THE UNIVERSITY OF ADELAIDE

SEDIMENTOLOGY OF THE BURRA GROUP IN THE EAST ROOKS AREA, NORTHEASTERN WILLOURAN RANGES, SOUTH AUSTRALIA

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Paul S. Heithersay B.Sc.

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Best wishes from
Paul Heithersay
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ABSTRACT

Detailed stratigraphic mapping and facies analysis in the East Rooks area has revealed 7 stratigraphic units representing distinct depositional events. These 7 units, designated ER1 (East Rooks) to ER7, reflect broad environmental changes indicated by lithology, sedimentary structures and energy regimes.

Early environments include locally developed distal alluvial fans and fluvial braid plains, marginal marine sabkhas and wave influenced fan deltas. The subsequent widespread phase of deposition occurred in marine to marginal marine environments.

This study has shown that Burra Group sedimentation was influenced by a palaeohigh to the north, thought to be an area of uplifted Callanna Beds.

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INTRODUCTION

Since the late 1800's the Willouran Ranges have been a target for base metal exploration. From 1964 onwards, various mining companies have held leases in the area and all have used geochemistry as their main exploration tool.

Since 1976, Utah Development Company has held the tenement in the Willouran Ranges and has undertaken a search for copper with an exploration philosophy relying on detailed mapping and sedimentological investigation.

This project was initiated under Utah Development Company sponsorship in order to map a previously unexplored part of their lease and to provide further sedimentological data for their copper search.

CHAPTER 1: PRELIMINARY DISCUSSION

1.1 Location and access

The Willouran Ranges lie to the northwest of the Flinders Ranges. Marree, which is 580km north of Adelaide, is situated on the alluvial plain on the northeastern edge of the Willouran Ranges. The East Rooks area lies to the north of Willouran Hill, and covers an area of 20sq.km. The total area lies between 29°46'S - 29°49'S and 137°57'E - 138°0'E (Fig. 1).

Access to the area is obtained using four wheel drive vehicles along well maintained tracks.

1.2 Aims of this project

1. To map and describe the stratigraphy of the East Rooks area.

2. To derive a palaeogeographic interpretation of the area during the deposition of the Burra Group.

1.3 Previous Investigations

No detailed study has previously been undertaken in the East Rooks area, however Mawson (1927) undertook a brief reconnaissance of the study area to the west of Breaden Hill. Murrell (1977) has mapped the study area as part of a regional investigation of the Willouran Ranges. The South Australian Department of Mines and Energy has mapped the region for inclusion on the 1:250,000 Curdimurka Sheet. Since 1964 various mining exploration companies have explored the Willouran Ranges, with Utah Development Company currently holding the tenement.

1.4 Regional stratigraphy

The Burra Group (Mirams and Forbes, 1964) is the second of the four cycles of sedimentation recognized in the

Adelaide System (Thomson et al., 1964). This lithostratigraphic unit of Torrensian to early Sturtian age is extremely widespread throughout the Adelaide "Geosyncline". It unconformably overlies either crystalline basement or the first cycle of sedimentation represented by the Callanna Beds. The type section for the Callanna Beds is located in the Willouran Ranges, and is described as a sequence of carbonaceous, pyritic siltstones and shales, micaceous and silty immature sandstones, grey limestones and buff dolomites. These were deposited under low energy evaporitic, tidal flat to subtidal basin conditions (Preiss, 1979).

The Burra Group represents a major tectono-sedimentary cycle commencing with widespread clastic sedimentation. Preiss (1979) and others suggested that this is a transgressive event, although work done by Utah Development Company may compel a revision (Rowlands, 1979, pers. comm.). Following this phase, a mixed clastic carbonate sequence, characterized by "primary" dolomite and magnesite developed. Burra Group sedimentation ended with the onset of early Sturtian tectonism.

Murrell (1977) has correlated rock units within the Burra Group in the Willouran Ranges with those on the 1:250,000 Copley Sheet (Coats et al., 1973). Fig. 2 exhibits the relation of the units within East Rooks with the stratigraphic nomenclature of Murrell (1977) and Utah Development Company (U.D.C. Report 301, 1977). Fig. 1 illustrates the distribution of Burra Group sediments within the Willouran Ranges.

1.5 Regional structure and tectonics

The tectonic framework of the Stuart Shelf and the Adelaide "Geosyncline" from pre-Adelaidean to early Sturtian times, is defined by a protracted period of strong intermittent tensional tectonism, followed by relative quiescence during Sturtian times (Preiss et al., in press). This is expressed by repeated uplift, caused by differential faulting, providing sediment source areas to the north and northeast of the Adelaide "Geosynclinal" area. Murrell (1977) has demonstrated these tectonic effects on Burra Group sedimentation. Murrell concluded that during Burra Group deposition the basin was a complex half graben between a hinge along the Norwest Faultline and a faulted margin along the East Willouran Fault.

Superimposed on this were second order half grabens, with characteristic facies and thickness changes. Faulting within the Adelaide Fold Belt is of great importance in controlling the differing patterns of deposition observed in the Lower Callanna Beds, the Burra Group and the Umberatana Group (Rutland and Murrell, 1975).

Murrell (1977) has recognized three periods of deformation within the Willouran Ranges. Pre-Burra Group deformation marks the first period of folding. Murrell (1977) notes, however, that most of the structures observed in the Callanna Beds are due to slumping and associated diapirism of sediments while soft or in a poorly lithified state prior to deposition of the Burra Group. The second period of folding occurred in pre-Umberatana Group times. This has been attributed to growth folding due to rotation of fault blocks during this period (Murrell, 1977). The youngest phase of folding evolved during the Early Palaeozoic Delamarian Orogeny (Thomson, in Parkin, ed., 1969), which is the main folding phase of the Adelaide Fold Belt.

On the eastern margin of the East Rooks area, easterly dipping Burra Group sediments contact with contorted carbonates of the Callanna Beds. This contact has been mapped as the East Willouran Fault by Murrell (1977).

1.6 The Callanna Beds/Burra Group unconformity

Preiss (1979) reports that recognition of an erosional break between the Callanna Beds and the Burra Group is currently unresolved. However Murrell (1977) concluded that deformation of the Callanna Beds occurred prior to Burra Group deposition. Stratigraphic thinning and persistent development of nearshore facies in the Burra Group against pre-Torrensian carbonates, shales and sandstones is difficult to resolve unless an unconformity is present (Preiss et al., in press). Detailed mapping by Utah Development Company has established that the Callanna Beds/Burra Group unconformity does exist in the Willouran Ranges (U.D.C. Report 301, 1977).

A disconformity defines the contact between the silicified carbonates and black shales of the Callanna Beds, and the relatively undeformed basal Burra Group on the western margin of the study area. This is based on the observation of a regolith breccia zone which can be traced along the contact. The disconformity exhibits a weathering induced mantle of silicification and ferruginization.

Murrell (1977) mapped an unconformity approximately 1km to the west of the contact proposed in this thesis.

1.7 Stratigraphic methods and definitions

1.7.1 Methods

Mapping was undertaken at 1:10,000 scale using colour photographs supplied by Utah Development Company.

Five lines of section totalling 15km were logged (Fig. 5) and data stored on "Previsionelle Diagram Coupes" (refer to Appendix 2).

Mappable units have been named ER1 to ER7. These units were derived in an attempt to reflect depositional events rather than pure lithostratigraphy. The Previsionelle Diagram documents sedimentological data from which Lombard Curves can be derived (refer to Appendix 2). This additional parameter shows changes in the energy of the depositional environments, reflected by the granulometry of the sediments. Coupled with extensive strike walking, the data leads to recognition of broad changes in depositional environment, which in turn leads to map unit selection.

Detailed Previsionelle Diagrams are held by Dr. V. Gostin at the University of Adelaide, and by Utah Development Company. Fig. 5 is included as an example.

1.7.2 Definitions

Tidal zone terminology; "supratidal", "intertidal" and "subtidal" are used to reflect degrees of subaerial exposure, and do not necessarily imply regular diurnal tides and associated tidal currents.

The term "basinal" is used in this thesis as a general term to describe any subaqueous reducing environment below wave base.

Throughout the text and diagrams, "sandstone" is taken to mean a quartz rich arenite or quartz arenite of Folk (1974).

CHAPTER 2: RESTRICTED PHASE OF BURRA GROUP DEPOSITION

2.1 Introduction

Distribution of Burra Group sediments suggests that the Burra Group "Sea" was a number of linear basins and large areas of shallow water (Murrell, 1977). Mapping by Utah Development Company has shown that discrete sub- basins existed in the earlier phases of Burra Group deposition. The style and type of sedimentation in these sub-basins is distinct and therefore restricted (U.D.C. Report 371, 1979). However both Murrell (1977) and Utah Development Company recognise that the sedimentary event represented in the East Rooks area by ER4, is a basinwide phenomena. This chapter discusses the early restricted phase of Burra Group deposition represented by ER1 to 3.

2.2 Formation description of ER1

The basal clastic unit of the Burra Group develops a maximum thickness of approximately 600m near traverse 3, and thins southward to a thickness of 455m at traverse 2 (Fig. 6). The northern and southern faulted boundaries juxtapose ER1 with contorted and brecciated carbonates and shales of the Callana Beds. The base of the unit is a disconformity which has been discussed previously.

Lithologically, ER1 consists mainly of white arkoses and subarkoses which are variably calcareous. Rhomb shaped voids which are possibly after calcite occur on the bedding planes of some outcrops. Grainsize varies from coarse to fine sandsize, however medium sandsized grains appear dominant. Orthoclase and microcline are the common feldspar minerals, although kaolinization of albite is widespread, so it is difficult to estimate its original abundance. Orthoclase is frequently perthitic. Quartz grains are generally subrounded to rounded and exhibit undulose extinction. A granitic terrain would be a suitable source area for these sediments. Green micaceous shales and muscovite rich subarkoses are also present within ER1.

The unit exhibits a blanket style of sedimentation. High flow regime conditions, reflected by horizontally laminated sediments dominate the unit. A possible parting lineation is also noted in some outcrops. Simple graded bedding, indicating decreasing current flow and competancy is commonly associated with the laminated sediments (Reineck and Singh, 1973).

Lower flow regime features, which are less common, include planar and trough cross-sets. Isolated trough cross-sets occur, which are usually 10cm to 20cm in set thickness. They indicate a current direction to the south and southeast.

Beds rarely attain a thickness of over a few metres but may only be differentiated by thin layers of fine sand and silt which commonly show dessication features.

Superimposed on this sedimentary pattern are minor, heterolithic,fining upward associations of fine grained subarkoses, and green siltstones and shales, which together develop flaser, lenticular and wavy bedding (Plate 1). Bifurcating ripple marks which show a form discordant cross lamination are common in this interval and are wave induced (Reineck and Singh, 1973; De Raaf et al., 1977). Symmetric ripple forms are more frequently observed than either the commonly occurring flat topped ripples, or rarely occurring interference ripples.

Emergence and arid conditions are indicated by dessication mudcrack casts, which often show two generations of dessication (Plate 1) and by pseudomorphs of halite and possible gypsum.

2.3 Palaeoenvironmental interpretation of ER1

The dominant high energy theme of ER1, coupled with the arkosic nature of the sediments, suggests rapid deposition from a source area with high relief. Upper plane bed conditions are obtained in the distal reaches of an alluvial fan by flood flows which expand at the downstream ends of channels (Reading, 1978). Graded beds are consistent with a surge like flood of sediment and lack of subsequent reworking.

Low flow regime features such as large scale trough cross-lamination indicates megaripple migration, while planar cross-lamination is known to form by migration of sandy foreset bars. Both features are common in distal braided rivers and alluvial plains (Rust, 1978).

Tidal marine influence, although minor, is indicated by (i) wave ripple marks, (ii) interference ripples, (iii) flat topped ripples, (iv) flaser, lenticular and wavy bedding, and (v) dessication mudcracks and evaporite minerals indicating emergence.

The high and low flow regime features discussed are consistent with a distal alluvial fan and sandy fluvial braidplain, respectively. The evidence of minor tidal influence suggests that a fluvial braidplain is more probable, however if the coast was sufficiently steep, then distal alluvial fans may have passed into a marine environment without an alluvial plain developing. However further work is required to justify either conclusion definitively.

The southerly thinning of ER1 can be explained by a palaeohigh which is known to have affected sedimentation at this stratigraphic level further south (U.D.C. Report 308, 1978).

2.4 Formation description of ER2

The base of ER2 represents a change in depositional environment from a vigorous clastic depository to a relatively quiet marginal marine environment. It is characterized by a mixed chemical/terrigenous style of sedimentation. The unit attains a maximum thickness of 505m near traverse 3 (Fig. 6) and thins gradually to the south. The northern half is marked by numerous, northwest trending, strike-slip faults which displace bedding in an en echelon fashion. The northern boundary is defined by a fault, which extends right across the northern extent of the mapped area.

Lithotope 1 is a green weathering, calcareous silt-shale which is black and carbonaceous when fresh. It is finely laminated and exhibits large pyritohedron shaped voids up to 1cm in diameter. This lithotope varies in thickness from less then 1m to a maximum of 30m.

Lithotope 2 is represented by a medium to fine grained, texturally mature subarkose. This lithotope exhibits positive relief and can be used as a marker horizon within ER2. It is dominantly parallel laminated although 10cm high cross-sets were found in one location, demonstrating a current direction towards the south. No current lineations are evident. Wave ripple marks are common and are variable in orientation. Flat topped ripples are well developed in this lithotope (Plate 2).

Lithotope 3 is represented by platy, very fine to fine grained, dolomitic subarkoses and silt-shales. Minor cryptalgal dolomites, exhibiting teepees, are also observed in this lithotope (Plate 2). It attains a maximum thickness of 40m and has low landscape relief. Fine subarkoses occur as thin beds which usually show wave ripple marks, while the silt-shales commonly have dessication cracks. Discrete beds of fine subarkoses have well developed sand filled pseudomorphs after halite. Individual pseudomorphs are scattered over a rippled surface and develop cubic form with a maximum size of 1cm (Plate 2). Lithotope 3 also presents evidence of other evaporite minerals. On one horizon, a very fine grained, dolomitic subarkose has voids randomly placed through the rock. They express triangular and diamond shapes in thin section and are infilled with an equigranular mosaic of dolomite (Plate 3). Similar features have been described as dolomite pseudomorphs after gypsum (Tucker, 1976b). The diamond shaped pseudomorphs are commonly 1cm in length. The host rock exhibits no depositional features possibly due to disruption following gypsum growth. Closely associated is a bed of randomly oriented, indurated clasts of dolomitic siltstone forming an intraclast conglomerate. Clasts vary from coarse sandsized particles, to plates of 7cm in diameter. Any suggestion of transport, such as imbrication, cannot be demonstrated, hence in situ formation must be concluded. Proximity of evaporite minerals suggest they may be part of a collapse breccia. This results when beds containing evaporites are exposed to percolating meteoric waters of low salinity, which dissolve the soluble evaporite minerals, resulting in the collapse of overlying sediments into the weakened sediments below (James, 1977).

Lithotope 4 is represented by very fine grained, dolomite grainstone and finely crystalline dolomite. The base of these beds is usually a yellowy-white, very fine, dolomite grainstone. The dolomite grains have been transported although no current features are preserved. Recrystallization is minor suggesting that dolomite may be primary. Minor silica occurs as lenticules and nodules. The top of the lithotope is a dark, finely crystalline, laminated dolomite. Dessication features are apparent but not widespread possibly due to lack of preservation rather than original abundance.

A noteworthy feature of ER2 is the presence of silica nodules and geodes similar to those reported as pseudomorphs after anhydrite (Plate 4) (Chowns and Elkins, 1974; Tucker, 1976a and 1976b). These silica nodules have a rounded "cauliflower" exterior, which exhibits fine ridges radiating out from the centre of the nodule. In thin section, flamboyantly radiating quartz emanating from a finely crystalline core defines these nodules (Plate 4). Within the radiating quartz small inclusions exhibiting high birefringence, moderate relief and orthorhombic form are noted. These are possibly relict anhydrite inclusions. The quartz geodes have a drusy quartz infilling, which grades out into microcrystalline quartz forming the "rind" of the nodule. Relict anhydrite is trapped as inclusions within the microcrystalline quartz "rind". Anhydrite characteristically forms as nodules, consisting of uncemented crystal aggregates in which growth is maintained by the development of new crystals within the framework of earlier ones (Shearman, 1966). Growth is "explosive" and complex nodules form, exhibiting surface morphologies similar to those observed in the quartz geodes and nodules (Chowns and Elkins, 1974; Shearman, 1966) (Plate 4). Disruption of the laminated host carbonate and the lack of occluded grains of carbonate in the quartz suggests that the original crystals were displacive hence formed after sedimentation (Tucker, 1976b). Silica nodules appear on their own or concentrated as beds and laminae. The quartz geodes often appear coalesced and distorted, possibly due to explosive growth and subsequent interference with adjacent anhydrite nodules, or perhaps due to compaction after burial (Plate 4).

Lithotope 5 consists of a structureless, recrystallized dolomite which contains grains of silica and chlorite. The dolomite has a pitted and etched exterior and abundant voids which are infilled with calcite. Lithotope 4 and 5 grade into each other along strike.

2.5 Palaeoenvironmental interpretation of ER2

The lateral continuity of facies within ER2 suggests that palaeoshore approximated a north south trend during deposition of ER2. Mapping by Utah Development Company has demonstrated that a palaeohigh influenced sedimentation at this stratigraphic level further south so it is possible that deposition of ER2 occurred in a local basin (U.D.C. Report 308, 1978).

The limited number of facies changes within ER2 prevent a Markov chain analysis. However the data suggests that the following idealized shallowing upward sequence may be valid (refer to Fig. 3).

The subtidal zone is represented by Lithotope 1 and the subaqueously formed part of Lithotope 2. Lithotope 1 formed in a restricted basinal environment with deposition occurring from suspension. The association of horizontally laminated sediments and wave generated ripples suggests that Lithotope 2 was deposited from suspension, due to wave processes (Reineck and Singh, 1973).

The intertidal zone is represented, in part, by Lithotope 2 and by Lithotope 3. The evidence supporting intertidal sedimentation lies in the wave ripple marks, which show multidirectional current directions, indicative of very shallow water and flat topped ripples indicative of shallow water and emergence. Emergence is further indicated by dessication mudcracks and halite casts. The association of flaser and wavy bedding in this lithotope indicates an alternation of current bedload transport, with suspension deposition during slackwater periods, typical of intertidal flats. Tidal channels are not recognized within Lithotope 3. This could be due, however, to the fine grained nature of the intertidal zone. Tidal channels are not recognized on the tidal flats of the Colorado River Delta as the fine grained sediments cannot maintain channels. Currents move over the flats as broad uniform flows (Thompson in Ginsberg, Ed., 1975).

Lithotope 4 and 5 and the upper part of Lithotope 3 record the supratidal zone. Dessication features and the evidence of evaporite minerals suggests that a sabkha environment is applicable. A modern analogue of marginal marine evaporite sedimentation is the coastal sabkhas along the Abu Dhabi coast of the Persian Gulf (Shearman, 1966). Anhydrite forms diagenetically both as a primary mineral and by alteration of earlier formed gypsum crystals (Shearman, 1966; Kendall, 1979). Groundwaters which are marine derived with subsequent modification by continental sources progressively become more hypersaline due to evaporation. Dissolution of earlier formed evaporites also contribute to the concentration of the brines. As a result gypsum precipitates within the intertidal sediments, while anhydrite forms in the capillary zone of the supratidal sediments above the groundwater table (Evans et al., 1969). Collapse breccias are also noted on modern sabkha environments (James, 1977).

The close association of Lithotope 4 and 5 suggest that Lithotope 5 formed as a carbonate mud, which was probably exposed for long periods of time allowing soil forming processes to act. Freshwater percolating through the mud would dissolve carbonate, forming voids and assisting in recrystallization.

The proposed "ideal" sequence follows a carbonate, shallowing upward sequence with terrigenous input superimposed on it (James, 1977). In a normal sequence, an algal mat should dominate the intertidal zone (James, 1977). Algal mat and teepee structures have been noted within Lithotope 3 but are not common, so the introduction of fine grained terrigenous material onto the intertidal flat may have suppressed algal development. The Lithotope 2 sandsheet probably represents episodic influxes of sand into the basin, which were confined close to shore as a result of longshore currents.

The source of dolomite within ER2 is open to speculation. Bathurst (1975) suggests that groundwaters, which precipitate gypsum, become depleted in calcium, which boosts the Mg/Ca ratio to a level where it can dolomitize aragonite deposited on the supratidal zone. Alternatively "primary" dolomite has been observed in modern environments, often associated with sulphates (Von der Borch, 1965a and 1965b). Dolomite occurring within ER2 is very fine grained or recrystallized. No evidence of pre-existing calcite ghosts or any obvious indications of late stage secondary dolomitization occur (Sabins, 1962). Consequently a penecontemporaneous or "primary" formation is preferred although cannot be demonstrated.

Replaced evaporites are present in the Mt. Norwest region, within Burra Group sediments (Teakle, 1979, pers. comm.). However they are not widespread throughout the Burra Group which supports the proposition that the evaporite association within ER2 is a localized occurrence and that the East Rooks palaeobasin was quite restricted at this time.

2.6 Formation description of ER3

ER3 forms a wedge shaped unit varying in thickness from 239m at traverse 5 in the north to 650m at traverse 1 in the south (Fig. 5). The base of the unit marks a change from a chemical/terrigenous style of deposition to dominantly terrigenous, with minor carbonate development. Moderately rapid lateral facies changes occur along strike, which is in contrast to Unit ER2. ER3 will be discussed in terms of two subunits; ER3.1 and ER3.2 (Fig. 5).

ER3.1 consists of fine grained, texturally mature sandstones and subarkoses; green grey, laminated coarse siltstones and green to dark grey finely laminated shales as the dominant lithologies. The sandstones develop horizontally laminated, to wave ripple cross-laminated beds. Bifurcating symmetric and asymmetric wave ripples are common with interference ripples often observed. Finely laminated coarse silts develop a "hummocky" cross-lamination (Harms et al., 1975) which is attributed to wave action (De Raaf et al., 1977). Dessication mudcracks and ridge casts forming sinuous "figure 8" forms in the troughs of ripple marked sandstones are common (Plate 5). In the past these features have been given the generic name Manchuriophycus Endo, 1933. However a more realistic interpretation is that they formed due to synaerisis (Plummer and Gostin, in prep).

Green to dark grey carbonaceous shales are interbedded throughout the subunit and increase in frequency and thickness to the south. Clearly this indicates enlarged basinal conditions in this direction. The shales of subunit 3.1 are finely laminated and often show small scale soft sediment slumping.

Subordinate in occurrence are continuous, thin beds of coarse to fine grained sublitharenite. These conspicuously red brown beds contain well rounded and angular dolomicrite clasts which have been transported from elsewhere in the basin. Microcrystalline quartz grains are also included in a moderate to poorly sorted array of well rounded quartz grains, which develop undulose extinction. These discontinuous beds thicken abruptly into lenses which form en echelon on successive stratigraphic levels. The dominant depositional feature is an horizontal lamination, developed by poorly sorted medium to coarse grains within well sorted fine grains. Wave ripple marks and dessication mudcracks are developed on top of these beds. Stromatolitic dolomites commonly overlie this lithology with a gradational contact suggesting that the two formed in closely associated environments. The browny yellow dolomite exhibits black and red brown chert concretions along the cryptalgal lamination. If stromatolites do not appear, then a well sorted and well rounded coarse grained sandstone overlies the horizontally laminated sublitharenite. This lithology commonly shows moderately large scale ripple marks with a wavelength of approximately 0.5m.

Stromatolites also occur as isolated pods within fine grained rippled sandstones. On approximately the same stratigraphic level small lenticular, sand filled channels are observed.

The dominant sedimentary structures and their occurrence are summarized on Fig. 4. Horizontally laminated sediments are dominant in the southern and northern portions of the ER3.1 unit. Climbing ripples are associated with horizontally laminated sediments in some outcrops. The middle of ER3.1 exhibits significantly more wave ripple cross-lamination and dessication mudcracks. It is in this zone that stromatolites and sublitharenite beds are best developed.

The dominant cyclity shown in ER3.1 are shallowing up couplets of horizontally laminated fine feldspathic sandstones passing up into wave rippled sandstones which may also show mudcrack casts. Coarsening up sequences, from shales to horizontally laminated sandstones are also seen. Noteworthy are the basal black shales of ER3.1 which interfinger with sandstones in the south of the area.

Subunit 3.2 is more homogeneous in grainsize than 3.1 and consists of fine grained well sorted sandstones and subarkoses with some interbedded silty shales which increase in number and thickness to the south. Stromatolites are absent in this unit. The subarkoses contain up to 15% feldspar with potassium feldspar predominant over plagioclase feldspars. Some specimens show bimodal grainsize distribution.

The dominantly horizontally laminated sediments occasionally develop moderately large scale planar and trough cross-sets which indicate sediment movement from the north. Shallow water and emergent features such as symmetric wave ripples and mudcracks are observed in ER3.2 but are not as wide spread as in ER3.1.

2.7 Palaeoenvironmental interpretation of ER3

The thickening wedge shaped unit and the prograding nature of the beds is schematically demonstrated in Fig. 4. The horizontally laminated sublitharenites which form lens shaped bodies are interpreted as braided channels due to their lithoclast content and horizontal lamination indicating upper flow regime conditions. The increased frequency of interbedded black shales to the south indicates more offshore basinal conditions in that direction. Infrequent large scale cross lamination and climbing ripple lamination indicates a southerly offshore current direction.

The combination of the above mentioned features suggests that delta forming processes deposited Unit ER3.

The absence of any large accumulations of crossbedded sands or point bar sequences suggests major trunk streams and main distributary channels typical of most modern deltas, were not featured in the formation of the ER3 delta. McGowan (1971) demonstrated that sediment transport and dispersal on a fan delta occurs by sheetflood and shallow braided streams, with no main channel system being formed. This was the probable mechanism of sediment dispersal on the ER3 delta. The high proportion of horizontally laminated sediments is consistent with fan delta development. This forms by migration of longitudinal bars on the fan plain and by sheetwash on the distal fan (McGowan, 1971).

The thicker lenses of sublitharenite occurring in the lower parts of ER3, probably developed when the shallow braided streams were constrained into channels, after the water level in the basin dropped following a flood. Stromatolites which form in association with these channels may have formed in ponds formed after channel abandonment. Carbonate saturated fresh water would have filled these channels, allowing stromatolites to develop.

A large proportion of structures seen in ER3 are wave induced. Probable offshore bars forming at the base of ER3 also indicate that wave induced, destructional processes were active on parts of the delta. However the Burra Group "Sea" at this time was analogous to a shallow epeiric sea, hence wave influence should have been minimal, and thickening towards the source should occur (Visher et al., 1975).

However, a deeper basin existed to the south as shown by the thicker sequences of basinal shales in that direction. This may have formed locally due to tectonic instability and block faulting. Tectonic control of the basin is suggested by the "bend" in ER3 which appears to coincide with faulting in the middle of ER1 and 2. It also approximately coincides with the beginning of the basinal shales which predominate in the south. This synsedimentary tectonism would have caused sufficient depth of water to develop, allowing basinward thickening of sediments. With sufficient depth of water, storm and wind influenced waves could influence the deltaic sediments. Wopfner et al. (1970) has discussed tectonically induced deepening of sedimentary basins and development of offshore bars in the early Cretaceous epicontinental sea.

CHAPTER 3: WIDESPREAD PHASE OF BURRA GROUP DEPOSITION

3.1 Formation description of ER4

ER4 attains a thickness of 58m at traverse 5, in the north, (Fig. 5) and thickens slightly southwards. The unit defines a prominent valley, which divides the East Rooks area.

The base of the unit appears to be an erosional contact, suggested by the low angle discordance between the bedding of Unit ER3 and Unit ER4 (Fig. 4).

The dominent lithology is a finely laminated, blue grey to black carbonaceous, pyritic shale.

In the lower part of the unit, a stratigraphically confined sequence of interbedded dolomites occur. The weathered surface is dark brown and is studded with small euhedral plates of pennine. The dolomite is black when fresh and in thin section consists of 90% very finely crystalline dolomite, 7% pennine and 3% carbonaceous material. These dolomites form beds and lenticular bodies and show no internal structure.

3.2 Palaeoenvironmental interpretation of ER4

The finely laminated black shales of ER4 imply suspension settling in a reducing environment below wave base.

The dolomites formed in ER4 are distinctly different from other dolomites encountered in the study. As they show no internal structures, in situ formation is concluded. They appear to have formed as concretions within a reducing black shale environment. Weeks (1957) observed concretionary limestones in black shales and suggested that basinal muds are able to create enough local alkalinity to free calcium carbonate from solutions permeating the muds. The reason for the high Mg/Ca ratio sufficient for dolomitization remains a problem. Freidman (1972) reports that high magnesium calcite is forming in a basinal environment in the Red Sea due to degradation of sulphates, so the possibility of a sufficiently high Mg/Ca ratio developing in a basinal environment exists, although restricted access to the open marine environment is required.

ER4 represents a sudden reduction of sediment supply into the basin, with an accompanying transgression over the area, which reworked the top of ER3. Murrell (1977) reports that this unit is part of a basinwide phenomena.

3.3 Formation description of ER5

ER5 attains a thickness of 150m at traverse 5 (Fig. 5) in the northern part of the area, and gradually thickens to the south. The base of the unit is defined by an excellent coarsening upward sequence from the black shales of ER4.

Lithologically the base of ER5 consists of a yellow-white dominantly fine grained, well sorted subarkose. The dominant sedimentary feature is a heavy mineral defined, horizontal lamination. Minor small scale cross-lamination was also observed. A gradation occurs into sediments which can be divided into three lithologies: a sand lithotope, a heterolithic lithotope consisting of interbedded silts and sands, and a silt-shale lithotope.

The sand lithotope is horizontally laminated and wave ripple cross-laminated (Plate 6). Channel scours were observed in some outcrops (Plate 6). The heterolithic lithotope develops intercalations of fine grained, red-brown weathering, feldspathic and dolomitic sandstones and grey to brown finely laminated silts which together form flaser and wavy bedding. The thin intercalations of sandstone are commonly wave ripple cross-laminated. Symmetric wave ripples are dominant in ER5 however asymmetric, interference and flat topped ripples are also observed. Rill marks and possible foam marks are preserved in some outcrops.

3.4 Palaeoenvironmental interpretation of ER5

The well developed coarsening up sequence marking the transition from ER4 to ER5 implies prograding sand sheets into the basin. This coarsening up sequence may indicate a prograding offshore bar, barrier bar shoreface, or deltaic system. Palaeocurrent indicators are absent, however the well sorted nature of the sediments and the heavy mineral defined horizontal lamination indicates high energy conditions and reworking along a shoreface. However it could not be resolved if the horizontally laminated sediments were in fact low angle cross-laminated sands indicative of shoreface environments.

The overlying sequence presents fining up sequences which show good evidence of tidal flat development. The evidence includes (i) flaser, lenticular and wavy bedding, (ii) abundant wave ripple marks, interference ripple marks and flat topped ripples, (iii) rill marks, possible foam marks and probable mudcracks indicating subaerial emergence, and (iv) channel scours .

The scenario for ER5 is one of an initially broad sand sheet subject to by wave and current reworking with tidal flat development on the edges of the shallow marine basin.

3.5 Formation description of ER6

ER6 consists of laterally continuous beds of fine grained dolomitic subarkoses and sandstones with grey to black sandy shales and siltstones. This unit maintains a consistent thickness of approximately 200m along strike. The base of the unit is marked by the first brief appearance of dolomite and granule conglomerates. The sandstones are pyritic, variably dolomite and silica cemented and are generally moderately sorted with a weak grading evident in some outcrops. They are dominantly horizontally laminated with minor wave ripple cross-lamination developing. The shales occurring in ER6 vary from grey to black and are very carbonaceous. The heterolithic association of sandstones and shales typical of ER5 does not occur in this unit. Shales show shrinkage cracks but other features indicating emergence are absent.

3.6 Palaeoenvironmental interpretation of ER6

The paucity of sedimentary features in Unit ER6 coupled with the blanket style of sedimentation suggest widespread wave dominated conditions were operative during deposition. Palaeoshore cannot be defined. The interbedded sandstones and shales represent fluctuating periods of sand deposition and reworking into broad sand sheets followed by cessation of supply, which allowed silts to develop. Lack of associated emergent features suggests that shrinkage cracks observed in the shales are due to synaeresis.

It is probable that the fine grained horizontally laminated sandstones were deposited from suspension rather than from traction currents as cross-lamination is a minor feature.

3.7 Formation description of ER7

ER7 marks a depositional change in which carbonates become important in the system. It has a mixed chemical/terrigenous clastic format with terrigenous clasts predominating.

The marked cyclicity and rapidity of vertical facies changes is the characteristic feature of ER7. Individual beds are laterally continuous and lateral facies changes are minor. Five lithotopes can be recognized within ER7.

Lithotope 1 is a sandy, magnesite, dolomite conglomerate. Beds are usually less than 1m in thickness. The abundance of magnesite and dolomite clasts varies but coarse grained, well rounded quartz grains are always present. These have a frosted surface morphology which may be due to diagenetic reaction with dolomite. Frosting due to aeolian processes is unlikely due to the coarse grain size of the sand. Magnesite and dolomicrite clasts are well rounded and range in size from very coarse sand to granule size. This lithotope exhibits planar cross-sets, but more commonly is featureless in outcrop.

Lithotope 2 consists of wavy to parallel laminated, carbonaceous siltstones and shales. This lithotope has negative landscape relief and generally develops thicknesses of up to 5m.

Lithotope 3 is a fine grained dolomite cemented sandstone which forms prominant red brown ridges 5m to 15m in thickness. They usually exhibit wave induced ripple marks and are parallel laminated.

Lithotope 4 is a laminated sandy dolomite mudstone. However thin lenses containing intraclasts of finely laminated dolomite mudstone and creamy white magnesite commonly occur. Intraformational conglomerates form lenses within this lithotope (Plate 7). Sand content is variable and is matrix supported. Dessication mudcracks are evident but not widespread. The weathered outcrop is yellow and is dark grey when fresh due to the content of carbonaceous material. Beds are usually 3m to 5m in thickness.

Lithotope 5 is defined by a blue grey biostromal dolomite which has red and black chert along the cryptalgal laminations. Rare linked columnar stromatolites are developed in this lithotope. This lithotope is restricted to the base of ER7 and is not frequently developed.

3.8 Palaeoenvironmental interpretation of ER7

The rapid vertical facies changes are characteristic of shallow water carbonate sequences (James, 1977). The cyclicity developed suggests rapid changes in water level and sediment supply and possible tectonic influences (Uppill, 1979). The lateral continuity of individual beds and the minor, along strike facies changes reflect a low depositional slope (Preiss, 1973).

A suggested shallowing upward cycle is as follows. Lithotope 1 represents the initial transgression. It contains well rounded clasts reworked from underlying intertidal/supratidal sediments. Subsequently carbonaceous basinal sediments developed represented by Lithotope 2. This represents the maximum point of the transgression. Lithotope 3 represents a wave influenced subtidal sand sheet. No cross-lamination is evident in this lithotope, hence it is likely that the sand was deposited from suspension. Lithotope 4 represents the end of the shallowing upward cycle. Intertidal mudflats developed marginal to lagoons in which magnesite and dolomite precipitated. Emergence and dessication with subsequent erosion results in intraclasts being formed. Periodic flooding results in sheet conglomerates forming on the mudflats, which are now preserved as thin lenses in Lithotope 4 (Uppill, 1979) (Plate 7).

The infrequently occurring stromatolites in ER7 represents a low energy subtidal environment.

A noteworthy feature is the absence of "primary" magnesite beds which are common on the western side of the Willouran Ranges. This is related to the higher energy conditions prevailing in the northeastern basin during ER7 times as is evident by greater sand input in this area (Murrell, 1977).

The origin of magnesite and dolomite at this level in the Burra Group is discussed by Murrell (1977), and concludes that an evaporitive model involving an inland lake or sea, fed by magnesium carbonate bearing continental water would form dolomite, magnesite and aragonite as chemical sediments under evaporitive conditions.

The carbonates of ER7 contrast with those of ER2 in that no evidence of sulphates is found at this stratigraphic level.

3.9 Discussion of palaeohighs

Mapping in this study has demonstrated a disconformity which exists at the base of ER1. Units ER3, 4 and 5 thin to the north and overstep each other in that direction. ER3 demonstrates a change from basinal conditions in the south to more onshore conditions in the north. Furthermore, to the north of the study area, the Umberatana Group unconformably overlies the Callana Beds. Clearly this evidence suggests that Units ER1 to ER7 onlap a northern palaeohigh which defines the northern end of the East Rooks depositional basin. Stratigraphic evidence suggests that the palaeohigh may have been uplifted Callana Beds.

This evidence combined with the regional mapping by Utah Development Company suggests that the East Rooks depositional basin was restricted to a long narrow trough until ER4 time when uplands to the west became inundated by a more widespread Burra Group "Sea".

With this regional constraint a palaeogeographic synthesis can be undertaken.

CHAPTER 4: SUMMARY

Burra Group sedimentation in the study area began with an influx of sediments, probably derived from uplands to the north and west, which were deposited on distal alluvial fans or fluvial braid plains marginal to the restricted East Rooks basin.

As the basin progressively filled and shallowed sediment supply diminished and a tidal flat environment developed with a north-south trending palaeoshore. Pseudomorphs after possible gypsum, halite and anhydrite indicate the development of a sabkha type environment on the supratidal zone.

Synsedimentary tectonism subsequently led to deepening of the southern part of the basin into which a fan delta prograded from the north across the study area. Probable offshore sandbars indicate wave processes were active in the development of the delta.

A reduction in sediment supply and concomitant transgression led to basinal muds being deposited in a more widespread phase of Burra Group deposition. Subsequent to resumption of sediment supply, a prograding shoreline was reworked into a broad sandsheet with tidal flat development on the edges of the shallow marine basin.

The overlying interbedded sandstones and shales represent periodic influxes of sand reworked into broad sandsheets, and periods of minimal clastic input during which basinal muds developed.

The cyclity of sediments, which include dolomite and magnesite, in the final phase of deposition indicates rapidly changing water levels under shallow marine conditions.

Stratigraphic thinning and onlap to the north and associated facies changes indicate the dominating influence of a palaeohigh north of the study area, throughout deposition of the Burra Group.

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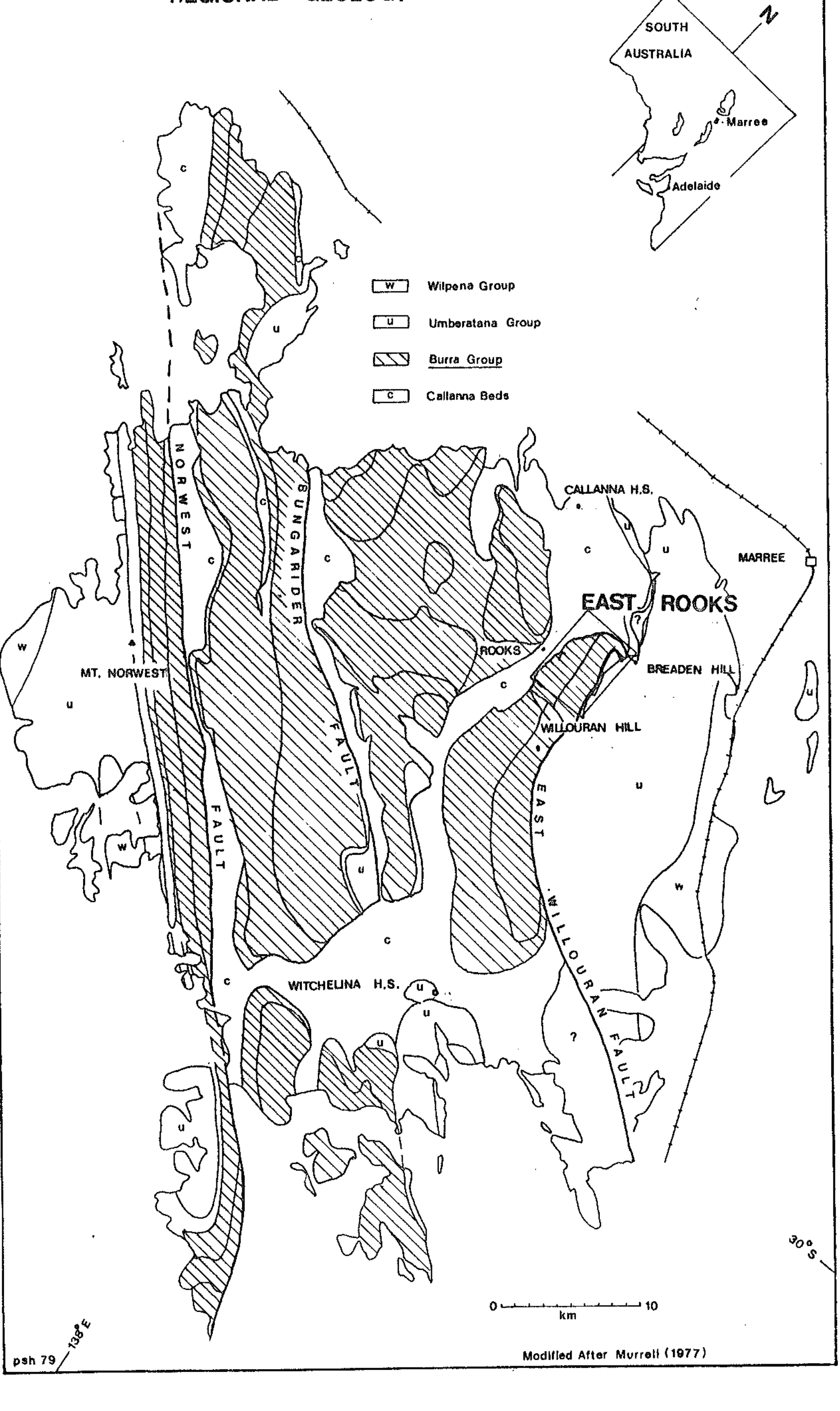
FIGURE 1 LOCATION MAP REGIONAL GEOLOGY



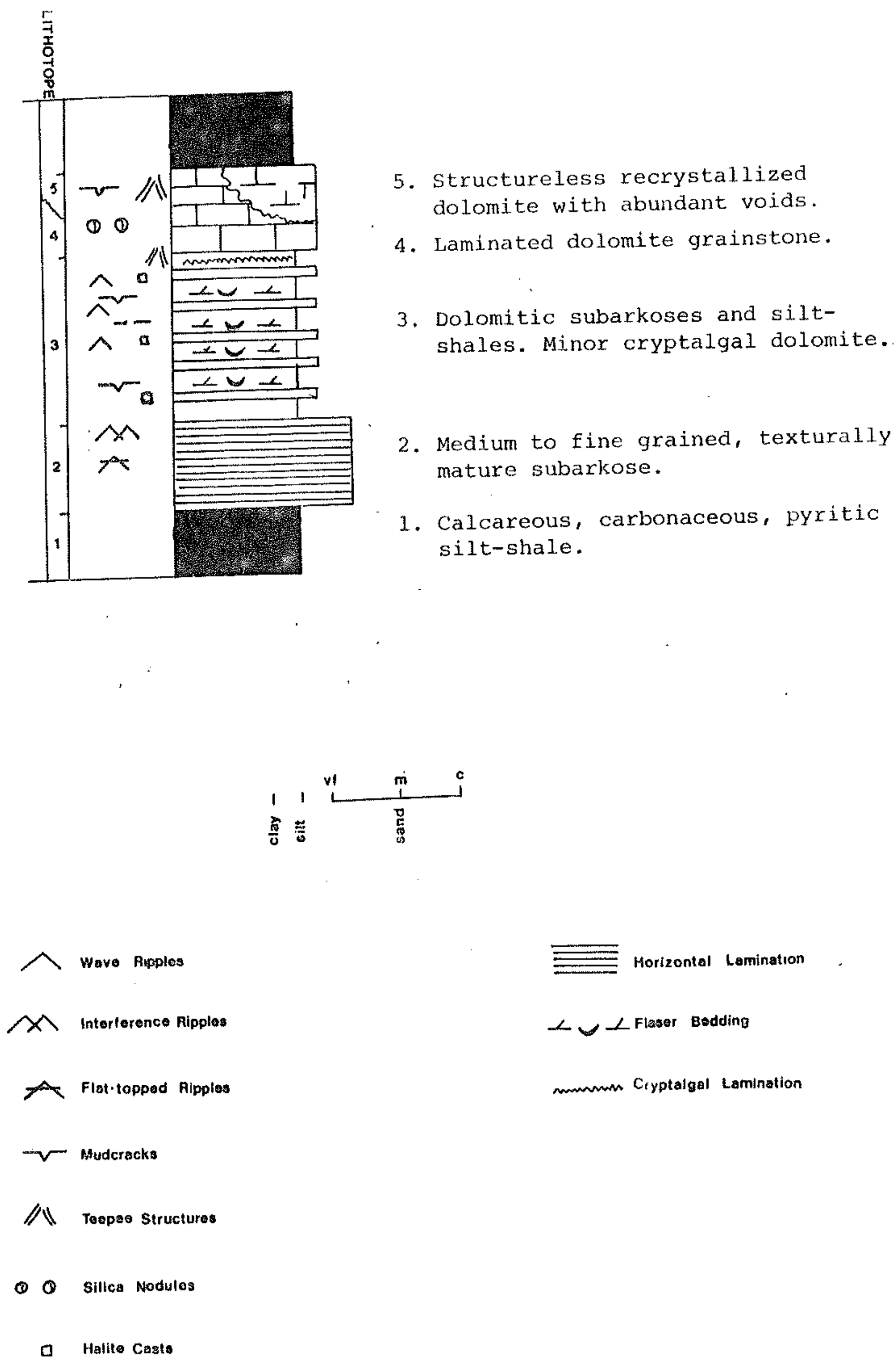
Modified After Murrell (1977)

FIGURE 2

<table>
<tr><th colspan="4">STRATIGRAPHIC CORRELATION</th></tr>
<tr><th>Utah Development Company (1979)</th><th colspan="2">Murrell (1977)</th><th>This Study</th></tr>
<tr><td rowspan="4">Skillogallee Dolomite</td><td rowspan="4">Skillogallee Subgroup</td><td rowspan="2">Mirra Formation</td><td>ER7</td></tr>
<tr><td>ER6</td></tr>
<tr><td>Tilterana Sandstone</td><td>ER5</td></tr>
<tr><td>Camel Flat Shale</td><td>ER4</td></tr>
<tr><td rowspan="4">Witchelina Quartzite</td><td rowspan="2">Witchelina Subgroup</td><td>Copley Quartzite</td><td>ER3.2</td></tr>
<tr><td>Top Mount Sandstone</td><td>ER3.1</td></tr>
<tr><td rowspan="3">Callanna Group</td><td rowspan="3">Dome Formation</td><td>ER2</td></tr>
<tr><td>ER1</td></tr>
<tr><td>Callanna Beds</td><td>Callanna Beds</td></tr>
</table>

FIGURE 3

'Idealised' Shallowing Upward Cycle for Unit ER 2



psh 79

PLATE 1

(a) Dessication mudcrack casts. The smaller casts within the larger polygonal casts indicate two generations of mudcracks.

(b) Heterolithic association of fine grained sub-arkose and green siltstone forming flaser, lenticular and wavy bedding.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PENTAX


ASAHI
PENTAX

PLATE 2

(a) Teepee structures in micritic cryptalgal dolomite occurring within ER2; Lithotope 3.

(b) Halite casts in a very fine grained dolomitic sandstone within ER2; Lithotope 3.

(c) Flat-topped ripples within ER2; Lithotope 2.


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PENTAX


0 1 2 3 4 5
cm


ASAHI
PENTAX

PLATE 3

(a) Diamond and triangular shaped voids after possible gypsum in a very fine grained dolomitic subarkose within ER2; Lithotope 3.

(b) Photomicrograph of lenticular and triangular shaped pseudomorphs after gypsum. They are in-filled with coarsely crystalline dolomite within a very fine grained dolomitic subarkose. (Width of photo: 8.6mm. Plane polarized light.)


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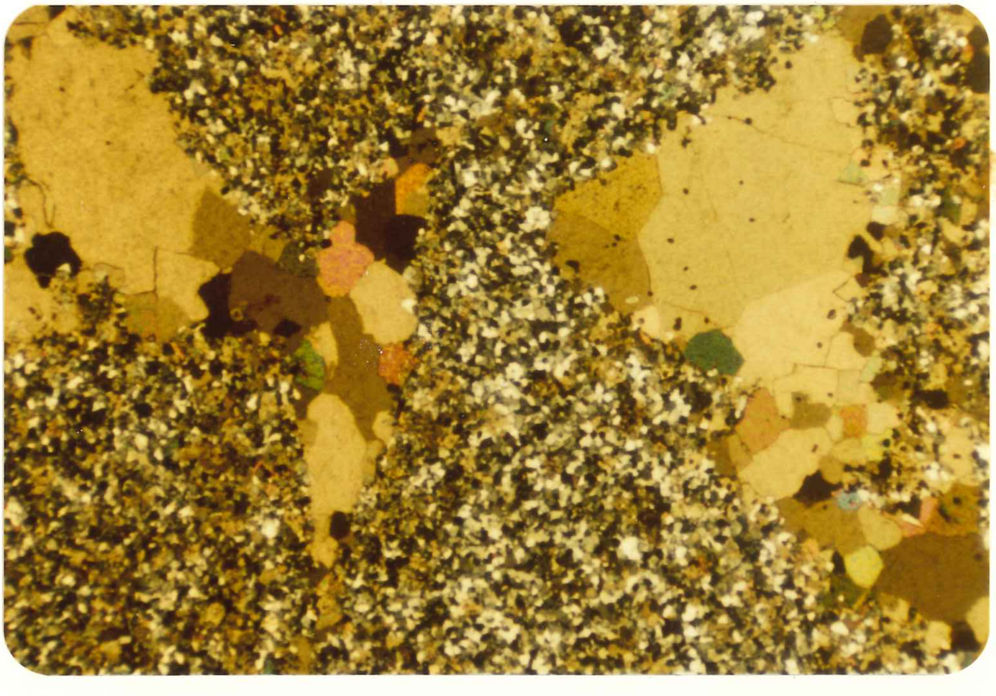

PLATE 4

(a) Coalesced quartz geodes within laminated dolomite. These are possible pseudomorphs after anhydrite. Note that the laminated dolomite is displaced about the geodes.

(b) Photomicrograph of a silica nodule exhibiting flamboyantly radiating quartz with a finely crystalline quartz core. Tabular inclusions which are possible relict anhydrite grains are included in the radiating quartz. (Width of photo: 8.6mm. Plane polarized light.)

(c) Silica nodules which are possibly after anhydrite, exhibiting a nodular "cauliflower" surface morphology. They occur within a laminated dolomite.


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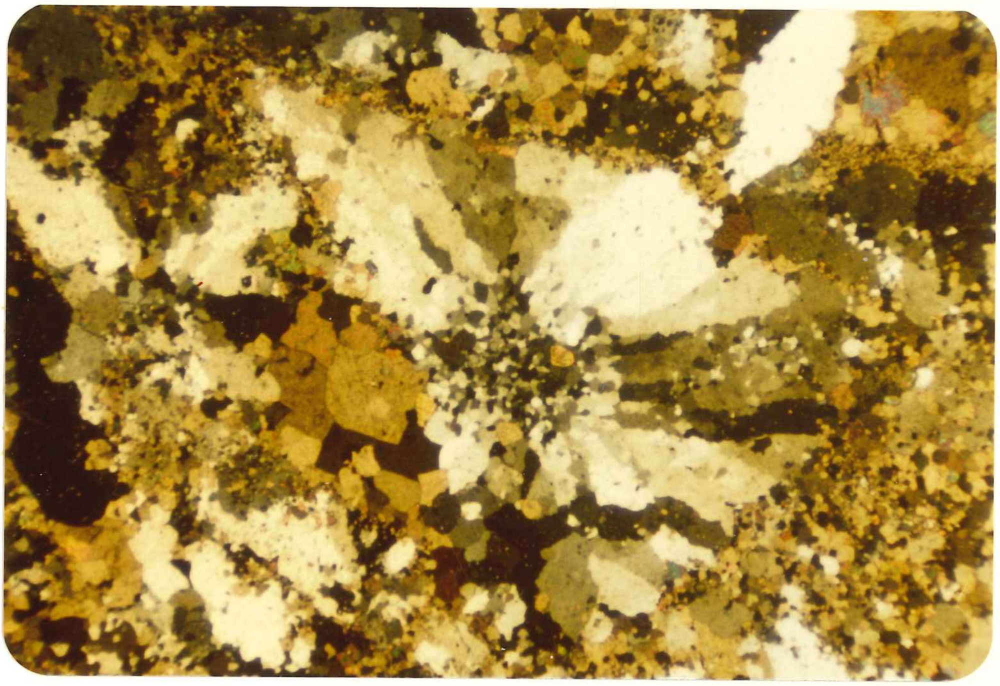


0 1 2 3 4 5
cm

PLATE 5

(a) Climbing ripples within Unit ER3.1.

(b) Symmetric wave ripple marks within Unit ER3.1.

(c) Sinuous "figure 8" casts occurring in ripple mark troughs within Unit ER3.1.

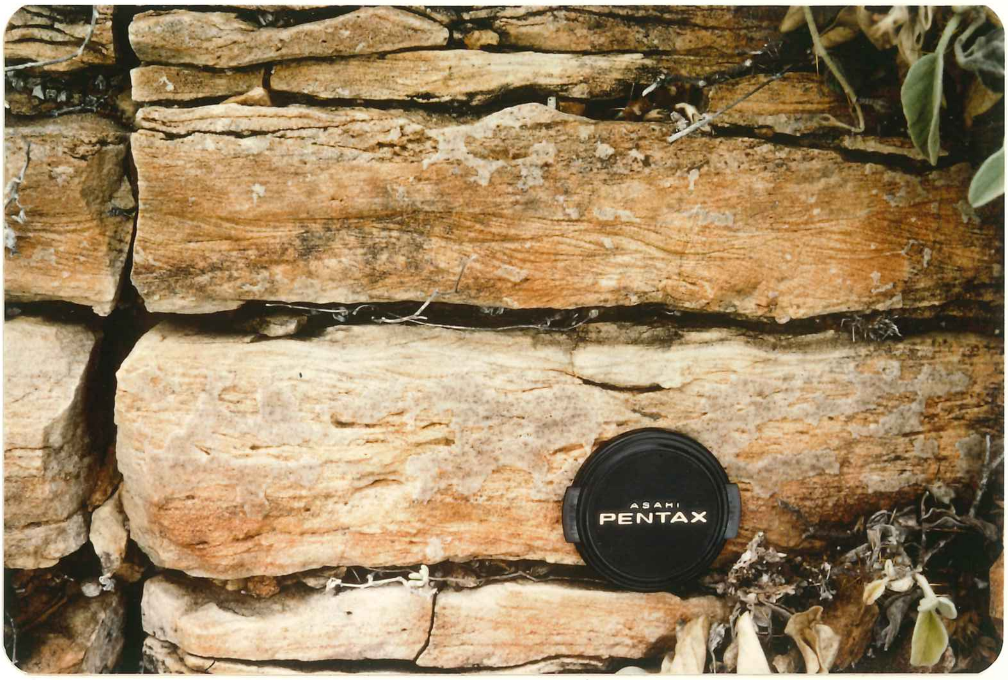
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PLATE 6

(a) Fining upward sequences within Unit ER5. A possible channel scour occurs in the left half of the photograph.

(b) Wave cross-laminated subarkose within Unit ER5. Note the chevron structure within the ripple crest (circled).


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PLATE 7

(a) Intraformational and magnesite conglomerates within a grey dolomite mudstone within ER7.

(b) Columnar stromatolites within Unit ER7.


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APPENDIX 1

THIN SECTION DESCRIPTIONS

A representative sample of thin sections examined are described here. Percentage compositions were determined by 10 visual estimates along a micrometer scale for each thin section.

Rock names after Folk (1974) are used where applicable.

In specimen numbers, A756 is the accession number for the University of Adelaide Tate Museum. The subsequent letters and numbers are grid coordinates (Fig. 6).

A756: A762/D065 ER1

Medium sandstone: silicified submature kaolinitic subarkose.

Macro: Horizontally laminated, orange yellow in outcrop. Laminations weather preferentially to give a ridged appearance to the rock. Coarser layers are kaolinitic.

Micro: Horizontal lamination is defined by grading from poorly sorted medium sand to well sorted fine sand. Poorly sorted layers exhibit voids from weathering of feldspar.

92% Quartz. Undulose and straight extinction. Semi-composite grains are minor. Subrounded to rounded grains which have sutured or concavo-convex grain boundaries.

7% Orthoclase. Commonly perthitic.

1% Albite, Microcline, Tourmaline.

A756: A510/C175   ER1

Very fine sandstone: mature silicified subarkose.

Macro: Brown tinged light grey. Homogeneous. Exhibits rhombic voids after calcite.

Micro: Angular quartz forming a close packed aggregate. Clots of muscovite and calcite occur. Calcite also appears interstitially.

80% Quartz. Undulose extinction dominant. Sutured and concavo-convex grain boundaries.
7% Microcline. Cross hatched twinning.
5% Orthoclase.
4% Albite.
3% Calcite.
1% Muscovite. Altering from potassium feldspar.

A756: A670/8070   ER1

<u>Fine sandstone</u>: silicified mature kaolinitic subarkose.

Macro: Weatered arkose. Parallel laminated.

Micro: Moderately sorted grains which are weakly bimodal. Muscovite grains sparsely disseminated.

85% Quartz. Straight and undulose extinction.
 9% Orthoclase. Commonly perthitic.
 5% Microcline. Crosshatched twinning.
 1% Albite.

A756: B464/E824D ER2

Macro: Quartz geode exhibiting distinctive cauliflower shape. It has a ridged and etched appearance. The geode is 1cm in diameter. The centre of the geode exhibits fine drusy quartz, some calcite and cubes of goethite. It is associated with yellow finely crystalline dolomite.

Micro: The centre of the cavity exhibits euhedral growth of straight extinguishing quartz. This grades into microcrystalline quartz forming the "rind" of the geode. Dolomite occurs as grains and as small euhedral rhombs throughout the quartz mosaic. Brown red euhedral grains of goethite occur around the perimeter of the centre of the geode. Inclusions of highly birefringent, possible relict anhydrite occurs within the quartz grains. Minor muscovite and chlorite occur within the dolomite.

60% Quartz. Euhedral and microcrystalline.
35% Dolomite.
5% Goethite.

A756: B430/E320 ER2

Macro: Silica nodule after anhydrite. Has nodular cauliflower shape. Silica exhibits radiating ridges from the centre of the nodule. The nodule is approximately 2cm in diameter and develops on the end of a lenticular mass of silica which appears to be coalesced smaller nodules. Where radiating ridges have not developed, small ridges and holes are randomly developed. It forms in association with a yellow finely crystalline dolomite. Dolomite is also included within the silica forming the nodule.

Micro: Coarse mosaic of straight extinguishing quartz which is inequigranular. This is superimposed by a coarser inequigranular mosaic of dolomite which is replacing some of the quartz as evident by inclusions of quartz within the dolomite. Dolomite has recrystallized to a certain degree as euhedral dolomite rhombs occur. Staining due to carbonaceous material is evident. Minor chlorite develops within the dolomite. Dolomite also appears along grain and subgrain boundaries within the quartz. Inclusions of highly birefringent anhydrite? occur as inclusions within quartz grains.

60% Quartz. Medium granoblastic texture.
40% Dolomite. Varying refractive index causing "twinkling"
Rhombohedral cleavage well developed.
Minor Chlorite.

A756: B480/E285   ER2

Very fine sandstone: silicified mature dolomitic subarkose.

Macro: Very fine grained dolomitic sandstone containing diamond and triangular shaped voids which have no preferred orientation through the specimen. This occurs in thin bedded horizons in association with dolomitic siltstones and very fine grained sandstones containing pseudomorphs after halite.

Micro: Dominantly very fine sand grains of angular quartz forming a mosaic with anhedral dolomite grains. Orthoclase microcline and to a lesser extent albite occur throughout. Scattered with random orientation are diamond and triangular shaped dolomite pseudomorphs after gypsum. Pseudomorphs are up to 15mm in length but commonly are less than 10mm. They are infilled with an equigranular mosaic of dolomite crystals. The non drusy fabric of the dolomite comprising the pseudomorphs seems to indicate in situ replacement rather than solution of the gypsum followed by dolomite precipitation into the mold.

72% Quartz. Angular. Very fine sand sized grains.
10% Microcline, Orthoclase. Abundant vacuoles occur in the orthoclase. Microcline exhibits typical crosshatched twinning.
15% Dolomite.
2% Albite.
1% Tourmaline.

A756: B430/E320 ER2

Macro: Pink yellow finely crystalline dolomite, containing small silica nodules exhibiting "anhydrite" rosettes, which occur within a discrete bedding interval, and disrupts the laminated dolomite bounding that interval. Voids rimmed with calcite occur. Surface features include small plates, ridges and small rosettes. Dolomite also appears coarsely crystalline within the interval.

Micro: Mosaic of coarse and finely crystalline dolomite and quartz. Quartz occurs as euhedral grains ans as circular clusters. Some quartz occurs as flamboyantly radiating quartz with undulose extinction eminating from a microcrystalline quartz core. Inclusions of possible anhydrite occur within the quartz grains, particularly in the radiating variety. Minor chlorite occurs within the dolomite.

44% Quartz.
55% Dolomite. Microcrystalline and coarsely crystalline.
1% Chlorite.

A756: B464/E824A ER2

Macro: Whitish yellow very fine grainstone exterior. Contains subordinate amounts of silica as nodules and recrystallized sand size grains. This lithology is not apparently laminated. It weathers to give a characteristic irregular etched surface.

Micro: Dolomite develops an aggregate of very fine sand to silt size grains. Recrystallization is not evident. Minor grains of silt size quartz occurs throughout the aggregate. Minor chlorite and muscovite occur within the dolomite suggesting some diagenesis. Silica accumulations which are roughly circular present undulose extinction and subgrain boundaries. These contain abundant inclusions some of which are dolomite. The dominant inclusion is highly birefringent tabular shaped and is possibly anhydrite. Minor opaques occur in contrast with the overlying lithology (B464/E824B).

90% Dolomite. Possibly detrital as no recrystallization is evident.
9% Quartz. Undulose extinction.
<1% Opaques, Chlorite, Muscovite.

A756: 8464/E824B ER2

Macro: Grey brown laminated medium crystalline dolomite. Exhibits a "sandy" exterior due to weathering. It is always associated with lenticules and nodules of silica. Quartz geodes with drusy quartz infills are typically developed in this lithology.

Micro: Fine to medium crystalline dolomite forming a subhedral mosaic. More coarsely crystalline dolomite occurs, possibly infilling voids. Euhedral grains of pyrite and limonite after pyrite and the carbonaceous material give the dark colour to this specimen. A certain amount of dolomite recrystallization has occurred as is evident by euhedral rhombic crystals. Highly birefringent tabular inclusions occur throughout the silica and are possibly anhydrite. Lathes of low birefringent chlorite occur within the dolomite.

85% Dolomite. Finely crystalline to medium crystalline.
10% Quartz. A mosaic with illdefined grain boundaries.
4% Opaques. Euhedral pyrite grains and diffuse carbonaceous material.
1% Chlorite.

A756: 8905/C360 ER3.1

Very fine sandstone: siliceous mature subarkose.

Macro: Irregular wavy fine laminae. Green grey in outcrop. Low relief in the landscape.

Micro: Very fine grains of angular quartz and feldspar forming a well sorted aggregate, with "stylolitic" traces of muscovite defining the lamination. Muscovite also appears disseminated through the thin section.

85% Quartz. Undulose extinction.
5% Orthoclase.
5% Muscovite.
3% Albite.
2% Opaques. Limonite staining dispersed through the slide.

A756: B785/C630A ER3.1

Very coarse sandstone: dolomite and silicified mature sublitharenite.

Macro: Forms bold red outcrop. Graded beds are a dominant feature and are differentiated by alternations of silicified and less silicified layers.

Micro: Well rounded grains of quartz and dolomite lithoclasts form a poroua assemblage with the cement being authigenic quartz with dolosparite replacing the quartz to varying degrees. Minor grains of well rounded microcrystalline quartz also appear.

79% Quartz. Composite grains.
10% Dolomicrite.
2% Feldspar.
9% Silica and dolosparite cement.

A756: C190/B925 ER3.2

1. Fine sandstone: siliceous bimodal mature feldspathic quartz arenite.

2. Siltstone: calcareous submature micaceous subarkose.

Macro: At outcrop scale, the planar cross laminated sandstone exhibits load structures into the underlying brown, fine siltstone which is featureless.

1. Micro: Exhibits bimodal grainsize distribution. Coarse well rounded grains "float" within fine sand size grains. Authigenic overgrowths occur on the coarser grains. Feldspar grains are subrounded.

91% Quartz.
9% Microcline.

2. Micro: Consists of fine to coarse silt size particles of quartz and iron stained calcite. Minor grains of muscovite occur throughout. Accessary opaques are disseminated throughout.

53% Quartz. Undulose extinction.
32% Calcite. Grains are very fine to coarse silt size. Some grains have euhedral form and have iron stained cores.
9% Opaques.
6% Alkali Feldspar. Very fine grained.

A756: C275/D250 ER4

Very finely crystalline carbonaceous dolomite

Macro: This forms lenticular shaped chocolate brown weathering dolomite in outcrop. Euhedral black chlorite flakes are scattered over the weathered surface and is structurally featureless.

Micro: Very finely crystalline dolomite with carbonaceous material dispersed throughout. Lathes of chlorite randomly oriented throughout.

91% Dolomite.
7% Chlorite. Pennine.
2% Carbonaceous material.

A756: C660/8760 ER5

<u>Fine sandstone</u>: silicified mature subarkose.

Macro: White, fine grained, exhibiting parallel lamination which is partially defined by heavy minerals. 1cm layer of medium to coarse poorly sorted feldspathic sandstone occurs within the specimen.

Micro: Well sorted mosaic of anhedral quartz and feldspar. Carbonaceous material is dispersed throughout in minor amounts. Coarser layer is poorly sorted and weakly bimodal. Tourmaline and zircon are the heavy minerals present. Minute grains of rutile are also noted.

85% Quartz. Angular fine grains. Coarse grains are subangular to subrounded and have undulose extinction.

10% Alkali Feldspar. Dominantly orthoclase and lesser microcline. Microcline is perthitic.

4% Albite. Commonly has inclusions of sericite due to alteration.

1% Chlorite and Muscovite, Tourmaline, Zircon and Rutile.

A756: C785/B775 ER5

Very fine sandstone: silicified mature dolomitic subarkose.

Macro: Red, fine grained sandstone.

Micro: An aggregate of well sorted, very fine grained sand size grains of quartz and feldspar. Anhedral dolomite also contributes to the mosaic. Tourmaline and sphene occur. Minor amounts of muscovite dispersed throughout. Albite occurs, containing alteration sericite blebs.

76% Quartz. Very fine grained, angular to subangular.
15% Dolomite. Medium crystalline grains, subhedral to anhedral.
4% Orthoclase. Contains abundant vacuoles. Subhedral to euhedral grains.
3% Albite. Blebs of sericite within the grains.
1% Tourmaline. Green pleochroic.
<1% Muscovite and Sphene.

A756: C605/D805A ER6

Fine sandstone: siliceous mature dolomitic subarkose.

Macro: Grey siliceous, slightly dolomitic and is horizontally laminated to featureless in outcrop.

Micro: Moderately sorted and weak grading evident. Grains are angular to subangular. Dolomite appears as interstitial cement. A possible doloclast occurs within the thin section. Euhedral pyrite occurs throughout as does graphitic material. Minor low birefringent chlorite occurs associated with the carbonate.

79% Quartz. Sutured and concavoconvex grain boundaries. Grains exhibit undulose and straight extinction.
10% Dolomite. Medium crystalline.
5% Microcline and Orthoclase. Microcline exhibits well developed crosshatched twinning, and is the dominant alkali feldspar. Grains are anhedral.
3% Albite and untwinned Plagioclase. Commonly shows minute sericite blebs due to alteration.
3% Opaques. Euhedral authigenic pyrite and carbonaceous material.

A756: C605/D805B ER6

Sandy silt-shale: silicified immature subarkose.

Macro: Grey black featureless to finely laminated shale. Exhibits shrinkage cracks.

Micro: Fine sand to silt size quartz enveloped by sericite. Euhedral pyrite grains sparsely scattered throughout.

62% Quartz. Dominantly silt sized, angular.
30% Sericite.
7% Alkali Feldspar.
1% Opaques.
1% Albite.

A756: C420/F490 ER7

Sandy magnesite dolomite conglomerate.

Macro: Rounded grains of quartz and clasts of dolomite and magnesite forming a grain supported conglomerate. The outcrop weathers dark grey to brown with coarse grains of well rounded quartz on the surface, which have a frosted appearance.

Micro: Rounded dolomicrite clasts with fine sericite flakes dispersed in the clasts. Magnesite clasts are rounded. They occur within a sparry dolomite cement. Quartz grains are generally equant and well rounded. Carbonate clasts are very coarse sand size while quartz is coarse sand size.

35% Dolomicrite. Carbonaceous.
30% Magnesite.
25% Quartz.
10% Dolomite. Cement.

A756: C470/F610 ER7

<u>Fine sandstone:</u> dolomitic submature quartz arenite.

Macro: Dark grey with black specks. Minor limonite after pyrite.

Micro: Fine to very fine sand size grains which are moderately sorted within a dolomite cement.

75% Quartz. Generally subangular with straight to slightly undulose extinction.

19% Dolomite. Occurs as detrital grains and as interstitial cement.

6% Opaques. Limonite after pyrite.

1% Albite, Chlorite.

APPENDIX 2

VERTICAL PROFILE ANALYSIS.

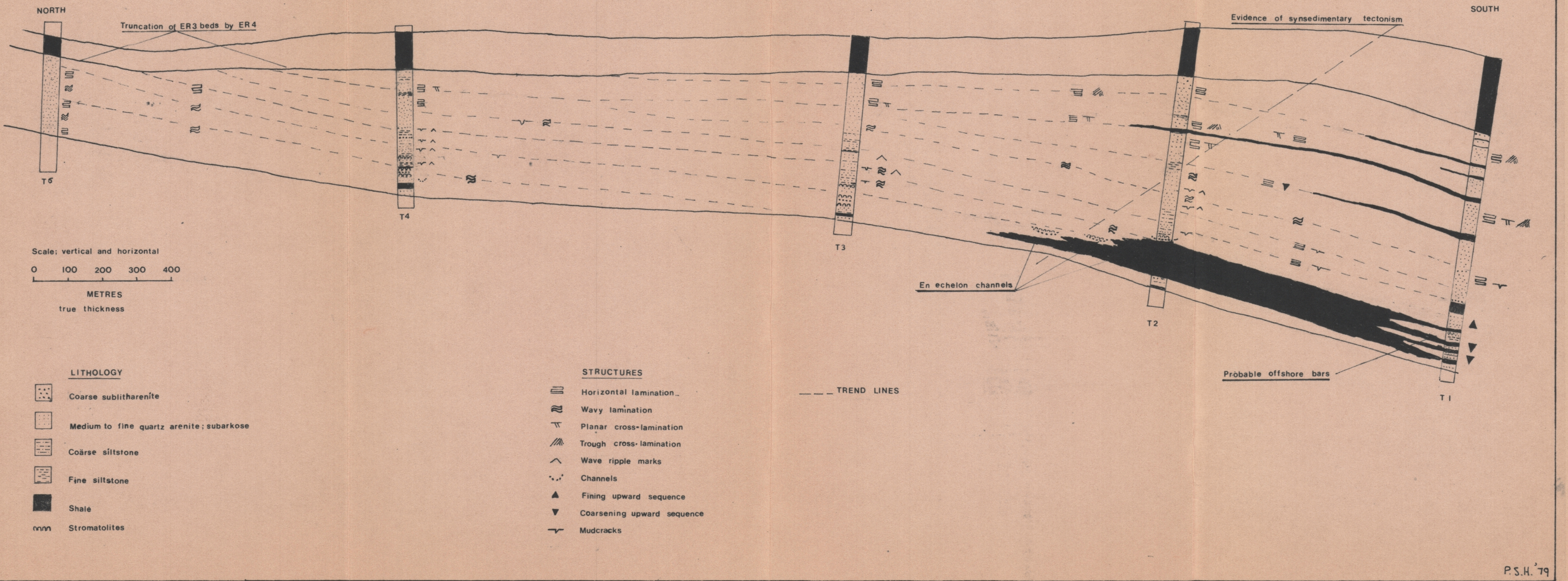
This study utilized a vertical profile analysis method inspired by Lombard (1972) which is used as an exploration tool by Utah Development Company.

Method: A "local"Standard Sequence" is constructed for the area. This is a general list of rock types which cover those encountered in the study area. These are listed in decreasing order of grainsize and are assigned numbers accordingly. When logging sedimentological data on a vertical profile, each rock type is assigned a Lombard number. Sedimentological data is plotted on a Previsionelle Coupe and Lombard numbers are plotted to form a Lombard Curve. Together this forms a Previsionelle Diagram. Similarly a standard set of environments of deposition can be determined, with each rock type assigned to a depositional environment number. Consequently an environment curve can be derived as an additional parameter.

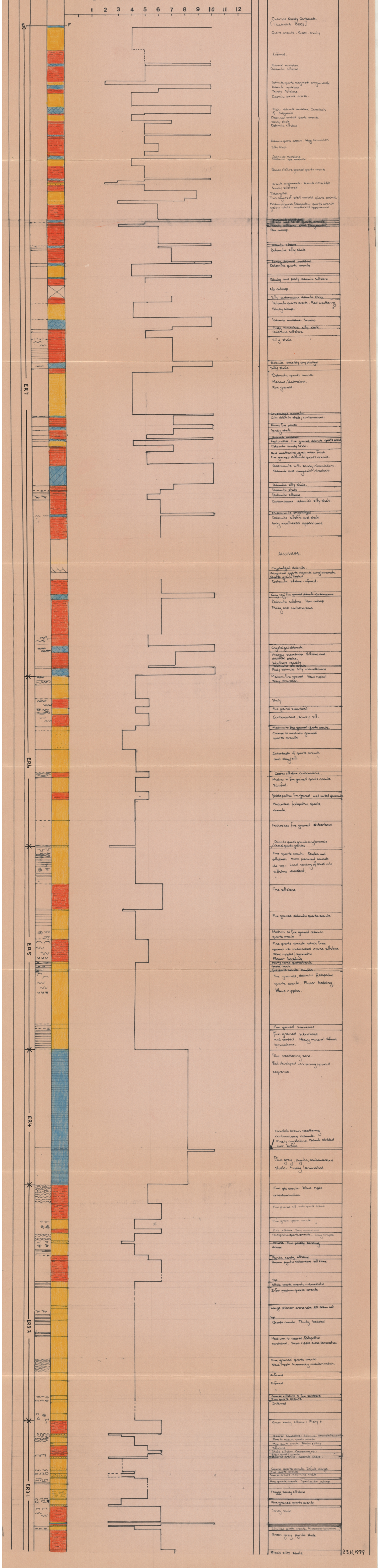
Lombard Curves are a method of identifying sedimentary cyclicity from perspective of the energy that prevailed when the depositional units were being formed. The energy curve is quantified by the granulometry of the sediments.

Construction of a Lombard Curve for a given vertical sequence aids in recognition of palaeoenergy domains, which in turn aids subclassification of sedimentary environments. It also gives an additional parameter in recognizing sedimentary cyclicity. This curve also lends itself to mathematical processing.

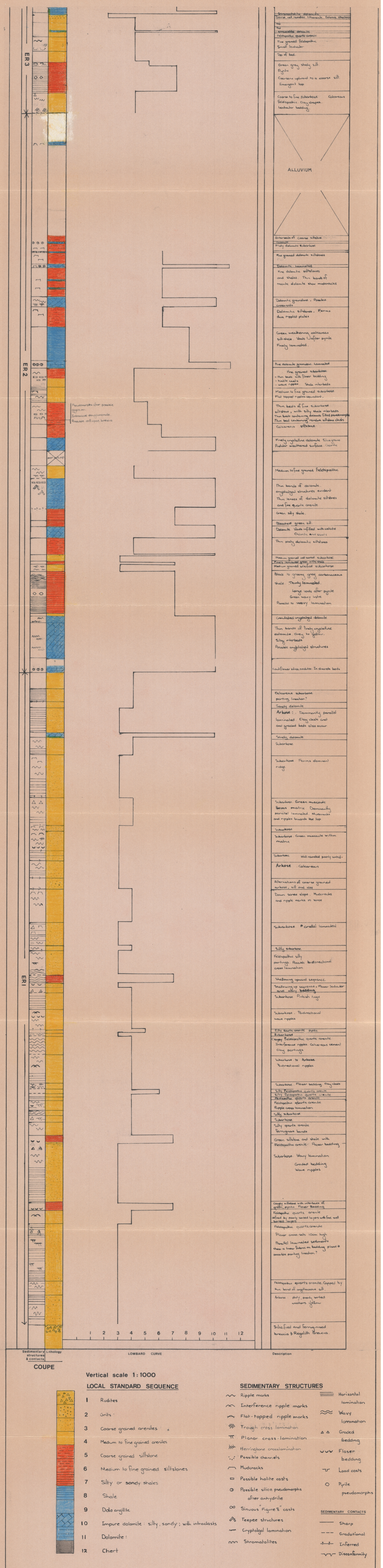
FIG. 4 Detailed structure of stratigraphic Unit ER3



Traverse 4



1 2 3 4 5 6 7 8 9 10 11 12
ER7
ER6
ER5
ER4
ER3.2
ER3.1
ALLUVIUM
P.S.H. 1979



Previsionelle Diagram

FIGURE 5

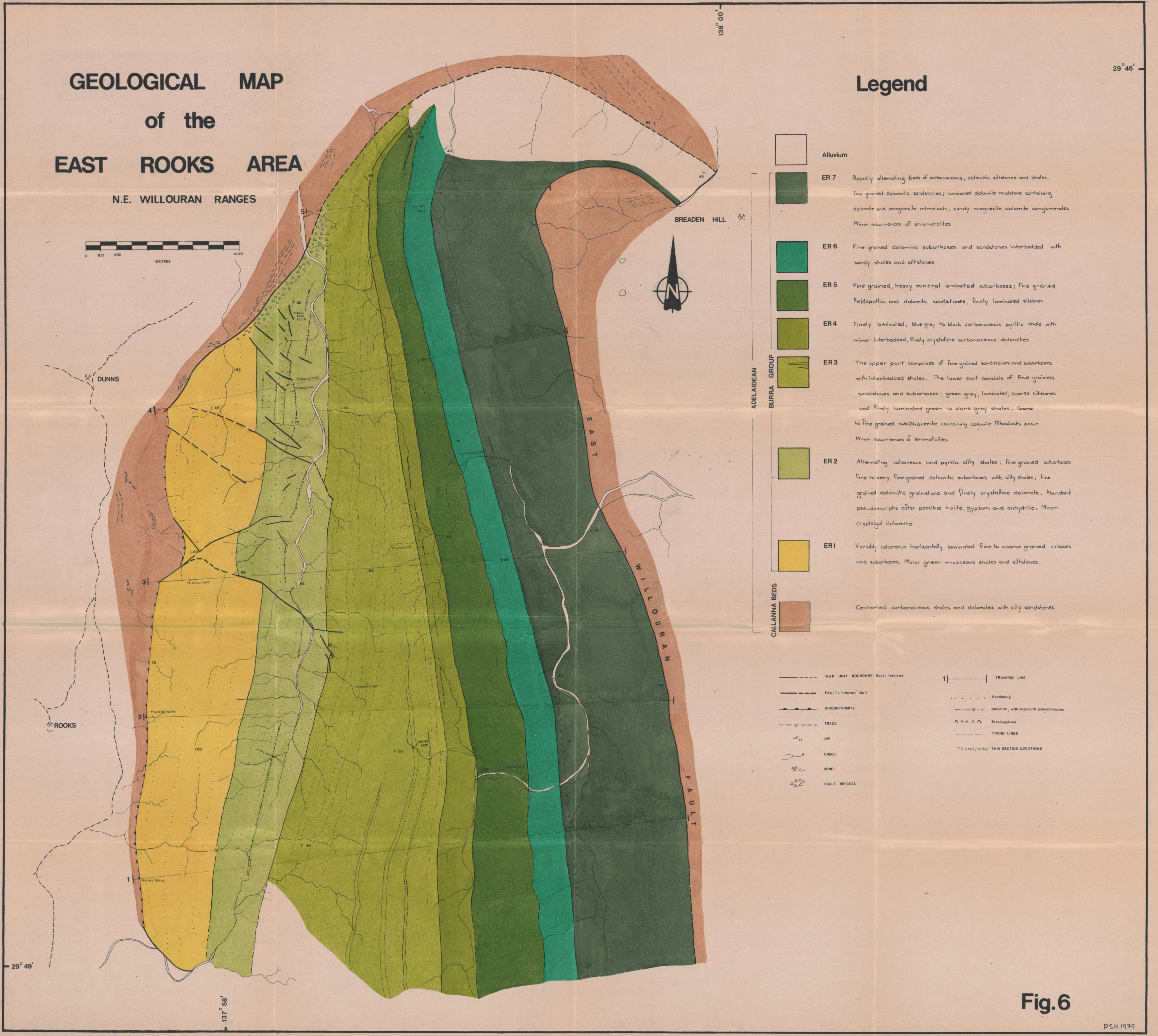

GEOLOGICAL MAP
of the
EAST ROOKS AREA
N.E. WILLOURAN RANGES
0 100 200 1000
METRES
Legend
Alluvium
ER 7 Rapidly alternating beds of carbonaceous, dolomitic siltstones and shales, fine grained dolomitic sandstones; laminated dolomite mudstone containing dolomite and magnesite intraclasts; sandy magnesite, dolomite conglomerates. Minor occurrences of stromatolites
ER 6 Fine grained dolomitic subarkoses and sandstones interbedded with sandy shales and siltstones
ER 5 Fine grained, heavy mineral laminated subarkoses; fine grained feldspathic and dolomitic sandstones; finely laminated siltstones
ER 4 Finely laminated, blue grey to black carbonaceous pyritic shale with minor interbedded, finely crystalline carbonaceous dolomites
ER 3 The upper part comprises of fine grained sandstones and subarkoses with interbedded shales. The lower part consists of fine grained sandstones and subarkoses; green grey, laminated, coarse siltstones and finely laminated green to dark grey shales. Coarse to fine grained sublitharenite containing dolomite lithoclasts occur. Minor occurrences of stromatolites
ER 2 Alternating calcareous and pyritic silty shales; fine grained subarkoses fine to very fine grained dolomitic subarkoses with silty shales, fine grained dolomitic grainstone and finely crystalline dolomite. Abundant pseudomorphs after possible halite, gypsum and anhydrite. Minor cryptalgal dolomite.
ER 1 Variably calcareous horizontally laminated fine to coarse grained arkoses and subarkoses. Minor green micaceous shales and siltstones.
Contorted carbonaceous shales and dolomites with silty sandstones
ADELAIDEAN
BURRA GROUP
CALLANNA BEDS
MAP UNIT BOUNDARY; Real; Inferred
FAULT: Inferred fault
DISCONFORMITY
TRACK
DIP
CREEK
MINE
FAULT BRECCIA
TRAVERSE LINE
Sandstone
Dolomite; with evaporite pseudomorphs
Stromatolites
TREND LINES
TS C785/B760 THIN SECTION LOCATIONS
BREADEN HILL
DUNNS
ROOKS
EAST WILLOURAN FAULT
138° 00'
29° 46'
29° 49'
137° 58'
PSH 1979

Fig.6