsay - Renison Mine area but is quite variable in thickness. In the Mount Lindsay-north Dunkley Tram area it is only a few metres thick, whereas in the Owen Meredith-south Dunkley Tram-Argent Dam area it is two discrete beds 10 to 20m thick separated by shale and siltstone, and at Dreadnought Hill it is a single bed 15m thick that thins to nothing on the southeast side of Renison Bell and Steobins Hills (Figs 3, 6, 7, 8). Contacts are sharp and regular to irregular with the Renison Bell lower and Dalcoath upper units

The No. 3 Dolomite is generally thought of as massive but in polished slab textures related to the presence of impurities, to original deposition and to diagenetic alteration are evident. The No. 3 Dolomite locally has margins approximately 50cm thick consisting of laminated buff, brown, green or pink impure dolomite. The impurities are quartz, chlorite, talc, muscovite, or tourmaline that are concentrated in laminae or beds alternating with fairly pure dolomite (Plate 2A). The laminae may be regular and even, wispy to lenticular, and in thicker quartz-rich horizons, normal graded.

The interior part of the No. 3 Dolomite is light grey to dark grey variable recrystallised dolomite in which the original faintly laminated or pella texture (Plate 2E, F) is variably overprinted by colour

mottling, patches, pseudobreccia, veins and massive replacements. These features are of diagenetic, metamorphic and hydrothermal origin and are described in detail in the next chapter.

In the Owen Meredith-Dunkley Tram-Argent Dam area the No. 3 Dolomite is split in two by a sequence of siltstone and shales referred to as the inter-No. 3 (Fig. 3). The inter-No. 3 is up to 25m thick and consists of even laminated black shale and grey siltstone with thin interbeds of nodular dolomite and local concentrations of pyrite laminae and framboids. There is a distinct gradation from siltstone in the lower part to carbon-rich shale with nodular dolomite and pyrite laminae in the upper part. This is the same type of gradation evident in transitions to the main carbonate beds from the Renison Bell and Dalcoath Members. This suggests the inter-No. 3 and No. 3 upper are a repetition of the regular gradational cycles that characterise the Dalcoath-No. 3 and Renison Bell-No. 2 elsewhere. The No. 3 dolomite itself in the Owen Meredith-Dunkley Tram-Argent Dam area is rather more impure than it is in the Renison mine area. It contains carbonaceous partings with irregular patches and veins of pyrite; bands of pyrite framboids; nodular textured dolomite and pebble beds with carbonate clasts, K feldspar crystals and contorted laminae.

The fine laminated and pelletal texture of the dolomite is characteristic of intertidal to supratidal mudflats where crystalline laminae form by evaporation following flooding and the impure pelletal and carbonaceous laminae form by growth of algae between floods. Algae form pellets by coating grains, trap clastic grains by a baffle effect and leave carbonaceous remains. The absence of dessication cracks and vesicles and of intraclastic breccia within the dolomite suggest there was limited periods of exposure. The regular fine lamination and the above features are more consistent with an intertidal rather than supratidal model. Similar dolomites are forming today in the Coorong Lagoon of South Australia (von der Borch & Lock, 1979).

3.1.6 Renison Bell Member

The Renison Bell Member is the 30 to 80m of sandstone, shale, siltstone, nodular dolomite and pebble beds that separate the No. 2 and No. 3 Dolomites. The normal subdivision of the Renison Bell Mem-

ber into a lower unit of sandstone and pebble beds, a middle unit of shale and siltstone, a nodular dolomite (2.2 horizon) and an upper unit of dolomitic shale and siltstone is valid only in a gross sense. Detailed correlation within the Renison Bell Member (Figs 6, 7, 8) shows that the individual units have lenticular distribution, that there are complete repetitions of sandstone-shale-dolomitic siltstone sequences (eg S613, Fig. 8) and that there are several horizons of pebble beds and nodular dolomite. Consequently it is more meaningful to describe the rock types of the Renison Bell Member rather than the individual units.

Sandstone. Bodies of sandstone typically 10 to 15m thick but locally to 40m thick occur mainly in the lower part of the Renison Bell Member (Figs 6, 7, 8). The sandstone is massive, white to grey, fine to very fine grained quartz sandstone locally with bands of pebbles and thin wispy partings of carbonaceous shale or more rarely buff siltstone or dolomite (Plate 1, G, H). Where the shale partings are closely spaced, pyrite laminae are present, there is some normal grading in the sandstone and local cross-bedding. Where siltstone partings are present, there may be concentrations of coarse quartz grains within the parting and where the parting is dolomite there is nodular texture or contorted bedding.

Pebble Beds. Pebble beds a few 10's of centimetres thick and rarely to 10m thick are typically associated with the sandstone in the Renison Bell lower unit. At Dreadnought Hill the pebble beds are one to 10m thick, located above the sandstone (Fig. 6) and consist of imbricated, well rounded, but non-spherical pebbles averaging 5mm long. At Stebbins Hill the pebble beds are within and above the sandstone, relatively thin and discontinuous and consist of more angular pebbles and granules (Fig. 7 ; Plate 1, H). At Renison Bell Hill the pebble beds are typically below the sandstone but locally within and above as well (Fig. 8). The beds are variable in thickness but the pebbles are typically subangular, pebble to granule size and not imbricated.

Typical pebble beds have sharp irregular contacts with the adjacent rock (Plate 1, H). They consist of poorly sorted, subangular to rounded pebbles and granules of grey and white carbonate (calcite in one analysed specimen), silicified carbonate, calcite-iron oxides,

pyrite-replaced carbonate and quartz sandstone. The matrix is typically quartz sandstone, but in one specimen (S371-364.9m) a carbonate-rich matrix is variably removed by stylolitisation and the rock is partly silicified.

The pebble bed that underlies sandstone at Renison Bell Hill is rather different from those elsewhere. It is an intraclastic conglomerate consisting of flat angular pebbles of siltstone, shale and carbonate similar to those in the immediately underlying sequence.

If the intraclastic pebble beds represent erosion of the underlying dolomite and associated rocks they may be the source of the more rounded clasts in the other pebble beds. In modern environments with similar sequences, intraclastic conglomerates originate from erosion of supratidal flat dolomites along the margins of tidal channels which cut the flat. The material transported in such channels must be deposited where the channels debauch into the subtidal or intertidal clastic environment. Such pebbles may then be washed up on beaches that fringe the subtidal-intertidal flats. The thick imbricated pebble beds probably represent the tidal channels whereas the thinner beds are those washed up on the beaches represented by the massive quartz sandstone.

Shale, Siltstone and Sandstone. Very thin laminated black shale with local thin laminae of siltstone or thick laminae of sandstone is characteristic of the middle part of the Renison Bell Member between the Owen Meredith area and the mine. Northwest of the Owen Meredith area there is more grey siltstone than shale in this part of the Renison Bell Member. Within the mine area there is considerable variation in the relative proportions of shale, siltstone and sandstone. For example, at Dreadnought Hill there is 20 to 50m of black shale with siltstone laminae overlying a relatively thin section of quartz sandstone and pebble beds (Fig. 6). At Stebbins Hill shale is a minor component of the Renison Bell Member compared with sandstone and siltstone (Fig. 7) whereas at Renison Bell Hill all rock types are present but the section is variable (Fig. 8).

The characteristic features of these sequences is that they are

even where shale and siltstone are involved but uneven where sandstone is present. Light grey very fine grained sandstone is typically lenses less than 1cm thick with fine wavy shale partings, shale intraclasts local cross-bedding, bulbous often loadcast margins and slump folds (Plate 1, B-F). Adjacent to the sandstone lenses, shale and siltstone may be included in the slumps, contain intraformational faults and be normal graded in units 5 to 20mm thick. This is the flaser bedding which is also common in the Dalcoath Member. Calcite-cemented pyrite framboids and laminae of angular granule-sized pyrite grains are often associated with the sandstone (Plate 1, D). Elsewhere pyrite grains are disseminated throughout sandstone laminae (Plate 1, B, C).

The thin laminated shale-siltstone sequences may occur as sets alternating with sandstone on centimetre scale (Plate 1, E), as sets on the tens of centimetre scale with occasional sandstone lenses or as thick sequences on metre to tens of metre scale with little or no sandstone. Typically there is a gradation away from the thicker sandstone beds typical of the Renison Bell lower to sandstone-bearing siltstone-shale sequences to shale-dominated sequences then into dolomite-bearing sequences. The shale-siltstone sequences appear to be fairly evenly laminated but in detail the siltstone laminae tend to be lenticular on the scale of a few centimetres. Locally the siltstone laminae exhibit the sedimentary structures typical of the sandstone laminae. In shale-rich sequences, pyrite laminae are common (Plate 1, E).

The overall laminated character, the sedimentary structures in the sandstone and siltstone laminae, the evidence for reworking of shale and pyrite laminae by the sandstone and the overall association of these sequences is similar to the intertidal mudflats already described for the Dalcoath Member.

Carbonate and Carbonate-rich Rocks. A discrete dolomite bed (the Renison Bell 2.2 dolomite) and a variety of carbonate-bearing siltstones and shales are typical of the upper part, but also occur near the base of the Renison Bell Member (Figs 6, 7, 8). The Renison Bell 2.2 dolomite occurs throughout Owen Meredith-Renison Mine area and is correlated with a thin oolitic chert unit in the Mount Lindsay area. The 2.2 dolomite is approximately one metre thick and is characterised by a nodular texture wherein the dolomite laminae are disjointed segments

floating in a brown to black fine laminated shale-siltstone matrix (Plate 2C). There is a gradation from discrete calcite-rich crumpled laminae with rounded pull-apart-type terminations to amalgamated, broken, stylolite margined 'dolomite-rich' laminae (Plate 2C). It is possible that the calcite-rich variety is the original rock and the dolomitic, stylolitized variety is a diagenetic alteration product. The matrix is comparable to the adjacent clastic rocks and is buff, brown, grey or black finely laminated siltstone or shale that 'wraps-around' the associated folded or broken carbonate laminae.

The carbonate-bearing sequence that typically occurs above the 2.2 Dolomite is referred to as the Renison Bell upper. It is usually a few metres, but locally up to 10 metres thick with sharp contacts against the 2.2 dolomite and the No. 2 Dolomite. It is characterised by a buff to light green colour, although it is locally grey or even black, and consists of laminated siltstone, carbonate sandstone and minor shale (Plate 1, A). The carbonate sandstone laminae exhibit all the sedimentary structures present in sandstone laminae of the Renison Bell middle suggesting this sequence is simply an extension of the shale-siltstone-sandstone sequences with clastic carbonate as an added component. There are also discrete carbonate laminae up to 2cm thick which consist of sand size calcic grains or nodular very fine grained dolomite. The textures of these laminae are similar to those in the Renison Bell 2.2 dolomite.

There is considerable variability from drill hole to drill hole in the distribution of these various lithologies within the Renison Bell upper (Figs 6, 7, 8) but a strong similarity to the Dalcoath upper in terms of rock types and sedimentary structures. Overall the Renison Bell middle and upper are directly comparable to the upper units of the Dalcoath Member and hence, are interpreted to be of intertidal origin as well.

3.1.7 No. 2 Dolomite

The No. 2 Dolomite is present throughout the Renison Mine-Mount Lindsay area. In the mine area it is 5 to 30m thick, in the Owen-Meredith-Argent Dam area it is less than 5m thick and at Mount Lindsay it may be as much as 200m thick. Contact with the Renison Bell Member is sharp and regular, but with the Red Rock Member varies

from even and conformable in the mine area to scour channels with underlying solution breccia along the Pieman Dam Road.

Textures in the No. 2 Dolomite related to original deposition and impurities are similar to those in the No. 3 Dolomite but include several additional features. The green, grey, red and brown laminated impure margins may be several metres thick in the No. 2 Dolomite, particularly at the lower margin. Impurities include distinct shale and siltstone laminae sets up to one centimetre thick wispy laminae of quartz, chlorite and talc that may outline a nodular texture in the dolomite, beds of breccia comparable to those in the Red Rock Member and isolated rounded pebbles of hematitic jasper that are interpreted as dropstones (Djakic, 1980).

The interior part of the No. 2 Dolomite is light grey to dark grey faintly laminated and pelletal dolomite identical to that in the No. 3 Dolomite. There is one specimen (S614 - 24.8m) from the No. 2 Dolomite that consists of angular clastic grains of crystalline dolomite in a very fine dolomite matrix. Diagenetic alteration of the No. 2 Dolomite, particularly the Late Diagenetic red-lined cavities, is more extensive than in the No. 3 Dolomite.

The carbonate rocks correlated with the No. 2 Dolomite in the Dunkley Tram-Mount Lindsay area are quite distinct from those of the mine area. In hole S705 at Dunkley Tram the No. 2 Dolomite contains algal stromatolites (Plate 3, D), bands of stromatolite debris (Plate 3, E), oolites and pisolites, possible dolomitised evaporites, and interbeds of red and green fluvial sandstone and siltstone. At Misty Valley and Mount Lindsay equivalent but thicker units are variably silicified (Plate 3). In hole ML34 (Fig. 3) the No. 2 Dolomite is 33.5m of white fine-grained but granular dolomite with distinct laminae of carbon-rimmed pisolites (c.f. Plate 3, F, G) concentrated in the upper third. In ML56 (Fig. 3) the No. 2 Dolomite is 201.5m thick of which the lower 43.5m contains all the characteristic structures and the upper 158m is a series of 35 to 45m units of massive white crystalline dolomite with irregular pisolitic interbeds (Plate 3, H) and grey fine grained dolomite with white crystalline fragments of uncertain origin (Plate 3, I). The lower unit has a lower zone of partly silicified pisolitic and stromatolite fragment dolomite, a middle zone of completely silicified dolomite originally similar to the lower zone and an upper zone of cream granular dolomite

with folding (enterolithic texture) stylolitic margins and interstitial impure fine-grained dolomite (Plate 3, J) that most likely represents replaced evaporites.

The evaporite-pisolite-stromatolite association, the zones of silicification and the association with fluvial sandstone and siltstone are characteristic features of supratidal to intertidal carbonate sequences (Lucia, 1972). Compared with No. 2 Dolomite of the mine area this sequence contains more evidence of evaporation dessication and algae growth and less evidence for regular sediment influx and reworking. This is more consistent with a supratidal environment where periods of exposure are longer.

3.1.8 Red Rock Member

The Red Rock Member is a distinctive marker unit found throughout the Renison Mine-Mount Lindsay area. It is 10 to 45m thick in the mine area and generally thicker elsewhere although the absence of the No. 1 Dolomite makes thickness definition difficult (Fig. 3). In the mine area a cavity or clay gouge generally separates siltstone of the Red Rock Member from the No. 2 Dolomite. On the Pieman Dam Road similar contacts represent solution cavities in the top of the No. 2 Dolomite filled with siltstone, carbonaceous material and red conglomerate. Siltstone at the top of the Red Rock Member is in sharp regular contact with the No. 1 Dolomite.

Although a general sequence of rock types is commonly recognised within the Renison Bell Member (Table 2), detailed correlation (Figs 6, 7, 8) suggests that the subunits in fact have lenticular distribution. There are no obvious changes in the rock types themselves throughout the area, just differing proportions and sequences from place to place. Three main groupings of rock types have been used for correlation: a siltstone fragmental-tuffaceous group; a conglomerate-grit-sandstone-carbonate group; and a chert-iron formation-carbonate group.

Siltstone, Fragmentals and Tuffaceous Rocks. White, grey, green buff or red siltstone is associated with intraclastic breccia and tuffaceous rocks near the base of the Red Rock Member and with hematitic chert and tuffaceous rocks near the top of the Red Rock Member. The siltstone typically occurs in normal graded units 10 to 95cm thick

with scoured bases, a lower section of intraclast breccia with a swirled siltstone or tuff matrix, a massive to cross bedded section of siltstone/sandstone or tuff and an upper section of irregularly laminated locally cross-laminated siltstone with intraformational faults and irregular beds of intraclasts or lapilli tuff.

Most of the white or grey sequences have intraclast breccias consisting of variably flattened mostly angular clasts of carbonate rocks, siltstone, shale and quartz sandstone locally with hematitic chert, rounded quartz sandstone and volcanic rocks. The green sequences generally contain more quartz sandstone, the brown sequences have a tuffaceous matrix with more exotic clasts than intraclasts and the red sequences are typically associated with cherty rocks rather than breccias but have some plagioclase porphyritic basalt clasts. There are some beds with pumiceous lapilli but these are invariably associated with clasts of other rock types as well.

These rock types consist dominantly of clastic material derived from the underlying units of the Renison Mine sequence with some admix of material from the Oonah Formation and from a volcanic sequence not represented within the mine sequence. All volcanic material observed so far is not in its original site of deposition, it is reworked from elsewhere.

Conglomerate, Grit, Sandstone and Carbonate. The bulk of the Red Rock Member in most areas consists of a mixture, often in normal graded units several metres thick, of conglomerate, grit, sandstone, locally siltstone, and carbonate. The conglomerates are clast supported, poorly sorted mixtures of clasts to tens of centimetres diameter in an often red matrix of finer clasts, sandstone and siltstone. The clasts are white, buff or pink fine-grained dolomite rarely with veins or stylolites, silicified oolitic carbonate chert, hematitic siltstone, flattened intraclasts similar to those in the fragmental units, quartz sandstone, quartz grains, basalt, rhyolite tuff and rare schist and granitoids. The grits and sandstones are composed of similar material with a higher proportion of siliceous rocks. The siltstone is similar to that in the other unit but is often capped by a few centimetres of white, buff or pink dolomite or chert.

Chert, Iron Formation and Carbonate. Bedded or nodular, locally hematitic, oolitic chert, iron formation, carbonate and hematitic siltstone are characteristic of the middle to upper part of the Red Rock Member. Nodules or nodular beds of hematitic chert locally with septarian cracks filled with quartz-pyrite or quartz-hematite are associated with red hematitic siltstone which wraps around the nodules. Locally nodular bedded cream chert with marginal cracks is associated with fine laminated magnetite and hematite and red hematitic siltstone. Where clastic carbonate is associated with the magnetite and hematite the laminae are highly contorted in swirl or bullseye structures and much of the hematite has an oolitic texture. Hematitic oolites of this type associated with quartz and chert grains locally constitute a grit that is interbedded with the iron formation. Textural evidence in the oolitic cherts and siltstone suggest some of the chert is a replacement of carbonate (Patterson, 1979, p. 20).

Combinations of these cherty rocks typically constitute the top portion of graded units of conglomerate grit, sandstone and siltstone suggesting they were formed as part of the same sedimentary process. However, the top of the Red Rock Member typically consists of red hematitic siltstone with cherty tuffaceous and carbonate interbeds.

The Red Rock member as a whole can be considered as a margin of silty intraclastic breccia and tuffaceous rocks overlain by a graded sequence of conglomerate, grit, sandstone, siltstone and cherty rocks and capped by siltstone and chert rocks.

The colour of the Red Rock, the general sequence of rock types, the complexity of distribution and composition of the individual rock types and the relationships to the underlying strata suggest the Red Rock is of fluvial origin (see Visher, 1972, Fig. 11). In particular, the scouring of the No. 2 Dolomite and infill with carbonaceous and intraclastic material represents the channel lag; the graded conglomerate to siltstone sequences original channel fill and point bars; and the chert, iron formation, laminated siltstone and dolomite deposits in back swamp or cut off lakes.

3.1.9 No. 1 Dolomite

The No. 1 Dolomite has not been identified outside the Dunkley Tram-Argent Dam-Renison mine area (Fig. 3). Thickness varies from five to 25m with 15m typical in the mine area. Both upper and lower contacts are sharp against siltstone of the Red Rock and Dreadnought Hill Members. The No. 1 Dolomite is characterised by impure margins often up to five metres thick consisting of fine laminated grey, green and buff silty dolomite (Plate 2, A), red or pink hematitic dolomite and pink hematitic calcite sandstone (Plate 2, D). Discrete laminae of siltstone and sand-size hematite oolites occur locally. The interior portion of the dolomite is faintly laminated or pelletal and hence similar to the No. 2 and No. 3 Dolomites. However, the development of diagenetic texture is much more restricted than in the No. 2 Dolomite particularly. The Late Diagenetic cavity-fill texture has not been observed in the No. 1 Dolomite. The poor development of diagenetic textures is typical of the impure margins of all three dolomite horizons.

The No. 1 Dolomite is an impure equivalent of the No. 2 and No. 3 Dolomites, but is associated with rather different clastic rocks and has a more limited distribution. The apparently conformable relationship of the No. 1 Dolomite with the siltstones, carbonates and cherty rocks of both the overlying and underlying sequences suggest the No. 1 Dolomite formed in areas between major channels where there was overflow of only fine suspension material (the impurities in the No. 1) into an intertidal region where carbonate precipitation predominated. Toward the supratidal environment represented in the No. 2 Dolomite at Dunkley Tram such areas would be more limited in extent, and hence No. 1 Dolomite might not be represented.

3.1.10 Rocks Overlying the No. 1 Dolomite

Rocks overlying the No. 1 Dolomite are generally referred to the Dreadnought Hill Member of the Crimson Creek Formation. However, in the mine area there is typically 15m of red to maroon hematitic siltstone, cherty siltstone and lapilli tuff underlying massive greywacke and interbedded greywacke and siltstone that is more characteristic of the Crimson Creek Formation elsewhere. Although a detailed study has not been made of the hematitic unit it has more features in common with the Renison mine sequence than with the Crimson Creek Formation. In hole S376 south of Argent Dam (Figs 3, 2) this unit is 45m of laminated

black shale and grey siltstone with local sandstone flasers and pebble beds and an upper portion 18m thick with bleaching and broken sandstone beds that is identical to the contorted and carbonaceous and non-carbonaceous units of the Dalcoath Member. The unit is referred to as the upper contorted unit for correlation purposes (Fig. 3) as it is considered a distinct stratigraphic entity occurring above the normal mine sequence. The sequences and sedimentary structures are equivalent to an inverted sequence in the Dalcoath upper. This suggests a progression from shallow intertidal dolomite (No. 1) to intertidal mudflat (lower part of upper contorted) to channel-margin or possible subtidal environment (upper part of upper contorted).

3.2 Depositional Environment

In the previous section, a shallow water origin was suggested for all the units of the Renison mine sequence on the basis of lithologies and sedimentary structures. Within the Renison mine sequence there are notable similarities between individual units and between sequences of units suggesting that the sedimentation was cyclic. In an idealised model of the Renison mine sequence, two major retrogressive cycles and a partial transgressive cycle have been recognised (Fig. 9). The lower retrogressive cycle is approximately 110m thick in the Dalcoath Member and No. 3 Dolomite. It records progressive shallowing from the intertidal to possibly subtidal channel margin collapse breccias of the Dalcoath contorted and lower Dalcoath carbonaceous and non-carbonaceous, through the intertidal mixed flat and mudflat environments of the upper Dalcoath carbonaceous and non-carbonaceous to the intertidal to supratidal saltmarsh environment of the Dalcoath upper and algal flat environment of the No. 3 Dolomite. The upper retrogressive cycle in the Renison Bell Member, No. 2 Dolomite and lower part of the Red Rock Member is approximately 90m thick. It records initial erosion of the onlap, onto the No. 3 Dolomite by an intertidal sandbar (Renison Bell lower) followed by progressive shallowing from intertidal mixed flat and mudflat in the Renison Bell middle, through the intertidal to supratidal saltmarsh of the Renison Bell 2.2 Dolomite and Renison Bell upper, the algal flat environment of the No. 2 Dolomite, and into the fluvial environment of the Red Rock Member. The partial retrogressive cycle in the upper Red Rock Member, No. 1 Dolomite and Upper Contorted Unit is approximately 30m thick. Whereas the conglomerate-grit-sandstone-siltstone sequence in the middle part of the Red Rock Member represents

UCU			pool	intertidal	3
No 1		laminated pelletal	algal flat	supratidal	
RRM		graded intraclasts scour	overbank channel fill lag	fluvial	
No 2		laminated pelletal	algal flat	supratidal	2
RBu		tidal bedding		intertidal	
RB2		nodular	saltmarsh		
RBm		tidal bedding flaser	mudflat mixed flat	shallower intertidal deeper	
RB1		flaser graded intraclasts	sandflat or bar	intertidal	1
No 3		laminated pelletal	algal flat	supratidal intertidal	
DMu		nodular tidal bedding flaser	saltmarsh		
DMc		tidal bedding flaser graded colour mottled slumped	mudflat mixed flat channel margin	intertidal	
R&G		red & green	channel	fluvial	1
DM c & nc		slumped flaser	channel margin	intertidal subtidal	

FIGURE 9 : Sedimentary cycles in the Renison mine sequence, based on interpreted depositional environments. The lower two cycles are retrogressive and the third cycle is partial but transgressive.

fill of a fluvial channel, the chert-bearing and silty rocks in the upper part of the Red Rock Member probably formed adjacent to but outside the channel levee in ponds and marshes that were an extension of the intertidal-supratidal flat in which the No. 2 Dolomite formed. The overlying No. 1 Dolomite and red siltstone and cherty siltstone of the Upper Contorted Unit probably formed in a similar environment whereas the contorted black shales and siltstones which locally characterise the Upper Contorted Unit are intertidal to subtidal channel margin breccias and hence represent relatively deeper water conditions. The interpretation of the overlying Dreadnought Hill Member as marine turbidites (Patterson, 1979) reinforces the idea that there is a change in the Red Rock Member from shallowing to deepening water and hence that the partial cycle is transgressive.

Although the cyclic model is generally applicable to the Renison mine sequence, on a local scale there are complexities. In detailed correlation for the mine area it is evident that individual units have lenticular distribution and hence are not present everywhere. For example, the sandstone of the Renison Bell lower wedges out in the Dreadnought Hill area (Fig. 6) whereas the associated thick and persistent shale sequence is barely recognisable in the adjacent Stebbins Hill area (Fig. 7). Reconstruction of palaeogeography by mapping the distribution of individual units explains their lenticular distribution. For example, the Renison Bell lower was a sandbar elongate parallel to regional strike that was separated by a thin pebble horizon from the shale, siltstone and carbonate of the intertidal lagoon. Elsewhere, there are complete repetitions of the regressive cycles that are limited to very small areas. For example, at Renison Bell Hill there is a complete regressive cycle between the No. 3 Dolomite and the sandstone of the Renison Bell lower in hole S613 and partial cycles in the adjacent holes (Fig. 8). On a larger scale there is the major facies change in the No. 2 Dolomite between the Mount Lindsay-Dunkley Tram area and the mine area.

Cyclic sequences similar to those described here are characteristic of modern and ancient tidal flats (Reineck, 1972; Ginsburg, 1975;

Button & Vos, 1977 and other papers in the same volume). For example, the present day tidal flat sequences of the Netherlands and Germany (Reineck, 1972; Reineck & Singh, 1975) are similar in every-

thing but seals to the Renison Bell Member. The 400m thick sequence in the Lower Proterozoic Pretoria Group of South Africa (Button & Vos, 1977) is a mixed clastic-carbonate sequence that contains facies similar to both the typical mine sequence and the stromatolitic oolitic dolomites of the Dunkley Tram-Mount Lindsay area. The model proposed for the Pretoria Group sequence (Fig. 10) can be invoked for individual cycles within the Renison mine sequence with a few modifications. In particular, the Renison Bell lower is interpreted as sandbars separating the main part of the tidal flat from the subtidal shelf which is not represented in the Renison Bell Member-No. 2 Dolomite-Red Rock Member cycle (Fig. 10, block 2, 3).

The sequence of oolitic and intraclastic dolomite, silicified and stromatolitic dolomite, dolomitised enterolithic evaporites and massive dolomitised evaporite described from the No. 2 Dolomite in hole ML56 is very similar to a retrogressive cycle from the sabkha environment of Abu Dhabi (Reading, 1978). In particular, the oolitic facies represents sand bars which protected the intertidal to supratidal environment, the stromatolite facies a fringe separating the intertidal flats and channels from the supratidal sabkha, the enterolithic facies the impure fringe of the sabkha and the massive facies the cottage cheese textured sabkha interior.

Although no detailed work is yet described from the literature, preliminary descriptions of the Smithton Dolomite (Preiss & Forbes, 1981) suggest a similar environment to the Dunkley Tram-Mount Lindsay dolomites. If this is correct, then the mine sequence proper represents a relatively narrow zone of dominantly clastic deposition adjacent to a very extensive supratidal carbonate platform (Smithton Dolomite). In this context, the mine sequence probably represents an embayment in the carbonate platform possibly where a river issued into a lagoon. This interpretation might be consistent with the observation that the Success Creek Group is absent from the area around Zeehan (Williams, 1978) in that the presence of such a river may have led to non-deposition of the carbonate platform or its erosion.

The overall model for northwest Tasmania in the Proterozoic is of a 600 to 1500m thick supratidal carbonate shelf covering the Rocky Cape block giving way to the south and east to a sequence of subtidal sands? (Dalcoath lower) capped by a thin sequence of intertidal and

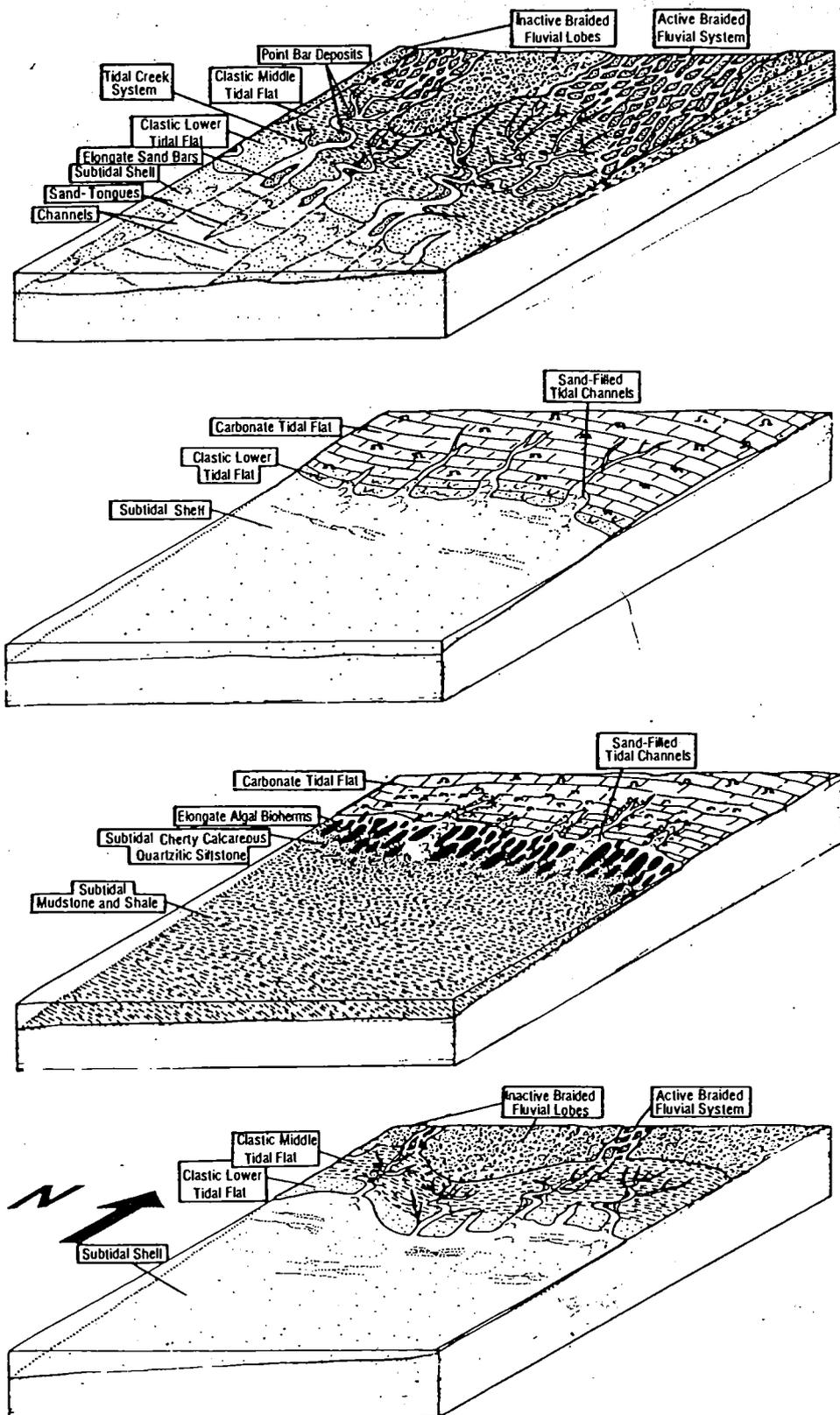


Figure 10 : Interpreted depositional environment for the retrogressive cycle of the Renison Bell Member-No. 2 Dolomite-Red Rock Member. Sandbars between the subtidal shelf and clastic lower tidal flat should be more emphasised to better represent the Renison Bell lower in blocks 1 and 2. Block 3 represents the Renison Bell upper and No. 2 Dolomite and Block 4 represents the Red Rock member. Diagram modified from Button & Vos (1977).

supratidal clastic and carbonate rocks (Renison mine sequence). The logical extension of this model suggested by the southeasterly thinning of the Renison mine sequence is that a sand barrier or shelf separates the Renison mine sequence from deep-water sedimentary rocks to the southeast. Such rocks may be included in the lower part of the Crimson Creek Formation or buried by the Crimson Creek Formation. This model suggests there is not much extension of the Renison mine sequence to the east or southeast of its present outcrop distribution. However, similar sequences may be present adjacent to the Smithton Dolomite elsewhere.

4. CARBONATE ROCKS OF THE RENISON MINE SEQUENCE

4.1 Description of Alteration Stage

Observation on over 200 hand-specimens, petrographic descriptions of 70 thin-sections and over 300 chemical analyses suggest the carbonate rocks in the Renison mine sequence have undergone diagenetic, contact metamorphic and hydrothermal alteration which has progressively obliterated original textures. The same sequence of alteration types affects all the carbonate horizons even though there are variations in intensity of alteration types related to the presence of impurities, stratigraphic position and proximity to faults or mineralisation. Consequently, the carbonate horizons can be considered together and described in terms of alteration stages.

4.1.1 Original Stage

Dolomites which retain original depositional texture are best preserved away from mineralised zones, near impure margins of beds and in the No. 1 Dolomite. Such dolomites are typically mid- to dark-grey and faintly laminated or pelletal in hand specimen (Plate 2, F). In thin section the laminae are alternations of light coloured 10 to 20 m crystalline dolomite with only minor accessory silicates and dark coloured $< 5\mu\text{m}$ anhedral dolomite with concentrations of carbon, talc, chlorite, muscovite, quartz and locally clastic grains and pyrite (Plate 4, top left (T.L.)). Elsewhere there are massive units or thick laminae consisting of ovoid pellets typically $150\mu\text{m}$ diameter but up to 1mm diameter, with dolomite or caloite with the same impurities as the

dark laminae in a matrix the same as the light coloured laminae (Plate 4, top right (T.R.)). Locally, particularly in impure bed margins, and in the No. 1 Dolomite there are laminae or beds of clastic grains that may be clusters of dolomite grains or pellets similar to the laminated and pelletal rocks or composites of calcite, chlorite, talc and muscovite.

Dolomite in the laminated and pelletal rocks is calcium-rich with a few percent FeCO_3 (Table 3) which makes it comparable to supratidal, subtidal or early diagenetic dolomites elsewhere in the world (Fig. 11). The clastic grains are notably more calcium-rich than this but contain very little FeCO_3 impurity (Table 3) suggesting they are more likely of subtidal or early diagenetic origin (Fig. 11).

The laminated and pelletal textures are interpreted as products alternating algal bloom and seawater flooding wherein the impure layers and pellets are products of algal growth and the crystalline dolomite is a direct precipitate from seawater during flood in a supratidal to intertidal environment. The composition of the dolomite in the clastic grains and the association with calcite suggest formation in the subtidal environment with emplacement of grains in the intertidal to supratidal environment during storms or peak tides. Dolomites are generally not considered to be direct precipitate from seawater but replacement of pre-existing calcite and hence are referred to an early diagenetic origin (Fritz & Jackson, 1972). Although no detailed studies have been made of calcite/dolomite relations at Renison there is no strong evidence that the dolomite is not an original precipitate. The similarity of Original dolomite from Renison to that described from the Coorong of South Australia as of direct precipitative origin (von der Borch & Lock, 1979) reinforces this idea.

4.1.2 Early Diagenetic Stage

Dolomite of the Early Diagenetic stage is the typical light grey dolomite described from the interior portion of the major dolomite units at Renison. Such dolomites are light grey to white or mid-grey, faintly laminated (Plate 2, E) to massive or patchy (Plate 2, H) and locally pseudo-pelletal (Plate 2, I) or pseudo-brecciated (Plate 4, B.R.). In thin section, the dolomite is a mosaic of 15 to 100 μm white dolomite

TABLE 3 : SUMMARY OF ALTERATION STAGES IN CARBONATE ROCKS. DATA IN APPENDICES.

STAGE	TEXTURE	GRAIN SIZE (μ m)	Dolomite Composition (mole %)				CALCITE
			CaCO ₃	MgCO ₃	FeCO ₃	MnCO ₃	
Original	laminated	< 20	56	42	2	0	trace, low Mg
	pelletal	< 20	55	43	2	0	trace, low Mg
	clastic grains	< 20	59	41	0	0	common, low Mg
Early Diagenetic	light coloured	40 (15-100)	57	42	1	0	trace, low Mg
	crystalline	40 (15-100)	55	44	1	0	trace, low Mg
	patches, veins pseudobreccia						
Late Diagenetic	silicification						
	cavities	80 (20-100)	55	42	3	0	minor, Mg-bearing
	veinlets and patches	> 100	54	35	10	1	absent
Contact Metamorphic	veins	> 100	53	32	14	1	common, Mg-bearing
	gash veins	100-1000					common, low Mg
	patches						
Hydrothermal	tourm veins	< 3mm	54	33	9	4	common, Mg-bearing
	ore veins	< 3mm	53	23	20	4	common, Mn-bearing
	with siderite	2-3mm	52	24	18	6	absent
	siderite	2-3mm	1	19	67	13	absent
	talc patches						common, Mn, Fe-rich

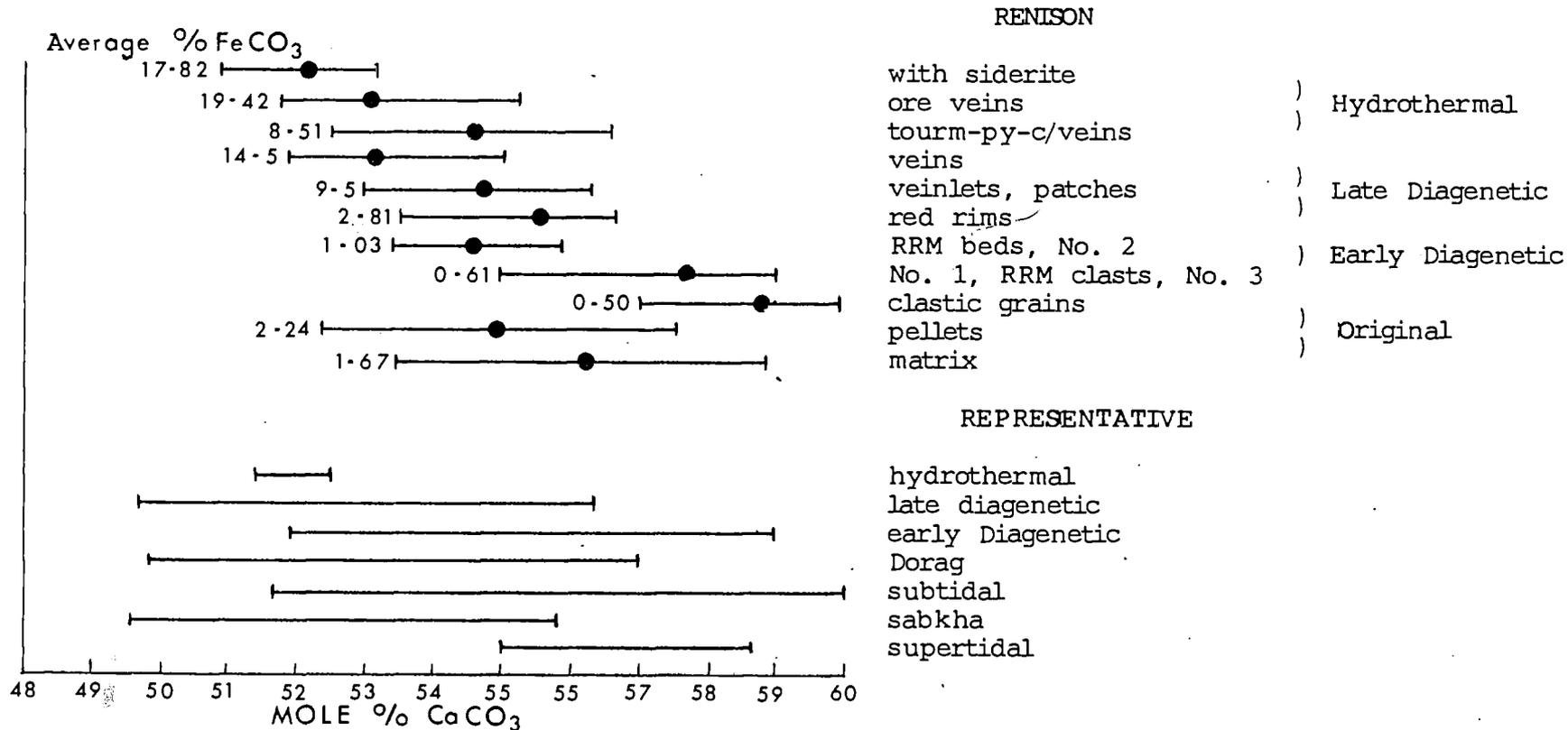


Figure 11: Average composition of various dolomite types from the Renison mine sequence compared with representative analyses from various environments (after Mattes & Mountjoy, 1980).

crystals that variably replace dolomite with original texture (Plate 4 B.L.). The replacement of original texture begins along stylolites filled with talc, chlorite, carbon and dolomite, along veins with dolomite and along bedding planes (Plate 2, H). Progressive overlap of stylolites and veins results in a patchy, pseudo-pelletal or pseudo-breccia texture locally with rims of crystalline dolomite separating remnants and matrix and with veins and stylolites cutting the remnants but terminating in the matrix (Plate 4 B.L., B.R.: Plate 5 T.L.).

Typical Early Diagenetic dolomite has less CaCO_3 and less FeCO_3 than coexisting Original Dolomite (Table 3). Presumably, the impurities are concentrated in stylolites during Early Diagenetic recrystallisation. For some reason, not yet explained, there is significantly more CaCO_3 in Early Diagenetic dolomites of the No. 1 Dolomite, clasts in the Red Rock Member and No. 3 Dolomite compared with beds in the Red Rock Member and the No. 2 Dolomite (Table 3). The range of compositions is within the field of representative early diagenetic dolomites (Fig. 11). Calcite is present in many samples of Early Diagenetic dolomite but it is not clear whether it is relict from Original dolomite or part of the Early Diagenetic stage.

The distribution and texture of Early Diagenetic dolomite and the association of stylolites and veins suggest it formed by compaction and recrystallisation in the presence of a fairly saline probably interstitial fluid. Hence, formation of the Early Diagenetic dolomite considerably postdates deposition which is contrary to the conventional interpretation of early diagenesis (Fritz & Jackson, 1972).

4.1.3 Late Diagenetic Stage

Early Diagenetic and Original dolomites are cut by a complex series of patchy replacements, veins, stylolites and cavity fillings that have been assigned a late diagenetic origin. The most distinctive feature of the Late Diagenetic stage is the red-lined cavities and veins composed of finely banded Fe-bearing dolomite (Plate 2, K, L, M). Cavities of this type are most common in the upper part of the No. 2 Dolomite but have also been observed in the No. 3 Dolomite. Along the Pie-man Dam road cavities several metres across contain breccia fragments

rimmed with red Fe-bearing dolomite in a matrix of lag that is part of the overlying Red Rock Member. This suggests the cavities are related to dissolution and reprecipitation prior to emplacement of the Red Rock Member. Veins and stylolites related to the Late Diagenetic Stage are common throughout the No. 2 and No. 3 Dolomites.

The earliest manifestation of the Late Diagenetic stage is silicification wherein patches, veins and overgrowths of quartz are connected by quartz-dolomite veins (Plate 5 B.L.). Replacement of this type is spatially associated with pseudobreccia (Plate 2, G, 5 T.R.) and cavity fill (Plate 2, L). The pseudobreccia (Plate 5, T.R.) is superficially similar to the Early Diagenetic pseudobreccia (Plate 5 T.L.) except that the matrix is coarse crystalline Fe-dolomite that is more a cavity fill than a recrystallisation product. Typical cavities are patchy or in part stratigraphically controlled (Plate 2K) and characterised by a rim of delicately banded red dogtooth Fe-dolomite spar and an infill of quartz, Mg-calcite and locally magnetite (Plate 5, B.L.). Stylolites with chlorite, quartz and Fe-dolomite and branching veins with Fe-dolomite and rare quartz cut relics but terminate in the rims or cavity cores. Distinctive ladder veins with quartz and Mg-calcite cut the cavities locally.

Dolomite of the Late Diagenetic stage is characterised by its red colour and by a progressive enrichment in iron relative to magnesium from the early cavities to the late cross-cutting veinlets and veins (Table 3). The range of calcium contents of the Late Diagenetic dolomites is comparable to representative late diagenetic dolomites but the iron content of the veins is considerably higher than that reported elsewhere.

The distribution and textures of the Late Diagenetic dolomites is consistent with an original by dissolution, brecciation and reprecipitation during exposure of the No. 2 Dolomite prior to emplacement of the Red Rock Member. Iron enrichment of up to 5% Fe_2O_3 is common in late diagenetic karst environments where oxidised groundwater is able to transport and precipitate iron. The presence of banded iron formation in the Red Rock Member suggests supersaturation of groundwater with respect to iron during Late Diagenesis. This may explain the anomalous iron enrichment in some of the Late Diagenetic dolomites

and the presence of magnetite in Late Diagenetic cavities.

4.1.4 Contact Metamorphic Stage

The silicate minerals talc, chlorite and serpentine disseminated throughout the dolomites are products of contact metamorphism of original clay minerals presumably during emplacement of the Pine Hill granite. It has been tacitly assumed that such metamorphism has not significantly affected the texture and composition of the original and diagenetic dolomites. However, there are patches, stylolites and veins containing metamorphic silicates and carbonates that are superimposed on the diagenetic alteration types. Veins of this type are typically stylolite-margined gash veins that appear to wedge out into stylolites (Plate 2, N). The veins typically have a margin of pure dolomite dogtooth spar oriented perpendicular to the vein margin that gives way to fine talc plus calcite then coarse talc plus calcite toward the vein core.

In impure carbonate rocks there is evidence that contact metamorphism has modified local carbonate composition. For example, ovoid patches up to 1mm diameter consisting of muscovite and calcite in some coarsely recrystallised dolomites are interpreted as former pellets in which the original clay and olomite have reacted to produce an Mg-rich silicate plus calcite (Plate 6, T.R.). It is also possible that some of the calcite in laminated impure carbonate rocks is of similar origin.

Nearly all the calcite of the Contact Metamorphic stage is associated with silicates and is of low $MgCO_3$ content (Table 3, Appendix 10). The silicate ^{minerals} of the Contact Metamorphic stage are also readily distinguishable on the basis of composition from their hydrothermal counterparts. In particular, talc and chlorite are characterised by much lower iron content (Appendix 15, 16).

4.1.5 Hydrothermal Stage

Apart from the generally narrow zone of massive coarse-grained siderite that separates the pyrrhotite-cassiterite ore from dolomite there are a variety of stylolites, veins and patches that are interpreted to be of hydrothermal origin. Observations underground and in core suggest there is no systematic zonation of the alteration types away from the massive siderite. Rather there may be a concentration of hydro-

thermal stylolites, veins and patches adjacent to the siderite zone or anywhere a fault or major fracture cuts a carbonate horizon.

Hydrothermal stylolites are relatively straight, both cut and are cut by veins, are usually brown or black and contain talc-chlorite-tourmaline-sulphide minerals and calcite. Stylolites in the siderite zone and massive sulphides appear to be of hydrothermal origin rather than relicts of diagenetic stylolites. Veinlets, veins and patches both merge with and cross-cut one another. They may be enclosed by, cut or terminate in stylolites or the siderite zone (Plate 2, O, 6 B.L.). They consist of variable mixtures of quartz, Fe Mn dolomite, siderite, chlorite, talc, tourmaline, pyrite, pyrrhotite and magnetite. The sulphide-bearing veins typically originate in the massive sulphide and cut the siderite zone whereas veins with carbonate, chlorite, talc and tourmaline may terminate in or at the contact of the massive siderite. The massive siderite zone is a mosaic of 2-3mm siderite and Fe Mn dolomite grains variably cut by stylolites and veins as already described. There are patches, disseminated grains and locally bands of quartz, muscovite and tremolite and relicts of dolomite with coarse siderite rims.

Carbonate minerals of the hydrothermal stage are characterised by a high content of Mn and Fe but there is considerable variation in composition between different settings. Veins without sulphide minerals have Fe, Ca and Mg content similar to Late Diagenetic dolomite but significantly higher Mn (Table 3). The average composition of dolomite in sulphide-bearing veins outside the siderite zone is similar to dolomite which coexists with the siderite itself (Table 3). Calcite in hydrothermal veins and patches contains up to 5% $MnCO_3$ so is distinct from non-hydrothermal calcites. The hydrothermal silicates talc and chlorite are notably Fe-enriched compared to their Contact Metamorphic counterparts (Appendix 15, 16).

The high Fe and Mn content of hydrothermal carbonate minerals at Renison is characteristic of Hydrothermal carbonates world-wide (Fig. 11). The association of Fe-rich dolomite with siderite, the relatively high Mg content of the siderite and the geologic relationships suggest the siderite zone forms by replacement of the dolomite while retaining much of the dolomite's Mg.

4.2 Evolution of the Carbonate Rocks

The stratigraphy, sedimentology, textures and compositions suggest the dolomitic rocks at Renison originated in supratidal to intertidal flats possibly as direct precipitates from saturated seawater or in part by replacement of calcite that originally formed in the subtidal environment. Calcite is still a common constituent in the upper parts of the major clastic units adjacent to the dolomite horizons suggesting that dolomitisation was incomplete. The extensive but not pervasive Early Diagenetic recrystallisation was related burial of the carbonate units. Stylolite growth accompanying the recrystallisation suggests there was compaction and redistribution of impurities at this stage. The Late Diagenetic stage was related to subaerial exposure and karstification of the No. 2 Dolomite prior to or concomitant with deposition of the Red Rock Member. There could be a significant time break at this point, but the presence of dolomite similar to the No. 2 Dolomite above the Red Rock Member suggests this is probably not the case. All the diagenetic alteration is hence interpreted to be of Upper Proterozoic age.

Contact metamorphism during emplacement of the Devonian Pine Hill granite converted clay minerals in the carbonate horizon to talc chlorite and serpentine and gash veins possibly related to deformation during pluton emplacement were also formed. Hydrothermal alteration and ore-formation are then interpreted as post-magmatic but still related to the Pine Hill granite.

5. IMPLICATIONS FOR EXPLORATION

5.1 Regional Stratigraphy

The concept that the Renison mine sequence is a marginal facies of the Smithton Dolomite rather than the basal unit of the Dundas Trough suggests that areas of Upper Proterozoic dolomites as well as the western margin of the Dundas Trough are possible sites of Renison or Mount Bischoff type dolomite-clastic sequences. If the association of dolomite with black shale is important, as will be discussed later,

then the general decrease in proportion of black shales underlying the dolomites in the Misty Valley-Mount Lindsay area makes that area less favourable than the mine.

5.2 Local Stratigraphy and Sedimentology

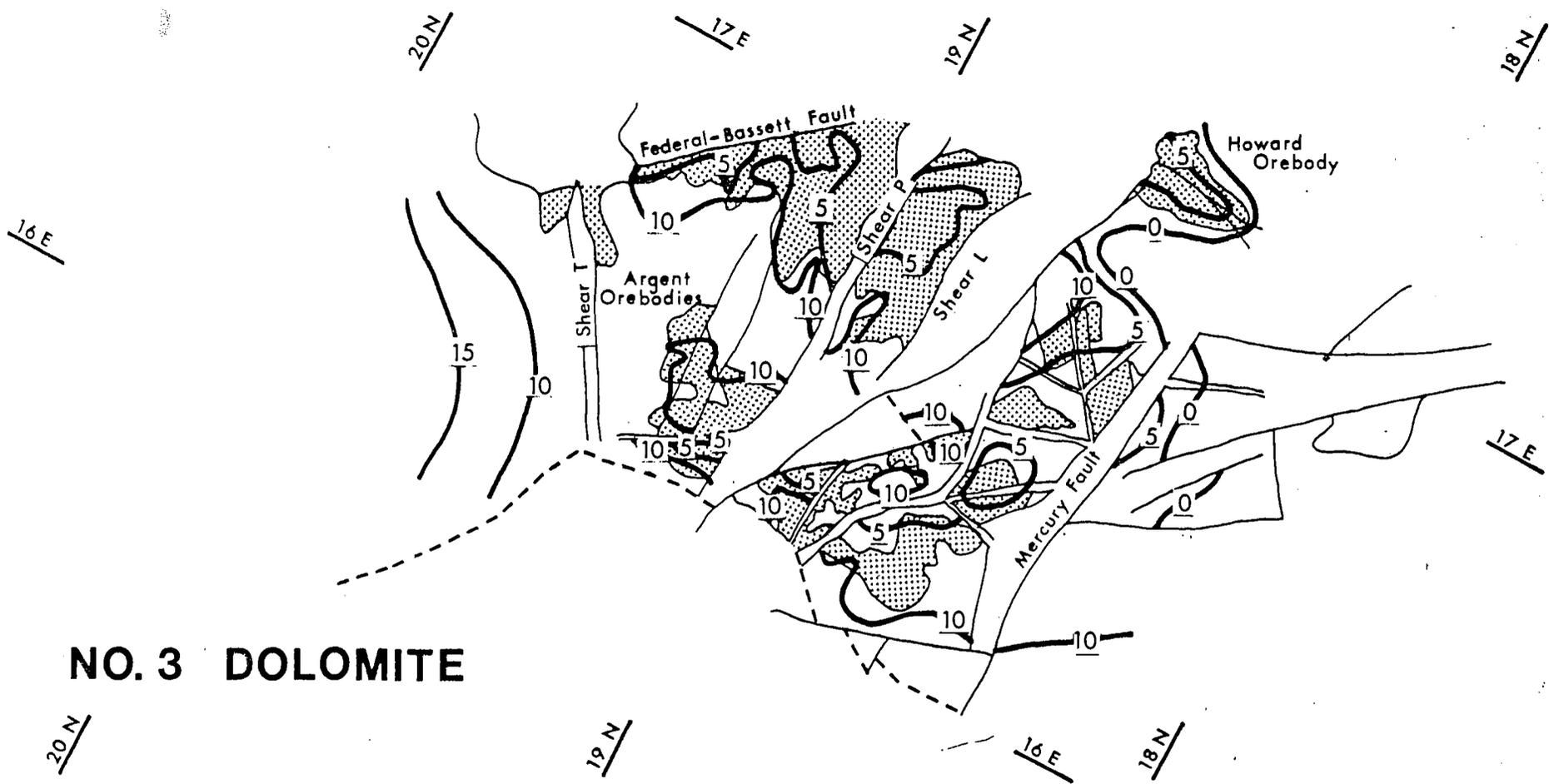
The cyclic model of sedimentation proposed for the Renison mine sequence and the lenticular nature of individual units within the mine sequence suggest there may be additional dolomites and hence additional mineralised horizons on the mine lease. For example, the 2.5 horizon is part of a mini-cycle within the Renison Bell Member and hole S613 (Fig. 8) has a mini-cycle with carbonate-bearing rocks in the lower part of the Renison Bell Member. There is also the mineralised carbonate-horizon associated with the Upper Contorted Unit in the area south of Argent Dam and the possibility of more dolomite horizons within or below the Dalcoath contorted unit.

Although more work is required, the interpretation of the Upper Contorted Unit as a discrete unit above the normal mine sequence rather than a faulted section of the Dalcoath Member suggests the whole mine sequence may not have been tested in the area south of Argent Dam. Drilling through the Contorted Unit is essential to establishing stratigraphic relations in this area.

The interpretation of the Red Rock Member as a fluvial channel and overbank sequence, the recognition of the reworked clastic origin of most of the volcanic material in the Red Rock Member, and the interpretation of the iron formation and chert as lacustrine rather than marine in origin adds weight to the argument that the Red Rock Member and the mineralisation at Renison are not of volcanic origin.

5.3 The Carbonate Horizons

Plans of true thickness contours for the three major carbonate horizons show some interesting relationships to stratigraphy, structure and ore distribution. In the No. 3 Dolomite (Fig. 12) there is a stratigraphic thinning from greater than 15m around Dreadnought Hill to nothing around Stebbins and Renison Bell Hills. There is some structural thinning toward the Federal-Bassett Fault but not toward the Argent



NO. 3 DOLOMITE

Figure 12: Thickness contours (heavy lines) at five metre intervals on the No. 3 Dolomite. Location of orebodies (dots), major faults (fine lines) and stratigraphic limit of the unit (dashed line) also shown. Notable features are the parallelism of the 10 metre contour and orebody margins and the stratigraphic thinning of the unit from north to south.

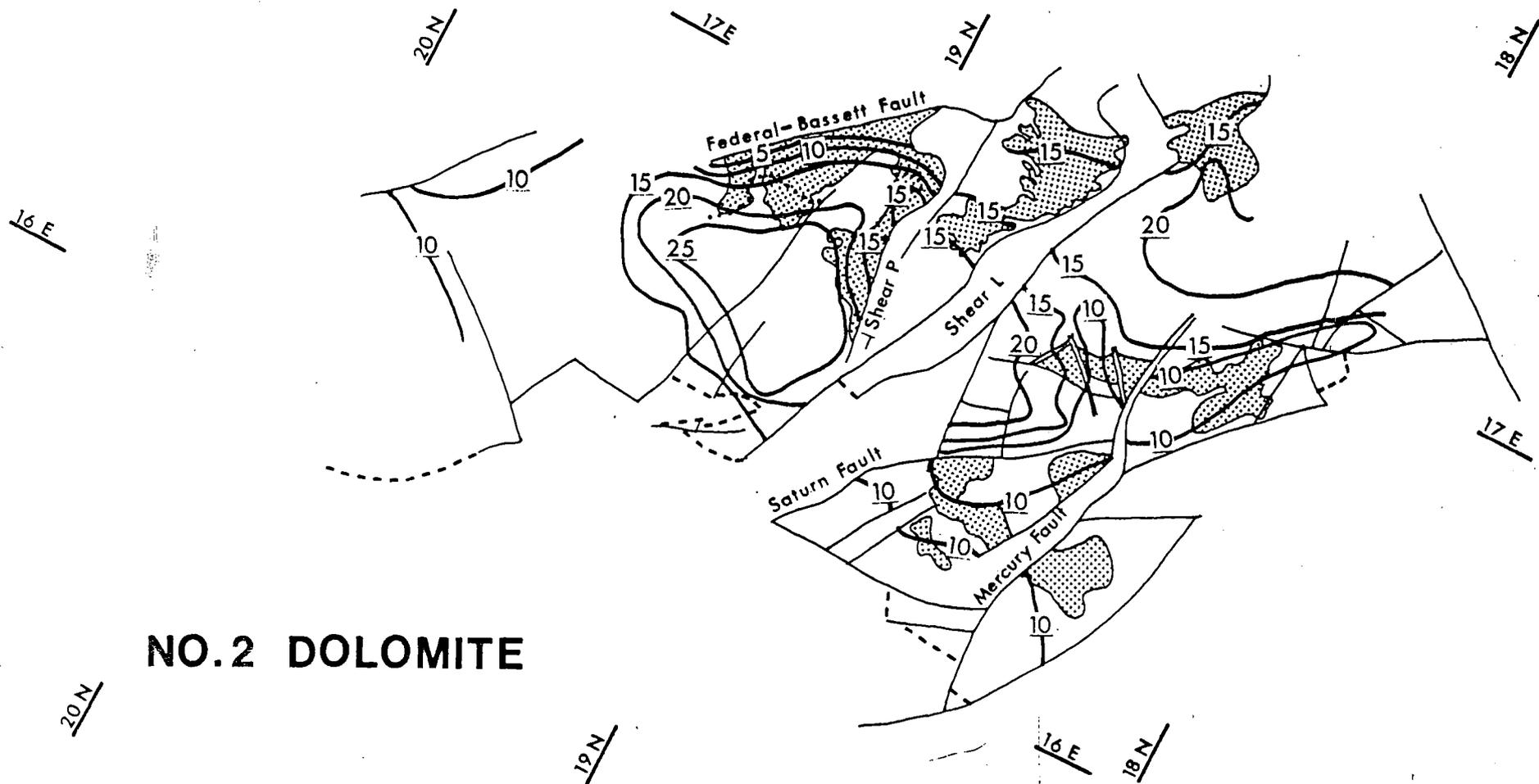
Fault. The margins of the Penzance, Colebrook and Argent orebodies parallel but fall just inside the 10m thickness contour. The other orebodies are also in areas where the No. 3 Dolomite is less than 10m thick. The Howard orebody is U-shaped in plan with its wide end terminated by a shear and its axis occupied by a fault. The margin of the Howard orebody is a fingering out where the host dolomite gives way to shale.

In the No. 2 Dolomite there is no clearcut stratigraphic changes (Fig. 13). Rather, there is a bulls-eye pattern of thickness contours reflecting structural thinning of the No. 2 Dolomite toward the Federal-Bassett and Saturn fault systems. In the Murchison, Dreadnought and Stebbins orebodies, the horizon is completely replaced by ore where it is less than 15m thick, partly replaced where 15-20m thick and generally unmineralised where thicker than 25m .

The No. 1 Dolomite is thickest in the vicinity of the Federal-Bassett Fault and generally thinner to the southwest around Renison Bell Hill where the whole ~~men~~ sequence is also thinner (Fig. 14). The best mineralisation is in the Renison Bell Hill area but there is extensive development of siderite within the No. 1 and locally mineralisation within the underlying Red Rock Member.

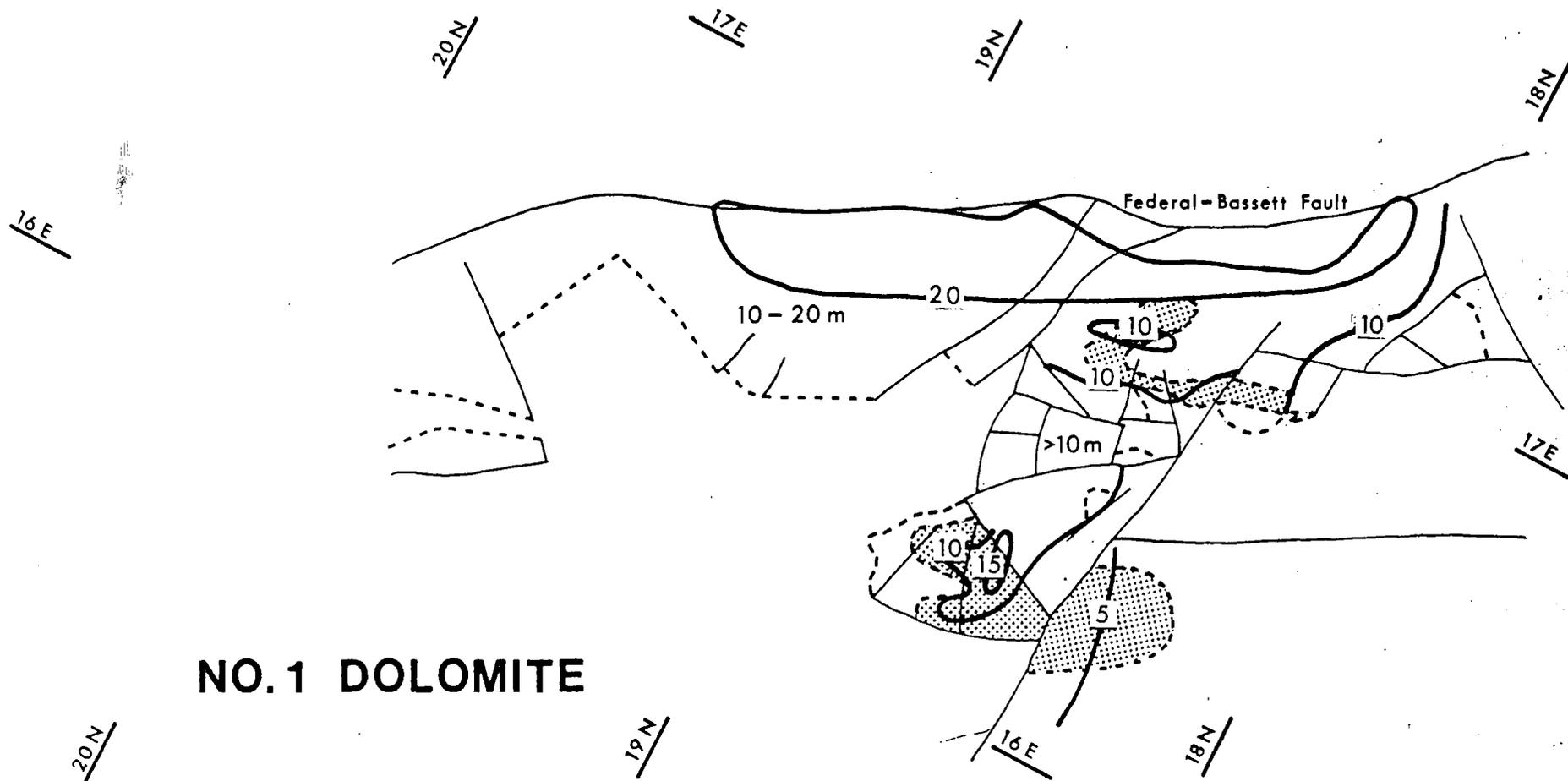
The implication of these relationships is that away from the faults which are the conduits to the ore-forming fluid, the thickness of the host dolomite controls the distribution of the ore. For example, in the thin No. 3 Dolomite, mineralisation is more massive and laterally extensive than in the thicker No. 2 Dolomite. This suggests there is a uniform volume of replacement throughout each horizon so that in the thinner No. 3, mineralisation was more extensive but more completely controlled by bed thickness than in the thicker No. 2 Dolomite.

In the Dreadnought and Penzance orebodies, the grade is generally poorer near the upper and lower margins than in the middle. In specimens of this ore there may be complete replacement of the dolomite but the ore from the margin contains considerably more impurities than that from the middle. It seems likely that where the concentration of silicate impurities is high in the margin of the host dolomite replacement of the dolomite by ore, the silicate impurities remain to effectively



NO. 2 DOLOMITE

Figure 13 : Thickness contours (heavy lines) at five metre intervals on the No. 2 Dolomite. Location of orebodies (dots), major faults (fine lines) and stratigraphic limit of the unit (dashed lines) also shown. Notable features are the 'bullseye' contour pattern presumably reflecting structural thinning of the unit toward the Federal-Bassett and Argént Faults and the restriction of ore to the portions of the unit 15 metres thick or less.



NO. 1 DOLOMITE

Figure 14: Thickness contours (heavy lines) at five metre intervals on the No. 1 Dolomite. Location of mineralised areas (dots), major faults (fine lines) and stratigraphic limit of the unit (dashed lines) also shown. Notable features are greater thickness adjacent to the Federal-Bassett fault and the restriction of mineralisation to thinner, faulted areas away from the Federal-Bassett fault.

dilute the ore. The higher concentration of impurities in the margin of the No. 2 Dolomite compared with the No. 3 Dolomite may in part, explain the more sporadic distribution of ore grade material in the No. 2.

The observation that the location of the siderite front does not appear to be controlled by the distribution of pre-hydrothermal alteration in the dolomite suggests the nature of the dolomite is not an important control on the distribution of ore. Even though on a micro-scale stylolites and bedding planes are preferred loci for siderite development, by far the most important control is the distribution of faults and fractures. The dolomite may simply be considered as a chemically reactive rock that was much more readily replaced than the adjacent clastic rocks.

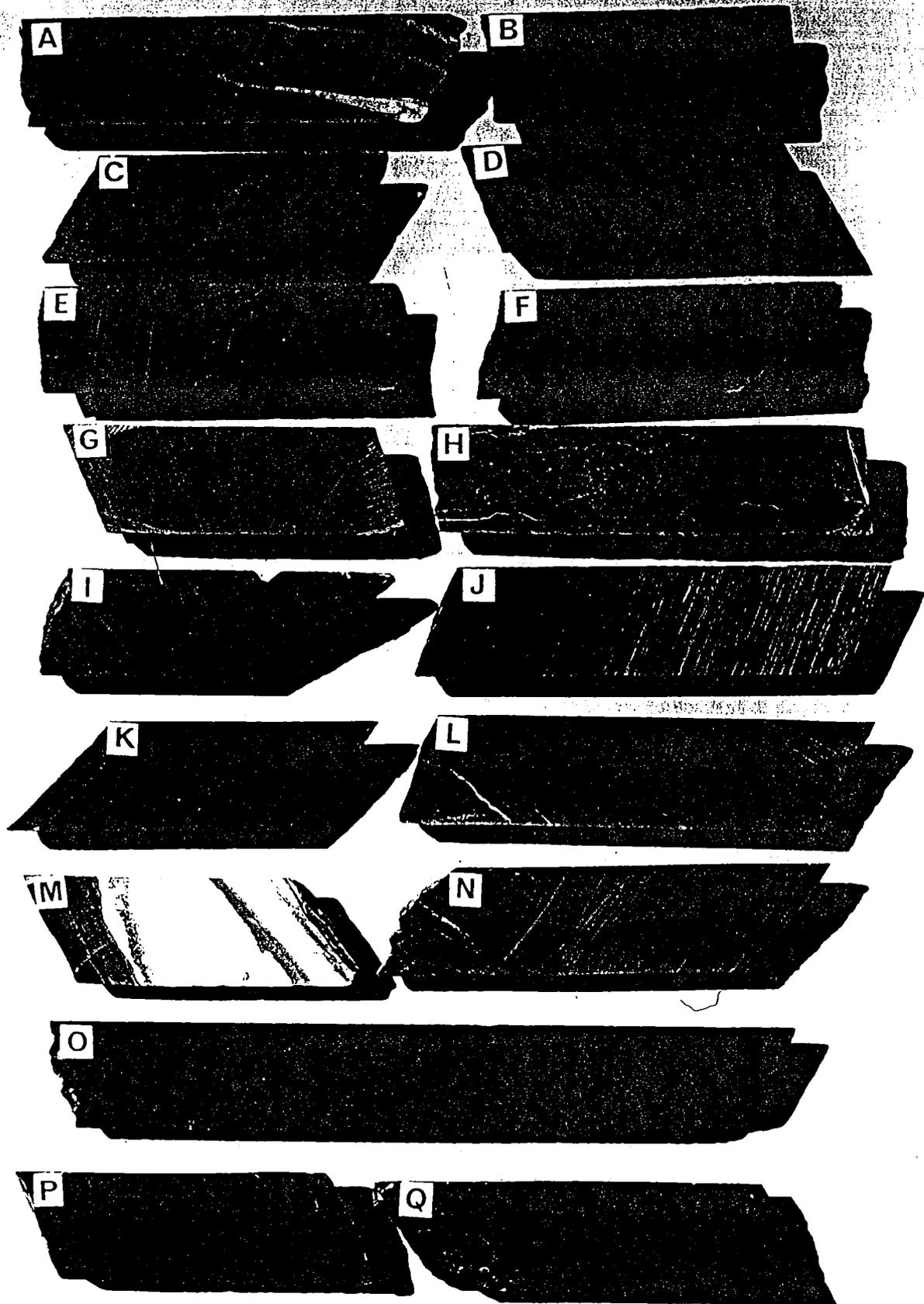
5.4 Fluid-Rock Interactions

Experimental data suggest tin is transported in reduced hydrothermal fluids and hence that precipitation of cassiterite from the fluid may occur where the fluid becomes oxidised (Eadington & Giblin, 1979). In the Renison mine sequence reaction of the original reduced hydrothermal solution with quartz sandstone probably has little effect, whereas reaction with carbon-rich pyritic shales would tend to further reduce the solution, and reaction with carbonate rocks would oxidise the solution. This suggests that the presence of black shale in the mine sequence may be a factor in the enrichment of tin in the hydrothermal solution immediately beneath the chemically reactive and oxidising dolomites. The abundance of shale in the Renison Bell Member around Dreadnought Hill (Fig. 8) may have been an important factor in localising the biggest orebodies in the No. 2 in this area compared with the Stebbins Hill area where quartz sandstone is much more abundant (Fig. 9).

This redox model may also explain the lack of significant mineralisation in the No. 1 Dolomite. The most distinctive feature of the No. 1 Dolomite is not that it is more impure than the other dolomites or more calcite-rich, but that it occurs above the Red Rock Member rather than the shale-siltstone sequences, typical of the Renison Bell and Dalcoath Members. A sequence as oxidised as the Renison Bell

Member may effectively have trapped the tin of the hydrothermal solution in the underlying No. 2 Dolomite rather than allowing it to pass up into the No. 1 Dolomite. It is significant that there is extensive development of siderite in the No. 1 Dolomite but little mineralisation. This suggests a hydrothermal fluid did pass through the No. 1 but that it was not carrying or did not deposit tin. It is also significant that the best mineralisation in the No. 1 Dolomite is in the area of Renison Bell Hill where the whole mine sequence is much thinner than normal. This suggests a uniform volume of fluid penetrated the major faults but was not as readily depleted of tin by the relatively thin stratigraphic sequence.

PLATE 1



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cm

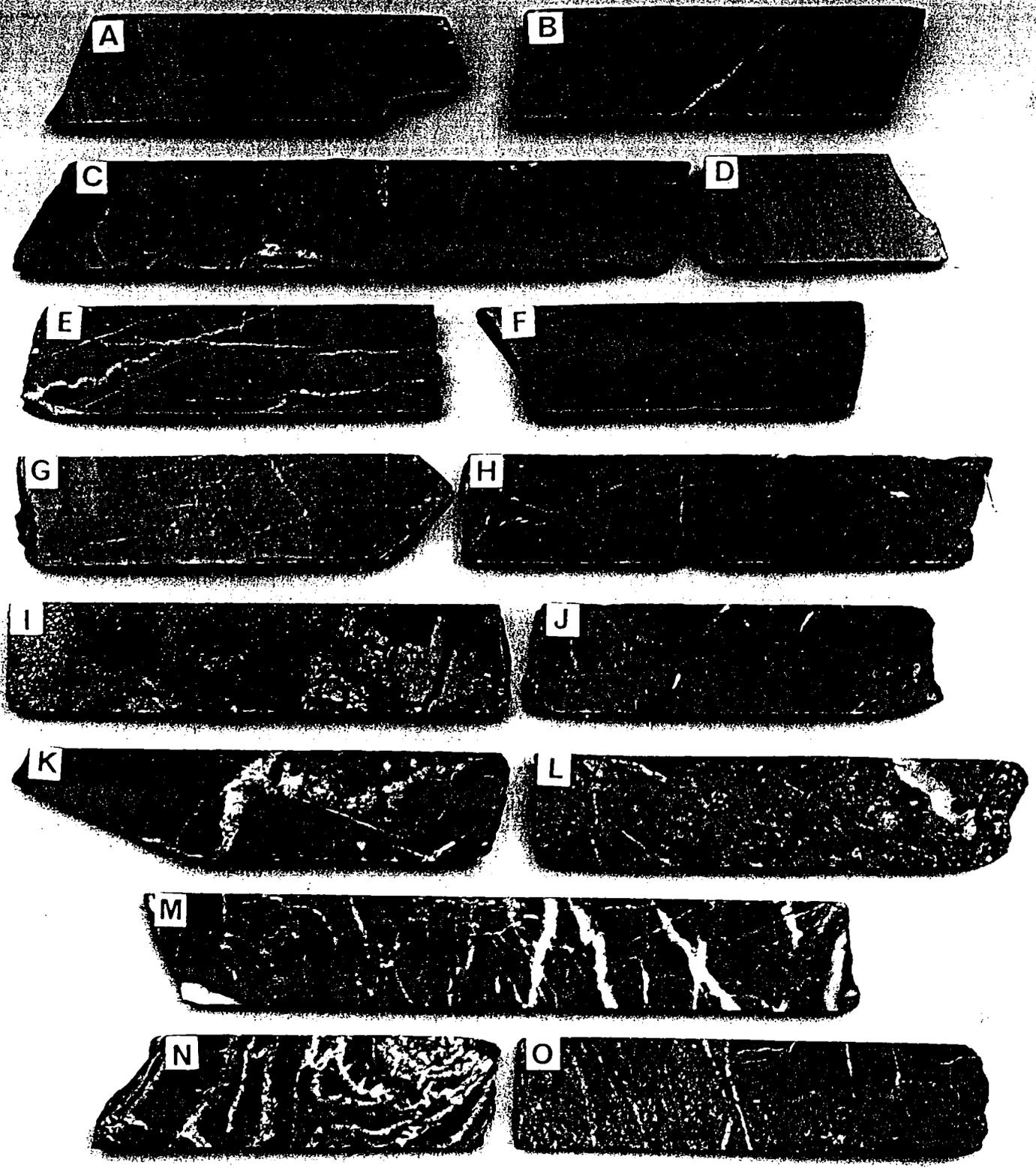
PLATE 1

Sedimentary Structures in the Renison Bell & Dalcoath Members

- A: Buff-green siltstone typical of the Renison Bell upper. Thin laminated, interbedded green siltstones, buff dolomitic siltstone and white quartz sandstone with dolomite matrix and local concentrations of pyrite. Sandstone beds are of irregular thickness, locally lenticular and load cast. Sedimentary structures are comparable to the rest of the Renison Bell Member but the dolomitic impurity and lighter colour is distinctive. Specimen D9-59, S614 - 59.2m, Renison Bell Hill.
- B: Typical sedimentary structures of sandstone laminae in the Renison Bell middle. The sandstone laminae are light grey, lenticular, locally crumple folded, have bulbous margins, wavy shale laminae and disseminated pyrite grains. The intervening areas are thin laminated black shale with thin laminae of sandstone exhibiting the same structures as the thicker laminae. Flaser texture of sandstone typical of Renison Bell middle. Specimen S913 - 66m, Renison Bell Hill.
- C: Load cast, lenticular, pyrite-rich quartz sandstone laminae in fine laminated black shale. Typical flaser bedding in Renison Bell middle. Specimen S913 - 60.8m, Renison Bell Hill.
- D: Calcite-cemented pyrite framboids and laminae of angular sand-sized pyrite grains associated with sandstone flasers in finely laminated shale. Common feature of Renison Bell middle. Specimen S697 - 284.3m, Owen Meredith area.
- E: Thick laminae sets of grey quartz sandstone with local shale partings and faint normal-graded laminae alternating with flaser laminated, pyrite-rich black shale with local intraformational faults. Renison Bell middle, specimen S609 - 102.9m, Dreadnought Hill.
- F: Load cast, lenticular, massive grey quartz sandstone laminae associated with fine evenly laminated pyrite-rich black shale and grey siltstone. Renison Bell middle, specimen D9-61, S609 - 75.3m, Dreadnought Hill.
- G: Thick laminated, cross-bedded grey quartz sandstone alternating with fine laminated wispy buff siltstone. Siltstone-rich portion of Renison Bell lower, specimen D9-68, S556 - 139.1m, Stebbins Hill.
- H: Pebble bed consisting of sub-angular to sub-rounded carbonate and minor quartz sandstone and pyrite granules and pebbles in sharp contact with massive grey quartz sandstone. Renison Bell pebble beds, specimen D9-69, S556 - 150.6m, Stebbins Hill.
- I: Quartz-tourmaline filled fractures and bedding planes with dark alteration haloes in bleached, laminated siltstone and shale. Intercalated dolomites are probably replaced by massive pyrrhotite nearby. This style of alteration is typical of the Dalcoath Upper unit close to mineralised No. 3 Dolomite. Specimen S556 - 168.4m, Stebbins Hill.

- J: Irregularly laminated siltstone and shale with nodular carbonate laminae. The nodules consist of fibrous carbonate with the fibres oriented perpendicular to bedding and pushing the bedding apart. This is the diagenetic cone-in-cone texture (Coneybeare & Crook, 1968, p. 49). Marker unit near base of Dalcoath Upper Unit. Specimen S594 - 286.1m, Owen Meredith area.
- K: Laminated siltstone and fine sandstone composed of irregular laminae of quartz sandstone with shale wisps and bulbous margins and more regular laminae of siltstone defining units approximately 1.5cm thick. Structure is similar to tidal bedding (Reineck & Singh, 1975, p. 108). Dalcoath Carbonaceous and Non-Carbonaceous Unit. Specimen S556 - 170.9m, Stebbins Hill.
- L: Quartz sandstone with irregular wisps and wavy laminae of black shale that define flaser bedding (Reineck & Singh, 1975, p. 98). From sand-rich lower portion of Dalcoath Carbonaceous and Non-Carbonaceous Unit. Specimen S705 - 329.7m, Dunkley Tram area.
- M: Yellow carbonate caliche with green siltstone stylolites and laminae, typical of the uppermost part of graded units in the Red and Green Siltstone Unit and in the Red Rock No. 1 Unit of S705. Specimen S705 - 177.6m, Dunkley Tram area.
- N: Edgewise conglomerate of green mudstone and mudstone laminae with dessication cracks associated with cross-bedded green sandstone in the Red and Green Siltstone Unit. Specimen S574 - 190.3m, Argent Dam area.
- O: Colour-mottled texture typical of laminated shale and siltstone in parts of the Dalcoath Contorted Unit. Lighter coloured portion is dominantly siltstone with contorted and broken shale laminae and minor fine sandstone laminae. Darker portion is folded laminae and larger fragments of shale with irregular siltstone laminae. The colour mottling is mainly related to the changing proportions of black shale and grey siltstone in the original sediment but there may also be some bleaching by oxidation of organic matter during exposure to the air or during diagenesis. Specimen S574 - 154.0m, Argent Dam area.
- P: Broken and contorted bedding typical of sandy portions of the Dalcoath Contorted Unit. The two large fragments are laminated fine sandstone floating in a matrix of grey siltstone and black shale. The siltstone laminae are partly fragmented, partly contorted into flame-type structures and everywhere in wavy, irregular contact with the shale. Specimen S574 - 252.1m, Argent Dam area.
- Q: Breccia texture typical of sand-rich portions of the Dalcoath Contorted Unit. The angular light grey fragments are fine sandstone whereas the mid-grey masses are fractured and locally brecciated siltstone. The matrix is black shale. Specimen S574 - 252.0m, Argent Dam area.

PLATE 2



0 1 2 3 4 5
cm

PLATE 2

Sedimentary & Diagenetic Textures of Carbonate Rocks

- A: Fine irregularly laminated texture typical of the margins of all the carbonate beds. Laminae are typically chlorite + quartz + talc, after clay minerals, locally concentrations of pellets and in this case, concentrations of clastic calcite grains as well. No. 1 Dolomite, specimen D9-13, S562 - 66.9m, Stebbins Hill.
- B: Brown, irregularly banded, impure carbonate with bands, veins, patches and stylolites of tourmaline + Mn-calcite + chlorite of contact metamorphic or hydrothermal origin. No. 1 Dolomite, specimen D9-10, S562 - 59.6m, Stebbins Hill.
- C: Nodular - broken bed texture typical of the Renison Bell 2.2 dolomite. The dolomitic beds are attenuated into lenses and locally cracked and broken whereas the adjacent shale or silt beds wrap around the lenses. Renison Bell 2.2 dolomite, specimen D9-64, S574 - 44.3m, Argent Dam.
- D: Pink carbonate sandstone with graded bedding consisting of sand to silt grade dolomite with apatite, calcite and quartz. Similar to some clastic beds in the No. 1 Dolomite. Specimen is a clast from conglomerate in the Red Rock Member, D9-19, S650 - 455.1m, Owen-Meredith area.
- E: Faintly laminated mid-grey dolomite typical of most dolomite beds. Consists of 50 μ m diameter recrystallised pure dolomite with laminae that are concentrations of carbon and talc. The light coloured veins contain Late Diagenetic Fe-rich dolomite and the dark veins are hydrothermal pyrrhotite-quartz-calcite-talc locally with cassiterite. Bed in Red Rock Member, specimen D9-40, S556 - 33.8m, Stebbins Hill.
- F: Faintly laminated dark grey pelletal dolomite typical of Original Stage. Consists of randomly distributed 300-500 μ m diameter pellets of 20-30 μ m Fe-bearing dolomite with chlorite and quartz in a partly recrystallised matrix with some 40-60 μ m pure dolomite and calcite. No. 2 dolomite, specimen D9-51, S562 - 123.0m, Stebbins Hill.
- G: Pseudo-breccia or pseudo-pelletal texture in light grey recrystallised dolomite. 'Fragments' are 60-120 μ m pure dolomite of Early Diagenetic Stage surrounded by a dark radial rim of 150 μ m Fe-bearing dolomite which face cavities with Mg-calcite of the Late Diagenetic Stage. No. 2 Dolomite, specimen D9-49, S556 - 69.2m, Stebbins Hill.

- H: Distinction between Original and Early Diagenetic Stages. Dark grey portion is Original 1-2 μm Fe-bearing dolomite associated with talc, chlorite and pyrite. Light grey spots, patches and stylolite margins are Early Diagenetic 15-50 μm pure dolomite. No. 3 Dolomite, specimen D9-73, S556 - 159.3m, Stebbins Hill.
- I: Spotted texture of partial recrystallisation in stromatolitic-oolitic dolomite. Cream areas are origin 1-2 μm pure dolomite whereas mid-grey veins and matrix are 50 μm pure dolomite of the Early Diagenetic Stage. In this area, the stromatolitic-oolitic dolomite is characterised by disseminated euhedral grains to 1mm of Fe-Mn-rich dolomite that pseudomorph gypsum. Recrystallisation destroys the pseudomorph texture but produces a radial rim of Fe-Mn-rich dolomite around the relicts. No. 3 Dolomite, specimen D9-77, S835 - 201.0m, Dunkley Tram.
- J: Vein and stylolite pseudobreccia of contact metamorphic or hydrothermal origin. Variably veined fragments of 40 μm pelletal Fe-bearing dolomite with disseminated talc and carbon and 50-100 μm crystalline Fe-bearing dolomite with a rim of carbon and a matrix of Fe-talc, calcite and minor chlorite, muscovite and quartz. No. 2 Dolomite, specimen D9-500, S562 - 121.8m, Stebbins Hill.
- K: Stratigraphically controlled band of Late Diagenetic red-lined solution cavities in dark grey, laminated, pelletal, Fe-bearing dolomite. The red lining is radial, delicately zoned Fe-bearing dolomite whereas the cavity fill and associated cross-cutting veins are quartz, calcite and locally magnetite. No. 2 Dolomite, specimen D9-56, S614 - 52.7m, Renison Bell Hill.
- L: Patchy texture of Early Diagenetic authigenic quartz and partial recrystallisation, and development of Late Diagenetic red-lined cavities in Original pelletal dolomite. Light grey pelletal relicts are < 10 μm Fe-rich dolomite separated by carbon-rich stylolites from a matrix of mid-grey, 60 μm , Fe-rich dolomite with patches of euhedral authigenic quartz overgrowths on carbonate cores and local veins and masses of quartz. Late Diagenetic cavities are lined by red, radial, delicately zoned, Fe-bearing dolomite with cores of quartz. No. 2 Dolomite, specimen D9-55, S614 - 48.4m, Renison Bell Hill.
- M: All the alteration stages in one specimen. Dark grey Original < 5 μm pure to Fe-bearing dolomite; light grey to buff bands and patches of Early Diagenetic mostly 50-80 μm crystalline pure to Fe-bearing dolomite associated with clastic quartz and pyrite; late Diagenetic red-lined veins and patches of Fe-bearing dolomite with calcite-quartz cores cut by veins of 100 μm Fe-rich dolomite; and Contact Metamorphic ladder veins with calcite-quartz. These veins have quartz only where they cut the quartz-bearing portion of Late Diagenetic cavities. No. 2 Dolomite, specimen D9-58, S574 - 27.5m, Argent Dam.

- N: Contact metamorphic gash veins in dolomite. Dark grey 20 μ m Fe-bearing dolomite with associated calcite, talc and chlorite, cut by calcite veins and stylolites and by zoned gash veins with 3mm dogtooth pure dolomite at their margins grading to Fe, Mn bearing calcite, then fine grained talc + calcite then coarse talc + calcite. No. 1 Dolomite, specimen D9-16, S562 - 83.5m, Stebbins Hill.
- O: Hydrothermal siderite in contact with dolomite. Dark grey pelletal 15-25 μ m Fe-bearing dolomite becoming progressively coarser and more Fe, Mn rich over 2mm towards veins and massive siderite. The siderite zone is 2-3mm Mg, Mn-rich siderite and Fe, Mn-rich dolomite coexisting with quartz but altered to Fe-talc near veins and patches of magnetite-talc-quartz-Mn-rich siderite-Fe, Mn-rich dolomite-pyrrhotite which in this case separates massive siderite and dolomite. No. 2 Dolomite, specimen D9-52, S609 - 67.7m, Stebbins Hill.

PLATE 3

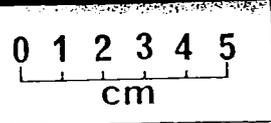
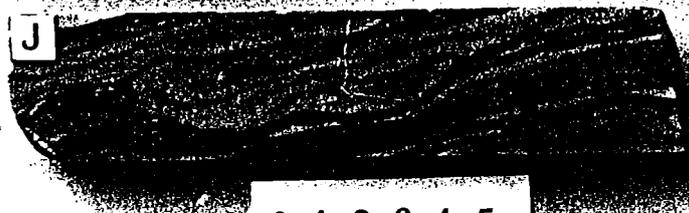
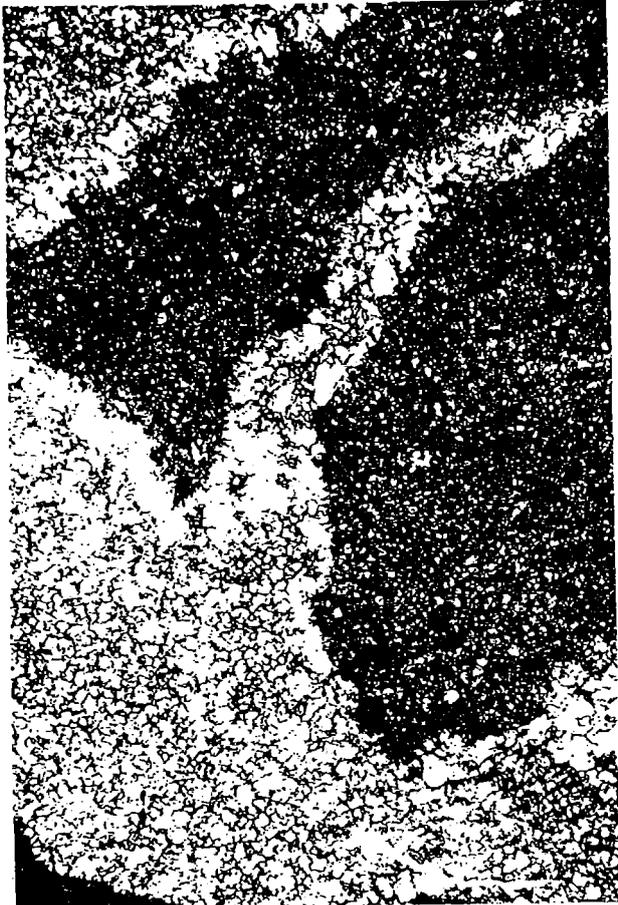
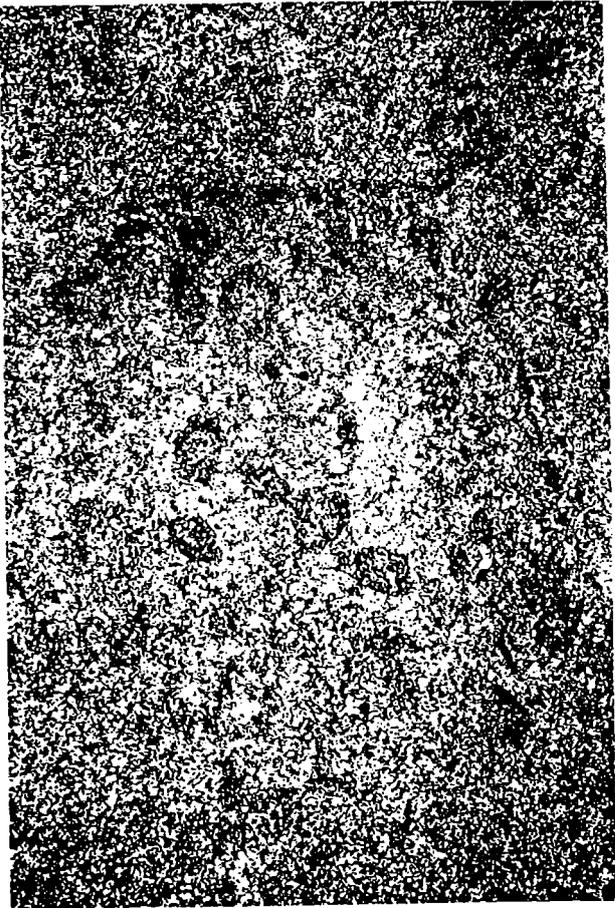


PLATE 3

Silicified Stromatolitic and Oolitic Dolomite

- A: Silicified domal stromatolite. Float from track to old Misty Valley campsite, north of Pieman River.
- B: Partly silicified columnar stromatolite in a matrix of stromatolite fragments and black silicified oolites. In situ outcrop of the No. 2 Dolomite, at 24.5km on the Pieman Dam Road, Mt. Lindsay area.
- C: Silicified stromatolite-oolite breccia with angular fragments of stromatolites in a matrix of black silicified oolites. Float from track to old Misty Valley campsite, north of Pieman River.
- D: Portion of a finely-laminated domal stromatolite (left) in a matrix of stromatolite fragments. In situ, No. 2 Dolomite hole S705 - 186.8m, Dunkley Tram area.
- E: Typical matrix of stromatolites in dolomite consisting of stromatolite fragments and dolomite mudstone with irregular shaly partings. No. 2 Dolomite, hole S705 - 187.0m, Dunkley Tram area.
- F: Coarse oolites, locally carbonaceous in a dolomite matrix. No. 2 Dolomite, 23.1km on the Pieman Dam Road, Mt Lindsay area.
- G: Carbon-sheathed ovoid fossils in a matrix of dolomite oolites. May be carbonaceous oolites similar to those in F. No. 2 Dolomite, 23.1km on the Pieman Dam Road, Mt. Lindsay area.
- H: Massive crystalline dolomite with patches of pyrite cubes and silicified oolites. No. 2 Dolomite, hole ML56 - 408.3m, Mt. Lindsay.
- I: Grey crystalline dolomite with fragments and coated grains that are variably silicified. No. 2 Dolomite, hole ML56 - 290.6m, Mt. Lindsay.
- J: Nodular or enterolithic texture typical of evaporites but now pure and impure dolomite. No. 2 Dolomite, ML56 - 175.2m, Mt. Lindsay.



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PLATE 5

Microscopic Textures of Late Diagenetic Stage in Carbonate Rocks

- Top Left: Pseudopelletal texture due to Early Diagenetic recrystallisation in the stromatolitic-oolitic dolomite. Original dark central core of 1-2 μ m Fe-bearing dolomite with a few clots of white Fe-bearing dolomite that pseudomorphs gypsum, a zoned margin of mid grey granular 50 μ m pure dolomite, a radial rim of 100 μ m pure dolomite in a matrix of 20 μ m pure dolomite. The veins that terminate in the rim are pure dolomite whereas those that cross-cut are Fe-rich dolomite (Late Diagenetic). Similar texture to Plate 2I, No. 3 Dolomite, specimen D9-79, S835 - 213.0m, Dunkley Tram. PPL, X 15.
- Top Right: Late Diagenetic pseudopelletal or pseudobreccia texture. The 'fragments' or 'pellets' are partly crystalline 60 to 120 μ m pure dolomite with concentrations of carbon, chlorite, talc and quartz near their margins, a radial rim of 150 μ m Fe-bearing dolomite and a matrix or cavity of Mg-calcite. The composition of the phases and the 'cavity-fill' texture distinguishes Late Diagenetic from Early Diagenetic (previous photo) pseudopelletal texture. Same specimen as Plate 2G, No. 2 Dolomite, specimen D9-49, S556 - 69.2m, Stebbins Hill. PPL, X23.
- Bottom Left: Zoning sequence related to Late Diagenetic solution cavities. Dark rectangle near centre is relic of original <5 μ m Fe-bearing dolomite within a zone of lighter coloured partly crystalline 20 μ m pure to Fe-bearing dolomite that is surrounded by delicately zoned dogtooth-shaped red Fe-bearing dolomite which faces cavities filled with quartz. Same specimen as Plate 2K, No. 2 Dolomite, specimen D9-56, S614 - 52.7m, Renison Bell Hill. PPL, X 18.
- Bottom Right: Quartz-carbonate veins connecting patches and euhedral crystals with quartz overgrowths in partly recrystallised, Early Diagenetic Dolomite. Elsewhere this is cut by the red-lined cavities. Texture similar to Plate 2L. Same specimen as above. PPL, X 37.

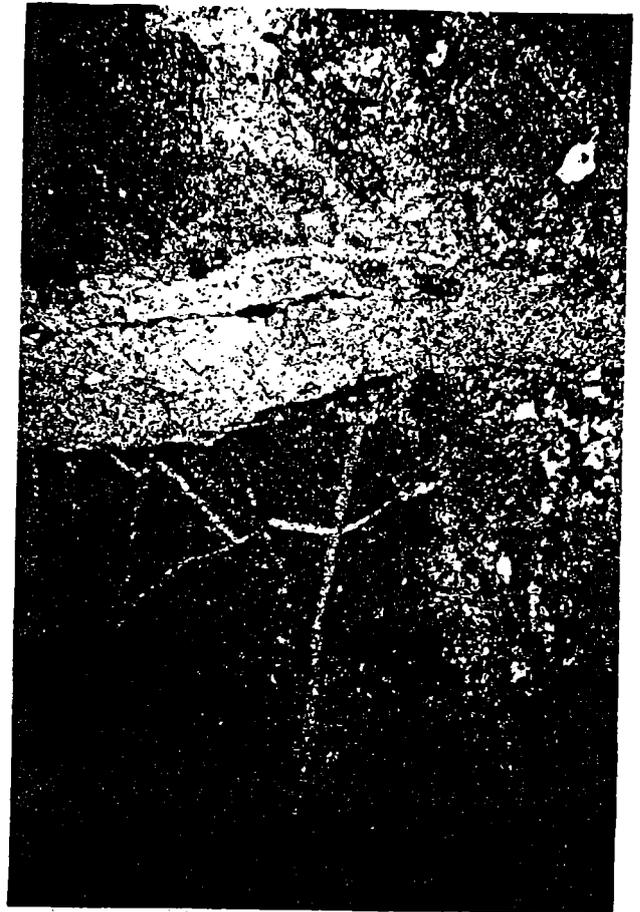
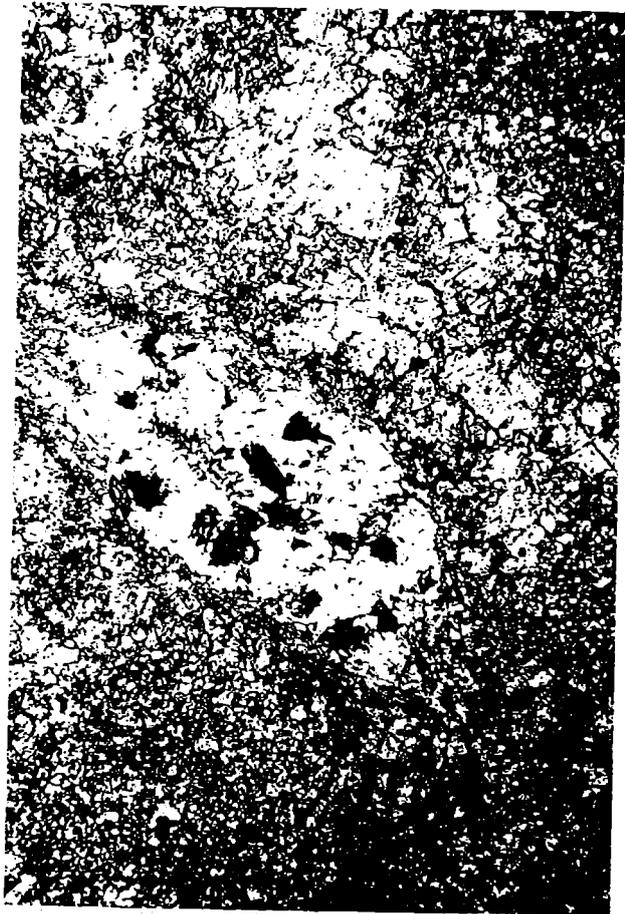
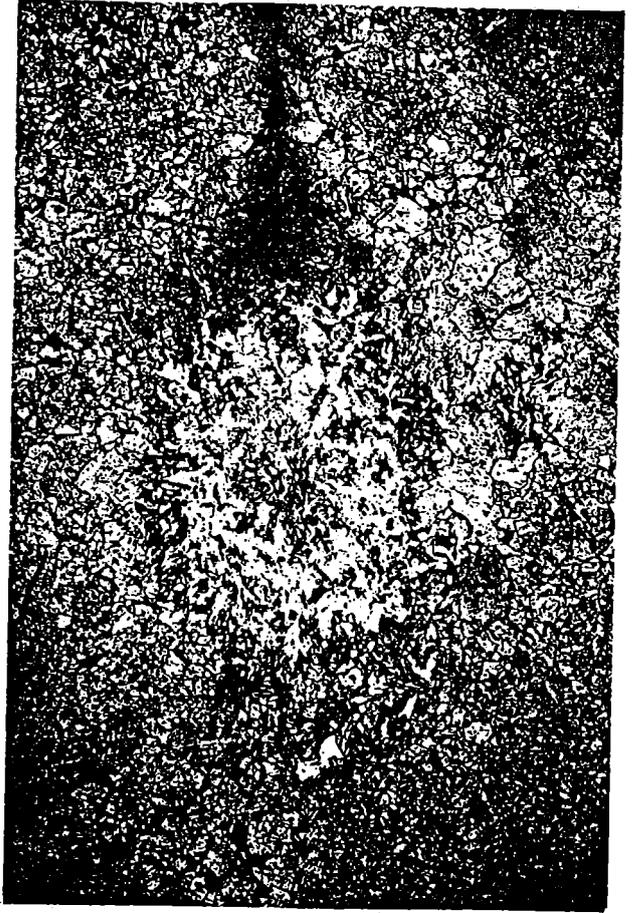


PLATE 6

Microscopic Textures of Contact Metamorphic and Hydrothermal
Stages in Carbonate Rocks

- Top Left: Stylolite separating Original dark < 20 μ m Fe-bearing dolomite cut by calcite veins from Contact Metamorphic coarse dogtooth pure dolomite that grades to talc + calcite. Same specimen as Plate 2N, No. 1 Dolomite, specimen D9-16, S562 - 83.5m, Stebbins Hill. PPL, X 37.
- Top Right: Muscovite-calcite patch formed from original clay-rich pellet by reaction with surrounding dolomite during contact metamorphism. No. 2 Dolomite, specimen D9-48, S556 - 68.0m, Stebbins Hill. PPL, X 37.
- Bottom Left: Patch with chlorite-talc-calcite-tourmaline close to a calcite vein and related to hydrothermal alteration. No. 1 Dolomite, specimen D9-14, S562 - 68.9m, Stebbins Hill. PPL, X 47.
- Bottom Right: Irregular but sharp contact between vaguely pelletal partly recrystallised 1-2 μ m Fe-bearing dolomite and the siderite zone. The recrystallised (lighter coloured) portion is progressively enriched in Fe and Mg toward the contact. The siderite zone (to right of picture) is siderite, Fe, Mn-rich dolomite and quartz as is the broad vein and the joining veinlets. No. 3 Dolomite, specimen D9-75, S594 - 236.4m, Owen-Meredith area. PPL, X 18.

APPENDICES 1-14 : CARBONATE MINERAL ANALYSES

Most analyses were performed by Peter Jackson on the University of Melbourne JEOL JSM35 scanning electron microscope (SEM) using an accelerating voltage of 15kV, a take-off angle of 30 degrees and a current of 0.5×10^{-10} A. An EDAX lithium-drifted silicon detector was used and the results processed on a VAX computer using the programme of Ware, 1981 (Computers and Geosciences, vol. 7, p. 167-184).

The remaining analyses (identified by only reporting SiO_2 , Al_2O_3 , BaO , Na_2O , CaO , MgO , FeO , MnO) were performed by Peter Jackson on the University of Melbourne JEOL JXA-5A electron microprobe using a beam current of 0.1mA, an accelerating potential of 15kV and a moving beam of approximately 10um diameter. Data reduction used the programme of Mason, Frost and Read, 1969 (London, U.K. Nat. Phys. Lab., Div. Inorganic Metallic Structure, Dept. 2, 45 p.).

The reported analyses have been subdivided according to genetic stages (Original, Early Diagenetic, Late Diagenetic, Contact Metamorphic, and Hydrothermal) then further subdivided on the basis of texture (e.g. matrix, pellets and clastic grains of Original genetic stage) and subdivided further still on the basis of stratigraphic units.

The data in the upper part of the tables is the composition of the minerals as reported by the computer. As the machine does not measure volatile species such as CO_2 and H_2O the analyses are incomplete and hence totals are not reported here. The reported content of NiO is a result of interference with a calcium peak and should not be considered as the true NiO content of the mineral.

The lower part of the table is the composition of the carbonate mineral based on the four endmembers CaCO_3 , MgCO_3 , FeCO_3 , MnCO_3 and calculated as follows:

1) where the content of minor elements is significant (e.g. SiO_2 0.5%, Al_2O_3 0.2%, K_2O 0.1%, P_2O_5 0.1%) the analysis has been recalculated by eliminating the minor

elements as the following accessory minerals: apatite for P_2O_5 , muscovite for K_2O , chlorite for Al_2O_3 after the removal of some Al_2O_3 as muscovite, and talc or quartz for SiO_2 based on petrography. The compositions of the accessory minerals are based on averages for each mineral reported in Appendices 15-19 and recalculated to 100% using volatile contents reported for the mineral by Deer, Howie and Zussman 1963 (An introduction to the rock-forming minerals, Longmans, London). The average analyses are listed below. The asterisk * in the tables shows where the calculation has been made for the minerals 1 = quartz, 2 = talc, 3 = chlorite, 4 = muscovite, 5 = apatite. The effect of the recalculation is to lower CaO in the case of apatite and to lower MgO in the case of muscovite, chlorite and talc. FeO is lowered slightly in the case of talc and chlorite.

	quartz	talc	chlorite	muscov.	apatite
SiO_2	100.00	59.92	28.25	53.90	
TiO_2				0.09	
Al_2O_3		0.54	20.19	29.31	
FeO		3.84	11.52	0.45	
MnO		0.14	0.02		0.16
MgO		30.36	27.13	0.95	0.20
CaO		0.04	0.13		56.12
NiO			0.05		
K_2O			0.08	9.80	
P_2O_5					43.51
Cl			0.04		
SO_3			0.04		
H_2O		5.16	12.76	5.50	
Total	100.00	100.00	100.00	100.00	99.99

2) The oxides CaO, MgO, FeO, MnO were then recalculated to ideal carbonate endmembers. The totals for carbonate ranged from 90 to 110 per cent largely as a result of current drift in the machine. However, duplicate analyses performed at different times show that analyses recalculated to 100 per cent are consistent and hence all analyses have been recalculated to 100 per cent.

APPENDIX 1 : Matrix of Original Stage - analyses and calculated compositions
of carbonate rocks

UNIT	No.1							R.R.M		NO.2	
SAMPLE	16-1a	16-1b	16-1c	16-1d	17-1a	17-1b	17-1c	22-1b	42-1	56-1	58-1
SiO ₂	0.15	0.58				0.02	0.11	3.53		0.95	0.62
TiO ₂				0.31							
Al ₂ O ₃		0.72						1.06		0.04	0.24
NiO			0.18	0.31	0.35	0.33	0.12	0.09	0.15	0.20	0.26
BaO											
Na ₂ O											
K ₂ O						0.04		0.29		0.06	0.02
P ₂ O ₅				0.01		0.06					
V ₂ O ₅											
Ol			0.02						0.04	0.11	0.02
SO ₃										0.10	
CaO	29.27	29.51	29.26	49.98	49.85	52.56	33.33	29.58	34.12	31.95	30.68
MgO	16.87	17.57	19.29	0.65	0.53	2.01	21.20	20.05	23.36	21.27	20.55
FeO	2.22	0.58	0.39	0.07				0.75		0.86	0.24
MnO	0.43	0.39	0.15	0.28	0.15	0.24			0.03	0.26	0.03
*								1,4			2,4
CaCO ₃	53.45	54.23	55.36	97.89	98.27	95.32	57.25	54.99	55.41	55.15	56.24
MgCO ₃	42.20	44.17	42.86	1.50	1.46	4.28	42.75	43.74	44.54	43.11	43.54
FeCO ₃	3.64	0.96	1.52	0.12	0.00	0.00	0.00	1.26	0.00	1.34	0.16
MnCO ₃	0.71	0.65	0.26	0.50	0.27	0.40	0.00	0.00	0.05	0.40	0.06

Appendix 1 : Matrix of Original Stage - analyses and calculated compositions
of carbonate minerals. (contd.)

UNIT	No. 3									
SAMPLE	72-1	72-7	73-1c	73-7	74-1	75-2	76-1	77-1	80-1	82-7
SiO ₂		0.02	0.01	0.18	0.08	0.06	0.43		0.20	0.08
TiC ₂										
Al ₂ O ₃							0.22			
NiO	0.06	0.24	0.07	0.05	0.09	0.04	0.11	0.13	0.18	0.15
BaO										
Na ₂ O										
K ₂ O		0.01		0.03		0.04	0.10		0.02	0.06
P ₂ O ₅		0.02			0.08		0.02		0.05	0.10
V ₂ O ₅										
Cl			0.01			0.02	0.05		0.12	0.08
SO ₃			0.08						0.11	0.07
CaO	39.42	38.67	32.06	32.07	33.21	38.11	30.43	37.52	36.88	39.40
MgO	23.47	23.20	19.89	21.86	21.24	23.15	20.54	22.20	21.78	23.59
FeO	2.69	0.51	2.33	0.18	2.55	1.15	0.77	0.13	2.62	2.08
MnO	0.38	0.02	0.54		0.21	0.16			0.24	0.31
*										
CaCO ₃	56.51	58.25	55.26	55.39	54.76	57.33	55.08	58.90	56.70	56.89
MgCO ₃	39.50	41.03	40.25	44.33	41.12	40.89	43.65	40.92	39.32	39.99
FeCO ₃	3.49	0.69	3.63	0.28	3.81	1.56	1.26	0.18	3.64	2.72
MnCO ₃	0.49	0.03	0.85	0.00	0.32	0.22	0.00	0.00	0.34	0.41

APPENDIX 2 : Pellets of Original Stage - analyses
and calculated compositions of carbonate minerals.

UNIT	No.1	No.2			R.B.M.
SAMPLE	13-1	50-1a	50-1b	51-1a	60-1
SiO ₂	2.84	1.73	0.88	0.05	1.15
TiO ₂					
Al ₂ O ₃	1.22	1.63	0.60		0.30
NiO				0.13	0.10
BaO					
Na ₂ O		0.27			
K ₂ O					0.20
P ₂ O ₅					0.04
V ₂ O ₅					
Cl				0.01	0.05
SO ₃				0.17	0.03
CaO	53.10	28.88	29.23	29.94	31.40
MgO	0.77	16.90	17.93	19.57	18.70
FeO	0.37	1.56	1.52	1.15	1.19
MnO	0.41	0.21	0.17		0.04
*					3,4
CaCO ₃	97.09	53.90	52.54	55.49	57.61
MgCO ₃	1.61	43.15	44.74	42.59	40.35
FeCO ₃	0.62	2.61	2.46	1.92	1.98
MnCO ₃	0.68	0.34	0.27	0.00	0.06

APPENDIX 3 : Clastic grains of Original Stage - analyses and calculated compositions of carbonate minerals.

UNIT SAMPLE	No.1	R.R.M. clasts					R.R.M.	R.B.M.				No.3
	13-3	19-8	19-1	19-2	19-3	19-4	22-1	61	67-1c	69-1d	71-1	81-4
8iO ₂	1.10		0.30	0.77	1.03	1.58	11.70	3.19	0.21	1.19	0.20	0.16
TiO ₂				0.23	1.06	0.87						
Al ₂ O ₃	0.01						0.07			0.25	0.41	
NiO							0.09	0.42	0.36	0.36	0.40	0.10
BaO				0.03	0.07	0.07						
Na ₂ O				0.08	0.08	0.24						
K ₂ O	0.01						0.04		0.14			0.03
P ₂ O ₅										0.19		0.03
V ₂ O ₅												
Cl										0.03		
SO ₃												0.06
CaO	51.66	34.71	33.50	32.42	32.23	31.36	29.30	53.54	54.32	52.34	70.20	36.26
MgO	3.21	19.91	16.34	16.27	15.00	15.95	18.29	0.36	0.17	1.08	1.21	23.09
FeO	0.47		0.14	0.28	0.61	0.81		0.17	0.45	0.61	0.02	0.26
MnO	0.34	0.06	0.04	0.15	0.53	0.32		0.22	0.83	0.80	0.17	
CaCO ₃ [*]	93.19 ³	59.70	59.77	58.85	59.94	57.85	57.70 ¹	98.57 ¹	97.56	96.25 ^{1,2,5}	97.78	57.00
MgCO ₃	5.61	40.21	39.94	40.42	38.16	40.27	42.30	0.78	0.36	1.61	1.98	42.63
FeCO ₃	0.64	0.00	0.23	0.47	1.01	1.34	0.00	0.28	0.73	0.79	0.02	0.37
MnCO ₃	0.56	0.10	0.06	0.25	0.90	0.54	0.00	0.37	1.35	1.35	0.22	0.00

Appendix 4 : Recrystallised grains of Early Diagenetic Stage
in the No. 1, RRM clasts and No. 3 - analyses
and calculated compositions of carbonate minerals.
(contd.)

UNIT SAMPLE	R.R.M. clasts						No. 3			
	20-2c	20-1	21-1a	21-1b	28-2	28-3	72-2	72-5	73-2a	73-3a
SiO ₂		2.05	3.13	2.70	0.43	18.49		0.05	0.03	0.06
TiO ₂										
Al ₂ O ₃	0.02	0.34	0.15	0.37	0.11	0.26				
NiO	0.44	0.22	0.01	0.18			0.26	0.45	0.22	0.22
BaO					0.09	0.13				
Na ₂ O					0.05	0.08				
K ₂ O		0.09	0.03	0.13			0.01	0.02		
P ₂ O ₅		0.12						0.22		
V ₂ O ₆										
Cl		0.03	0.03	0.02				0.04	0.01	0.01
SO ₃		0.04		0.04						
OaO	56.66	33.78	30.10	30.65	30.81	31.50	38.51	65.68	32.17	32.72
MgO	0.22	20.31	18.98	18.52	16.36	15.80	23.09	0.96	21.51	22.11
FeO	0.02	0.99	0.25		0.77	0.79	1.36	0.35	0.13	0.06
MnO	0.53	0.10	0.18	0.06	0.53	1.02	0.11	0.50		
*		3,4,5	1,4	1,4		1				
OaCO ₃	98.68	58.72	57.05	58.45	56.67	57.52	57.52	97.18	55.90	55.71
MgCO ₃	0.45	40.04	42.22	41.45	41.16	39.49	40.49	1.68	43.89	44.20
FeCO ₃	0.03	1.09	0.43	0.00	1.28	1.30	1.84	0.47	0.20	0.09
MnOO ₃	0.84	0.16	0.31	0.11	0.89	1.69	0.15	0.67	0.00	0.00

Appendix 4 : Recrystallised grains of Early Diagenetic Stage in
the No. 1, RRM clasts and No. 3 - analyses and cal-
culated composition of carbonate minerals. (contd.)

UNIT	No. 3										
SAMPLE	76-2a	76-3a	76-2b	76-3b	76-4	77-5	77-3	80-3	80-4	80-5	82-2
SiO ₂	0.25		0.47	0.07		0.45	0.26			0.21	0.58
TiO ₂											
Al ₂ O ₃			0.07				0.17			0.11	0.23
NiO	0.13	0.19	0.08	0.02	0.06	0.07	0.18	0.11	0.09	0.27	0.12
BaO											
Na ₂ O											
K ₂ O	0.06					0.11	0.11			0.07	0.03
P ₂ O ₅		0.05						0.07		0.14	0.07
V ₂ O ₅											
Cl						0.06	0.09	0.05	0.04	0.09	0.02
SO ₃										0.08	
CaO	30.97	31.77	40.80	40.15	39.81	39.25	40.13	38.34	37.77	37.80	39.43
MgO	21.22	22.10	25.41	24.94	23.92	24.02	23.87	22.80	23.12	22.63	22.96
FeO	0.34		0.35		1.00	0.54	0.50			0.44	1.48
MnO			0.04		0.02			0.01	0.01	0.12	0.12
*											
CaCO ₃	55.13	55.05	57.47	57.83	57.85	57.77	58.49	58.88	58.18	58.26	58.13
MgCO ₃	44.39	44.95	42.03	42.18	40.81	41.51	40.85	41.11	41.81	40.96	39.74
FeCO ₃	0.55	0.00	0.44	0.00	0.95	0.72	0.66	0.00	0.00	0.62	1.97
MnCO ₃	0.00	0.00	0.05	0.00	0.03	0.00	0.00	0.01	0.01	0.17	0.16

APPENDIX 5 : Recrystallised grains of Early Diagenetic Stage in
RRM beds; No. 2 and RBM - analyses and calculated
compositions of carbonate minerals.

UNIT	R.R.M.	No. 2							
SAMPLE	40-1	44-1d	44-4	47-1	48-1	48-1b	49-1a	49-1b	49-4
SiO ₂	0.07		0.37	0.66				0.27	
TiO ₂									
Al ₂ O ₃	0.02		0.09					0.08	0.05
NiO	0.17	0.09	0.17	0.21	0.09	0.34	0.14	0.16	0.37
BaO									
Na ₂ O									
K ₂ O	0.08		0.05	0.03	0.06				0.02
P ₂ O ₅					0.02		0.08		0.21
V ₂ O ₅								0.21	
Ol					0.06				0.03
SO ₃					0.05				0.11
CaO	32.31	30.65	30.09	32.89	30.28	52.95	32.80	32.89	33.34
MgO	22.70	21.75	21.34	22.59	20.75	0.42	22.66	22.48	22.88
FeO	1.05	0.94	0.60	1.09			0.92	0.31	0.30
MnO	0.07	0.45	0.60	0.34		0.19	0.03		0.04
*									
CaCO ₃	53.87	53.35	53.51	54.18	55.41	98.75	54.42	53.70	55.85
MgCO ₃	44.44	44.46	44.55	43.70	44.59	0.92	44.15	45.84	43.92
FaCO ₃	1.58	1.48	0.97	1.61	0.00	0.00	1.38	0.46	0.18
MnCO ₃	0.10	0.71	0.97	0.51	0.00	0.33	0.05	0.00	0.06

Appendix 5 : Recrystallised grains of Early Diagenetic Stage
in RRM beds, No. 2 and RBM - analyses and cal-
culated composition of carbonate minerals. (contd.)

UNIT	No. 2					R.B. 2
SAMPLE	51-2b	56-2	56-3	58-2	58-3	63-2
SiO ₂				0.82	0.22	0.08
TiO ₂						
Al ₂ O ₃				0.43	0.06	
NiO		0.12	0.14	0.25	0.04	0.38
BaO						
Na ₂ O	0.38					
K ₂ O				0.20		
P ₂ O ₅			0.02	0.08	0.30	
V ₂ O ₅						
Cl				0.03		
SO ₃				0.01		
CaO	50.95	32.39	30.93	30.83	32.03	53.75
MgO	0.23	21.30	21.68	21.07	21.24	0.48
FeO	0.07	1.00	0.57	0.77	0.61	0.26
MnO	0.23	0.04	0.19	0.05		0.29
*				4,5	5	
CaCO ₃	98.95	55.52	54.19	54.67	55.38	98.06
MgCO ₃	0.52	42.88	44.60	44.01	43.65	1.02
FeCO ₃	0.12	1.55	0.91	1.24	0.96	0.43
MnCO ₃	0.41	0.05	0.30	0.08	0.00	0.48

APPENDIX 6 : Cavity lining and related veins of Late Diagenetic Stage - analyses and calculated composition of carbonate minerals.

UNIT	No.2											
SAMPLE	49-1c	49-1d	55-4a	55-4b	55-4c	55-4c	55-4c	55-4c	55-4c	55-4d	55-4e	55-4f
SiO ₂	0.09	0.13	0.20	0.11	0.12	0.17	0.16		0.07	0.18	0.04	0.12
TiO ₂												
Al ₂ O ₃		0.45			0.07							
NiO	0.06	0.14	0.26	0.24	0.03	0.06	0.12	0.01	0.22	0.18	0.15	
BaO												
Na ₂ O												
K ₂ O			0.04		0.06	0.04						
P ₂ O ₅		0.07	0.13						0.06		0.03	
V ₂ O ₅		0.23										
Cl		0.06		0.04	0.05	0.05	0.01	0.03	0.05	0.05	0.10	0.03
SO ₃	0.05								0.20		0.40	0.01
CaO	31.64	32.14	37.95	37.23	30.63	31.07	30.47	30.49	30.72	37.29	37.61	37.36
MgO	19.76	19.37	23.06	23.17	20.87	20.65	19.76	20.70	20.20	23.75	23.16	23.14
FeO	2.33	4.77	2.13	1.03	1.26	1.77	1.92	1.84	2.94	0.70	2.24	1.52
MnO	0.33	0.24	0.16	0.47	0.23	0.21	0.39	0.17	0.20	0.02	0.30	0.12
*												
CaCO ₃	55.27	54.09	56.56	56.58	54.23	54.40	54.91	53.36	53.63	56.64	56.05	56.60
MgOO ₃	40.53	38.28	40.35	41.35	43.39	42.46	41.80	42.93	41.41	42.36	40.52	41.16
FeCO ₃	3.68	7.26	2.87	1.42	2.02	2.80	3.00	2.94	4.64	0.96	3.02	2.09
MnOO ₃	0.52	0.37	0.22	0.65	0.37	0.34	0.29	0.28	0.32	0.04	0.41	0.16

Appendix 6 : Cavity lining and related veins of Late Diagenetic Stage - analyses
and calculated composition of carbonate minerals.

UNIT	No.2		No.3						
	58-5a	58-5b	73-4a	73-6	74-2b	74-3	74-5b	74-5a	76-5
SiO ₂		0.03			0.04				0.14
TiO ₂									
Al ₂ O ₃				0.02					0.09
NiO	0.11	0.23		0.22	0.30	0.10	0.15	0.16	0.40
BaO									
Na ₂ O									
K ₂ O	0.02				0.02				
P ₂ O ₅		0.01		0.08			0.08	0.01	0.13
V ₂ O ₅									
Cl				0.01	0.04			0.01	0.09
SO ₃				0.01	0.03		0.03		0.17
CaO	31.33	31.71	31.78	31.82	32.47	32.03	32.65	31.77	37.70
MgO	19.56	21.03	21.35	20.99	20.24	21.38	20.57	19.97	23.58
FeO	1.10	1.11	1.59	1.42	1.37	1.38	1.35	3.25	1.94
MnO		0.04		0.02	0.16	0.09	0.13	0.11	0.25
*									
CaCO ₃	56.67	55.20	54.53	55.08	56.35	54.79	56.16	54.53	55.96
MgCO ₃	41.54	42.99	43.01	42.66	41.24	42.94	41.54	40.25	41.09
FeCO ₃	1.80	1.75	2.45	2.23	2.15	2.13	2.10	5.04	2.60
MnCO ₃	0.00	0.06	0.00	0.03	0.25	0.14	0.20	0.17	0.34

APPENDIX 7 : *Cavity lining and related veins associated
with quartz of Late Diagenetic Stage - analyses
and calculated composition of carbonate minerals.*

UNIT	No. 2			No. 3	
	49-4a	49-4b	49-3	74-2a	74-4
SiO ₂	0.19				
TiO ₂					
Al ₂ O ₃					
NiO	0.09	0.26	0.34	0.25	0.35
BaO					
Na ₂ O					
K ₂ O					
P ₂ O ₅				0.09	0.12
V ₂ O ₅					
Cl				0.02	
SO ₃					
CaO	54.71	54.40	55.37	54.92	54.70
MgO	2.15	0.83	1.49	0.28	0.94
FeO	0.21	0.18	0.17	0.31	0.36
MnO	0.36	0.37	0.19	0.41	0.24
*					
CaCO ₃	94.74	97.37	96.40	98.24	97.08
MgCO ₃	4.37	1.74	3.04	0.59	1.95
FeCO ₃	0.33	0.29	0.26	0.50	0.58
MnCO ₃	0.56	0.60	0.30	0.66	0.39

APPENDIX 8 : Veins patches and matrix finer than 100 μ m of Late Diagenetic Stage -
analyses and calculated composition of carbonate minerals.

UNIT	No. 2											
SAMPLE	48-2	48-1c	48-1b	48-1a	55-1	55-1c	55-2a	55-2c	55-1b	55-3a	55-3b	59-4
SiO ₂			0.03		8.78	6.00	0.36	2.06	4.50	1.66	0.12	
TiO ₂												
Al ₂ O ₃							0.11	0.88		0.36		
NiO	0.15	0.23	0.10			0.14	0.22	0.21	0.21	0.29		0.17
BaO												
Na ₂ O												
K ₂ O		0.06	0.03					0.36	0.04	0.10	0.02	
P ₂ O ₅			0.07							0.62	0.02	0.01
V ₂ O ₅												
Cl		0.04	0.04						0.02	0.10	0.02	0.04
SO ₃										0.09	0.06	0.10
CaO	28.76	28.92	29.49	29.42	34.65	29.12	36.90	29.96	35.53	36.54	31.53	31.43
MgO	14.87	14.22	19.25	18.88	13.43	15.83	20.46	18.67	17.83	20.65	19.11	18.65
FeO	7.95	9.38	3.18	2.83	5.51	6.67	6.00	3.33	7.92	5.04	5.85	5.29
MnO	0.41	0.49	0.25	0.03	0.48	0.47	0.36	0.26	0.65	0.30	0.40	0.50
*					1	1		4	1,4			
OaCO ₃	53.47	52.92	53.42	54.26	56.15	52.39	55.34	54.36	55.33	55.45	53.94	53.66
MgCO ₃	32.47	30.66	41.04	40.88	35.07	34.96	36.03	39.76	32.60	36.79	36.38	37.39
FeCO ₃	13.37	15.60	5.21	4.72	9.07	11.35	8.14	5.46	11.15	6.91	9.05	8.17
MnCO ₃	0.69	0.82	0.42	0.13	0.71	0.80	0.49	0.42	0.92	0.85	0.63	0.78

Appendix 8 : Veins patches and matrix finer than
 100 μ m of Late Diagenetic Stage - analyses
 and calculated composition of carbonate minerals (contd.)

UNIT	R.B.M.	No. 3		
SAMPLE	60-3	72-3	72-4	72-6a
SiO ₂	4.94	0.12		
TiO ₂				
Al ₂ O ₃	2.92			
NiO	0.16	0.12	0.25	0.19
BaO				
Na ₂ O				
K ₂ O	1.30	0.01	0.02	
P ₂ O ₅				0.01
V ₂ O ₅				
Cl	0.06	0.05		
SO ₃	0.11			
CaO	35.95	36.80	36.85	37.30
MgO	19.10	16.85	19.61	20.72
FeO	7.35	11.66	7.82	5.90
MnO	0.10	0.67	0.50	0.29
*				
CaCO ₃	55.26	54.32	54.67	55.46
MgCO ₃	34.38	29.21	34.16	36.21
FeCO ₃	10.22	15.57	10.49	7.94
MnCO ₃	0.14	0.90	0.68	0.39

APPENDIX 9 : Veins coarser than 100 μ m of Late Diagenetic Stage - analyses and calculated compositions of carbonate minerals.

UNIT	R.R.M. beds			No. 2					
SAMPLE	40-2	40-3b	40-3a	47-2	47-3	47-4	48-4	51-3	53-3
SiO ₂		0.01				0.23			
TiO ₂									
Al ₂ O ₃									
NiO	0.12		0.25	0.06	0.06	0.17		0.22	0.06
BaO									
Na ₂ O									
K ₂ O			0.04	0.01				0.01	
P ₂ O ₅				0.01				0.01	
V ₂ O ₅									
Ol		0.03			0.02	0.01		0.02	0.02
SO ₃			0.04	0.10					
CaO	31.78	31.62	31.13	32.56	32.71	32.34	28.39	28.20	28.63
MgO	18.20	17.03	16.72	16.30	15.45	17.47	14.00	15.65	14.39
FeO	7.68	7.85	9.32	10.60	10.92	8.56	10.58	8.44	8.52
MnO	0.42	0.30	0.15	0.44	0.80	0.54	0.25	0.17	0.39
*									
CaCO ₃	52.55	53.60	52.48	52.77	53.22	52.94	51.97	51.87	53.42
MgCO ₃	35.34	33.90	33.09	31.03	29.52	33.58	30.09	33.80	31.53
FeCO ₃	11.48	12.04	14.20	15.55	16.07	12.67	17.52	14.04	14.38
MnCO ₃	0.63	0.46	0.23	0.65	1.19	0.80	0.42	0.29	0.66

Appendix 9 : Veins coarser than 100µm of Late Diagenetic Stage - analyses and calculated compositions of carbonate minerals (contd.)

UNIT	No. 3				
SAMPLE	74-6	74-7	76-6	76-4b	80-6
SiO ₂	0.02		0.06		
TiO ₂					
Al ₂ O ₃					0.31
NiO		0.27	0.12	0.15	0.13
BaO					
Na ₂ O					
K ₂ O	0.03	0.03			
P ₂ O ₅			0.07	0.06	
V ₂ O ₅					
Cl		0.02		0.01	0.01
SO ₃					
CaO	30.74	30.29	37.31	37.73	35.21
MgO	16.57	16.03	17.96	17.94	15.11
FeO	9.26	9.94	12.03	11.02	11.21
MnO	0.16	0.20	0.39	0.35	0.93
*					
CaCO ₃	52.35	51.98	53.58	54.62	55.07
MgCO ₃	33.13	32.29	30.29	30.49	27.75
FeCO ₃	14.27	15.42	15.63	14.43	15.86
MnCO ₃	0.25	0.31	0.51	0.46	1.32

APPENDIX 10 : Breccia matrix and veins of Contact Metamorphic Stage - analyses and calculated compositions of carbonate minerals.

UNIT	No. 1						No. 2						
SAMPLE	16-2a	16-2b	16-5	16-6a	16-6b	16-6c	50-1	50-2	50-3a	50-3b	50-3c	50-4	50-4a
SiO ₂		0.67	0.01	0.09		0.15		0.02	0.19	0.62			1.61
TiO ₂													
Al ₂ O ₃		0.39	0.09			0.04			0.38	0.60	0.01		0.76
NiO	0.32	0.34	0.28		0.46		0.39	0.35			0.40	0.26	
BaO						0.17			0.07				
Na ₂ O				0.08		0.19			0.19				
K ₂ O													
P ₂ O ₅								0.09				0.03	
V ₂ O ₅													
Cl					0.04								
SO ₃					0.04								
CaO	48.52	49.53	50.71	53.33	49.78	53.34	55.07	54.66	53.58	51.98	54.78	54.33	52.12
MgO	2.04	0.51	0.76	0.20	1.70	0.26	0.42	0.75	0.13	0.65	0.57	0.44	0.65
FeO	0.11	0.05	0.24	0.23	0.12	0.25	0.11	0.21	0.27	0.46	0.08	0.01	0.31
MnO	0.54	0.35	0.30	0.36	0.31	0.43	0.24	0.47	0.37	0.48	0.58	0.36	0.61
*													
CaCO ₃	94.32	98.09	97.34	98.50	95.43	98.25	98.54	97.33	98.61	96.75	97.73	97.95	96.80
MgCO ₃	4.56	1.19	1.71	0.51	3.82	0.64	0.88	1.57	0.32	1.67	1.19	0.93	1.66
FeCO ₃	0.19	0.09	0.42	0.38	0.20	0.40	0.18	0.34	0.44	0.78	0.13	0.02	0.52
MnCO ₃	0.93	0.63	0.53	0.61	0.54	0.71	0.39	0.76	0.63	0.80	0.94	0.59	1.02

APPENDIX 11 : Veins with sulphides and/or tourmaline of Hydrothermal Stage - analyses and calculated composition of carbonate minerals.

UNIT	No.1					No.2			R.B.M.	No.3
	10-1c	R.R.M. 20-2	29-3	29-4	42-1	44-2	44-3	44-3c		
SiO ₂	1.81	14.28	1.26	1.75	0.01			0.09	0.05	0.01
TiO ₂										
Al ₂ O ₃	0.01		0.38	0.79	0.02	0.08	0.06	0.30		
NiO	0.36	0.31			0.27		0.09		0.18	
BaO			0.15			0.08		0.09		
Na ₂ O			0.11	0.05		0.11		0.03		
K ₂ O	0.03				0.06					
P ₂ O ₅	0.11	0.07					0.03			
V ₂ O ₅										
Cl					0.06				0.03	
SO ₃					0.12					
CaO	53.19	47.39	28.50	27.99	31.79	29.90	30.42	29.20	39.88	54.39
MgO	0.74	0.10	12.99	12.35	17.93	14.74	17.66	13.28	20.17	0.90
FeO	0.25		6.22	5.90	2.72	5.61	4.88	6.36	7.97	0.19
MnO	1.04	0.58	3.21	3.64	4.36	2.08	1.52	1.99	1.12	0.44
*		1	1,2	1,2						
CaCO ₃	96.30	98.65	55.37	56.64	53.22	52.47	53.41	53.20	55.55	97.09
MgCO ₃	1.58	0.25	29.10	28.18	35.22	35.39	36.41	33.10	32.99	1.89
FeCO ₃	0.41	0.00	9.88	8.52	4.11	8.84	7.75	10.42	10.04	0.31
MnCO ₃	1.71	1.10	5.56	6.67	7.45	3.90	2.48	3.28	1.42	0.71

APPENDIX 12 : Veins with Fe-talc of Hydrothermal Stage -
analyses and calculated composition of
carbonate minerals.

UNIT	R.R.M			
SAMPLE	31-1	42	42	42-2
SiO ₂	0.14		0.15	
TiO ₂				
Al ₂ O ₃		0.07		
NiO	0.43	0.38	0.42	0.31
BaO				
Na ₂ O				
K ₂ O				
P ₂ O ₅				
V ₂ O ₅				
Cl	0.03			0.03
SO ₃				
CaO	60.16	51.69	53.07	53.26
MgO	1.86	1.02	0.89	0.79
FeO	1.74	0.36	0.44	0.26
MnO	4.05	3.53	3.23	3.42
*				
CaCO ₃	83.99	91.61	92.37	92.31
MgCO ₃	3.23	2.12	1.82	1.61
FeCO ₃	2.33	0.58	0.69	0.69
MnCO ₃	5.45	5.69	5.11	5.39

APPENDIX 13 : Veins and breccia matrix adjacent to siderite of Hydrothermal Stage -
analyses and calculated compositions of carbonate minerals.

UNIT	R.R.M. clasts				No.2	No.3				
SAMPLE	18-1	18-2	18-3	22-3	52-1b	75-2b	75-3	82-1a	82-1b	82-3a
SiO ₂	1.32	0.23	0.11			0.07	0.05	0.34	2.19	
TiO ₂										
Al ₂ O ₃	0.26	0.23				0.06	0.04	0.17	1.27	
NiO	0.11	0.03	0.11	0.17		0.09	0.09	0.10	0.13	0.17
BaO										
Na ₂ O										
K ₂ O	0.02			0.01		0.14	0.06	0.06	0.46	
P ₂ O ₅	0.08					0.19	0.01			0.05
V ₂ O ₅										
Cl					0.01	0.04	0.07	0.01		0.02
SO ₃						0.12	0.11			
CaO	28.47	29.53	30.08	29.91	27.55	35.71	36.43	17.88	35.82	38.50
MgO	9.14	10.34	11.79	12.07	13.47	11.57	11.76	7.00	13.51	14.17
FeO	12.36	14.16	12.64	13.07	8.33	14.99	18.64	6.06	13.12	12.93
MnO	4.58	2.10	2.47	1.37	2.50	4.71	1.22	1.57	3.55	3.04
* CaCO ₃	1 52.19	52.37	52.16	52.33	51.81	53.19	53.41	4 54.17	4 53.64	55.32
MgCO ₃	19.67	21.53	24.01	24.80	29.74	20.23	20.24	24.90	23.76	23.91
FeCO ₃	20.50	22.72	19.95	20.68	14.17	20.22	24.72	16.61	17.77	16.81
MnCO ₃	7.64	3.39	3.88	2.18	4.28	6.36	1.63	4.32	4.84	3.97

APPENDIX 14 : Siderite and co-existing Fe dolomite of Hydrothermal Stage -
analyses and calculated composition of carbonate minerals.

UNIT	vein outside siderite		massive siderite				veins cutting siderite					with mt-ta-g-po
SAMPLE	75-4a	75-4b	52-4	75-5	82-4	82-6	52-3a	52-3b	52-3c	75-6	82-5	52-5a
SiO ₂		0.46	0.02	0.08	0.24	0.36	0.16	0.04			0.20	0.09
TiO ₂		0.12				0.04		0.02		0.21		
Al ₂ O ₃		0.09		0.13		0.08	0.05		1.85	0.25	0.10	0.15
NiO	0.18			0.05		0.19	0.37		0.03	0.06		
BaO												
Na ₂ O												
K ₂ O		0.07		0.06	0.06	0.08	0.10			0.07	0.05	0.06
P ₂ O ₅							0.12					0.03
V ₂ O ₅												
Cl	0.05				0.02	0.02	0.03	0.02		0.08	0.01	0.09
SO ₃				0.16			0.17	0.11		0.18	0.13	0.09
CaO	36.13	0.75	0.20	0.71	0.50	0.37	25.58	0.32	24.71	0.52	0.13	0.53
MgO	12.16	10.97	11.98	10.47	14.29	13.27	10.38	7.03	10.88	10.39	6.35	8.71
FeO	18.35	48.49	41.39	46.43	47.47	47.40	7.36	41.11	8.35	48.12	58.07	40.67
MnO	1.26	8.95	4.42	12.14	10.02	9.82	5.13	4.85	3.86	10.92	9.73	9.04
*												
CaCO ₃	53.02	1.15	0.36	1.07	0.72	0.55	52.11	0.64	50.90	0.79	0.19	0.95
MgCO ₃	20.95	19.63	25.24	18.63	24.20	22.99	24.82	16.45	26.32	18.44	10.81	18.34
FeCO ₃	24.35	66.82	67.18	63.65	61.93	63.27	13.56	74.11	15.55	65.76	76.16	65.97
MnCO ₃	1.68	12.41	7.22	16.65	13.15	13.19	9.51	8.80	7.23	15.02	12.84	14.75

APPENDIX 15 : Uncorrected analyses of talc. Analyses should include approx. 5.2% H₂O.
 73-5c* recalculated to 95% removing CaO, MnO in Mn calcite.

SAMPLE	Contact metamorphic						Hydrothermal				
	14	16-5	16-6a	16-6b	17-1c	50-2	42	73-1b	73-5	73-5c	73-5c*
SiO ₂	66.84	44.98	54.04	45.24	53.91	61.13	61.40	57.34	59.22	22.75	54.60
TiO ₂											
Al ₂ O ₃	0.63	3.43	0.23	0.81	4.22		0.26	0.36	0.31	0.26	0.62
FeO	0.89	1.84	1.68	1.48	1.20	2.98	4.13	5.34	4.76	2.08	4.99
MnO					0.07		0.06			0.18	
MgO	29.36	22.40	26.64	22.07	31.64	29.83	29.32	26.31	28.11	14.47	34.73
CaO		3.88	0.48	0.25	0.15		0.37	0.11		29.42	
NiO		0.02			0.06					0.02	
Na ₂ O											
K ₂ O				0.02							
P ₂ O ₅											
V ₂ O ₅											
Cl		0.07		0.04	0.02				0.04		
SO ₃											
H ₂ O											
Total	97.72	76.62	83.07	69.92	91.27	93.94	95.54	89.45	92.43	69.18	95.00

APPENDIX 16 : Uncorrected analyses of chlorite. Analyses should include approx. 12.8% H₂O.

SAMPLE	Contact metamorphic								Hydrothermal	
	47-2	47-3c	47-3r	51-1	53-2	59-1	67-1b	73-1a	29-2	29-3
SiO ₂	29.68	33.15	23.26	28.43	25.83	48.94	29.72	27.59	24.57	26.93
TiO ₂									0.04	
Al ₂ O ₃	21.99	20.80	16.92	19.51	18.76	20.77	21.37	19.30	18.70	20.78
FeO	12.36	8.74	21.97	3.37	14.50	15.86	9.96	17.40	29.76	33.72
MnO			0.27				0.06	0.03	0.66	0.38
MgO	28.58	28.69	16.11	32.08	22.44	24.05	28.40	23.13	11.93	8.58
CaO	0.02	0.34	2.76	0.15	0.34			0.16	0.40	
NiO	0.04	0.10	0.02	0.04	0.10	0.11		0.05	0.13	0.25
Na ₂ O										
K ₂ O	0.06	0.01	0.04	0.26	0.02	0.34	0.05	0.03	0.03	0.23
P ₂ O ₅										
V ₂ O ₅										0.02
Cl	0.06	0.07	0.02		0.03	0.07	0.06	0.05	0.04	0.04
SO ₃					0.01	0.29		0.17	0.08	
H ₂ O										
Total	92.79	91.89	81.38	83.84	82.03	110.43	89.62	87.90	86.34	90.93

APPENDIX 17 : Uncorrected analyses of apatite. Analyses should include 3-4%
F + Cl + OH. 19-6* recalculated to 100% removing SiO₂ as quartz.

SAMPLE	14	22-1	19-6	58-4	61-1b	63-1d	69-1b	72-5b	73-5d	76-3c	81-2
SiO ₂		0.30	13.92	1.93			0.13				
TiO ₂		1.13									
Al ₂ O ₃				1.12	1.14		0.01				
FeO			0.10				0.01				
MnO		0.15	0.29	0.17	0.23	0.27	0.24	0.02	0.09	0.39	0.02
MgO	0.66	0.28	0.26	1.11		0.41	0.15		0.17	0.18	0.04
OaO	58.97	56.61	48.45	52.05	57.74	59.19	55.47	59.36	57.72	73.15	66.23
NiO		0.24	0.36	0.43	0.51	0.41	0.44	0.46	0.32	0.54	0.50
Na ₂ O											0.03
K ₂ O			0.01	0.57	0.08	0.03					
P ₂ O ₅	45.75	43.91	36.20	37.83	44.55	47.41	38.25	54.26	45.54	57.10	49.29
V ₂ O ₅											
Cl		0.05			0.37	0.56	0.13	0.69	0.04	0.01	
SO ₃											0.16
H ₂ O											
Total	105.32	102.70	85.20	95.20	104.74	107.28	94.12	113.63	103.88	131.37	116.28

APPENDIX 18 : Uncorrected analyses of muscovite, biotite and tourmaline. Analyses should include 5.5% H₂O in muscovite, 3.4% H₂O in biotite and 10-11% B₂O₃ and 3-4% H₂O in tourmaline.

SAMPLE	Muscovite					Biotite			Tourmaline	
	67-1	81-1	81-3a	83-1b	84-1a	83-1a	84-1b	31	10	10
SiO ₂	54.36	64.30	51.89	68.09	64.79	57.02	17.21	45.02	37.00	36.67
TiO ₂			0.28	0.08	0.14	0.85		0.97	0.42	0.25
Al ₂ O ₃	35.50	28.18	31.83	28.55	27.44	29.27	9.89	18.87	30.97	31.00
FeO	0.43	0.33	0.63	0.69	3.79	3.66	8.80	22.56	3.36	3.57
MnO							0.28	0.19		
MgO	0.26	1.70	1.05	1.27	1.77	9.70	5.06	16.96	10.80	10.75
CaO		1.18	1.52				37.97		1.08	1.59
NiO							0.25		0.07	0.07
Na ₂ O									1.14	1.25
K ₂ O	12.08	10.41	8.57	11.06	11.17	12.40	4.58	9.75	0.03	0.01
P ₂ O ₅										
V ₂ O ₅										
Cl							0.04	0.11		0.02
SO ₃							0.03			
H ₂ O										
Total	102.63	106.10	95.77	109.74	109.10	112.90	84.10	114.45	84.88	85.17

APPENDIX 19 : Uncorrected analyses of magnetite, rutile and pyrite.
 Total iron is reported as FeO.

SAMPLE	Magnetite				Rutile	Pyrite	
	52-5	52-4	52-4	52-3	61-1	47-3	82
SiO ₂	0.14	0.30	0.40	0.76	0.30		
TiO ₂	0.07	0.17	0.26	0.27	102.56	0.45	1.17
Al ₂ O ₃	0.05		0.08	0.05	0.15		0.79
FeO	95.03	94.83	93.95	86.17	0.29	43.63	75.46
MnO			0.04		0.33		
MgO	0.12		0.34	0.01		0.05	0.43
CaO	0.02	0.10	0.20	0.30	0.81	2.25	0.01
NiO					0.44	0.27	0.62
Na ₂ O						8.71	0.91
K ₂ O	0.06	0.03		0.14	0.09	0.14	0.06
P ₂ O ₅							
V ₂ O ₆							
Ol	0.05	0.01	0.03	0.04		0.05	
SO ₃	0.09	0.01	0.21		0.20	87.23	171.75
H ₂ O							
Total	95.63	95.45	95.52	87.74	105.17	142.78	251.21

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