McArthur Basin

Revised sub-division and regional correlations of the McArthur Basin succession based on NABRE's 1995-8 sequence stratigraphic studies

M.J.Jackson, P.N.Southgate, P.R.Winefield, K.Barnett & I.Zeilinger

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INTRODUCTION

This report contains the results of stratigraphic research undertaken between 1995-98 by members of the North Australian Basins Resource Evaluation (NABRE) Project in the area northwest of the Murphy Inlier (**Fig 1**) – hereafter referred to by the general term 'McArthur River Region'. Complementary CD's are also available for the area southeast of the Inlier, and cover the region between Lawn Hill and Mount Isa (Bradshaw & Scott, 1999; Krassay et al., 1999; Southgate et al., 1999). An associated report (Tarlowski & Scott, 1999) covering geophysical investigations of North Central Australia, deals with the full NABRE area and also presents crustal models and a basement template for these Proterozoic successions (**Location Map**).

One of the main aims of the NABRE project was to develop a predictive framework for Proterozoic basin evolution in northern Australia to assist in building geological models for mineral exploration (Southgate et al., 2000a). Consequently, one of the initial tasks was to review and update the stratigraphic subdivisions and correlations between the various sedimentary successions that crop out in the Mount Isa – Lawn Hill – McArthur River regions. As explained later, this was done using a sequence stratigraphic (ie chronostratigraphic) rather than a lithostratigraphic (ie mainly descriptive) approach. It was supported and controlled by new U-Pb SHRIMP dating (Page et al., 2000) and palaeomagnetic studies (Idnurm, 2000).

The NABRE studies in the Lawn Hill area were significantly upgraded with the results of a re-interpretation of a 1986-91 COMALCO grid of reflection seismic lines. This sub-surface control facilitated integration of the drillhole and measured section data and produced a better-constrained 3D-interpretation (Bradshaw & Scott, 1999). Unfortunately, an extensive seismic grid is not available in the area covered by this report, but our interpretations have been guided by the regional implications from the Lawn Hill interpretation. Lindsay (1998) provides an interpretation of the stratigraphy and structure of a small grid of 1989 AMOCO seismic lines in the Broadmere area (Bauhinia Shelf) in the west of the area covered by this report (**Fig 1**). The reflection seismic lines provide reasonably good definition for the Roper Group part of the section, but the underlying successions are not well imaged and the ideas presented by Lindsay (1998) for McArthur Group equivalents are essentially unconstrained.

The results presented herein, for the southern McArthur River Region, represent largely a two-dimensional re-description and interpretation of the rock succession and, therefore, should be considered as the first stage of a revision of the basin's history and not the final answer. Even so, this re-packaging and new correlations have the potential to markedly alter ideas on how the basin evolved, which will influence theories and models of fluid flow and base metal mineralisation.

Terminology and classifications used

The term 'McArthur River Region' refers to the area within which the NABRE field research was undertaken between 1995-98 (**Fig 1**). It is similar, but not as extensive, as the area described in BMR Bulletin 220 (Jackson et al., 1987). The McArthur River Region is located at the southeastern extremity of the McArthur Basin and contains the best-exposed sequences. Sections were measured between the Bukalara Range in the southeast (lat 17^{o} 00'S long 136^{o} 30'E) and the Limmen Bight River in the northwest (lat 15^{o} 30'S long 135^{o} 30'E). Locality names are few and far between, and where these are lacking specific parts of the study area are often referred to the geological map sheet area within which they are located. Names of 1:250 000 map sheets are shown in large capitals (eg BAUHINIA DOWNS), whilst names of 1:100 000 map sheets are shown in italicised capitals (eg *BATTEN*).

The lithostratigraphic scheme for the McArthur Basin succession used throughout this report (**Fig 2**) is a slightly modified version of that published in Jackson et al., (1987, Fig 4). The latter was based on mapping mostly in the southern half of BAUHINIA DOWNS area. It incorporates the minor revisions suggested by Pietsch et al., (1991a & b) and Haines et al., (1993) from mapping in northern BAUHINIA DOWNS and MOUNT YOUNG, respectively, and also revisions in the middle part of the Tawallah Group described by Jackson et al. (2000a). Additional lithostratigraphic names for equivalent strata to the northwest are contained in Rawlings et al., (1997) and Abbott and Sweet (2000). Most rock unit names are formal lithostratigraphic names defined according to the Australian Stratigraphic Code (Staines, 1985). However, within the NABRE project we are developing a related, but different, sequence stratigraphic scheme, which is explained in more detail below. Rawlings (1999) has recently presented a new, large-scale, tectonostratigraphic-packaging scheme for the whole of the McArthur Basin, based on amalgamating laterally correlative lithostratigraphic units. Comments on how this relates to the NABRE sequence stratigraphic scheme are presented in the appropriate sections in this Record.

The classification of rock types, bedding, and sedimentary structures generally follows that illustrated in Jackson et al., (1987, Fig 6). Sandstone classification is that recommended by Pettijohn et al., (1972, p 155-160); bedding terminology is after Reineck and Singh (1975, p 82-84); and cross-stratification terminology follows McKee and Weir (1953). The classification and naming of carbonate rock types is essentially a field classification, in which the basic grouping is related to grainsize. For example, dololutite is composed of silt to clay-size dolomite, dolarenite of sand-size dolomite, and dolorudite of grains and clasts larger than 2mm. These names are then qualified by adding suitable adjectives or prefixes, usually referring to compositional or textural characteristics; for example, well-sorted, intraclastic, medium-grained oolitic dolarenite. Dolostone is the general term for a rock composed mainly of the mineral dolomite. It is commonly used where textures and structures are lacking, usually due to alteration, so that the more descriptive terms explained above could not be used. Geochemical studies of carbonates in the McArthur Basin (eg Brown et al., 1969, Large et al., 1998) have shown that almost all of the carbonates consist of dolomite.

There is a lithological legend accompanying the GEOLOG plots of measured sections and drillholes (**Table 1**). This shows the grainsize and compositional scheme used to describe the rock types identified throughout the whole of the NABRE Project study area; consequently some of these may not actually occur in the McArthur River Region. The GEOLOG plots (**Table 2**) also contain sedimentary structures.

PREVIOUS STRATIGRAPHIC WORK

Jackson et al., (1987) provide a review of government geological survey and company exploration work in the southern McArthur Basin from the first geological observations made in the later part of the 19th century up to about 1980. The Northern Territory Geological Survey issued a set of unpublished reports in 1989 called the *Exploration Series* for some of the 1:250,000 and 1:100,000 scale Map Sheet areas from the McArthur River Region. These provide details of all the known geological, geochemical, geophysical and drilling activities undertaken in these areas up to 1989 (Rawlings 1989 a,b,c,d and e). The reader is referred to these references for details.

The systematic mapping on 1:25,000 scale colour air photos and the associated sedimentological research undertaken by the BMR and NTGS teams between 1977 and 1990, provided the basis for our understanding of the stratigraphy at the start of the NABRE Project. This information was published in four Explanatory Notes (Pietsch et al., 1991a and b; Haines et al., 1993; Rawlings et al., 1993) and BMR Bulletin 220 (Jackson et al., 1987). Jackson et al., (1988) provide additional stratigraphic information on the McArthur and Roper Groups based on a program of research into Proterozoic oil in the basin. More recently, geoscientists at the Centre for Ore Deposit and Exploration Studies at the University of Tasmania have carried out extensive research in the Mount Isa to McArthur River area (1991 to the present). This includes geological, geophysical and geochemical work. Most of this work has been done as part of an industry-sponsored AMIRA Project and hence is not publicly available until after a certain period of confidentiality has elapsed. However, some of the earlier results from this work have recently been published (eg Leaman, 1998; Bull, 1998; Davidson 1998 and Large et al., 1998), and are referred to in this report.

Lithostratigraphy

An illustration of the pre-NABRE lithostratigraphic scheme is included here (**Fig 2**) as it forms the framework around which the NABRE Project sequence stratigraphic scheme has evolved. For reference, the lithostratigraphic names are also shown on the GEOLOG plots of the individual measured sections and drillholes.

The succession in the southern McArthur Basin has a cumulative thickness of around 12,000m. This has been arranged into about 40 formations, each a few tens to a few hundreds of meters thick, which have then been associated into four major groupings – Tawallah, McArthur, Nathan and Roper Groups. These groups are shown as being separated by major unconformities of regional significance (**Fig 2**). Our new work suggests that the significance of the unconformity shown separating the McArthur and Nathan Groups requires revision (see later). Most of the formations are lithologically uniform and can be traced laterally through the outcrop belt for many tens of kilometres in their respective stratigraphic positions. A few of these named formations are lateral equivalents - for example, the Westmoreland Conglomerate from the southeast is equated with the Yiyintyi Sandstone in the north. Some formations show subtle lateral variations and this information can be used in palaeogeographic reconstructions. Rare formations, for example the Barney Creek Formation, show rapid lateral facies changes related to syn-sedimentary tectonism. In general, however, the stratigraphy has been seen mostly as "layer-cake" in character, with much of the sedimentation within the respective groups as being thought of as more-or-less continuous and conformable. This impression was further strengthened in the early 90's, during NTGS-AGSO mapping in Arnhem Land some 400 kms north of this area, where remarkably similar lithofacies have been identified in several units at the equivalent stratigraphic level. (eg Haines, 1994). For example, the McCaw Formation, near the top of the Katherine River Group, in the MT MARUMBA Sheet area (Sweet et al., pers. comm. 12.5.1999) contains several distinctive carbonate lithofacies that are diagnostic of the Wollogorang Formation (Tawallah Group) from this area.

The new U-Pb SHRIMP dating and the NABRE sequence stratigraphic approach described in this report markedly refines, and in places, significantly changes the stratigraphic framework. The main changes identified are (1) the punctuated nature of sedimentation, (2) the presence of significant stratigraphic breaks at previously unsuspected levels, and (3) the presence of more widespread deeper water (probably marine) environments. An example of (2) is a previously unrecognised erosion surface in the Masterton Sandstone, at its type section, which probably has about 25 Ma of missing rock record. An example of (3) is the Balbirini Dolomite that is now interpreted to contain thick intervals of storm-deposited, mid shelf facies and thin intervals deposited beyond the reach of storms. Previous interpretations of the Balbirini Dolomite (Jackson et al., 1987; Muir, 1983; Walter et al., 1988.) favoured very shallow water, lacustrine and lagoonal environments.

Depositional Environments

Jackson et al., (1987) provided the first detailed sedimentological studies of the McArthur Basin succession. Stromatolites, a range of evaporite pseudomorphs, intraclast flat pebble conglomerates, desiccation cracks, and tepee structures were identified in several formations in the McArthur and Nathan Groups. This lead to many formations being interpreted as shallow water in origin. Peritidal, lagoonal, lacustrine and fluvial environments were thought to have dominated. Brown et al., (1969) interpreted *Conophyton* stromatolites from the Emmerugga Dolomite (middle McArthur Group) as probably subtidal, and there is discussion in several places in Jackson et al., (1987) about the problems of identifying marine versus none-marine environments of deposition (eg p. 92, 101, 130). However, in general, most of the carbonates were interpreted to be of dominantly peritidal or lacustrine origin. Similar interpretations were being made for stromatolites and evaporite pseudomorphs from similar aged rocks at Mount Isa (eg Neudert and Russell, 1981). These carbonates at Mount Isa, however, occur in thick successions of dominantly thin bedded to laminated siltstone and shale that are probably of deep-water origin (see discussion in Southgate et al., 2000b). As will be shown from the data presented in this study the dominance of very shallow water environments was probably over-emphasised and has led to problems in interpreting stratigraphic evolution and relationships.

Historical context

The preference for shallow water and emergent depositional environments, almost to the exclusion of any deeper water facies, needs to be viewed in a historical context. During the late 1960's and early 1970's the sabkha model for shallow water carbonates and evaporites (Shearman, 1966) and the Shark Bay model for stromatolites (Logan et al., 1974), dominated the interpretation of ancient carbonate successions. In 1974 Chowns and Elkins published a paper describing cauliflower chert nodules as pseudomorphs after sulphate evaporites that grew displacively in a sabkha setting. During the mid 1970's BMR and industry geoscientists identified similar nodules and other evaporite pseudomorphs in Proterozoic carbonates from the McArthur and lower McNamara Groups (Walker et al, 1977; Jackson et al., 1987; Hutton & Wilson, 1985) and also in lower Paleozoic carbonates from the Georgina Basin (Southgate 1988). A visit to northern Australia by D.J. Shearman (Imperial College, London) in 1979 served to reinforce use of the sabkha model in the interpretation of these Proterozoic successions. Stromatolites, flat pebble conglomerates, cauliflower chert nodules and teepees were all regarded as indicators of peritidal to emergent depositional environments and, in many cases, surface markings, which we now interpret as synaeresis cracks and dewatering structures, were misinterpreted as desiccation cracks.

During the late 1980's and 1990's our understanding of Proterozoic depositional environments has significantly improved. Stromatolites have been described from a variety of environments including peritidal and subtidal and rarely deep marine (Southgate, 1989; Sami & James 1993; Narbonne & James, 1996: Grotzinger & James, 2000). Use of the equations "laminated sediments = algal mats = tidal flats; and nodular anhydrite = sabkha = subaerial environment" in the interpretation of ancient carbonate deposits has received critical caution by Dean et al., (1975). Furthermore, Maliva (1987) has shown that contrary to popular belief, cauliflower chert nodules cannot be used as indicators of sabkha environments. Instead they may provide evidence for hypersaline pore waters during diagenesis. In many cases these nodules can be shown to have grown in subtidal, normal marine sediments, from downward percolating brines that formed at a later time.

A reliance on individual and suites of sedimentary structures, without full consideration of their associated vertical and lateral facies associations, and rock-body geometry, resulted in the emphasis on shallow water environments. As will become evident below, our approach involves the use of gamma logs to help interpret geological logs in the context of sequence stratigraphy, to better constrain facies trends which leads to enhanced interpretations of stratigraphic evolution through time.

BACKGROUND AND APPROACH TO CURRENT STUDY

As noted in the introduction, one of the main aims of the first stage of the multidisiplinary NABRE project was to provide an integrated structural and stratigraphic framework for the Palaeoproterozoic successions between Mount Isa and McArthur River. This involves a re-assessment of the evolution of, and correlations between, the Mount Isa, McNamara, Fickling, McArthur, and Nathan Groups.
To achieve this two critical datasets were required:

1. Continuous measured sections, necessary for the construction of two- and three dimensional models for facies architecture, and,
2. Chronostratigraphic control, at an order of resolution necessary for constraining facies architecture.

In Phanerozoic depositional systems fossils, chemostratigraphy, geochronology and palaeomagnetism provide independent age constraints. The problem is much more difficult in the Proterozoic where fossils are absent. Geochronology appears to be the only viable option at present and this is dependent on the presence of sufficient penecontemporaneous tuffaceous beds to provide zircons that yield a depositional age. We have also developed palaeomagnetic methods for relative dating in the Proterozoic (Idnurm, 2000), but primary signatures are frequently overprinted by later fluid flow events.

In the 1970's and 1980's, sedimentological research was primarily concerned with understanding facies patterns in modern and ancient sedimentary successions. Modern environments were described and used as analogues for the interpretation of ancient depositional systems. This phase of research led to the development of regionally applicable facies models (eg. Walker, 1979). Although this work advanced our understanding of depositional systems it lacked one critical element — time. Sedimentologists had a methodology for describing sedimentary successions and grouping the rocks into related packages, but the lack of a technique for constraining time meant that the resulting packages formed a mosaic of facies that 'floated' in both time and space. This, in effect, is where the pre-NABRE facies understanding stood.

Sequence stratigraphy provides an opportunity to consider the evolution of facies belts within time-significant stratal surfaces. Initially developed by Vail and co-workers at Exxon (Vail et al., 1977) the concepts were further explained in SEPM Special Publication 42 – Sea Level Changes: An Integrated Approach – (Wilgus et al., 1988) and since then have been the subject of numerous publications (see, for example, Emery & Myers, 1996). The methodologies have been used extensively and routinely in the petroleum industry for many years. The sequence stratigraphic technique provides geoscientists with a methodology for decoding the chronological signal preserved in sedimentary successions. It provides criteria for identifying and correlating chronologically significant surfaces within the stacking patterns of otherwise random facies mosaics.

An inability to correlate sedimentary successions within a chronological framework had significantly limited the use of basin analysis techniques in the Australian mineral industry. Although sedimentary basins host a major part of Australia's mineral deposits, exploration strategies in most Australian mineral companies focus on the integration of geophysical datasets, structural and tectonic interpretations and geochemical sampling programs rather than on integrated basin analysis methods. Models aimed at understanding fluid flow pathways and predicting the location of mineral deposits rarely receive significant input from the 'soft rock' side of geology. This situation has existed over the past 20-30 years because lithostratigraphic methods of correlation and facies subdivision provide diachronous facies models that lack chronostratigraphic constraints. In order to provide explorationists with the information necessary to model and predict pathways of fluid flow and potential traps it is necessary to define the structural and stratigraphic framework that existed at the time of fluid movement. Critical to this type of analysis is an understanding of basin shape and sequence stratigraphic architecture. Whereas lithostratigraphic subdivision correlates diachronous rock bodies, sequence stratigraphic subdivision identifies chronostratigraphic surfaces and uses these surfaces to reconstruct sedimentary architecture thereby providing a predictive and testable basin framework applicable to mineral exploration. The datasets collected during this study and presented in this Record form the basic information necessary for undertaking such an analysis.

OVERVIEW OF SEQUENCE STRATIGRAPHY

This summary is included for readers who have little or no familiarity with sequence stratigraphy. Similar sections have also been included in the companion CD's. The aim of this section is to explain some of the important concepts involved, terms used, and the basic methodologies of sequence stratigraphy and how we have attempted to use them in the NABRE project. Readers familiar with sequence stratigraphy can probably skip this section.

Introduction

Van Wagoner et al., (1990) define sequence stratigraphy as the study of rock relationships within a chronostratigraphic framework of repetitive, genetically related strata bounded by surfaces of erosion or non-deposition or their correlative conformities. Emery & Myers (1996) proposed an alternative and possibly simpler definition: sequence stratigraphy is the subdivision of sedimentary basin fills into genetic packages bounded by unconformities and their correlative conformities. At the large McArthur Basin scale, therefore, one could expect that there would be a close approximation between a sequence stratigraphic subdivision of the succession as attempted herein and the existing lithostratigraphic classification. After all, the boundaries between lithostratigraphically defined Groups are commonly disconformities and unconformities, and so wouldn't they bound genetically related units? As will become evident later on in this report this, unfortunately, is not always the case. At smaller stratigraphic scales (ie formations, members) this discrepancy sometimes becomes larger. As noted earlier sequence stratigraphy is used to provide a chronostratigraphic framework for the correlation and mapping of sedimentary facies and for stratigraphic prediction. Implicit in these definitions is the key distinction between lithostratigraphy and sequence stratigraphy. Whereas sequence stratigraphy is concerned with identifying chronostratigraphically significant surfaces that bound genetically related rock packages, lithostratigraphy is concerned with correlating similar rock bodies, which are commonly diachronous and lack time significance. Obviously an independent means of dating is implicit in the former.

Critical to an understanding of sequence stratigraphy is the concept of accommodation. Accommodation refers to the space available for sediment to accumulate and results from interplay between tectonically driven subsidence, oscillations in sea level and rates of sediment supply. It is the rate of change in accommodation and its effect on rates of sediment supply that ultimately controls the migration of sedimentary facies belts, stacking patterns of sedimentary cycles and therefore architecture of sediments filling a basin.
Three scenarios are possible (see Van Wagoner, 1990):

1. Accommodation rate < Rate of sediment supply - Progradational cycles,
2. Accommodation rate > Rate of sediment supply - Retrogradational cycles, or backstepping cycles, and
3. Accommodation rate = Rate of sediment supply - Aggradational cycles.

Based on the examination of stratal patterns in seismic sections, wireline logs and outcrop sections the Exxon Group (Van Wagoner et al., 1990) were able to show that cycles of progradation, retrogradation and aggradation occurred in a predictable order at a variety of scales. One of our main aims was to try and identify these patterns in the McArthur succession, and then to see whether this gave us a significantly different packaging of the sections than those based on previous studies. For example, and as shown in **figure 11**, some sections changed markedly, some only marginally. Furthermore, the Exxon Group related the cycles into genetic packages - systems tracts, parasequence sets and parasequences (definitions below), that combined to form a depositional sequence in which each systems tract reflected a particular stage of an accommodation cycle. For the McArthur River Region this type of 3-D analysis proved difficult because of the lack of lateral continuity of outcrop. However, it was possible in other parts of the NABRE project area (eg the Lawn Hill Platform) where outcrop, seismic and company drillholes provides good control (eg Bradshaw et al., 1999; Krassay et al., 1999; Southgate et al., 1999).

Depositional sequences are bounded by a chronostratigraphic surface termed a sequence boundary across which a basinward shift in facies (ie change from deeper to shallower water facies) occurs. Van Wagoner et al., (1990) recognised two types of sequences (type I and II), defined by the character of the sequence boundary at their base. Detailed discussions of the differences between these two sequences are found in Van Wagoner et al., (1990) and Emery & Myers (1996), but they are not particularly relevant here.

Most generalised sequence stratigraphic models are for extensional basins with a pronounced shelf break - the classic passive margin setting of many modern continental margins. These models are probably not directly applicable to the intracratonic McArthur River Region, but models developed for basins with a ramp margin are probably more applicable (eg Van Wagoner et al.,1990; Sarg, 1988). These are the types of models that we have used to analyse the McArthur, McNamara, Mount Isa and Fickling Groups. Importantly, the surfaces that bound sequences and internally divide them into systems tracts and parasequences are chronostratigraphic features that cut across diachronous lithofacies boundaries.

For the datasets included in this report, sequence interpretations are based largely on the vertical stacking patterns of sedimentary facies and the interpretation of gamma ray logs derived from outcrop and drill core. The gamma ray curves have proved particularly useful for sequence analysis of these Proterozoic sections. Whereas facies descriptions can be heavily biased by the previous experience of the geologist measuring the section, gamma ray measurements are objective. They simply record the K, Th and U content of the rocks and display these data as a curve. The K, Th and U content of the rock are commonly related to the amount of shale present in the rock and so the gamma ray curve enables facies trends to be recognised and aids in the identification of sedimentary cycles and their stacking patterns. This is especially so in sections that contain alternations of shale-rich and shale-poor facies. The curves are particularly useful in identifying sequence boundaries and their correlative surfaces, especially in situations where like facies occur above and below important stratal surfaces.

Well-Log Trends and Sedimentary Cycles

Regional correlations of wireline curves, and gamma ray curves in particular, are not based on identifying individual spikes on the curves. Instead, it is the broad, overall curve trends and associated lithofacies stacking patterns that allow improved regional correlations. A wealth of literature exists on methods for interpreting sedimentary cycles in well logs (eg. Rider, 1991; Emery & Myers, 1996). Few of these texts cover mixed carbonate-clastic successions in Proterozoic platform settings, but we have adopted the basic methodology to suit our localised situation. Emery & Myers (1996) identify five basic trends which they suggest can be related to changes in depositional energy and thus with patterns of sedimentary infill (see their figure 4.7):

1. *Cleaning-up* or *funnel-shaped* trends show an upward decrease in gamma counts, which, in a clastic setting, commonly indicates an upward increase in depositional energy, upward shallowing, and upward coarsening related to progradation of a depositional system. Cleaning-up trends will also result from a gradual change from clastic to carbonate deposition This is a common trend of many of the gamma ray logs presented in this report (see for example **Figs 11, 15, 20 & 26**).

2. A *dirtying-up* or *bell-shaped* gamma trend shows a progressive upward increase in gamma readings, which commonly indicates overall fining-upward successions, typically within shale-prone intervals. Dirtying up trends are common in fluvial successions, tidal channels, and estuarine fills. In shallow marine settings, dirtying-up trends often indicate the retreat or abandonment of a shoreline–shelf system. In deep marine settings, the dirtying-up motif may record the waning/abandonment period of submarine fan deposition. These trends are generally rare in sections measured in the McArthur River Region. However, they do occur in small small stratigraphic intervals (eg **Figs** lower **15,** upper **Fig 24**).

3. *Blocky* (Boxcar) gamma-ray curve segments are sharp-based low-gamma units with internally relatively consistent gamma readings set within a higher gamma background. The sharp boundaries with overlying and underlying units imply the existence of an abrupt switching from high gamma fine-grained units to low gamma coarser units. In clastic settings, blocky trends are commonly found in fluvial channel sands, turbidites, aeolian sands, and occasionally within evaporites. These are rare in the McArthur Basin but they are present opposite ‘massive’ or crystalline carbonate sections.

4. *Bow* or *symmetrical* trends consist of a cleaning-up trend overlain by a dirtying-up trend of similar thickness, with no significant break between the two. A bow trend is usually the result of a waxing and waning of clastic sedimentation rate in a basinal setting, where the sediments are unconstrained by base level, such as during the progradation and retrogradation of a mud-rich fan system. These trends are rare in the McArthur River Region.

5. *Irregular* trends have no systematic change in either the sand base line or shale base line, and lack the clean character of the blocky trend. In clastic settings, irregular trends generally represent aggradation of a shaly or silty lithology, and are typical of shelfal or deep water settings, a lacustrine succession, or muddy alluvial overbank facies.

Numerous examples are provided later of how we have used the integration of the gamma log trends and the lithofacies to interpret the patterns of sedimentary fill in this Proterozoic basins.

Parasequences, Parasequence Sets and Systems Tracts

Parasequences form the basic building blocks (cycles) of systems tracts and sequences. Van Wagoner (1990) defined parasequences as relatively conformable successions of genetically related beds or bedsets, bounded by marine flooding surfaces and their correlative conformities. In a wave- or storm-dominated, shallow water, siliciclastic setting a parasequence will occur as a decameter-thick coarsening upwards package where beds increase in thickness upwards, bioturbation decreases upwards and facies indicate shallowing upwards (see examples in Van Wagoner, 1990; Emery and Myers, 1996). The best known example of a parasequence in a carbonate depositional system is the 1-10m thick, shallowing upward succession characteristic of peritidal environments (eg James, 1984; Grotzinger, 1986). Several of the McArthur Basin carbonate units are characterised by these thin shoaling cycles, which we interpret as parasequences. The best examples are in the Tooganinnie Formation (see **Figs 17,18**) and the Emmerugga Dolomite (see **Fig 20**).

Parasequences are arranged into a succession of genetically related cycles that are termed parasequence sets. In a parasequence set the cycles are related by their stacking patterns to form progradational, backstepping or aggradational depositional systems. For example the latter can be seen clearly in the Emmerugga Dolomite (**Fig 21**). It is important to note that although a parasequence set may reflect transgression and a progressive deepening of the depositional environment, the overall deepening trend will generally be subdivisible into a series of smaller scale (thinner) progradational cycles or parasequences. In such a system successive parasequences typically display an increase in deeper water facies as rates of sediment supply are unable to keep up with subsidence rates. Thus successive cycles typically thin upwards until they become condensed and eventually merge in a relatively uniform package of siltstone and shale. Parasequences and parasequence sets are arranged into four depositional packages or 'systems tracts' that together comprise a depositional sequence. The four original systems tracts defined are:

1. Lowstand Systems Tract (LST)
2. Transgressive Systems Tract (TST)
3. Highstand Systems Tract (HST)
4. Shelf Margin Systems Tract (SMST)

The relative positions of these systems tract within type 1 and 2 depositional sequence are shown in the figures in Van Wagoner et al., (1990). The LST is deposited during a period of relative sea level fall and during the subsequent period of slow relative rise. In a basin with a shelf break the lowstand can be divided into three depositional systems - the basin floor fan, slope fan and lowstand wedge. In intracratonic settings, where pronounced shelf breaks are typically absent and ramp basins develop, LST deposits typically comprise prograding wedges of sediment. Criteria for recognising the basinward shift in facies and relative fall in sea level can be quite subtle, depending on the magnitude of the fall and the position on the ramp or platform.

The transgressive systems tract (TST) is the middle systems tract of a type 1 & 2 sequence. These sediments are deposited when the rate of increase in accommodation (relative sea level rise) exceeds the rate at which sediment is supplied. A backstepping set of parasequences accumulates. In a basinward position in a clastic setting low rates of siliciclastic deposition facilitate the accumlation of authigenic sediments. These include laminated and bituminous muds, glauconite, phosphorites, manganese nodules and organic-matter rich shales. Using criteria such as this, TST's have been identified at many stratigraphic levels in the Lawn Hill area (eg Southgate et al., 1997; Krassay et al., 2000), which was obviously in a more basinward position than the McArthur area for much of the sedimentation period analysed in the current project. In a more proximal basinal position, as applies to much of the McArthur River Region described in this report, the identification of backstepping parasequences is usually not easy. However, through the careful integration of gamma logs and subtle facies changes it is possible to identify deepening episodes, which probably equate with TST's, even in these shallower-water, marginal settings.

The highstand systems tract (HST) is the youngest and uppermost systems tract in a type 1 & 2 sequence. These sediments accumulate during a time of decelerating rate of relative sea level rise, enabling the rate of sediment supply to exceed the rate of accommodation. In HSTs parasequence-stacking patterns depend upon cycle position in the HST as well as facies position on the shelf or ramp. During the early to mid parts of HST's, sites in close proximity to the siliciclastic provenance or shallow water carbonate factory will receive relatively high rates of sediment supply and a progradational set of parasequences will form. In the late or terminal parts of HST's, when accommodation rates are in significant decline shallow subtidal to supratidal facies will dominate the shallowing upward cycles. This will result in an aggradational package of parasequences as like facies belts are superposed. In basinward positions, where rates of sediment supply are comparatively low, aggradational stacking patterns may occur in early highstand deposits. In some ramp settings a succession of basinward stepping prograding wedges can mark the terminal parts of HST deposits. These wedges of sediments are referred to as forced regressive wedges.

In some of the other companion CD's (eg Krassay et al., 1999; Southgate et al., 1999) detailed systems tract analyses have been attempted and these are shown on the accompanying GEOLOG plots. Because of the 'basin margin' setting of the McArthur Basin and lack of lateral control, the confident identification of systems tracts has seldom been possible in this area, consequently these have not been labelled on the GEOLOG plots.

Stratal Surfaces

Each of the systems tracts is bounded by a chronostratigraphic stratal surface.
Three surfaces are defined:

1. Sequence Boundary,
2. Transgressive Surface
3. Maximum Flooding Surface

The sequence boundary occurs at the base of the LST, or, where absent, at the base of the TST. Sequence boundaries are erosion surfaces, unconformities and correlative conformities associated with subaerial erosion and, in some places, correlative marine erosion. A basinward shift in lithofacies is usually found above sequence boundaries. Sequence boundaries are interpreted in well logs where evidence exists for an abrupt change in gamma-ray counts related to the sharp lithological change. In the most commonly reported cases, in a clastic setting, this change is a sharp fall, because low gamma value, shallow-water sands overlie higher value marine shales. However, in the mixed carbonate/clastic Nathan Group described in this report, sequence boundaries are identified by the opposite gamma log trend where "dirty" fluvial sands overlie "clean" deeper water carbonates (orange lines on **Fig 26**). In many cases, the gamma log trend immediately beneath a sequence boundary is progradational, indicating an underlying shoaling and coarsening-up event associated with a HST (eg 650-850m on **Fig 27**). The gamma-ray trend above a sequence boundary is progradational–aggradational if a LST is present, or retrogradational if immediately overlain by a TST. On seismic lines sequence boundaries are identified by terminations of seismic reflectors through either onlap and/or truncation. Obviously this sort of criteria could be used on the seismic lines in the COMALCO grid in the northern Lawn Hill Platform, but is inappropriate in this area that lacks seismic.

The transgressive surface (eg. Red lines on **Fig 26**) defines the top of the LST and marks the time of significant marine flooding across the shelf, platform or ramp (Van Wagoner et al., 1990). Transgressive surfaces are indicated in gamma logs by a change from overall aggradation or progradation to retrogradation. Here they are marked by 'clean' gamma log values over 'dirty' values. In seismic profiles, the transgressive surface is identified as the major onlap surface. A marine flooding surface shows evidence of an abrupt increase in water depth, commonly accompanied by minor submarine erosion or non-deposition (Van Wagoner et al., 1990). Marine flooding surfaces are usually interpreted where gamma values suddenly increase above a cleaning-up trend, but obviously this is very different to the motifs illustrated here.

The maximum flooding surface (mfs) marks the time of maximum rate of increase in accommodation. On seismic sections it coincides with the downlap surface which marks the switch from retrogradational trends to aggradational and progradational trends. In well logs, where higher resolution is possible, the mfs occurs within the condensed section (Loutit et al., 1988). In a clastic setting, such as the northern lawn Hill Platform, the condensed section is usually identified as a shale-prone, organic-rich interval. Elevated gamma radiation is caused by anomalously high uranium and thorium contents. These elements are associated with organic matter and mineralised hardgrounds containing authigenic manganese and phosphate. This also occurs in the McArthur River region (eg. 1000-1100m, **Fig 26**), but the mfs may also be marked by a deeper water stromatolite biostrome (eg 640m **Fig 26**).

Scales of Observations and Orders of Cyclicity

Because tectonic cycles of subsidence and uplift, and eustatic cycles of sea level change operate over different time periods, sequences can be classified in terms of their order of duration (Vail et al., 1977; Emery and Myers, 1996). Each depositional sequence is bounded top and bottom by an unconformity surface or correlative conformity and the age differences between these surfaces provide a maximum duration for the event (tectonic/eustatic) controlling the creation or destruction of space. A number of authors (eg Van Wagoner et al., 1990; Emery & Myers, 1996) have classified sequences into a number of orders depending on their duration. The largest is the long-term continental encroachment cycle with duration in excess of 50 Ma; this is called a first-order cycle. There are probably two of these “supercontinent cycles” in the Phanerozoic. The next scale down is the second-order cycle, the stratigraphic expression of which is the supersequence. This cycle is around 3-50 Ma in duration. This is the scale at which we are proposing the new, supersequence subdivisions of the Proterozoic succession in the NABRE area (see later). The next scale down is the third-order cycle, which is commonly 1-5 Ma in duration. Emery & Myers (1996) suggest that these are the foundation of sequence stratigraphy because they are often of a scale well resolved by seismic data. Similarly, MacNaughton et al., (1997) refer to these as ‘normal’ sequences. Most of our supersequences can be subdivided into 3rd-order sequences; especially in the Mount Isa – Lawn Hill area where thick and continuous clastic sections are preserved. If control is good enough, these ‘normal’ sequences can often be subdivided further into fourth-order cycles (0.1-1 Ma in duration) and, perhaps, even fifth-order cycles (probably less than 100,000 years duration). These small scale cycles in a stratigraphic succession comprise the parasequences/parasequence sets described above. As will become evident it is often difficult to subdivide up the Supersequences in the McArthur part of the NABRE area into their component sequences defined in the Lawn Hill part of the area.

There are contrasting views on the principal driving mechanism behind these cycles. At the larger scales (1st- and 2nd- order) tectonism is usually regarded as the principal driving mechanism (Emery & Myers, 1996). Vail et al., (1991) consider glacio-eustatic fluctuations as the principal driving force behind 3rd to 5th order cycles, but others (eg Cloetingh, 1988) believe that tectonism may still be a significant driving mechanism. In the Isa Superbasin there appears to be a close relationship between inflections on the APWP, which represent significant changes in the direction of movement of the craton and Supersequence boundaries (Idnurm, 2000). It is tempting, therefore, to see these as tectonic events defining these surfaces rather than purely eustatic. The role of tectonism at 3rd- and 4th- order sequence boundaries within the NABRE area appears to be variable and is addressed in the various reports.

The principal datasets for identifying stratigraphic sequences in the NABRE area are seismic sections, wireline logs, core and outcrop. Obviously the first of these in not applicable in this part of the area. Wireline logs are able to identify bed thicknesses at the meter scale. Observations on drill core and outcrop sections can be made at the centimetre scale, thereby providing increased resolution of stratigraphic detail. Determining the order of stratigraphic sequences requires access to the appropriate data set. Seismic datasets are used for the identification of 1st to 3rd order sequences. Outcrop, drill core and wireline logs are necessary for the identification of 4th and 5th order sequences, but can also be used for 2nd and 3rd order cycles.

The sequence stratigraphic subdivisions outlined in the various NABRE CD’s are interpreted as 2nd- to 5th order sequences. In the McArthur and Nathan Groups second-order cycles or supersequences have durations of approximately 10-15 m.y., third-order sequences several million years, and forth-order sequences less than 1 m.y. Fifth-order sequences are not classified. In the McArthur Basin supersequences are usually some hundreds to thousands of meters thick, 3rd-order sequences are tens to hundreds of metres thick, and 4th-order sequences usually several tens of meters thick. The equivalent order sequences are generally much thicker in the Lawn Hill Platform-Mount Isa area, where rates of accommodation appear to have been greater.

Sequence Stratigraphic Nomenclature

As noted earlier, lithostratigraphic nomenclature is largely descriptive and is constrained by a formal Stratigraphic Code with well-defined rules and unit naming procedures (Staines, 1985). In contrast, the sequence stratigraphic study undertaken here is highly interpretive, and is, therefore, subject to change as additional sequences are recognised and stratigraphic precision improved. Currently, there is no formal code for definition and naming of units using a sequence stratigraphic approach, although AGSO's Stratigraphic Indexing Group is currently in the process of proving guidelines for these purposes. We have adopted these guidelines as they stood in late 1999. Further, we have not introduced separate sets of sequence stratigraphic units for the widely separated areas covered by the Location Map (**Fig 1**). The aim of the NABRE research was to simplify regional correlations so we have introduced as fewer new names as possible, by defining at the supersequence scale, and also by using abbreviations of well-known names. We feel we have enough independent zircon dating, and sufficient geological and gamma ray logs to make reasonably sound correlations between units from widely separated localities. Although our sequence stratigraphic subdivisions are genetically different from the established lithostratigraphic scheme, we have attempted to develop a scheme that is simple to remember and easy to relate to the existing, well-known lithostratigraphic names. Rather than adopt an entirely new set of names for our units, we propose to use abbreviated forms of some of the existing stratigraphic names. Stratigraphic terminology for the 2nd- to 4th- order sequences identified in this study is classified in the following way. Each 2nd- order supersequence is named after an abridged version of the lithostratigraphic unit that contains its maximum flooding surface. The most complete stratigraphic sections come from the McNamara Group in the Lawn Hill Platform (Hutton & Sweet, 1982) so the formation names from this Group have been used. For example, the River Supersequence is informally named after the Riversleigh Siltstone; and the Gun Supersequence is named after the Gunpowder Creek Formation. The nine supersequences that comprise the 1690 to 1575 Ma Mount Isa Superbasin succession, that were defined in the Mount Isa – Lawn Hill area, have also been identified in the McArthur River Region. In the Lawn Hill – Mount Isa area most of these Supersequences have been subdivided into 3rd -order sequences and a few into higher-order cycles. A number follows the Supersequence name, the first integer identifies a third order sequence, and the number following the decimal point identifies each fourth order sequence. For example the Gun 1.5 sequence refers to the fifth 4th-order sequence in the first 3rd-order sequence of the Gun Supersequence. Due to the lack of control, sequence stratigraphic subdivision in the McArthur River Region is currently not as refined as that south of the Murphy Inlier.

Datasets and Methodology

The stratigraphic information presented in this report was collected mainly from outcrop sections, but it is supplemented by publicly available and Exploration Company drill core. The quality of outcrop provided the principal constraint in the selection of areas suitable for measuring sections. In most cases we were restricted to re-examining the key/type sections described in Jackson et al., (1987). Wherever possible areas of poor outcrop were supplemented by drill core. The 30 measured sections and drillholes are all from within the Batten Fault Zone area on **Fig 1**; the actual locations are shown on the maps accompanying the GEOLOG plots, (**Measured Sections)**. Some of the sections are composites from a series of smaller sections that were spliced together at prominent marker beds, or by the use of overlapping gamma ray curves in conjunction with facies descriptions. **Table 1** contains a full listing of the names of the individual sections. It also includes the coordinates for the base of each measured section, a thickness for the complete section, a generalised location and a listing of the units intersected. Where sections are composites the splice points are shown on the GEOLOG plots in (**Measured Sections**).

Sections were measured using a Jacob staff and Abney Level and the rocks were marked with a paint spot at 1.5 m intervals of true thickness. Gamma ray readings were collected at 50-cm intervals of true thickness using a hand held Scintrex GRS-500 spectrometer that measured total gamma ray counts. A beryllium standard was used to calibrate each spectrometer at two- to three-hourly intervals. Gamma readings were averaged over ten second intervals. Where existing down-hole wireline logs were available these were used for correlation. However, most mineral holes lacked this critical information. In these instances gamma ray data was acquired from drill core using AGSO's vehicle-mounted Exploranium GR-320 Envispec spectrometer. This is more sensitive than the hand-held spectrometres. The gamma ray count values recorded by the two systems are different in that the actual figures recorded and the amplitude of variations around a mean are about an order of magnitude different. As we are not attempting to compare absolute measurements of gamma radiation, but are looking to analyse curve trends this is not a major problem. The values from the 'Exploranium' spectrometer were adjusted in Excel spreadsheet charts, using an averaging formula, to give them a similar mean value and amplitude variation to that recorded by the Scintrex machine. Krassay (1998) provides a detailed description of the techniques used in acquiring gamma ray data and the accuracy of this method.

Sedimentary facies information, including grainsize, lithology, grain composition, sedimentary structures and bed thickness were collected along each stratigraphic section on paper field data sheets. A visual estimation of grain size was recorded as a continuous curve. One of the major problems with facies-based sedimentological datasets involves a mechanism to cost-effectively transfer the data to digital form. Furthermore, interpretations require the identification of vertical trends in facies patterns and the stacking patterns of sedimentary cycles as much as the description of rock units. The technique developed in this project, where outcrop-derived gamma ray and grainsize data are displayed as curves, complemented by lithology and facies information, enables these trends to be identified and stratal surfaces interpreted. Grainsize curves were digitised using a fax scanner and subsequently loaded into Mincom's Geolog 6 software. Lithologies were generated using a series of look-up tables keyed to observations made along each section. Sedimentary structures were hand-posted at the appropriate depths.

REGIONAL STRUCTURAL–TECTONIC SETTING

The McArthur Basin contains a 5-15 km thick platform cover succession of predominantly unmetamorphosed sedimentary rocks deposited between about 1800 and 1450 Ma. Intercalated mafic and felsic igneous rocks are also present, but these are mostly restricted to the lower part of the succession. The northern half of the basin is bounded to the west and east by older (~1870–1840 Ma) igneous and metamorphic basement rocks of the Pine Creek and Arnhem Inliers, respectively (Rawlings et al., 1997). In the southern part of the basin, however, the relationship between the basin sediments and basement (Murphy Inlier) is less clear. Granitic units intruding the metamorphic core of the Inlier have recently been dated at around 1840–1860 Ma (Page et al., 2000) so are of a similar age to the basement in the north. This Inlier forms a probable southeastern 'margin' to the basin and separates the Proterozoic sequences of the McArthur Basin from contiguous successions in the Lawn Hill and Mount Isa areas.

Plumb et al., (1980) Plumb and Wellman, (1987) and Plumb et al., (1990) provide overviews of the main structural elements of the McArthur Basin and models for its tectonic development. In Plumb et al., (1990) the model comprises northerly trending asymmetric rifts

(30-80km wide) separated by north-west trending transfer faults and transverse ridges (see Fig 5 in Plumb et al., 1990). The Walker Fault Zone/Trough, in the north, and the Batten Fault Zone/Trough, in the south, dominate the structure of the exposed eastern half of the basin. These 80 km-wide, meridionally trending features are zones of more intense faulting and much thicker preserved stratigraphic sections than on the adjacent shelves to the west and east. For example up to 12 km of section accumulated in the Walker Trough compared to around 4 km on the Arnhem and Caledon Shelves to the west and east, respectively (**Fig 1**). Further, the shelves are characterised by minor facies and thickness variations and less severe deformation. A third, west-trending fault zone, the Urapunga Fault Zone, appears to separate the Walker and Batten Fault Zones into two separate entities (**Fig 1**), but the evidence is indirect due to the sparse outcrop in the area where the three intersect. The Walker and Batten Fault Zones preserve broadly comparable successions; however, there are notable differences in detail indicating that the Urapunga Fault Zone was an important palaeogeographic feature. There is good stratigraphic evidence that indicates some faults actively controlled sedimentation during various phases of the basin's history. For example, there are marked facies and thickness trends into major faults in — 1) the Parsons Range Group (~1700 Ma); 2) the Balma and Habgood Groups (~1630–1650Ma); and 3) the Barney Creek Formation (1640 Ma). Detailed documentations of the structure and tectonic evolution in the various parts of the basin are found in the explanatory notes accompanying the 1:250,000 scale geological maps (for example Pietsch et al., 1991a; Haines et al., 1993; Rawlings et al.,1997).

Based on analysis of AGSO's regional gravity and magnetic data sets, Leaman (1998) has proposed a somewhat different model for the structural evolution of the southern part of the McArthur Basin that drastically downplays the importance of these fault zones. In contrast to our suggestion above, for a basin fill of around 5-15 km, Leaman suggests that up to 20 km of section is typical for the basin and that most of this is pre-Tawallah Group in age (ie pre ~1800 Ma). Unfortunately, justification for this different model is not convincing (Leaman, 1998). For example, on page 16 he states "recognisable rift patterns, or cells, remain even though there has been much differential uplift and erosion". However, on page 17 he suggests "The entire sequence is consistent with normal multistage rift and sag basin evolution which has not been massively uplifted". Later, on the same page, he states " There is no evidence for any gross regional rifting or trough development; rather moderate sized depressions have been formed as discrete cells and several formations formed individually within them appear to have lapped across cell divides to interlink with other sequences". In Summary, " the rift cells, as a group, without particular alignment, form the gross structure known as the McArthur Basin."

From our reading the size, shape and origin of his sediment containers or "rift cells" is ambiguous. Leaman's models are based on the old, unlevelled AGSO data set (see Tarlowski et al., 1996). Further, he invokes the presence of very thick sections of felsic and mafic rocks for which field evidence is lacking in the McArthur River Region. Leaman (1998) does not incorporate the well-constrained stratigraphic and structural data from the recent systematic mapping by NTGS-AGSO in the northern part of the basin. The resulting models are therefore considered less probable than those based on the recently published explanatory notes (listed above) and the revised potential field analyses presented in one of the companion NABRE reports (Scott et al., 2000).

The detailed sequence stratigraphic sections presented in this Report are located, with minor exception, within the southern part of the Batten Fault Zone (see **Fig 1**). The interpretation of this data has, however, been constrained by information from equivalent sections from the Lawn Hill area immediately south of the Murphy Inlier (Bradshaw et al., 2000).

REGIONAL STRATIGRAPHIC SETTING

As explained in the Introduction, one of the major tasks for this part of the NABRE project was to review and update the stratigraphic subdivisions and correlations of the Palaeoproterozoic successions between the Mount Isa–Lawn Hill area and the McArthur River Region. It soon became evident that the northern Lawn Hill Platform area, where there was a grid of seismic lines, several petroleum wells, numerous mineral exploration drillholes and good outcrop would become the key reference area for the project. In this area Bradshaw et al., (1998) identified a series of stacked basin successions that were collectively grouped into two major tectonostratigraphic packages. They coined the terms Leichhardt and Isa Superbasins for these two packages to distinguish them from existing large-scale lithostratigraphic subdivisions. Following additional SHRIMP dating and a detailed review of recently published structural papers from the Mount Isa area, Jackson et al., (2000a) revised this scheme and divided the Proterozoic successions between Mount Isa and McArthur River Region into four Superbasin Phases:

1. Leichhardt — preserving rocks aged between ~1800 Ma and 1750 Ma;
2. Calvert — preserving rocks aged between ~ 1735 Ma and 1690 Ma;
3. Isa — preserving rocks aged between ~ 1670 Ma and 1575 Ma; and
4. Roper — preserving rocks aged between ~ 1500 Ma and ~ 1420 Ma

Figure 3 shows the main features of this (2nd-order) classification scheme and relates it to Blake's (1987) widely used 'cover sequence' nomenclature for the Mount Isa region and also to the recently published scheme of Rawlings (1999). The later divides the McArthur Basin succession into a series of basin phases that he calls 'packages' which are basin scale depositional and magmatogenic rock units approximately equivalent in magnitude to 2nd-order basin cycles. Our scheme and Blake's emphasise the discontinuous nature of the preserved rock record. To date, most of the NABRE Project sequence stratigraphic research has been undertaken in the Isa Superbasin phase, but observations from the Leichhardt and Calvert Superbasins are included here. **Figure 4** (after Southgate et al., 2000) shows the currently available SHRIMP zircon age control and the more detailed sequence stratigraphic subdivision of the Calvert and Isa Superbasins.

LEICHHARDT SUPERBASIN SUCCESSION IN THE McARTHUR RIVER REGION

Most of the NABRE sequence stratigraphic research has been concentrated in the 1670-1575 Ma rocks that we assign to the Isa Superbasin. However, reconnaissance studies on parts of the underlying successions were carried out to help us understand the developing basin framework. These results, together with non-confidential information from CODES research on this package (eg Rogers & Bull, 1994; Bull & Rogers 1996) are reviewed here.

In the McArthur River region the Leichhardt Superbasin comprises units from the lower part of the Tawallah Group. Jackson et al., (1987), Pietsch et al., (1991a) and Haines et al., (1993) describe the Tawallah Group as a ~5 000 m thick conformable and concordant succession of largely shallow water clastics with minor carbonate, shale and volcanic rocks (**Fig 5**). A similar succession (**Figs 6** & **7**) but with subtle thickness and facies changes has also been described from the southern edge of the basin in the CALVERT HILLS sheet area (Ahmad & Wygralak, 1989). In both regions, these largely sedimentary packages overlie predominantly felsic igneous rocks that have been assigned to 'basement'. Much thicker time equivalent sections are preserved in the Leichhardt River Fault Trough near Mount Isa (**Fig 8**).

In the central McArthur River area the ‘basement’ is a 1000m+ thick succession of rhyolitic to dacitic ignimbrites with minor mafic flows and intrusions, together with volcaniclastic sandstones called the Scrutton Volcanics. A new U-Pb zircon age of 1851±7 Ma (Page et al., 2000) and geochemical characteristics indicate it should be associated with the 1870–1840 Ma ‘Barramundi’ felsic igneous suite of Wyborn (1988). The ‘Barramundi’ felsic igneous suite is part of Blake’s (1987) ‘Cover Sequence 1’ in the Mount Isa region, which is not considered part of the basement. At the southeast edge of the McArthur Basin (Murphy Inlier, CALVERT HILLS) the ‘basement’ was defined by Ahmad and Wygralak (1989) as an older Murphy Metamorphic complex – a metamorphosed, isoclinally-folded sequence [sic] of geosynclinal shale, siltstone, greywacke and volcanics – unconformably overlain by the 4000 m+ Cliffdale Volcanics and intruded by the Nicholson Granite Complex. The felsic igneous rocks are geochemically similar to the Scrutton Volcanics. Two new ages of 1856±3 and 1845±3 Ma, from different phases of the Nicholson Granite (Page et al., 2000), confirm that these rocks also form part of the ‘Barramundi’ association.

At Mount Isa Blake (1987) places the Leichhardt Volcanics (previously called the Leichhardt Metamorphics) at the base of his ’Cover Sequence 1’ and emphasises the low metamorphic grade of the unit and its similarity in metamorphism to other basin rocks and not the basement. In contrast, in the far north of the McArthur Basin, (ARNHEM BAY-GOVE) Rawlings et al., (1997) associate granites of this age (~1840 Ma) with metamorphic rocks of the Bradshaw Complex as part of the basement of the Arnhem Inlier. In summary, there is obviously regional stratigraphic, and presumably tectonic, variation in how different authors view this ~1870–1840 Ma felsic suite. For some it is within basement, for others it forms the basal part of the Proterozoic basin successions.

It is possible that these various felsic crystalline rocks, which have been considered basement to the overlying largely sedimentary successions in the McArthur area by previous authors, are the felsic component of Leaman’s, “large, concealed volcanic piles inferred and defined within the McArthur Basin sequence (Leaman 1998).” If the correlation between the Leichhardt Volcanics and Scrutton–Cliffdale Volcanics is accepted these units in the McArthur area may not significantly contribute to the regional magnetic susceptibilities as Blake (1987) reports the Leichhardt Volcanics to be weakly magnetic or non-magnetic.

To date, no detailed sequence stratigraphic studies have been undertaken in the Leichhardt Superbasin Phase within the NABRE Project, although Jackson et al., (2000a) provide reviews of the published stratigraphy and revised correlations from a sequence stratigraphic perspective (**Fig 9**).

CALVERT SUPERBASIN SUCCESSION IN THE McARTHUR RIVER REGION

As defined above, the Calvert Superbasin comprises rocks deposited between about 1735 and 1690 Ma (**Fig 3**). It is separated from underlying and overlying phases by large gaps in the rock record. For the base, there appears to be a complete absence of rocks deposited in the period between about 1750 and 1735 Ma throughout the whole McArthur – Mount Isa region. Jackson et al., (2000a) interpreted this as reflecting a prolonged tectonically-enhanced hiatus between the Leichhardt and Calvert Superbasins. Independent studies have identified major tectonic events around 1740-1750 Ma — the ‘mid-Tawallah compressional event’ in the McArthur Basin area (Rogers & Bull, 1994) and the Wonga event in the eastern part of the Mount Isa region (Pearson et al., 1992). It should, however, be noted that there are not many isotopic age determinations in the rocks either side of this apparent break (see **Fig 9**) so it is not well constrained.

There also seems to be a major (~20 m.y.) break between the Calvert and overlying Isa Superbasins throughout the whole McArthur – Mount Isa region (**Fig 3**). In the Mount Isa region major felsic igneous bodies (Carters Bore Rhyolite, Sybella Granite, **Fig 4**) were implaced around 1670–1680 Ma and Southgate et al., (2000b) interpret these as indicating tectonism and probable uplift.

Except for detailed studies on the Surprise Creek Formation near Mount Isa (eg Domagala et al., 2000) and on the lower part of the Gunpowder Creek Formation near Gunpowder (Sami et al., 2000) little detailed sequence stratigraphic work has been undertaken on rocks within the Calvert Superbasin. The few sequence stratigraphic observations made in the McArthur River Region are presented here.

Base of Superbasin

The Calvert Superbasin boundary is placed at the base of the Wunnunmantyala Sandstone, a quartz arenite to sub litharenite unit up to about 500m thick (**Fig 5**), originally identified and defined in the central part of the MOUNT YOUNG area (Jackson et al., 1987; Haines et al. 1993). Although these authors originally described the base of the Wunnunmantyala Sandstone as conformable, later work (Bull & Rogers, 1996) indicated that it was, infact, unconformable in this part of the McArthur Basin. Bull & Rogers suggested that there was probably a significant stratigraphic break between it and the underlying rocks (originally incorrectly mapped as the Aquarium Formation). Based on reconnaissance studies in the southern part of the basin (CALVERT HILLS area) in 1997, we have now further refined the stratigraphic relationships at this level in the succession. The results of this are described in more detail in Jackson et al., (2000a), but, in essence, a subtle regional unconformity at this level is now recognised across the CALVERT HILLS sheet area. Here a quartz arenite unit (map symbol Ptl) cuts across and incises a carbonate unit with the map symbol *Ptd* (McDermott Formation). Unit *Ptl* ("Sly" on **Fig 6**) was originally correlated by Ahmad & Wygralik (1989) with the Sly Creek Sandstone of the BAUHINIA DOWNS-MOUNT YOUNG area. However, our studies, and recent mapping by D. J. Rawlings, University of Tasmania (PhD, in prep) show that the *Ptl* unit is not the lateral equivalent of the Sly Creek Sandstone, but that it is better correlated with the Wunnunmantyala Sandstone. The revised scheme is shown on **Figure 9**. The Wunnunmantyala Sandstone (Wun), part of Association F, is tentatively identified in three of the sections, but not in the Mount Isa area. However, there is limited control on the age of the Bigie Formation and it may be older than shown in this diagram. Jackson et al., (2000a) discuss the regional implications of these changes to the correlation of units around the Murphy Inlier and further southeast in the Mount Isa area.

Infra-Calvert Sequence Boundaries

In **Figure 9**, Jackson et al., (2000a) show the Calvert Superbasin as containing three 'associations' of units, which they termed 'Associations F, G and H". By inference, they imply the presence of two breaks (sequence boundaries) between these associations with these breaks at ~1730 Ma and at ~1720 Ma, although there is a deficiency of dating. In a companion paper, however, Southgate et al. (2000a) show the same interval as being divided into only two supersequences, the Prize and Big, separated by a single break at ~1700-1705 Ma (**Fig 4**). This later scheme was based largely on the interpretation of seismic at the northern end of the Lawn Hill Platform and is poorly constrained (Southgate et al., 2000a, p 466).

Figure 10 is an attempt to clarify this apparent difference of opinion. The figure is a chronostratigraphic plot of Calvert Superbasin stratigraphic units that contain sequence stratigraphic information or recent good quality age information. We have included information from the western succession at Mount Isa (Wyborn 1988; Page & Sweet, 1998; Page et al., 2000; Southgate et al., 2000a) and results from the northern part of the McArthur Basin (Haines et al., 1999; Rawlings, 1999; Rawlings et al., 1997), in addition to that from the southern McArthur Basin which is the area of main concern here. Based on this plot it appears that there is potential for identifying at least five stratigraphic breaks ('Potential Sequence Boundaries', second column from right) within the Calvert Superbasin. Consequently, these may define six major episodes of sediment/igneous rock accumulation.

Despite the lack of age dating, these stratigraphic breaks and intervening periods of accumulation seem broadly comparable in duration to those in the more accurately defined Isa Superbasin. This may indicate that this Superbasin phase can also be sub-divided into (? 2^{nd} order) supersequences with durations of around 5-10 m.y. There is, however, at least one obvious difference between the two superbasin phases and that is in the character of the preserved rock record. In the Calvert Superbasin localised to sub-regional, high level intrusive/extrusive igneous episodes and laterally variable packages of immature clastics dominate the rock record. Thermal and tectonic controls on accumulation show a more obvious imprint on the rocks than is evident in the Isa Superbasin where more regional/widespread episodes of subsidence produced thicker sediments and more uniform facies. The Calvert Superbasin record may reflect significant cannabalisation of penecontemporaneous material, whereas the rocks in the Isa Superbasin may reflect less reworking of subjacent stratigraphy.

There is reasonably good stratigraphic evidence and isotopic dating information (Page et al., 2000) to document ***SB1*** (**Fig 10**). It is located within the Wollogorang Formation. Previously this unit of red mudstone–carbonate–black shale–sandstone had been mapped throughout the region as a concordant and conformable sedimentary succession (see Jackson et al. 1987; Ahmad & Wygralak, 1989). However, during a sequence stratigraphic re-assessment of the type section in 1995, we were struck by the marked shallowing in facies, from black laminated shales below to coarse cross-bedded sandstones above, that occurs in about the middle of the formation. This was interpreted as a basinward shift in facies and therefore a potential sequence boundary (Jackson et al., 1997). Subsequent U-Pb SHRIMP dating of tuff samples collected from above and below this horizon in drillholes indicates a difference of a few million years between the two successions. Tuffs from the black shales were deposited at around 1730±3 Ma, whereas a tuffaceous interbed from the coarser grained sandstones above the surface was laid down at 1723±4 Ma (Page et al., 2000). SB1 is therefore shown at ~1727 Ma, halfway between the two measured ages of 1730 and 1723 Ma.

SB2 is largely inferred. Its presence could most easily be confirmed by dating of the newly defined Echo Sandstone (Rawlings, 1999) and/or its associated and correlated clastic units (Warramana Sandstone, Pungalina Member). Stratigraphically, the Echo Sandstone and associated units lie between the Gold Creek Volcanics–Hobblechain Rhyolite felsic phase at 1725±2 Ma and the Tanumbirini Rhyolite at 1713±7, ie there is a gap of around 10 m.y. between their respective mean ages. Field relationships alone are not distinctive enough to enable a strong case to be presented for determining a more accurate location of the Warramana/Echo/Pungalina association on **Figure 10**. Rawlings (1999 & pers. comm. 21.3.2000) interprets the relationship between the Gold Creek Volcanics and overlying clastic units (Echo Sandstone and Pungalina Member) as conformable or unconformable. However, earlier (1999, p722), he commented that the lower conglomeratic Pungalina Member is an epiclastic/talus apron of the Hobblechain Rhyolite. This would suggest that there is minimal time missing between the basal Pungalina Member of the Echo Sandstone and the top of the underlying Hobblechain Rhyolite. In this scenario SB2 should probably be reduced in significance, the Echo and associated units brought down closer to the 1725 Ma felsic phase and SB3, by inference, may then represent a much longer none-depositional episode.

SB3 is located in the upper part of the Warramana Sandstone, which is a ~200-300 m thick shallow marine clastic unit that crops out extensively in northern BAUHINIA DOWNS and in eastern MOUNT YOUNG. Rawlings (1999) correlates it with the Echo Sandstone of southern BAUHINIA DOWNS and ROBINSON RIVER. The presence of a sequence boundary within it is inferred from the lithological description of ‘unit 2’ in drillhole BHP McA14 contained in Haines et al., (1993). They describe ‘unit 2’ as a 15 m-thick massive to pisolitic ironstone, haematitic mudstone and ferruginous pebbly sandstone. This is overlain by a sandstone (‘unit 3’) that is markedly different from the sandstone below the ironstone (‘unit 1’). They state "The ferruginous pisolitic interval within unit 2 may represent a palaeolaterite suggesting a minor hiatus at this level" (Haines et al., 1993, p. 27). Without isotopic dating the size of this "hiatus" is unknown, but the significant change in lithology from 'unit 1' to 'unit 3' may indicate it is an important sequence boundary. D. J. Rawlings (pers. comm. 21.3.2000) has identified a stratigraphic discontinuity in about the middle of the Echo Sandstone in ROBINSON RIVER, which may be a lateral equivalent of surface SB3. Stratigraphic and age controls in the equivalent rocks (Bigie Formation) in the Mount Isa region are lacking and do not add any light on these proposals.

The presence of ***SB4*** (**Fig 10**) is largely inferred from the Mount Isa area where the Surprise Creek Formation unconformably overlies the ~1720 Ma Bigie Formation, ~1760 Ma Myally Sub-Group and ~1780 Ma Eastern Creek Volcanics. The base of the Surprise Creek Formation has long been recognised as a significant stratigraphic break (eg Derrick, 1982; Blake, 1987; Nijman et al., 1992; O'Dea et al., 1997).

In the McArthur River Region ***SB4*** seems to be represented by a long period of non-deposition and/or erosion (**Fig 10**). There is a distinct gap in isotopic age dates from around 1713 Ma for the felsic Tanumbirini Rhyolite, and its associated epiclastic Nynantu Formation and conformably overlying Burash Sandstone (Rawlings, 1999), up to around 1650 Ma for the Tatoola Sandstone, which is some 600 m higher up in the McArthur Group.

SB5 (**Fig 10**) is based largely on the description of a "locally erosive contact" between the Mattamurta Sandstone and overlying Badalngarrmirri Formation of the Parsons Range Group in the northwest of the McArthur Basin (Haines et al., 1999). The Parsons Range Group has not been directly dated, so the age of this potential surface cannot be accurately pinned. It is between about 1705 Ma (approximate mean of several ages from the underlying West Branch and Fagan Volcanics) and about 1620 Ma (oldest age currently available from the overlying Balma Group, Haines et al., 1999). It is possible that SB5 may be represented by the incision recorded at the base of the Warrina Park Quartzite in the area north east of Mount Isa, but, again, there is a lack of isotopic ages.

In summary, we can identify several contenders for sequence boundaries (disconformities, unconformities, hiatuses) in the 1690 – 1735 Ma Calvert Superbasin (**Fig 10**). No doubt further field studies would identify others. There is limited isotopic dating which allows broad stratigraphic correlations to be proposed. However, specific sequence stratigraphic research and additional SHRIMP-style dating would be essential to advance these initial proposals any further, and also to gain an appreciation of the relative order of these various surfaces.

"Lower" Masterton Sandstone

The Masterton Sandstone is a prominently outcropping reddish-brown sandstone that Jackson et al., (1987), defined as the base of the McArthur Group. On **Figure 4**, and in the event charts in various NABRE papers (eg Southgate et al., 2000a; Krassay et al., 2000a; Scott et al., 2000) the Masterton Sandstone is split into two components. An older "lower Masterton" which has been placed within the Big Superseqence of the Calvert Superbasin and an "upper Masterton" which is shown at the base of the Gun Supersequence in the Isa Superbasin. By doing this we are implying a significant hiatus at this surface (approaching some 30-40 my.). During the initial NABRE field season we identified a significant internal disconformity/subtle angular unconformity in the type section of the Masterton Sandstone at Archies Creek in the McArthur River Region. Despite its definition in Jackson et al., (1987) as a single lithostratigraphic unit, the Masterton Sandstone is herein interpreted as comprising two genetically distinct sequences (**Fig 12**).

This is supported by Rawlings (1999) in his lithostratigraphic review of the McArthur Basin. He includes a formal revision of the Masterton Sandstone (Rawlings 1999, Appendix 1). He proposes that an older sandstone unit, which is exposed widely on the Wearyan Shelf (and which correlates with the lower Masterton in the type section), should now be referred to as the Echo Sandstone. The name Masterton Sandstone should only be used for a younger sandstone unit immediately below and conformable with the Mallapunyah Formation at the base of the McArthur Group. As mentioned above in the section on the Calvert Superbasin, Rawlings (1999, Fig 3) correlates the Echo Sandstone in the southeast of the basin with the Warramana and Burash Sandstone in the MOUNT YOUNG and TANUMBIRINI areas and shows these units as mostly slightly older than the Parsons Range Group in the northern part of the McArthur Basin. Hence in **Fig 4** the lower Masterton is shown as latest Big Supersequence whilst the Parsons Range Group is shown as Prize Supersequence and the upper Masterton as Gun Supersequence.

ISA SUPERBASIN SUCCESSIONS IN THE MCARTHUR RIVER REGION

As defined by Jackson et al., (2000a) and Southgate et al., (2000a) the Isa Superbasin Phase contains rocks deposited between about 1670 Ma and 1575 Ma (**Fig 4**). This is where most of the sequence stratigraphic research was conducted in the NABRE Project, consequently it is much better understood than the Leichhardt and Calvert Phases. The Isa Superbasin has been subdivided into seven second-order unconformity-bounded supersequences. These supersequences comprise preserved rock successions ranging in thickness from a few tens to a few thousands of metres thick. Recent SHRIMP dating indicates that on average these preserved supersequences were deposited over time periods commonly between 10 to 20 m.y., inferring broad equivalence to second order sequences as defined in the Phanerozoic (eg Emery & Myers, 1996). These second-order supersequences contain a series of nested third-, fourth- and fifth-order sequences. The complex relationships and characteristics of these various stratigraphic sequences/cycles are generally better understood in parts of the Lawn Hill Platform – Mount Isa area where there is extensive outcrop, well and seismic control. In the McArthur River Region the lack of regionally extensive outcrop limits the sequence analysis to largely a one-dimensional view of the stratigraphy. Information necessary for the construction of regional cross-sections and detailed 3rd to 4th order sequence subdivisions are generally lacking. Based on new SHRIMP dating and gamma ray logging of sections and wells, the seven supersequences defined in the Lawn Hill area can be tentatively identified in the McArthur Region and, in a few places, subdivided likewise into higher order sequences. However, correlation of these higher-order subdivisions is limited by lack of control.

Gun Supersequence

The Gun Supersequence was first defined by Southgate et al., (1999) using NABRE SHRIMP U-Pb ages and detailed gamma-ray logs through the basal part of the McNamara Group (Gunpowder Creek – Esperanza Formations) in the southern part of the Lawn Hill Platform. It is described in detail in Domagala et al., (2000); Sami et al., (2000) and Southgate et al., (2000 a & b). The basal part of the McArthur Basin succession has long been correlated with the basal part of the McNamara Group (eg Plumb et al., 1980) so we expected to find approximate equivalents of the Gun Supersequence near the base of the McArthur Basin succession.

Unfortunately, samples suitable for dating were not obtained from rocks in the McArthur Basin that we now equate with the Gun Supersequence (upper part of Masterton Sandstone and lower part of Mallapunyah Formation). The presence of the Gun Supersequence (**Fig 4**) is based largely on stratigraphic reasoning and inference, as described below.

To look for dateable material and to help define sedimentary trends we re-measured and gamma-logged the type sections of the Masterton Sandstone, Mallapunyah Formation and lower part of Amelia Dolomite in Archies Creek and the adjacent Kilgour River. These are shown as a composite section **Archie Creek Composite**, and in simplified form in the lower parts of **Figures 11, 12,13, 14**. We can add little to the detailed lithological description and facies interpretations presented by Jackson et al., (1987, Figs 37 and 53). However, using the gamma-ray log to identify gradational facies trends we suggest a different genetic subdivision of the succession and a revised evolution. Further, a new detrital SHRIMP zircon age, which helps to tie down the broad age of these rocks, was obtained from the Mallapunyah Formation. The gamma logs helped to identify two erosion surfaces (previously considered minor) which now define the bases of the Gun and Loretta Supersequences. A dateable zircon population was obtained from sample 9577.9041 from green mudstones, which produce a prominent gamma-ray spike at 230m in the **Archie Creek** section. The sample is located approximately 30 m below the top of the Mallapunyah Formation (**Fig 11**). The petrology of the sample and its heterogeneous zircon suite indicate that this immature fine-grained feldspathic rock is <u>not</u> an airfall tuff, but rather a reworked sediment; the SHRIMP analysis does not therefore yield a depositional age. The data from 88 sub-rounded zircons yield a variety of ages ranging from 3100 Ma (Archaean) to about 1650 Ma. Four replicate analyses on one grain (grain 350) produced a concordant age of 1653 +- 9 Ma, so Page et al., (2000) interpret this as an imprecise maximum age for this part of the succession. This age of around 1653 Ma equates this claystone either with upper part of the Gun Supersequence or the lower part of the Loretta Supersequence (approx. 1645-1655 Ma).

In outcrop there is a marked planar erosion surface and a major change in gamma log characteristics approximately 12 m below the level where the SHRIMP zircon sample was taken. Previous lithological logging had not originally identified a major change across this surface. However, the presence of quartzite and carbonate clasts (indicating incision and erosion of probably the Mallapunyah Formation and underlying Masterton Sandstone) in a gravelly ferruginous sandstone mantling the surface, together with the marked gamma ray log shift (at 219 m) are now interpreted to indicate a significant break in sedimentation. There is also a noticeable palaeomagnetic reversal across this surface (Idnurm et al., 1995). The underlying Mallapunyah Formation and upper half of the Masterton Sandstone are therefore associated with the Gun Supersequence (**Fig 11**).

In the Mount Isa region Southgate et al., (2000b) identify three 3rd-order sequences in the Gun Supersequence. These consist predominantly of thick successions of storm-deposited fine siliciclastics and minor carbonates deposited on a broad southeast-facing ramp that stretched from the Murphy Inlier in the northwest to the Mount Isa area in the southeast. With the information currently available it would be premature to suggest identification of these cycles in the terrestrial deposits preserved in the southern McArthur Basin. Although the gamma log does contain possible cycles (see for example **Fig 12**) the succession does not outcrop fully and it is dominated by saline and none-saline mud flat, fluvial/alluvial facies that indicate fairly low accommodation rates in a proximal location (**Figs 13** & **14**). Southgate et al. (2000b) comment on the gradual northward thinning of the Gun Supersequence on seismic sections, from a maximum of 1 700 m in the southeast (near Mount Isa) to around 100 m in the north (Murphy Inlier). The presence of a relatively thin dominantly continental facies in the McArthur region is consistent with this south to north palaeogeographic trend seen on the Lawn Hill Platform.

The only other age constraint we have for rocks in the **Archie Creek Composite** is an indirect regional stratigraphic age of about 1725 Ma for the Gold Creek Volcanics at the very base of the section (**Fig 12**). Along the southeast margin of the McArthur Basin, the Gold Creek Volcanics are overlain by the Hobblechain Rhyolite, dated at 1725 ± 2 Ma, and underlain by the Wollogorang Formation at around 1723 ± 4Ma (Page et al 2000). There is, therefore, about a 75 m.y. gap between the Gold Creek Volcanics and the upper Mallapunyah Formation into which we could fit the Gun Supersequence (lower Mallapunyah Formation and upper Masterton Sandstone) and the underlying Prize and Big Supersequences (lower Masterton Sandstone).

Loretta Supersequence

The Loretta Supersequence comprises a mixed succession of carbonates and siliciclastics deposited around 1650 Ma. In the Mount Isa-Lawn Hill area outcrop relationships are equivocal, but the broad stratigraphic characteristics of the Loretta Supersequence are visible on the COMALCO seismic lines in the northern Lawn Hill Platform (Bradshaw and Scott, 1999). Here it comprises a gradually northward-thinning package with a gentle regional unconformity at its base. Correlation between the seismic and outcrops at the northern margin of the Lawn Hill Platform suggest that it equates with the Walford Dolomite. This is supported by a SHRIMP age of 1649 ± 7 Ma for that unit. Further south (central Lawn Hill Platform) it is equated with the Lady Loretta Formation. This is based largely on a SHRIMP age of 1647±4 Ma from the upper part of this unit, near the Lady Loretta Mine. At Mount Isa the Loretta Supersequence is interpreted as comprising the Kennedy Siltstone and Magazine Shale (Southgate et al., 2000a), but this has not been confirmed by dating.
The presence of the Loretta Supersequence in the McArthur River Region is indicated by a depositional age of 1648 ± 3 Ma from a tuffaceous interval in the lower Tatoola Sandstone in Leila Creek.

As discussed in the previous section the base of the Loretta Supersequence is defined as the marked gamma ray and lithofacies change at 219m, in the **Archie Creek Composite**. The top of the supersequence is not tightly constrained by age dating. The next youngest SHRIMP age in the McArthur River Region is the 1639 ± 6 Ma age from the Teena Dolomite, some 900 m higher in the section (**Figure 11**). Assuming these Proterozoic rocks had similar depositional rates to Phanerozoic carbonates a significant break is suggested at the base of the succeeding River Supersequence. There are two likely contenders —

1. an erosion surface at the base of the Leila Sandstone, or
2. a karst surface near the base of the Teena Dolomite (Fig 11).

Option two is adopted in this report, although previously Southgate et al., (2000a, page 473) had preferred option 1. This apparent dichotomy is discussed in this section, but it can probably only be solved by additional SHRIMP dating.

Five sections – **Archie Creek Composite** (uppper part), **Kilgour-Tatoola, Mallapunyah Creek-Tatoola, Mid Kilgour Composite** and **Yellow Waterbore** contain detailed lithofacies and gamma-ray data for this Supersequence. **Figures 11 to 21** contain summarised lithofacies, gamma ray and environmental interpretations.

The basal conglomerate of the Loretta Supersequence in Archie Creek is overlain by a 50-m thick succession of interbedded fine grained, current-rippled sandstone and siltstone crowded with halite casts and moulds (**Figure 13**). On the gamma ray curve a pronounced shift to the right (230-270 m) characterises this stratigraphic interval. The evaporitic clastics were probably deposited in a restricted lagoonal setting permeated by highly evolved saline brines during deposition and early diagenesis.

At the top of the basal evaporitic clastics there is a sharp gamma kick to the left produced by “cleaner” carbonates (Fig 13,270 m) These comprise intraclastic, oolitic and stromatolitic facies. Generally, above here the gamma ray log pattern for the 200-m thick Amelia Dolomite hovers around the 100 counts per second value and this part of the Loretta Supersequence appears to be predominantly aggradational (**Fig 14**). There are several prominent peaks, especially around 330 and 360 m where values exceed 400 counts per second. These are related to poorly outcropping green shales (mostly less than a metre thick) between the stromatolitic carbonate beds. Initially it was thought that these might indicate an overall deepening of depositional environments, and the thicker shale-based cycles around 330 m may therefore represent the maximum flooding for a higher order cycle in the Supersequence. However, green shales and siltstones interbedded with stromatolitic carbonates are a common feature above this stratigraphic level, and in places where they outcrop well, they sometimes contain shallow water features.

There is a subtle difference between the character of the carbonate cycles in the upper third of the Amelia Dolomite when compared with those below about 360 m and this is accompanied by the distinct incoming of beds of quartz sand. As shown in schematic fashion on **Figure 13** the carbonate cycles in the lower two thirds of the Amelia Dolomite are dominated by domal and conical stromatolites with rare oolitic and intraclastic beds. Individual cycles are up to about 6 metres thick. The cycles in the upper Amelia Dolomite are thinner (mostly 2-3 m) and dominated by intraclastic dolostones, lacking well developed larger stromatolites. Accommodation space must have been gradually reduced in the upper Amelia and the depositional environments were obviously much more agitated and swept by strong storm currents. On **Figure 13** these two parts of the Amelia Dolomite are shown as "deeper" and "shallower" parts of a carbonate ramp or platform. If the shales around 330 m are accepted as defining a mfs for a higher order cycle the shallower ramp cycles deposited during a period with reduced accommodation would be consistent with a highstand setting.

An alternative interpretation is presented here, but this is considered less likely. In this alternative the lower two thirds of the Amelia Dolomite is dominated by lagoonal carbonates whereas the upper part is dominated by largely shoreline to barrier facies. In this scenario a basal evaporitic lagoon would have been replaced by an essentially none evaporitic lagoon which was then transgressed by a shoreline complex. Here, most of the Amelia Dolomite would be gradually transgressive. This later interpretation would, at least, fit in well with the interpretation of the succeeding Tatoola Sandstone as being a slightly deeper water mid-shelf clastic unit.

A marked increase in quartz sand associated with a reduction in carbonate defines what appears to be a gradational contact zone between the Amelia Dolomite and Tatoola Sandstone at this locality (**Fig 12**). Earlier work (Jackson et al., 1987, 73), suggested there may be an unconformable contact near the southwest margin of the basin between these two units. No obvious, sharp, basinward shift in facies could be identified at this level at the localities we examined. We suspect there must be some localised tectonic rejuvenation at this stratigraphic level to expose older sandstone units (Masterton Sandstone, for example) to act as a source for the quartz sand. The track of the APWP (Idnurm, 2000, Fig 17, 'B3") shows an obvious change in direction close to where the poles from the Amelia Dolomite and Tatoola Sandstone plot which may signify intraplate readjustment. Further study is needed to more accurately define the character of the contact zone.

Using the gamma ray log trends the Tatoola Sandstone can be subdivided into two sub-equal, symmetrical cycles of increasing then decreasing gamma ray values, each around 40 m thick (eg **Figs 12,13**). Using standard sequence stratigraphic models (see earlier) we were initially tempted to interpret this as two transgressive–regressive episodes. Detailed lithofacies logging, however, did not support this interpretation. The logs from the **Kilgour-Tatoola** and **Mallapunyah Creek-Tatoola** sections show that the rocks in the upper and lower parts of the unit are subtly different, but there is no clear evidence for two cycles of transgression followed by regression. The lower Tatoola Sandstone consists of stacked 1–2 m thick fining-up cycles of very fine-grained silty sandstone grading to mudstone. The upper Tatoola Sandstone is similar, but the cycles are less well-defined and large hummocky and swaley bed-forms replace the small wave and current ripples characteristic of the lower part of the unit. It also shows a distinct thickening- and coarsening-upward character. The upper gamma cycle seems therefore to be characterised by largely storm-dominated environments, whereas the lower part is dominated by normal shore-face waves and currents. Care is obviously needed in applying the sequence stratigraphic models and mottifs to the gamma ray logs summarised earlier in this report.

Both the lower and upper contact zones of the Tatoola Sandstone contain beds of sandy stromatolitic dolostone. These are usually reddish and ferroan, and contain low domes and small pseudocolumnar forms associated with carbonate intraclasts. The carbonate-precipitating stromatolitic environments and the storm to current-swept clastic environments presumably existed side-by-side in these mid Proterozoic seas.

There are subtle facies differences between the Tatoola Sandstone at Kilgour, which is coarser grained overall, and that at Mallapunyah Creek (35 km to the northwest), which is finer grained. The Kilgour Section also has few intact shale beds and lots of prod, groove and scape marks compared to Mallapunyah Creek, where mudstone beds are preserved and the predominant bedform (hummocky cross-stratification) is larger and there is a lack of surface markings. This suggests a palaeogeography with the subaqueous environments deepening to the north and/or west. This is consistent with previous observations. Jackson et al., (1987, p73) comment on northwest-aligned channels of loaded fine grained sandstone at Leila Creek (30 km north of the Mallapunyah Creek section) which might indicate a northwest-palaeoslope. Regionally, the Tatoola Sandstone appears to gradually thin northwards, so that by the southern MOUNT YOUNG sheet area (a further 80 km north of Leila Creek) it is only 50 m thick (Haines et al., 1993). We speculate that it may be this northward thinning and deepening of facies that is the reason the Tatoola Sandstone has not been identified as a mappable unit north of MOUNT YOUNG.

The middle part of the Loretta Supersequence consists of a cyclic carbonate and siltstone unit called the Tooganinie Formation (**Fig 11**). Although short sections of the Tooganinie Formation crop out in various parts of the McArthur River Region it is seldom preserved in long, continuous sections so we understand little of its lateral variability. Only one complete section was measured, the **Mid Kilgour Composite**, and even here the upper 20-30 m (of the ~320 m thick section) is poorly exposed and the contact with the overlying Leila Sandstone is obscurred.

Just above the base of the Tooganinie Formation the gamma ray log shows a sharp deflection to the right (**Fig 11**, 500-570 m). This is followed by a fairly uniform gamma ray trend with a distinctive “saw-tooth” pattern (**Fig 11**, 570-780 m). The basal shift is related to the change from the low gamma-ray counts of the interbedded (“cleaner”) quartz sandstones and stromatolitic dolostones in the Tatoola - Tooganinie contact zone to the high values recorded from green shales from the basal 70 m of the Tooganinie Formation. The sawtooth pattern in the rest of the Tooganinie Formation is related to the alternating “dirty” siltstone and “clean” stromatolitic dolostones that form the shoaling cycles so distinctive of the unit (**Fig 15**).

The green shales near the base are laminated and appear to lack the shallow water and evaporitic features seen in the other “dirty clastics” in the Loretta Supersequence. The shales are interpreted as reflecting a rapid deepening of the sedimentary environment and possibly represent the condensed deposits on a maximum flooding surface. In fact, Southgate et al., (2000) interpret them as the 2nd order Supersequence mfs. The shales are succeeded by stromatolitic cycles that Southgate et al., (2000a) describe as progradational highstand deposits. As discussed below we feel they are largely aggradational rather than progradatational.

The upper part of the underlying Tatoola Sandstone is clearly progradation and the contact zone with the Tooganinie Formation contains several scoured surfaces mantled with coarse-grained cross-bedded dolomitic sandstones with large carbonate intraclasts. These high-energy deposits are interbedded with sandy and silty carbonates with gypsum pseudomorphs indicating the presence of concentrated evaporitic brines during early diagenesis. Locally, the scour surfaces have a few decimeters of relief. They indicate limited accommodation space, which may reflect the presence of a subtle (higher-order) sequence boundary (**Figs 15** & **16**).

A plausible (but probably less likely) alternative interpretation for the Taoola/Tooganinie transition is also included here. This alternative is that the green shale section is lagoonal and was deposited in relatively quiet subaqueous environments landward of the high-energy shoreline at the top of the Tatoola Sandstone. In this scenario the fine-grained clastics occur at the culmination of the progradational trend seen in the upper Tatoola Sandstone, rather than in a new transgressive episode. The overlying non-cyclic dolosiltsones would then represent a transgressive interval grading into the aggradational carbonate cycles starting around 100m (**Fig 15**). The apparent absence of a second sandy shoreline within this model, in what would be the retrogradational interval, and also the fact that the shales in this "lagoon" are completely devoid of evaporite pseudomorphs (yet sulphate pseudomorphs occur immediately below) suggests that this second model is less likely.

Most of the middle part of the Loretta Supersequence comprises stacked carbonate cycles, shown schematically in **Figs 15** & **17**. These cycles are usually a few metres thick and comprise a lower shaly component, which produces a marked positive deflection in the gamma log, and an upper "cleaner" crystalline stromatolitic carbonate component, which kicks the gamma ray log to the left. This is what produces the saw-tooth gamma-ray motif. There is little vertical change in cycle thickness or character (except at the top, see later) so these cycles are assumed to keep pace with accommodation; they indicate the middle Loretta Supersequence was predominantly aggradational. Although there are minor differences in stromatolite types these cycles are very similar to those preserved in the Lady Loretta Formation at Wangunda Bore (some 450 km to the southeast). These are at approximately the same level in the Loretta Supersequence so imply the presence of similar carbonate platforms in the McArthur Basin and Lawn Hill Platform at this time.

A partial section through the Tooganinie Formation was measured near Top Crossing, 44km northwest of the Kilgour River section. An attempt was made to correlate this section with the mid Kilgour composite using visual pattern matching of the peaks and troughs on the respective gamma ray curves. A unique solution could not be obtained, but the most likely correlation is shown in **Figure 17**. This indicates that the parasequences are almost exactly the same thickness in the two localities and, except for near the top of the unit, they comprise identical facies. This suggests little lateral variety for the depositional history of the carbonate platform during this period. This situation contrasts somewhat with the situation reported earlier for the underlying Tatoola Sandstone where significant lateral variety has been documented.

The cycles in the Tooganinie Formation, however, do show lateral variations near the top (**Fig 17**). These variations are shown in schematic fashion in **Figure 18**. The stromatolite parasequences thicken markedly near the exposed top of the Kilgour River section, although there is no obvious change in rock types or stromatolite forms present. In contrast, the upper part of the Tooganinie Formation at Top Crossing is dominated by dolomitic siltstone/shale with only thin and poorly developed stromatolitic carbonates. The shales are interpreted as the deeper component of the cycle and as these thicken in the Top Crossing area this suggests deepening towards this area. So, if the proposed gamma log correlation of parasequences as shown in **Fig 17** is accepted a northwest-deepening of environments is implied. This is consistent with that suggested earlier for the Tatoola Sandstone.

With the limited control available alternative interpretations of this middle part of the Loretta Supersequence are possible. One is that the correlations of the respective gamma ray curves is not reliable and that 330 m in the Kilgour Composite Section correlates with about 180 m in the Top Crossing Section (alternative on **Fig 18**); this is basically a lithogical correlation, and involves correlating the shaley upper part of the formation at top Crossing with the no outcropping (?shaley) top at Kilgour. In this case, the scour surface at the base of the Leila Sandstone, evident in outcrop at Top Crossing, may have eroded further down into the stromatolitic section at Kilgour indicating deeper incision on this surface than previously documented. This would favour the interpretation in Southgate et al., (2000a) who interpret this surface as the River Supersequence boundary; an interpretation not followed in this report. Additional work is required to further investigate these alternatives.

Based on these reconnaissance studies it is possible that the local setting for the middle Loretta Supersequence involves a palaeogeography that was deepening to the north and/or west. This is the opposite sense to that seen south of the Murphy Inlier where the Loretta Supersequence deepens and thickens towards the southeast (Southgate et al., 2000a). This probably indicates that although very similar and contemporaneous Loretta Supersequences were deposited in the McArthur River and Lawn Hill Regions they were probably deposited on different carbonate platforms in structurally different sub-basins.

In this report, the upper part of the Loretta Supersequence is defined as the succession Leila Sandstone—Myrtle Shale—Emmerugga Dolomite (**Fig 11**). As noted earlier, this is different to the interpretation favoured by Southgate et al., (2000a), where these units occur at the base of the River Supersequence. The composite gamma ray log for this interval is very similar in shape, size and pattern to that seen in the Tooganinie Formation. In broad terms, the succession of facies is similar – "dirty" clastics at the base (Myrtle Shale) overlain by a succession of "cleaner" largely transgressive then aggradational stromatolite parasequences (Emmerrugga Dolomite). In detail, however, there are differences in the lithofacies. Again, we have an example where close integration of gamma ray logs and lithofacies is essential before a reasonable environmental interpretation can be deduced.

Compared to Southgate et al., (2000a) we "downgrade" the importance of the scouring at the base of the Leila Sandstone to, perhaps, a 3rd order sequence boundary, and "upgrade" the karst surface at the base of the Teena Dolomite to the 2nd order River Supersequence boundary. In addition to the large-scale similarity in gamma ray log pattern and lithofacies successions, the primary palaeomagnetic poles from the Tatoola, Tooganinie, Myrtle and Emmerugga all plot on one smooth section of the APWP (Idnurm, 2000). This is consistent with deposition in related settings on a smoothly moving plate. In contrast, the section above the Emmerugga Dolomite has a much more variable gamma log signature. This is related to a wider range of rock types deposited in a variety of environments controlled by active syn-depositional faulting. In addition, the track of the APWP for units above the Emmerugga Dolomite is the opposite trend of that seen in the units below. An episode of major plate readjustment could be expected to result in a major stratigraphic break.

As noted in Jackson et al., (1987) the Leila Sandstone seldom outcrops well. We only examined a short section of it in the Top Crossing area. We can add little to that presented in Jackson et al., (1987), except that near Top Crossing the base of the unit is clearly erosional as it scours into the underlying shaly carbonates of the Tooganinie Formation.

Most of the information on the Myrtle Shale–Emmerugga Dolomite–Teena Dolomite in Jackson et al., (1987) is from the Top Crossing area or near the McArthur River mine. In 1996 we measured a well-exposed section through low cliffs at a locality called Yellow Water Bore about half way between these other two localities. This detailed log is shown in the **Yellow Waterbore** section. Simplified schematic representations of this section are also shown in **Figures 19–21**.

Jackson et al., (1987) interpret the Myrtle Shale as a largely lacustrine and/or low gradient alluvial plain deposit with a possible evaporite solution collapse breccia near the contact with the overlying Emmerugga Dolomite. Our studies confirmed this broad interpretation. The Myrtle Shale is a red bed, continental facies containing a range of evaporite pseudomorphs and desiccation cracks and was deposited in a saline playa-mudflat type of environment. Despite the similar gamma-ray log pattern (**Fig 11**) to that of the Tooganinie Formation, it was obviously deposited in a much shallower, more proximal environment. It is gradationally replaced by evaporitic stromatolitic cycles as accommodation space gradually increased. At this locality the shoaling tops of the lowermost 15-20 stromatolite cycles are richly evaporitic (shown schematically in **Figure 20**) with the basal 6 cycles containing laterally continuous thin breccias, which are probably related to collapse after dissolution of more extensive beds of halite.

The upper half of the Emmerugga Dolomite consists of much thicker stromatolite cycles (up to about 20 m thick). These contain both large domal forms and both solitary and branched '*conophyton*' stromatolites. The tops of the cycles consist of silty dolostones with discontinuous stratification, current ripples, intraclasts and rare minute halite casts. It is these "dirty" beds that produce the strong gamma log kicks that clearly define the cycles. This is the opposite of the Tooganinie Formation where the gamma kicks are produced by the deeper water shales in the lower halves of the parasequences. The gradual thickening of the stromatolite cycles evident in the Yellow Water Bore section (see **Fig 20**, above about 1000 m) is interpreted to indicate gradual deepening of the environment due to a gradual increase in accommodation rates. It would appear, therefore, that this part of the supersequence is largely transgressive. The presence of the minute evaporite pseudomorphs at the tops of the individual cycles still indicates an influence from a ?terrestrial source area of evolved brines. Also, in places the '*conophyton*' stromatolite biostromes show marked asymmetry which is probably related to strong tidal current influence. Presumably, this locality records inner carbonate ramp or platform environments of deposition.

The grey "massive" crystalline dolostones that commonly occur near the top of the Emmerugga Dolomite (upper Mara and Mitchell Yard Members) appear, in this section, to be replacing former grainstone and intraclastic facies. These grainstone facies also contain branching, bilaterally-symmetrical '*conophyton*' stromatolites so were deposited in environments also swept by strong current, possibly offshore bars or barriers?

The upward reduction in siliciclastic input and evaporitic overprint, above about 1000 m (**Fig 20**), combined with the gradual increase in cycle thickness and stromatolite size is interpreted as indicating a gradual increase in accommodation rates. This continuing transgressive trend is truncated by a sharp erosion surface and basinward shift in facies (**Fig 20**, at ~1230 m). The character of the karst surface marking the top of the Loretta Supersequence is described in the section on the River Supersequence.

Southgate et al., (2000a, Fig 6) show the Loretta Supersequence of the Lawn Hill Platform as one major second-order supersequence containing two third-order sequences within it. The highstands of both second-order sequences comprise thick uniform packages of subtidal tempestite cycles, that largely consist of stacked shoaling shale-stromatolite parasequences. The stromatolite cycles in the McArthur Basin are similar, but here we appear to have three major packages of shoaling stromatolite cycles separated by "dirty" intervals dominated by clastic units (**Fig 11**). The parasequences at McArthur River are more variable, much sandier and contain more obvious erosion surfaces suggesting they are more proximal in character. The maximum floodings for the Loretta third-order sequences in the Lawn Hill Platform are interpreted to occur within laminated shale units, approximately 200 and 400 m above the base of the Supersequence. In the McArthur River Region significant facies deepenings (floodings) occur at three levels:

1. the middle Amelia Dolomite;
2. the Tatoola Sandstone and
3. within the shales at the base of the Tooganinie Formation.

These are at approximately 100 m, 200 m and 300 m above the base of the Supersequence. The floodings in the McArthur River Region are probably not as "deep" as the floodings on the Lawn Hill Platform, indicating that the Lawn Hill Platform area was one of overall higher accommodation rates. With the limited control, it is not possible to confidently correlate the flooding episodes at McArthur River with those on the Lawn Hill Platform.

River Supersequence

The River Supersequence in the McArthur River Region is a thick and lithologically variable package of rocks deposited around 1640 Ma. It contains the world famous McArthur River

Silver–Zinc–Lead mine in a unit called the Barney Creek Formation. Unlike most other supersequences in the McArthur area that are dominated by carbonates, this supersequence contains thick intervals of black siltstone and shale and clear evidence of syn-depositional tectonism (Jackson et al., 1987; Hinman 1995). As discussed earlier, we have modified the definition of the contact between the Loretta and River Supersequences from that presented in Southgate et al., (2000a). As defined herein the River Supersequence now comprises the stratigraphic interval of the Teena Dolomite up to and including the Yalco Formation (**Fig 2**).

This current grouping of units is very different to that of the previous lithostratigraphic scheme (Jackson et al., 1987). The base of the Supersequence is defined at the base of the Teena Dolomite within the Umbolooga Subgroup. A distinctive karst surface is exposed at the contact between the Teena Dolomite and the underlying Mitchell Yard Member (Emmerugga Dolomite) in the **Yellow Water Bore** section. It comprises vertical to inclined irregular cracks and cavities several metres deep rimmed with carbonate cements and filled with pinkish silty dolomitic material. This later material is K-rich and produces prominent gamma ray kicks (**Fig 20**). The Teena Dolomite and overlying W-Fold Member (of the Barney Creek Formation) are rich in pink and green tuffs (Jackson et al., 1987) so this pinkish silty material at the base is probably also tuffaceous. The basal carbonate of the Teena Dolomite contains medium to coarse grains of quartz sand, suggesting localised inversion to provide a source for clastic detritus. At various localities in the southern part of the McArthur Basin the Mitchell Yard Member is absent from the top of the Emmerugga Dolomite; this would also be consistent with a major stratigraphic break at this level, but detailed mapping of the surface would be required to confirm this.

The top of the River Supersequence is defined by the base of the overlying Term Supersequence which is stratigraphically located at the base of the Stretton Sandstone (see later). The River Supersequence, therefore, comprises the upper part of the Umbolooga Subgroup and the lower part of the overlying Batten Subgroup. Although this may seem like an unlikely grouping, in light of the existing lithostratigraphic associations, it looks much more reasonable when viewed from the perspective of the recent SHRIMP zircon dating (Page et al., 2000). In this data there is a distinct grouping of units including the Teena Dolomite, Barney Creek Formation and Lynott Formation all with ages around 1640 Ma. Above the grouping there is an apparent ‘gap’ of around 10-15 million years without preserved stratigraphic section, before the overlying Stretton Sandstone at about 1625 Ma (**Fig 4**).

Palaeomagnetic data also point to the likelihood of a sequence boundary at approximately Emmerugga time. The evidence, in the form of a hairpin bend in the northern Australian apparent polar wander path at ~1640 Ma (Idnurm, 2000), indicates a radical change in the direction of movement of the region, suggesting a major tectonic event at that time. The primary pole from the Emmerugga Dolomite lies near the apex of the hairpin (although the data are not precise enough to indicate if the pole precedes, follows or coincides with the apex). The top of the Emmerugga Dolomite contains the only suspected regional unconfomity for that part of the stratigraphic column, suggesting a link with the ~1640 Ma tectonism. It should be noted that the next youngest available primary pole, from the 1636 +/- 4 Ma Lynott Formation, lies north of the bend and therefore post-dates the tectonism.

The stratigraphic locations of the various sequence boundaries within the supersequence are poorly constrained and will be subject to revision as more data (especially age dating) become available.

The River Supersequence is preserved in the McArthur Basin and Lawn Hill Platform areas. It is not present in the Mount Isa region, presumably because of removal associated with erosion during and following the Isan Orogeny.

Only limited sequence stratigraphic work was undertaken on this supersequence during the NABRE project and most of this was done by Peter Winefield as part of his PhD studies at the University of Tasmania (1996 to 1999). His study concerned primarily the setting and evolution of the Teena Dolomite and Barney Creek Formation. Early results from this study have been included in several AMIRA/ARC Project P384A reports (confidential to sponsors), but external publication of the results is in progress (eg Winefield, 2000).

To assist in this study, AGSO gamma ray logged existing core from several holes drilled near the HYC deposit (now McArthur Mine), and also open file exploration company drill core stored at the Department of Mines in Darwin. We used information from existing company geological logs and core photographs to produce GEOLOG plots for most of these drillholes (see **Table 2**). Martin Neudert and Mark McGeough carried out the core photography and bed thickness and grainsize determinations which formed the basis of our log descriptions on the drillholes supplied by MIMEX. We have not undertaken our own systematic geological re-logging of these holes, so are not able to provide the sort of integrated analysis presented for the other supersequences. In fact, time restrictions did not allow us to do any studies on the Reward Dolomite, Lynott Formation or Yalco Formation during the NABRE Project.

Most previous studies in this part of the stratigraphic section have documented extensive and variable syn-depositional tectonic activity (eg Jackson et al., 1987; Hinman, 1995; Neudert & McGeough, 1996; Bull, 1998). It is likely, therefore, that the sequence stratigraphic models described in the introduction to this report — where the facies changes are interpreted mostly in terms of a predictable set of relative sea level changes — will not be directly applicable to this supersequence. The cycle boundaries (sequence boundaries) and "maximum floodings" tentatively identified on the GEOLOG plots probably represent tectonically-driven accommodation events.

Where best preserved, in the southern Lawn Hill Platform, the River Supersequence comprises eight third-order sequences which attain a total thickness of around 3,500 m (Krassay et al., 2000). Six of these sequences (River 3–8) are represented by mid shelf to deep marine, commonly turbiditic clastic facies of the Riversleigh Siltstone. Information from seismic lines indicates there is a major incision surface at the base of the River Supersequence and that the package gradually thins and onlaps to the north. Age dating results also suggests that older parts of the Supersequence are only preserved in the south of the Lawn Hill Platform. At the northern end of the Lawn Hill Platform, where the sections onlap the Murphy Inlier, the River Supersequence is represented by the Mt Les Siltstone, with a SHRIMP age of 1640 ± 7 Ma. Bradshaw et al., (2000) note that only three (River 5,6,7) of the eight sequences recognised at the southern end of the Lawn Hill Platform are present in the north. As at McArthur River, the rocks are dominated by dolomitic siltstone with Zn-Pb-Cu mineralisation (Walford Creek Prospect).

The implications of this south to north attenuation of the River Supersequence across the Lawn Hill Platform for the McArthur River region are not clear, but it suggests that the River Supersequence in the McArthur Area may not contain equivalents of all of the eight sequences preserved in the southern Lawn Hill Platform. The fact that the mean value for the oldest SHRIMP age from the River Supersequence at McArthur River (1639 ± 6 Ma from the Teena Dolomite) is a few million years younger than a good SHRIMP age (1644 ± 8 Ma) from the middle part of Riversleigh Siltstone suggests that only the younger sequences are likely to be preserved in the McArthur River Region.

Based on an initial review of composite gamma ray logs produced from the wells and outcrop sections in the McArthur River Region, Southgate et al., (1997) tentatively subdivided the stratigraphic interval we now call the River Supersequence into five tectonically-driven depositional cycles. They used terms such as SB (sequence boundary) and mfs (maximum flooding surface) and showed these in an illustration (Figure 1) accompanying the extended Abstract. We reproduce their figure in this report (**Fig 22**) with some of our newer informal nomenclature from the GEOLOG plots. From oldest to youngest they named the tectonically-driven cycles — Teena Cycle, Barney Cycle, Reward Cycle, Lynott Cycle and Yalco Cycle. Each of these cycles appears to commence with a phase of rapid subsidence during which organic-rich dolomitic siltstones and shales were deposited and preserved. These commonly produce deflections to the right on the gamma ray logs (mfs on **Fig 22**). These are then overlain by a wide variety of facies which in general display "cleaning-up" (aggradational to progradational?) gamma ray log characteristics. As noted above, how these five cycles correlate to the eight sequences on the Southern Lawn Hill Platform is not known.

Most of the drillhole and outcrop sections that were measured are also shown at reduced scale in SECTION 1 and SECTION 2. **Section 1** is a 100 km long, north-south section running from near Bing Bong to the HYC Deposit. **Section 2** is a 50 km long, west-east section, at the southern end of the outcrop belt. Taking into account the reservations expressed earlier about the application of sequence stratigraphic concepts to these rocks, the lack of independent time control, and a desire not to overly force the interpretations, we have not used sequence stratigraphic nomenclature on these sections. Instead we have attempted to correlate the sections using:

1. similar gamma ray trends;
2. unusual or distinctive peaks or troughs; and,
3. a few chronostratigraphically significant "events" (eg tuff beds).

Initially, the gamma ray correlations were undertaken using plots from Excel charts, with the gamma logs stretched horizontally to enhance trends and breaks. This is basically all that was done for the composite curve that Southgate et al., (1997, Fig 1) used for their initial interpretations. These gamma ray based subdivisions/correlations were then refined/modified as the various lithologic logs were obtained and added to the data base. But, as noted above, this data is of variable source and probably of variable reliability.

The features we attempted to identify in the River Supersequence and the codes used on **Section 1** and **Section 2**, are shown in the following table:

Table 3 Codes and Features of River Supersequence

Code	Feature
LF (Lynott Flooding)	Prominent gamma peak in Lynott Fm
LP (Lynott Peak)	Gamma peak (tuff unit) in Bulburra Depression
LB (Lynott Base)	Gamma Low (start of new depositional cycle near base Lynott Fm)
RP (Reward Peak)	Gamma high ?tuffaceous unit in Reward
RF (Reward Flood)	Gamma high in section usually identified as Reward Dolomite
RM (Reward Mast)	Localised distinctive gamma low opposite large blocks of Masterton Sandstone in mega breccia beds within shale (Emu 9 & 13 only)
RB (Reward Base)	Prominent gamma low
BF (Barney Flooding)	Zone of high gamma values (most clay rich)
BT (Barney Tuff)	Gamma peak (tuff bed, locally traceable)
BO (Barney Ore)	Ore sequence (lithological information only) not distinctive on gamma
BB (Barney Base)	Generally sharp base of interval with elevated gamma values

Because of space restrictions, the gamma ray logs on these two cross-sections have been squeezed horizontally. In some cases, what appear to be obvious peaks/troughs/trends on the (stretched) Excel gamma logs are more subdued on these GEOLOG plots, and, therefore, look less obvious than on the original plots we used. However, most of the picks/trends should be reasonably self-evident. As emphasised above we have done very little work on this part of the basin's section and these correlations should be considered very tentative.

Some of the more interesting points to emerge include:

- Gamma logs may indicate alternative interpretations to those based solely on lithological criteria. For example compare:

  1. the gamma ray curves and our suggested subdivisions for the three Amelia Basin drillholes (far right, **Section 1**) — the interval geologically logged (by MIM mine geologists) as Barney Creek Formation in Amelia Basin 5 has a very similar gamma log pattern to the interval mapped as Barney Creek Formation <u>and</u> Reward Dolomite in Amelia Basin 6.

  2. the lithostratigraphic subdivisions for Bing Bong_2 and McArthur Basin_5 as proposed by the respective well-site geologists with our suggested gamma ray log correlations.

- The marked thickening of the Barney Creek Formation into the Bulburra Depression at HYC. This has previously been well-documented by Logan (1979) and Williams (1978a & b).

- The "Upper Breccias" (local mine geology terminology) of the Barney Creek Formation at HYC (ie the yellow coloured coarse beds in the middle part of Emu_13) fit better into our Reward Cycle rather than in to the Barney Creek Cycle. There is thus a marked difference between the previous lithostratigraphic correlations and our new associations using the gamma ray logs. Hinman (1995) identifies an inversion event in upper HYC sedimentation time, that effectively breaks the Barney Creek Formation into two genetic packages (at least locally). He interprets this inversion along the Emu Fault zone as probably the event that produced a local source of material for the "Upper Breccias". It is very likely that this event/surface is the RB surface that we have tentatively identified and traced through several wells/sections.

- An attenuated section of the River Supersequence appears to be preserved at Mt Birch, which is near the Roper River at the northwestern extremity of the area covered by this Record. In 1996 we logged a 300 m thick section at this location and collected pink ?tuffaceous beds for SHRIMP dating (**Mount Birch Composite**). Here, a lower carbonate and siltstone unit (now defined as the St Vidgeon Formation, Abbott et al., in press) contains very similar facies and evaporite pseudomorphs to those seen in the Teena Dolomite and Barney Creek Formation at HYC. A SHRIMP age of 1640± 4 Ma (Page et al., 2000) confirms that they are of the same age. The overlying mixed clastic and carbonate section (65-160 m on the **Mount Birch Composite**) has a markedly different set of facies and gamma ray log response. A SHRIMP age of 1634± 4 Ma indicates this is a slightly younger sequence, but it is still within the general age range of the River Supersequence. It is probably a lateral equivalent to the Lynott Formation. Lack of control does lot allow confident correlation between this sequence and the River sequences defined on the Lawn Hill Platform.

Term Supersequence

The Term Supersequence comprises a dominantly clastic package deposited between about 1630–1620 Ma. In the McArthur River Region it is represented by the Stretton Sandstone and overlying Looking Glass Formation. In the southern Lawn Hill Platform it is represented by the Termite Range Formation and lower part of the Lawn Hill Formation. In the northern Lawn Hill Platform it is represented by the lower part of the Doomadgee Formation

(Southgate et al., 2000b). As was the case with the River Supersequence, the Term Supersequence is best preserved in the southern Lawn Hill Platform, where it is up to 2 500 m thick. Here it consists of turbiditic and hemiplegic sandstones and shales, which gradually onlaps and thin to the northwest (Krassay et al., 2000). Along the southern margin of the Murphy Inlier only the upper part of the supersequence is preserved as unit Pfd3 of the Doomadgee Formation. The Term Supersequence has been subdivided into five third-order sequences (Term sequences 1 to 5).

The presence of the Term Supersequences in the McArthur Basin is indicated by a SHRIMP U-Pb zircon age of 1625 ± 2 Ma from a pink tuffaceous sandstone from the upper part of the Stretton Sandstone (Page et al., 2000). We measured two detailed sections through the Stretton Sandstone, one at Gum Yard at the southeastern end of the Abner Range (**Gumyard-Stretton**) and one at a locality 20 km to the northwest (**Burlcamp-Stretton**). Simplified and generalised logs of these, together with a gamma log from Amoco drillhole 82-7 (10 km southwest of Burl Camp) and the log from Mt Birch, are shown on **Figure 23**.

The gamma logs from Burl Camp and Amoco 82-7 show a similar trend — high gamma values near the base followed by a gradual trend towards lower values. In the Burl Camp section the facies show a gradual upward-coarsening and bed thickening, probably indicating gradual progradation and shallowing. The deepest water facies seen in the three sections occurs just above the base of the supersequence in the Gum Yard Section. Here there is a 10m-thick section of parallel laminated green siltstone and shale, lacking evidence of wave and current activity. Surprisingly, this shaly interval does not produce a shift to the right on the gamma log (**Fig 23**) — it provides another example of the danger of interpreting gamma ray logs in isolation (see, Jackson et al., 2000b). Above this the gamma ray trace has a vertical (aggradational?) trend with prominent peaks opposite pink beds, which have previously been identified as reworked tuffaceous units (Jackson et al., 1987). Gentle, undulatory stratification, a product of storm waves, is the dominant bedform in all sections, but sharp-based beds with rippled tops probably attest to normal fairweather waves in places. A setting of mid-shelf to inner-shelf seems most likely.

The limited data does not allow palaeogeographic trends to be established with any confidence, but the facies differences between the Gum Yard and Burl Camp sections suggests the basin may have deepened towards the south. The section at Gum Yard also preserves many more of the pink beds, which is consistent with a deeper marine environment with less reworking. This trend of deeper environments locally, towards the south, is the reverse of that seen earlier during the Loretta Supersequence.

Our more recent studies further support the interpretation of the Stretton Sandstone as a marine unit (Jackson et al., 1987) rather than a regressive fluvial unit as preferred by Muir et al., (1980). In fact, the absence of coastal plain and shallow shoreline deposits in the uppermost part of the Stretton Sandstone suggests that the prograding trend evident in these two sections is truncated, and that the Stretton Sandstone probably represents only the preserved remnant of an originally much thicker depositional package. At both sections the boundary between the Stretton Sandstone and the overlying Looking Glass Formation carbonates is sharp. Lateral tracing of this boundary at Gum Yard over a few hundred metres showed relief of a few metres. The much thinner section of Stretton Sandstone in AMOCO 82-7 could be due to much more extensive erosion on this surface, and may indicate that the Hot Springs Fault, that separates these sections, was active, shortly after the Term Supersequence was deposited, so that this area to the west was uplifted and denuded.

The Term Supersequence may also be present at Mt Birch (**Fig 23**). As described earlier, recent SHRIMP dating from the lower part of the Mt Birch section (Page et al., 2000) indicate there are equivalents of the River Supersequence. We suggest that the interval from 157 - 260 m at Mt Birch is probably the lateral equivalent of the Stretton Sandstone. The facies and the gamma log patterns are very similar to those in the three sections east of the Abner

Range, described above, and it is of similar thickness to the Burl Camp and GumYard Sections.

As there are no significant internal base-line shifts in the gamma log trends, nor any significant lithofacies discontinuity's in these four McArthur Basin sections, the Stretton Sandstone is tentatively interpreted to represent only one of the five 3rd order sequences defined on the Lawn Hill Platform, which one is not known. The erosion surface identified at the base of the Looking Glass Formation probably defines the sequence boundary at the base of another of the Term Sequences. With the currently available information it would be unwise to attempt correlations between these and the five sequences in the southern Lawn Hill Platform. Krassay et al.,(2000a) identifies "condensed facies" carbonaceous siltstones in the upper part of Term Sequence 2 as the maximum flooding for the second-order supersequence. This would obviously represent a period of widespread inundation on the Lawn Hill Platform, so this may be a likely contender for inundation in the McArthur River Region. However, the SHRIMP zircon ages of 1625 ± 2 Ma for the Stretton Sandstone compared to the ages of between 1636 ± 10 and 1630 ± 5 Ma from the Termite Range Formation may indicate that sedimentation in this Supersequence started earlier on the Lawn Hill Platform. Southgate et al., (2000a) suggest that Term Supersequence sediments in the McArthur River Region probably represent the preserved remnants of the Term 3 and 4 onlapping wedges of the Lawn Hill Platform.

Lawn, Wide & Doom Supersequences

As defined by Southgate et al., (2000a, Fig 4), the Lawn Supersequence contains rocks deposited between about 1615 Ma and 1605 Ma; the Wide Supersequence contains rocks deposited between about 1600 and 1585 Ma; and the Doom Supersequence, rocks younger than about 1580 Ma. All three are well developed and preserved on the Lawn Hill Platform, each of them has a maximum thickness of around 1000 m. Thin proximal equivalents occur along the southern edge of the Murphy Inlier (Bradshaw et al., 2000), but more extensive equivalents occur in the McArthur Basin, where a total thickness of about 1200 m is preserved (Jackson et al., 2000a; Jackson et al., 2000b).

On the Lawn Hill Platform the Lawn Supersequence has been subdivided into four third-order sequences; the Wide into three; and the Doom into five (Krassay et al., 2000a, Krassay et al., 2000b).

On the Lawn Hill Platform, the basal part of the Lawn Supersequence comprises largely tuffaceous sandstones, but the remainder is dominated by deep marine, outer shelf carbonaceous shales. Over-thickened sections, confined by northwest- and northeast-trending faults attest to continued synsedimentary faulting. Geochronological constraints are provided by SHRIMP zircon ages of 1616 ± 5 and 1611 ± 4 Ma from tuffs in unit Pmh2 of the Lawn Hill Formation (Page et al., 2000).

On the flanks of the Murphy Inlier these deep water facies are replaced by shore-face and inner ramp facies of the upper part of the Doomadgee Formation (Bradshaw et al., 2000) recently dated at 1613 ± 5 Ma (Page et al., 2000). Here, only one third-order sequence (Lawn 1) is preserved, younger sequences have probably been truncated by the sequence boundary at the base of the Wide Supersequence.

On the Lawn Hill Platform the Wide Supersequence has a lower shale prone section with the upper three quarters dominated by more proximal, feldspathic, sand-rich submarine fans. Again there are marked lateral thickness variations which have been interpreted as due to active wrench faulting (Krassay et al., 2000b). Along the edge of the Murphy Inlier a thin fluvial-shallow marine package (uppermost Doomadgee Formation) is all that is preserved.

On the Lawn Hill Platform, the Doom Supersequence comprises a largely progradational coarsening-up package of feldspathic siliciclastics. These sediments are interpreted as indicating the gradual closing of the Isa Superbasin (Krassay et al., 2000b). There are no known equivalents on the southern margin of the Murphy Inlier.

Recent SHRIMP ages around 1610-1614 Ma from samples of the lower part of the Nathan Group from outcrops near Balbirini Homestead indicate the Lawn Supersequence was deposited across at least the southern part of the McArthur River Region. During NABRE studies we measured one composite section through the Nathan Group at Balbirini in 1996. This is reproduced in the well logs as the **Balbirini Composite**. In addition to the Lawn Supersequence, this section also includes detailed logs for the overlying Wide and Doom Supersequences. Generalised and simplified plots of the gamma log, lithostratigraphic subdivisions and environmental interpretations are shown on **Figures 24**, **25** and **26**.

A detailed description of this composite section and its sequence stratigraphic interpretation is contained in Jackson et al., (2000a) and Jackson et al., (2000b). The details are not repeated here; however, the most important stratigraphic revisions are summarised below, they include:

- The 1200m-thick Nathan Group (**Fig 24**), that had previously been interpreted as a more-or-less continuous record of sedimentation (eg: Muir 1983; Jackson et al. 1987; Walter et al., 1988) is, in fact, noticeably discontinuous (**Fig 28**).

- It can be subdivided into three Supersequences — the Lawn, Wide and Doom (**Fig 28**). Each Supersequence is a few hundred metres thick, and each was probably deposited over a time period of a few million years. The Lawn and Wide Supersequences are constrained by recent SHRIMP dating (**Fig 28**). The Doom Supersequence is, as yet, completely unconstrained.

- Analysis of the gamma ray logs suggests that each of these supersequences can be further subdivided into several third-order sequences, often with similar gamma-ray log motifs (eg **Fig 27**). Unfortunately, with the current level of control, these sequences can not be confidently correlated with the third-order sequences in the Lawn Hill Platform. However, there are some remarkably similar trends in lithofacies changes in the two areas which may be more than just coincidental.

- Based on gamma ray characteristics and the recent SHRIMP zircon dating the base of the Lawn Supersequence is defined at the base of the Amos Formation. That is, the major stratigraphic break in this part of the basin’s history is now placed below the Amos Formation, not above it, as in all previous lithostratigraphically based studies (eg Jackson et al., 1987).

- The rocks in the Lawn Supersequence were deposited in predominantly high energy continental and shoreline environments. The sediments in the Wide Supersequence were deposited in similar environments in their lower parts, but their transgressive and highstand components also include deeper water environments. The Doom Supersequence shows a return to predominantly shallow water environments, before its truncation by the much younger (~1500 Ma) Roper Group. Overall, the McArthur successions are shallower (more proximal) in character than those in the Lawn Hill Platform; they are also dominated by mixed carbonate and clastic facies. These were deposited on a series of probably south-west facing carbonate platforms or ramps. Although control is limited in the McArthur River Region there does not seem to be the same degree of active synsedimentary faulting as in the Lawn Hill Platform area. Further, the successions on the Lawn Hill Platform contain much more clastic detritus so presumably were closer to the clastic hinterland. Krassay et al., (2000a & b) provides suggestions on the likely clastic source areas for the various Supersequences.

- The “maximum flooding” (time of maximum generation of accommodation space) for the Nathan Group in the McArthur River area probably occurs within the second Wide

Sequence (cycle number 5 on **Fig 27, 28**) in a stromatolite unit called the *Kussiella kussiensis* stromatolite biostrome. The equivalent interval in the Lawn Hill Platform is also within the lower part of the Supersequence in either Wide 1 or 2.

- There is a major gamma ray log and lithofacies change between the Balbirini Dolomite and Dungaminnie Formation, near the top of the preserved section in the McArthur River Region. This is used to define the contact between the Wide and Doom Supersequences (**Fig 28**), although we do not have any age control on the Dungaminnie Formation. In both the McArthur Basin and Lawn Hill Platform areas the rocks near the base of the Doom Supersequence are feldspathic to arkosic implying a major change in provenance. Jackson et al., (2000b) and Krassay et al., (2000b) suggest this may be due to crustal shortening and uplift during the early parts of the Isan Orogeny.

LIST OF FIGURES

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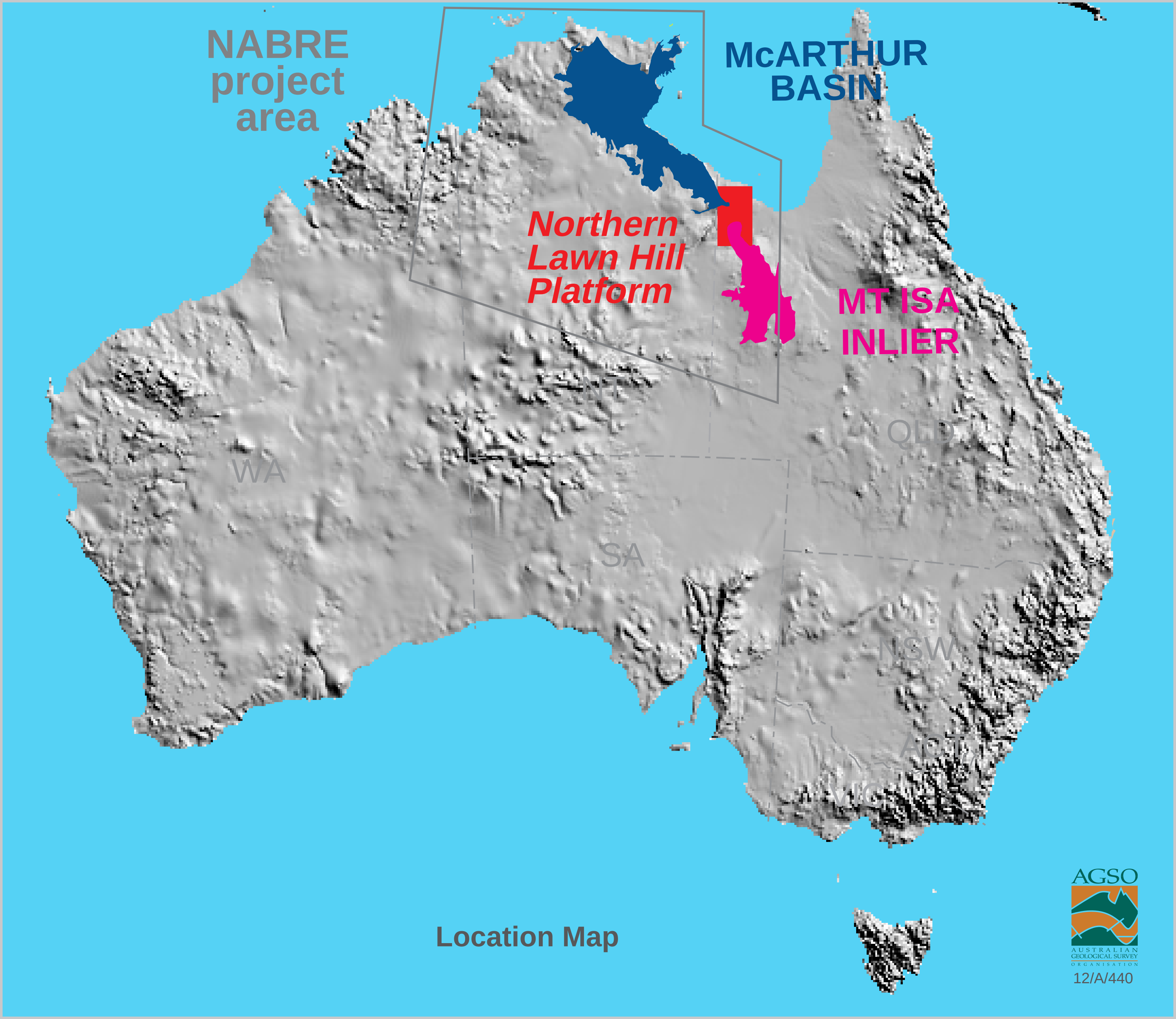
Table 1

Section/Drillhole name	Thickness	Formation intersected (as originally shown by section measurer or site geologist)	Easting	Northing	General location
ARCHIE CREEK COMPOSITE	403	Masterton Sandstone, Mallapunyah Formation, lower Amelia Dolomite	595500	8110300	Archie Creek, type section from 1977
BALBIRINI COMPOSITE	1376	Amos Formation, Balbirini Dolomite, Dungaminnie Formation	578722	8146484	Tablelands Hwy 5km Sth of Heartbreak Hotel
BMR BAUHINIA DOWNS 3	153.5	uppermost Balbirini Dolomite	586500	8160400	N end Abner Range
BURL CAMP-STRETTON	106	uppermost Yalco Formation, Stretton Sandstone	603900	8152500	Burl Camp, E side Abner Range
GUM YARD-STRETTON	118.3	uppermost Yalco Formation, Stretton Sandstone	612975	8137065	Gum Yard, SE end Abner Range
KILGOUR-TATOOLA	107	Tatoola Sandstone, basal Tooganinie Formation	598400	8114300	Kilgour River, 1977 type area locality
MALLAPUNYAH CREEK-TATOOLA	87.3	Tatoola Sandstone	589600	8128400	Dungaminnie Creek, 6 km SE Top crossing
MID KILGOUR COMPOSITE	472.5	Tatoola Sandstone, Tooganine Formation, Leila Sandstone, Myrtle Shale, lower Emmerugga Dolomite	599835	8115960	Kilgour Gorge, type section from 1977
MT BIRCH COMPOSITE	280	uppermost St Vidgeon Formation, Nagi Formation	466153	8366580	Mt Birch, near Roper Bar
YELLOW WATER BORE	415	upper Myrtle Shale, Emmerugga Dolomite, lower Teena Dolomite	507792	8165471	Yellow Water Bore, 5 km NE Leila Hill
NOTE: all sections below here deal with the Barney Creek Formation and associated units					
AMELIA BASIN 4	258	Teena Dolomite, Barney Creek Formation, Reward Dolomite, Lynott Formation	621700	8160100	"Amelia Sub basin" few km SW of HYC
AMELIA BASIN 5	240.5	Barney Creek Formation, Reward Dolomite, Lynott Formation	622100	8157820	"Amelia Sub basin" few km SW of HYC
AMELIA BASIN 6	334	Barney Creek Formation, Reward Dolomite, Lynott Formation	620340	8158500	"Amelia Sub basin" few km SW of HYC
BARNEY CREEK 3	352.7	Barney Creek Formation, Reward Dolomite, Lynnott Formation	615996	8182612	Near Barneys Hill at HYC
BINGBONG 2	442.9	upper Teena Dolomite, Barney Creek Formation, Reward Dolomite, lower Lynott Formation	603700	8253900	west of Bing Bong Creek , 40 km N of HYC
EMU 09	709	upper Emmerugga, Dolomite Teena Dolomite, Barney Creek Formation, Reward Dolomite	615561	8186162	Emu Plains sub basin NW of HYC
EMU 11	760	Barney Creek Formation, Reward Dolomite, Lynott Formation	613910	8186492	Emu Plains sub basin NW of HYC
EMU 13	1255	Barney Creek Formation, Reward Dolomite	616571	8186340	Emu Plains sub basin NW of HYC
GORGE COMPOSITE	568.5	Teena Dolomite, Barney Creek Formation, Reward Dolomite	606149	8120265	Winefield's Kilgour Prospect (lower)
I20/32S	210	Barney Creek Formation	617488	8182443	at HYC deposit
I22/55	356	upper Emmerugga Dolomite, Teena Dolomite, Barney Creek Formation	617506	8182666	at HYC deposit
LYNOTT WEST 3	396.5	Teena Dolomite, Barney Creek Formation, Reward Dolomite, Lynott Formation	610678	8185465	west of Emu Plains sub basin
LYNOTT WEST 4	344	Teena Dolomite, Barney Creek Formation, Reward Dolomite, Lynott Formation	604830	8185559	west of Emu Plains sub basin
LYNOTT WEST 5	375	Teena Dolomite, Barney Creek Formation, Reward Dolomite, Lynott Formation	607884	8186136	west of Emu Plains sub basin
MCA 05	495.97	Teena Dolomite, Barney Creek Formation	618440	8249240	east Bing Bong Creek , 40 km N of HYC
MCA 10	365	Emmerugga Dolomite, Teena Dolomite, Barney Creek Formation	602718	8174487	15 km SW of HYC deposit
TOP CROSSING NORTH	270	upper Emmerugga Dolomite, Teena Dolomite, Barney Creek Formation, Reward Dolomite	576850	8152300	about 3 km S of Heartbreak Hotel
TOP CROSSING SOUTH	234	upper Teena Dolomite, Barney Creek Formation, Reward Dolomite	574926	8143531	about 2 km SW of Heartbreak Hotel
TOP CROSSING WEST	348	upper Tooganinie Formation, Leila Sandstone, Myrtle Shale, lower Emmerugga Dolomite,	575900	8153000	6 km due west of Top Crossing
WEIRK WATERHOLE	264	Emmerugga Dolomite, Teena Dolomite, Barney Creek Formation, Reward Dolomite	557302	8125391	Wierk Waterhole, 60 km SW of Top Crossing

Table 2

Sections and Drillholes - Plot Files			
Measured Sections	Map sheet	Files for plotting (.ps)	
McArthur River Region		1:1000	1:500
Archie Creek Composite	Kilgour	Archie Creek	No
Balbirini Composite	Mallapunyah	Balbirini	No
Burl Camp-Stretton	Mallapunyah	Burlcamp	Burlcamp
Gorge Composite	Mallapunyah	Gorgecomp	No
Gum Yard-Stretton	Glyde	Gumyard	Gumyard
Kilgour-Tatoola	Kilgour	Kiltat	Kiltat
Malapunyah Creek-Tatoola	Mallapunyah	MalpunCk	MalpunCk
Mid Kilgour composite	Kilgour	Midkilgour	No
Mount Birch Composite	Urapunga	MtBirch	No
Top Crossing North	Mallapunyah	TopCrsN	No
Top Crossing South	Mallapunyah	TopCrsS	No
Top Crossing West	Mallapunyah	TopCrsW	No
Weirk Waterhole	Mallapunyah	WeirkWH	No
Yellow Water Bore	Mallapunyah	YellowWB	No
Drill Holes	Map Sheet	1:1000	1:500
Amelia Basin 4	Glyde	Amelia_4	No
Amelia Basin 5	Glyde	Amelia_5	No
Amelia Basin 6	Glyde	Amelia_6	No
BMR Bauhinia Downs 3	Mallapunyah	Bauhin3	Bauhin3
BingBong 2	Bing Bong	Bingbong	No
Emu 11	Borroloola	Emu_11	No
Emu 13	Borroloola	Emu_13	No
Emu 9	Borroloola	Emu_9	No
I20/32s	Borroloola	I2032s	No
I22/55	Borroloola	I2255	No
Lynott West 3	Borroloola	Lynwest_3	No
Lynott West 4	Batten	Lynwest_4	No
Lnott West 5	Borroloola	Lynwest_5	No
McA10	Mallapunyah	McA_10	No
MaA5	Mallapunyah	McA_5	No
Section Name	Cross Sections	1:2000	
Cross Section 1 Barney A		CS_BARNEYA	
Cross Section 2 Barney B		CS_BARNEYB	


NABRE
project
area
McARTHUR
BASIN
Northern
Lawn Hill
Platform
MT ISA
INLIER
WA
SA
QLD
NSW
ACT
VIC
Location Map
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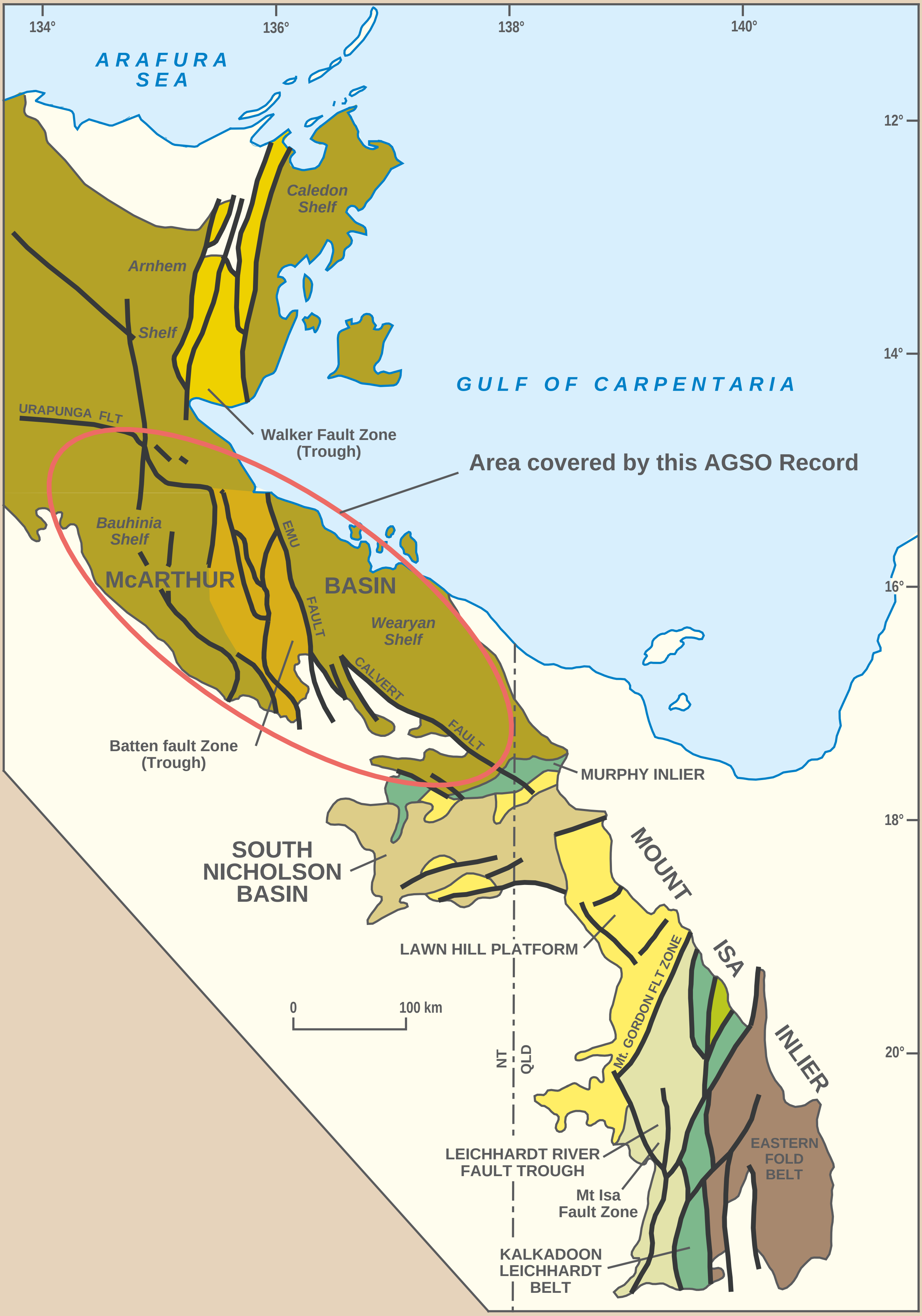

Figure 01 Location map showing regional subdivisions of Northern Australia and the area covered by this CD.

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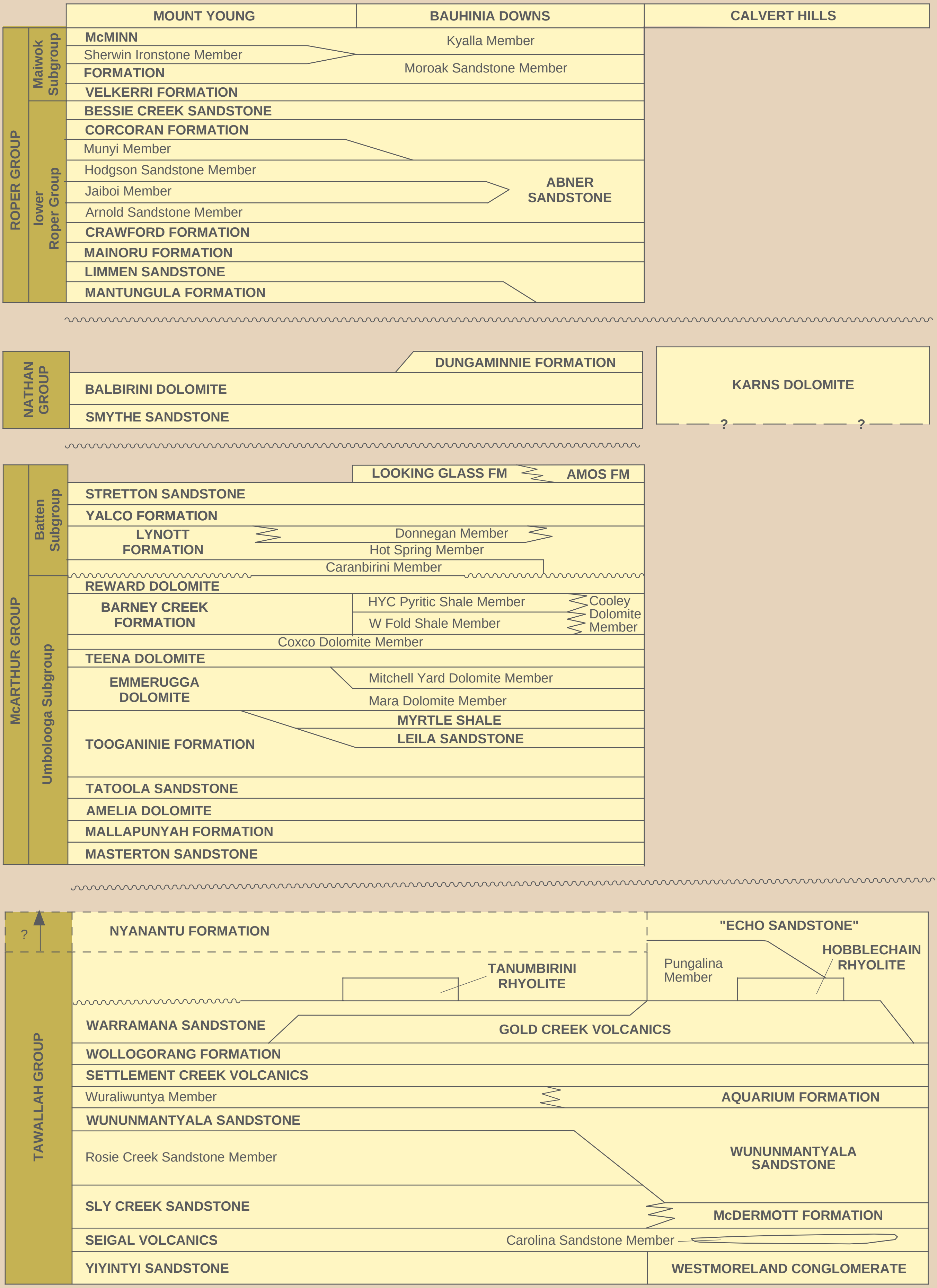

Figure 02 Lithostratigraphy of the southern McArthur Basin, modified after Jackson et al., (1987, figure 4) and Haines et al., (1993, figure 5). Recent change suggested by Jackson et al. (2000) at the level of the Aquarium Formation - Wununmantyala Sandstone have also been incorporated into this diagram.

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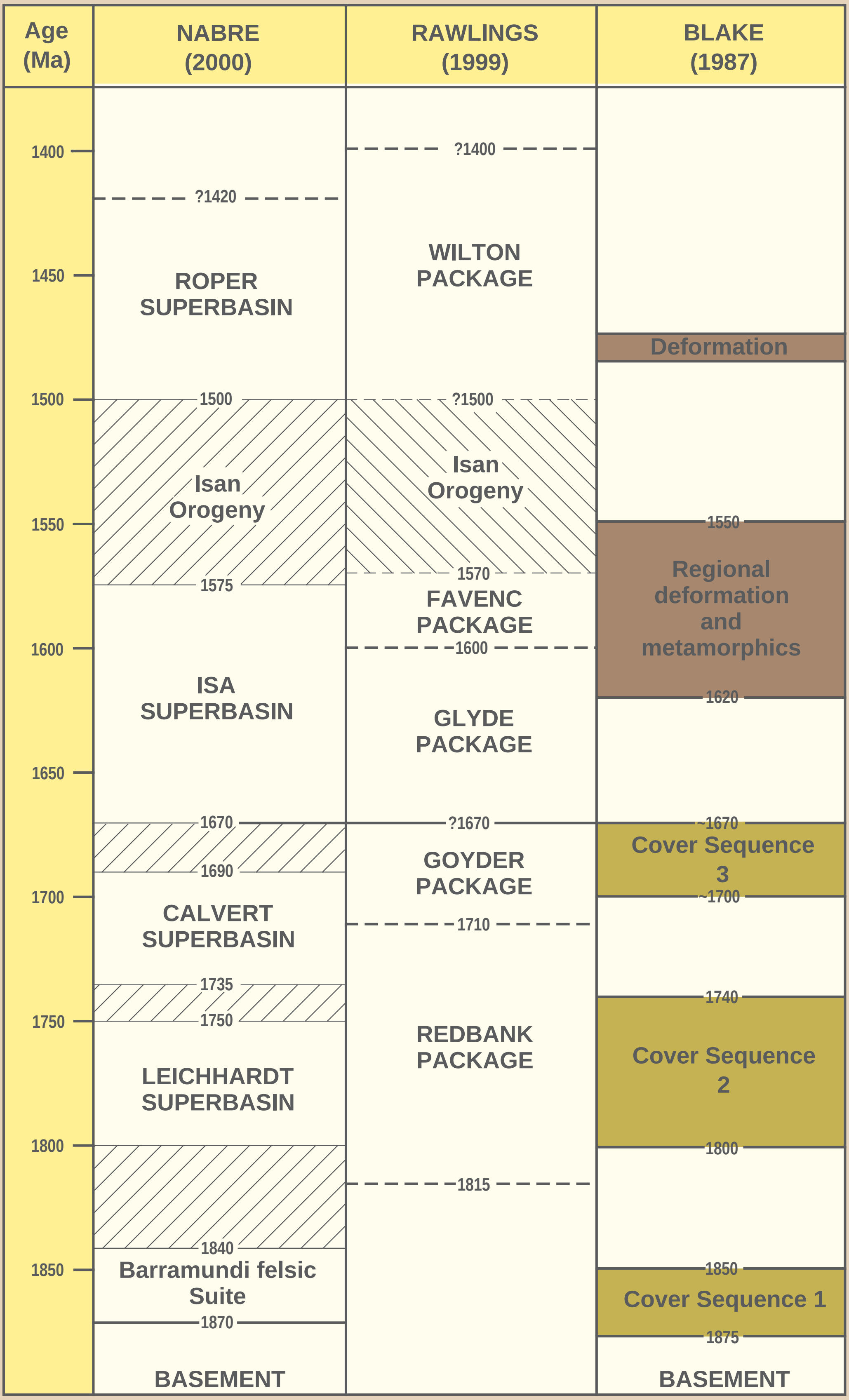

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Figure 03 Simplified chronostratigraphic chart comparing NABRE Superbasin nomenclature with the 'Package' nomenclature of Rawlings (1999) and the 'Cover Sequence' nomenclature of Blake (1987). Note that the NABRE scheme highlights both the periods of deposition and preservation (superbasin phases) and the interveening episodes of erosion/non-deposition. Note also that there are major differences between this and the other schemes, related largely to our better geochronological control.

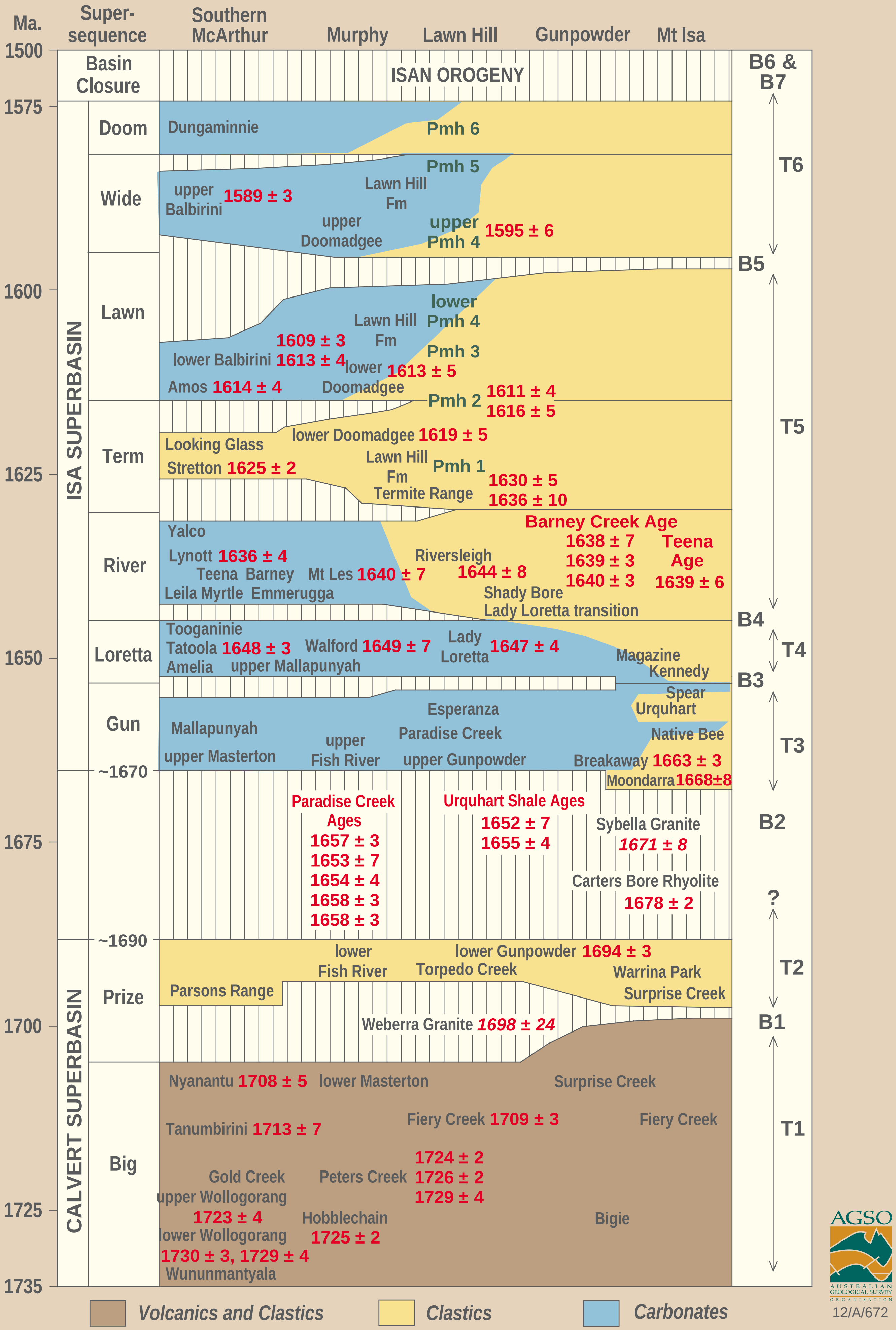

Figure 04 NABRE Supersequence chart for the Isa and Calvert Superbasins showing recent zircon ages, major breaks in sedimentation, and abbreviated names of major lithostratigraphic units (note: not all units are shown). the approximate positions of straight track segments (T1, T2, etc) and bends (B1,B2, etc) on the APWP (Idnurm, 2000) are shown on the right.

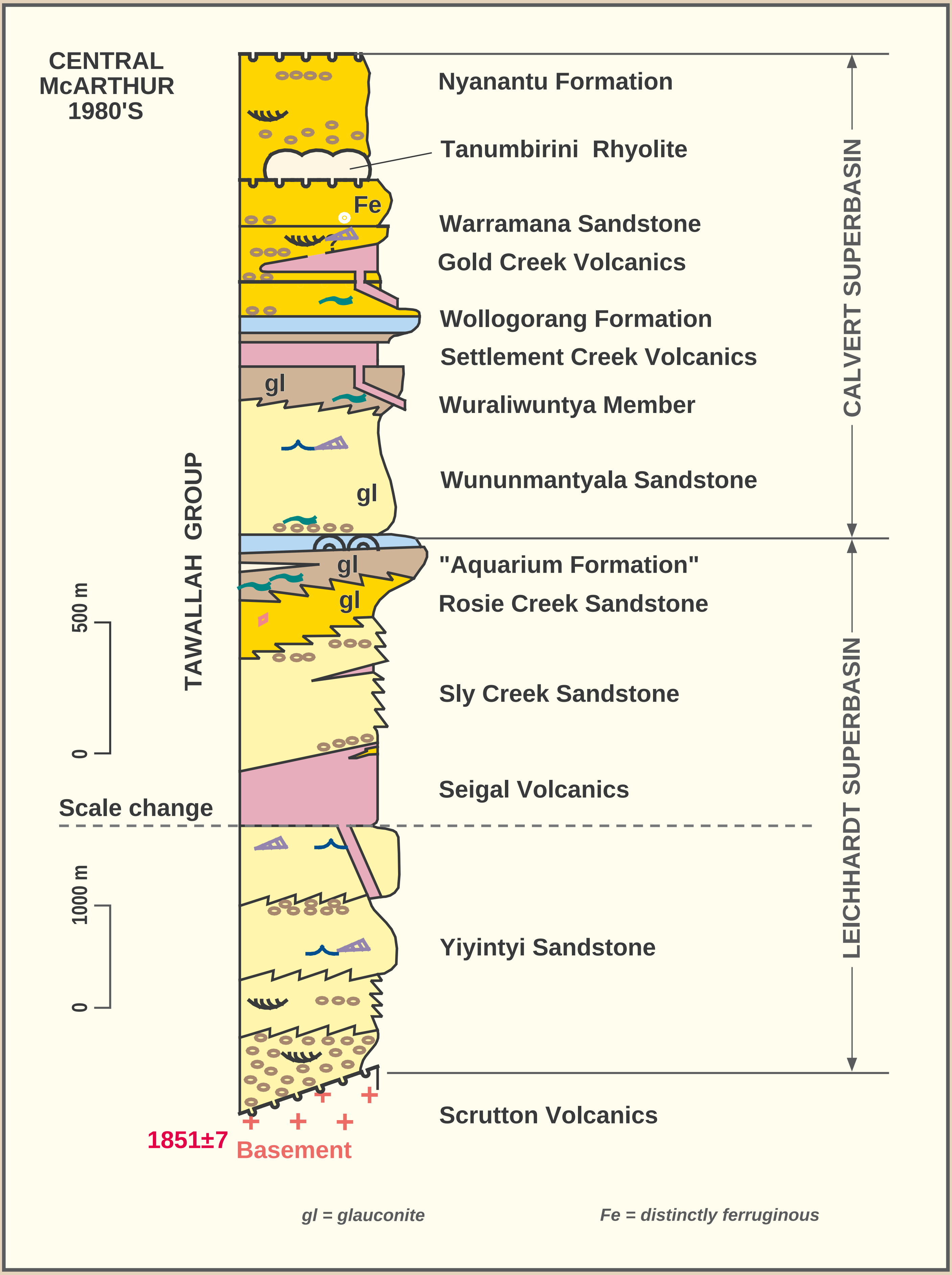

Figure 05 Composite and simplified lithostratigraphic column for the Tawallah Group from the central part of the McArthur Basin using information (mostly from regional mapping) up to about 1985 (modified after Jackson et al., 1998, p218). The new NABRE superbasin scheme is also shown. Refer to Figure 8 for symbols

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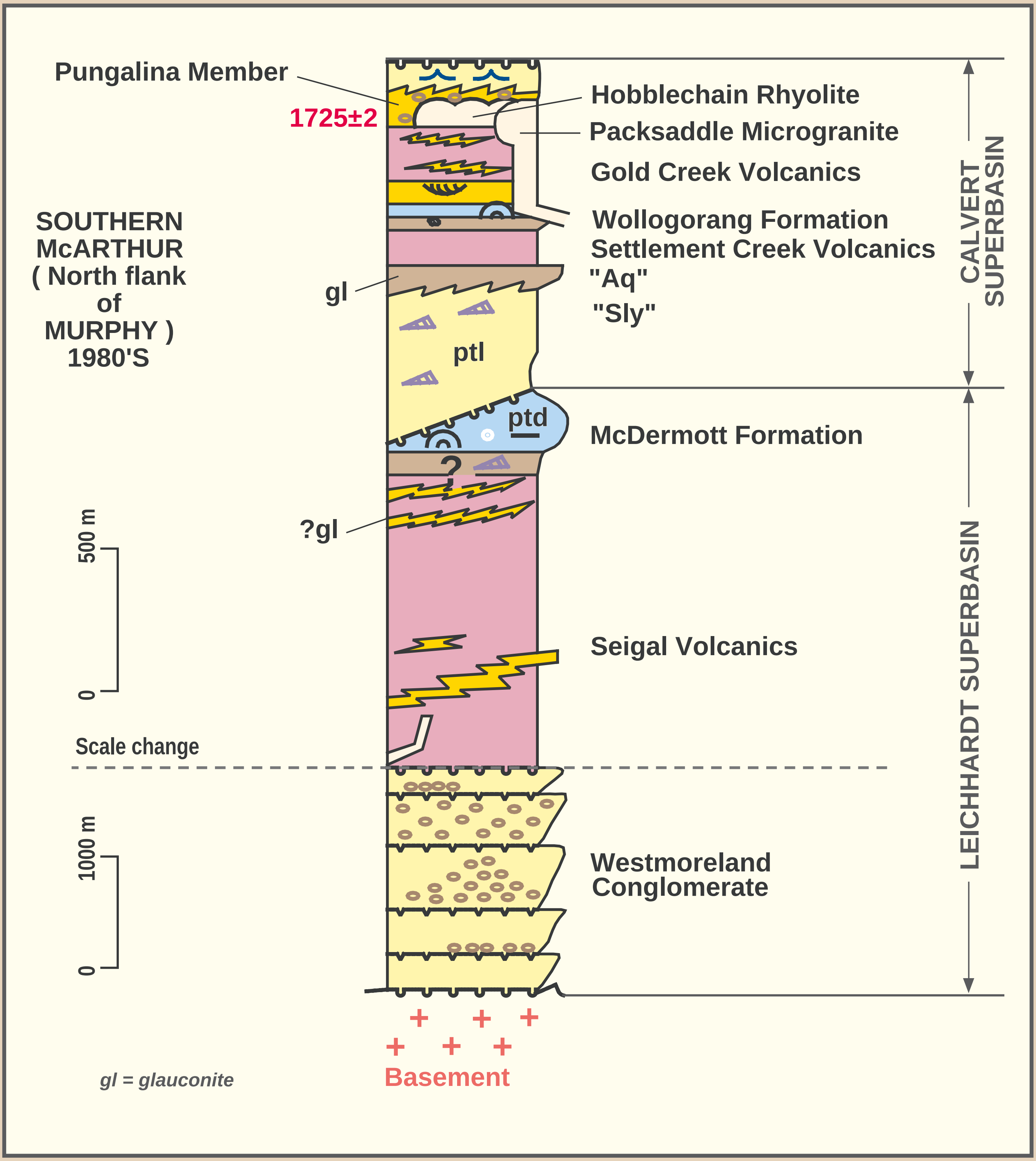

Figure 06 Composite and simplified lithostratigraphic column for the Tawallah Group from the southern margin of the McArthur Basin using information (mostly from regional mapping) up to about 1985.
The names of the formations are as defined in Ahmad and Wygralak, (1989).
The units "Sly" and "Aq" are the units Sly Creek Sandstone (Ptl) and Aquarium Formation (Ptq) shown on the 1989 CALVERT HILLS SE53-8 1:250 000 Metallogenic Map.
More recent mapping (D. Rawlings, pers. comm.) indicates that these are not the same units as those mapped as Sly Creek Sandstone and Aquarium Formation in the BAUHINIA DOWNS and MT YOUNG map sheet areas, but are in fact, equivalent to the Wununmantyala Sandstone.
Refer to Figure 8 for symbols

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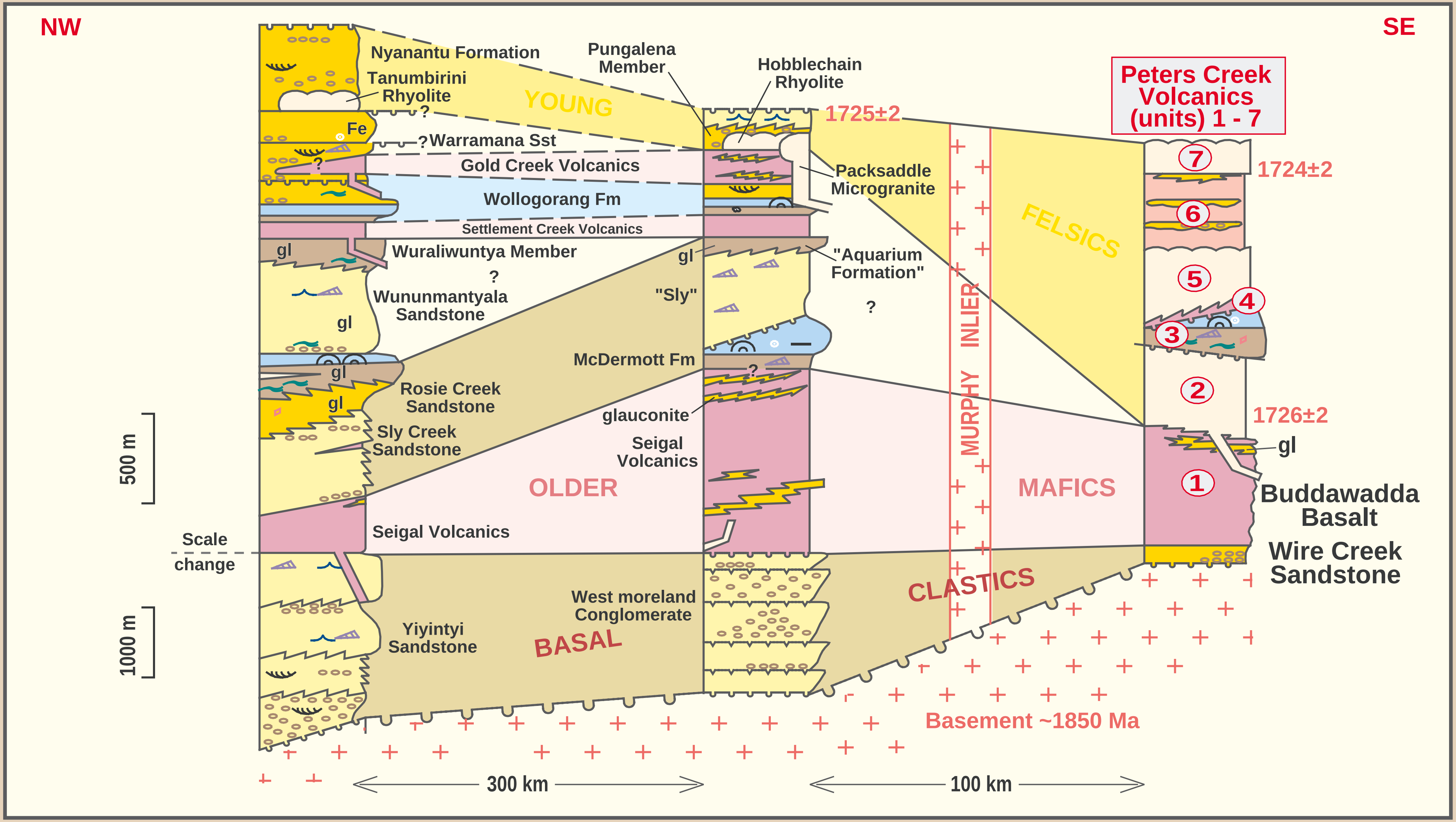

Figure 07 "Old" correlations of composite lithostratigraphic columns from the southern part of the McArthur Basin based on regional mapping up to about 1990. Left column is from Bauhina Downs area, centre column from Calvert Hills area, and right column from southern flank of Murphy Inlier. Note: the apparent lateral continuity of units near the tops and bottoms of the stratigraphic columns, but the complexity and lateral variations in the middle part of the diagram. Contrast this with the chronostratigraphicdiagrams developed during the NABRE project and contained in this report.
Refer to Figure 8 for symbols.

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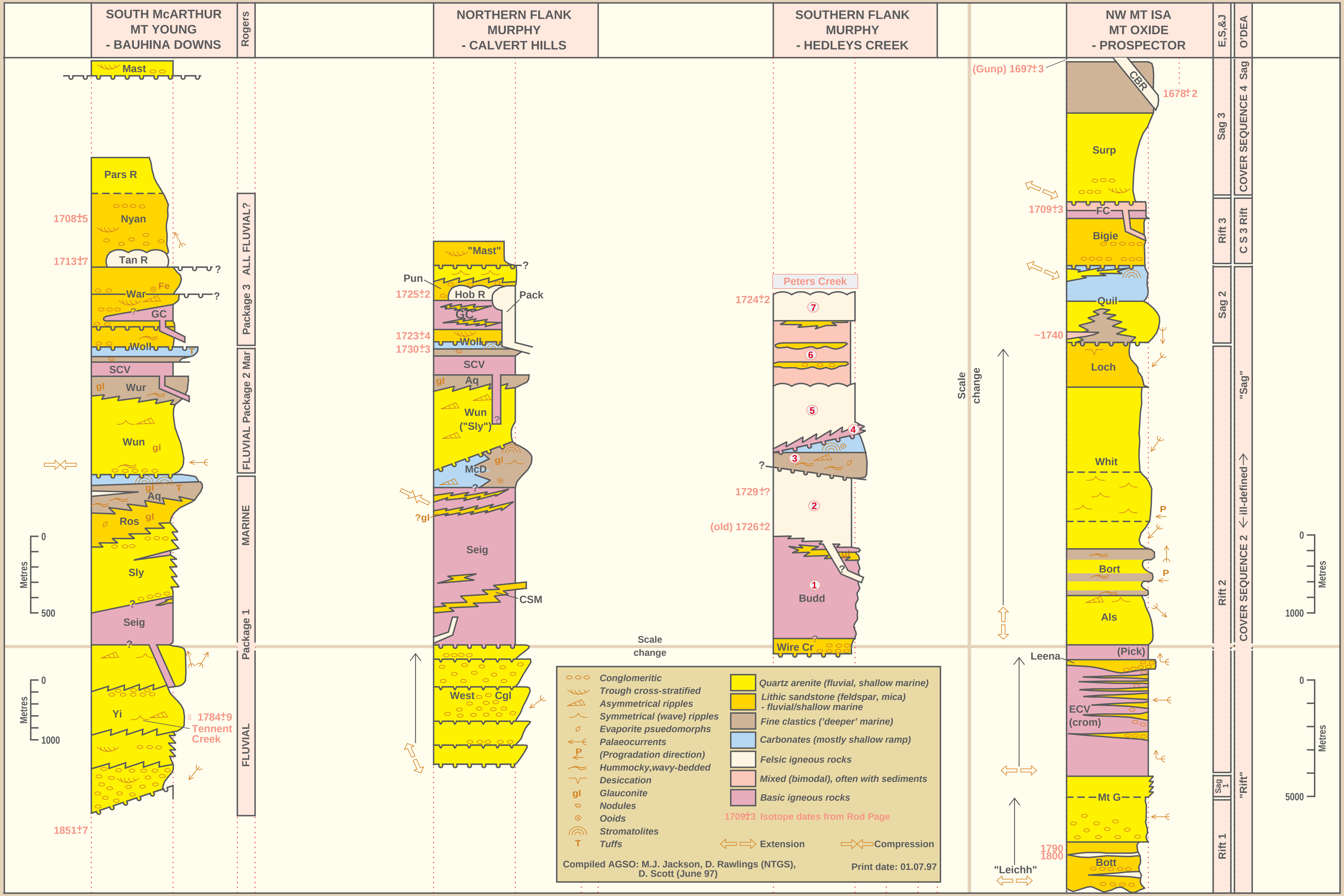

Figure 08 Composite lithostratigraphic columns from various parts of the McArthur/Mt Isa region based on regional mapping up to about 1990. Lithostratigraphic names have commonly been abbreviated for clarity; full names are used in the text. The pink column at right show the tectonic setting suggested for various intervals in two recent papers. E, S, J - paper by Eriksson et. al, (1993); O'Dea paper in Tectonics (1997).

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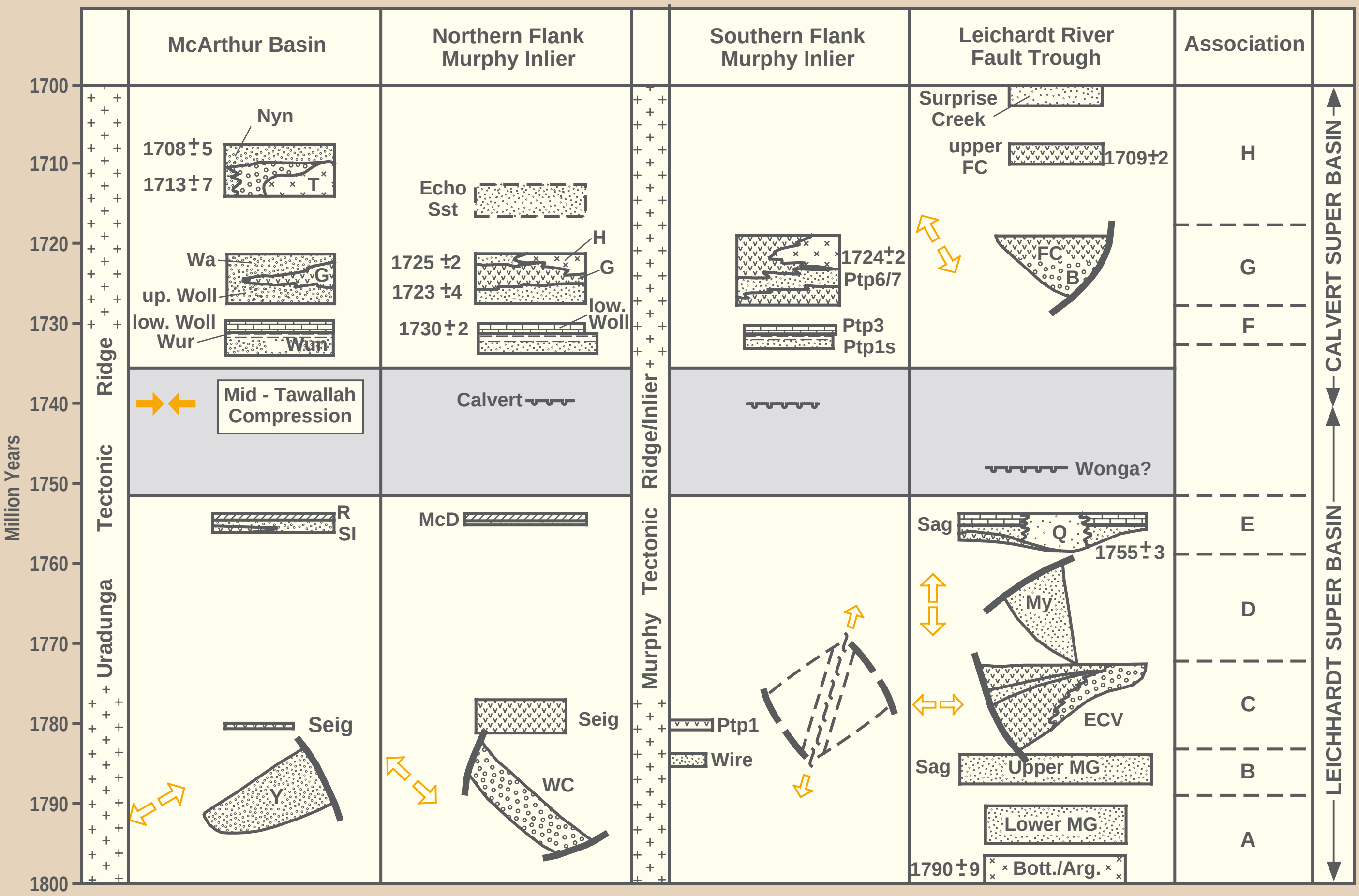

Figure 09 Tentative chronostratigraphic correlation of major depositional episodes between 1700-1800 Ma across part of northern Australia (modified, from Jackson et al., 2000). As absolute time control is so sparse most correlations are poorly constrained. The depiction of individual associations is shown in cartoon-style to reflect the simplified shape (in cross-section) and approximate orientation of the basin container at that time (where this is very poorly constrained the container is shown as a rectangle by default). Simplistic extensional (<>) and compressional (><) tectonic vectors indicated. The vertical axis of the diagram is linear time. However, due to lack of constraints, the 'vertical thickness' of individual boxes in each association reflects the relative thickness of the preserved package, and not the time duration over which the package was deposited. For example the Eastern Creek Volcanics of Association, C in the Leichhardt River Fault, are up to about four times thicker than their approximate time equivalents, the Seigal Volcanics, on the northern flank of the Murphy Inlier. Although a scale factor of about 1:300 000 was generally used for the thickness of the boxes (ie 1mm = 300 m), it has not been strictly adhered to; the thickness of some associations have been exaggerated for clarity.

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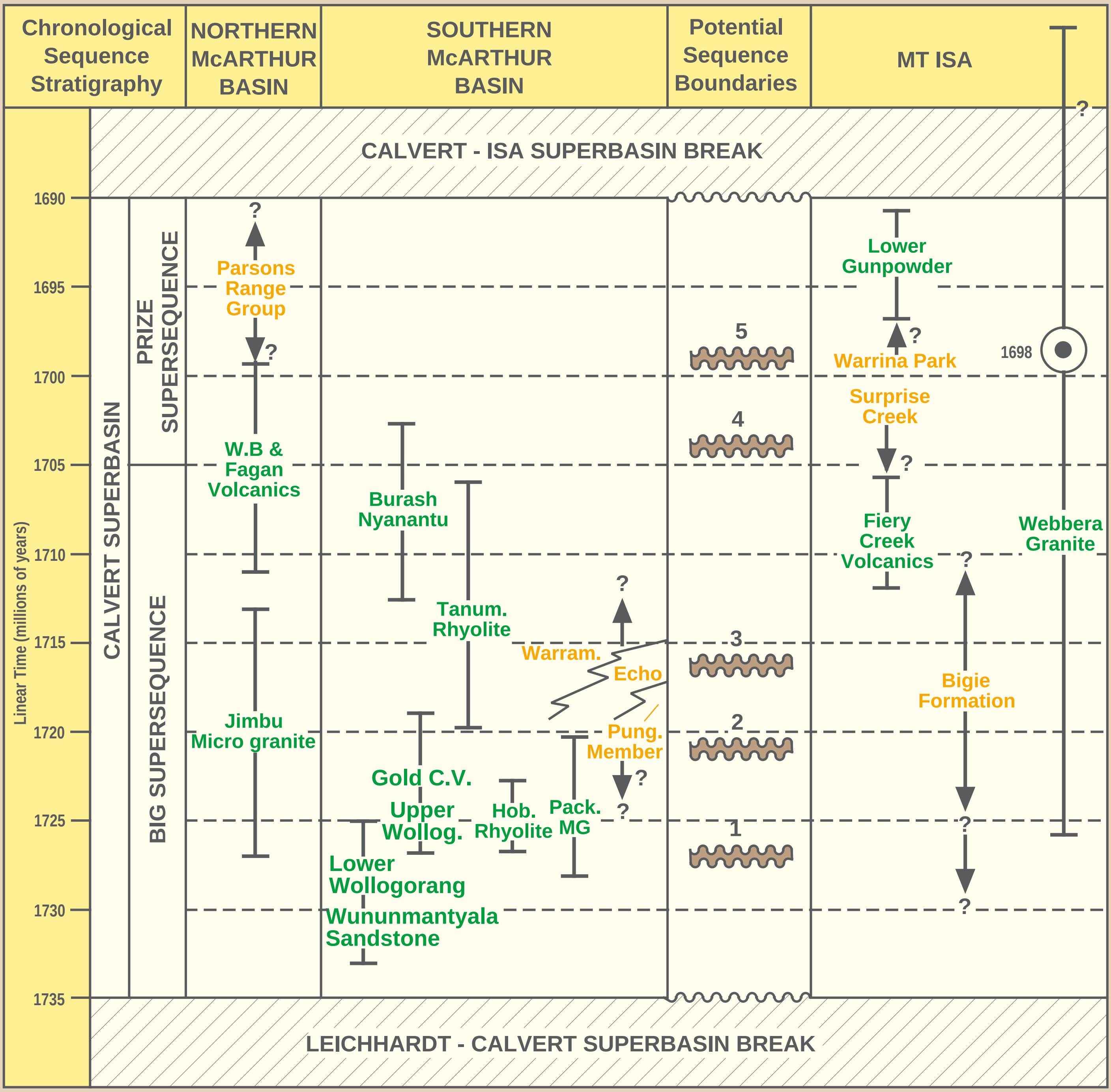

Figure 10 Chronostratigraphic plot of selected units in the Calvert Superbasin Phase from the northern and southern parts of the McArthur Basin and also from the western succession at Mt Isa. Lithostratigraphic names have commonly been abbreviated for clarity; full names are used in the text. Stratigraphic units (orange text), have not been directly dated so are only constrained by stratigraphic relationships. Units with reliable isotopic dates (Page et. al., 2000) (green text), are centred on the mean SHRIMP age and the bars above and below show the 95% confidence limits to the ages. The column potential sequence boundaries, shows the major breaks discussed in the text (1 to 5).
These boundaries are shown arbitarily as of the same size and duration. However, this is almost certainly not the case as there are few age constraints to indicate their relative magnitudes. The intrusive age of the Webbera granite is poorly constrained by conventional SHRIMP zircon studies at 1698 +28 -21 Ma (Wyborn et al., 1988). Field relationships and geochemical information suggest it is coeval with the Fiery Creek Volcanics, so this is where it has been plotted, but the mean 1698 Ma age is also shown.

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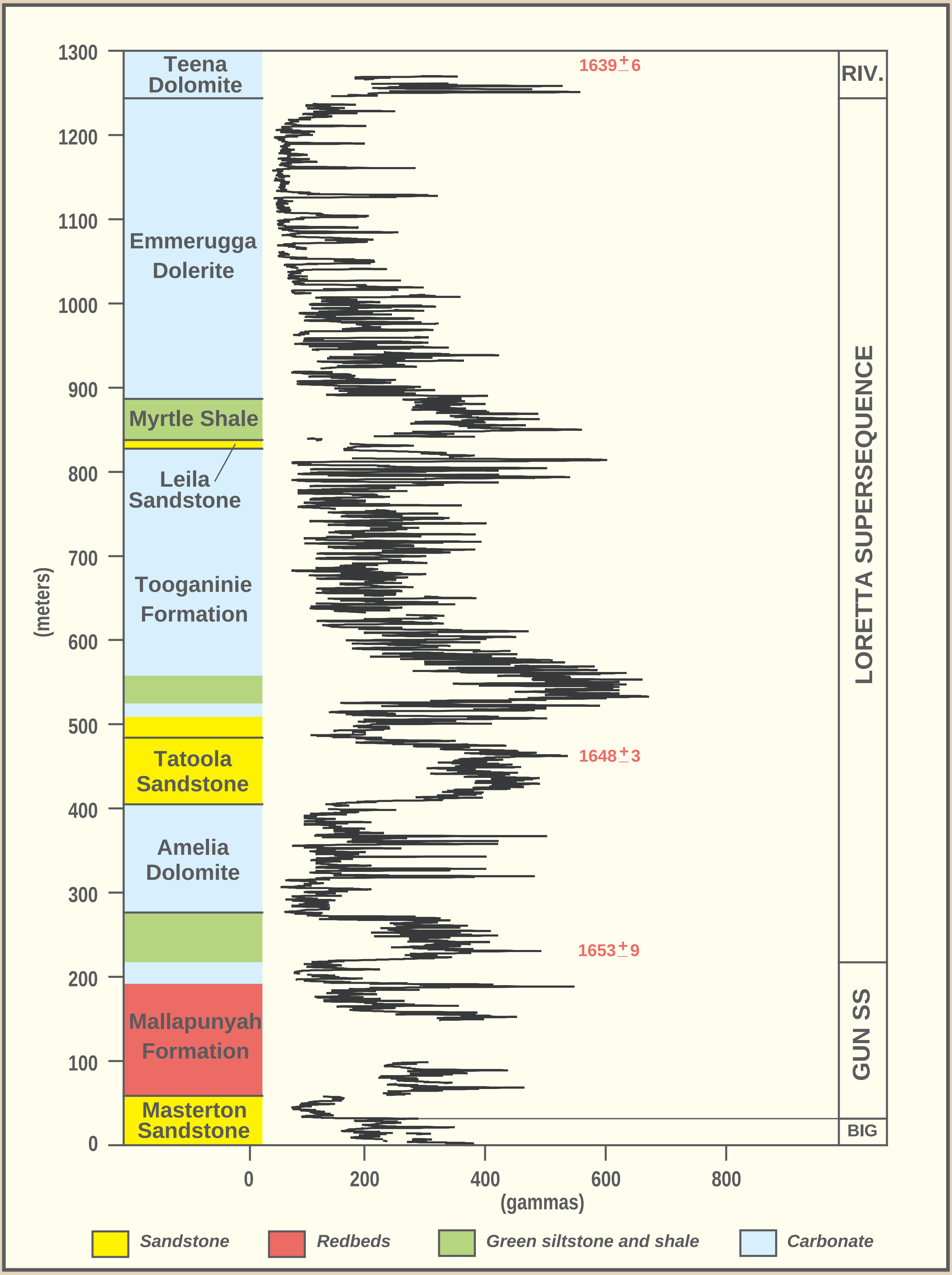

Figure 11 Composite gamma ray log for the lower part of the McArthur Group. Lithostratigraphic subdivisions shown in left column, main rock types shown by colour.

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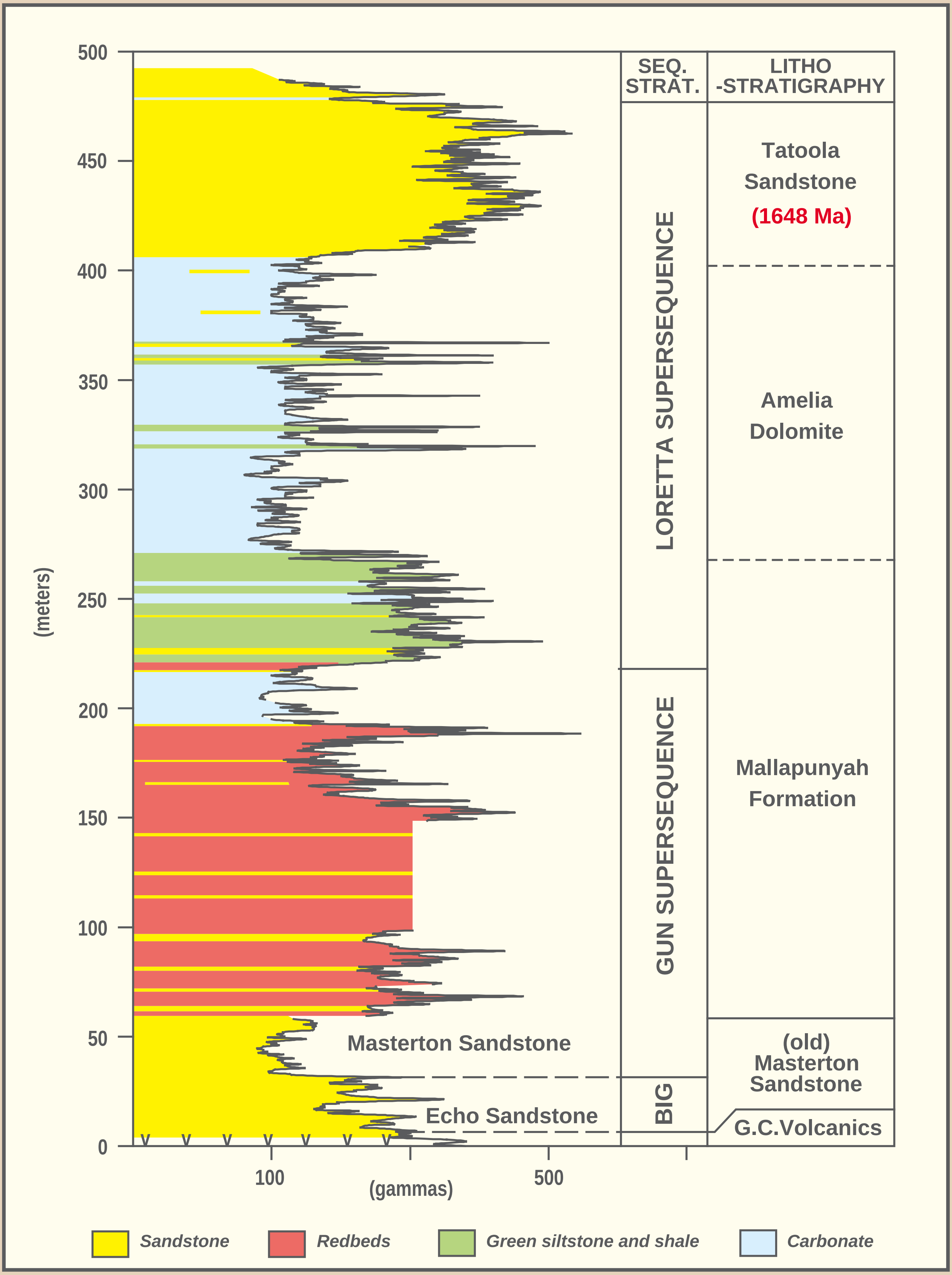

Figure 12 Simplified and generalised gamma ray log for the Big, Gun and lower part of the Loretta Supersequences in the southern McArthur Basin. Sequence stratigraphic and lithostratigraphic units compared. Latest revisions to Masterton Sandstone shown in italics.

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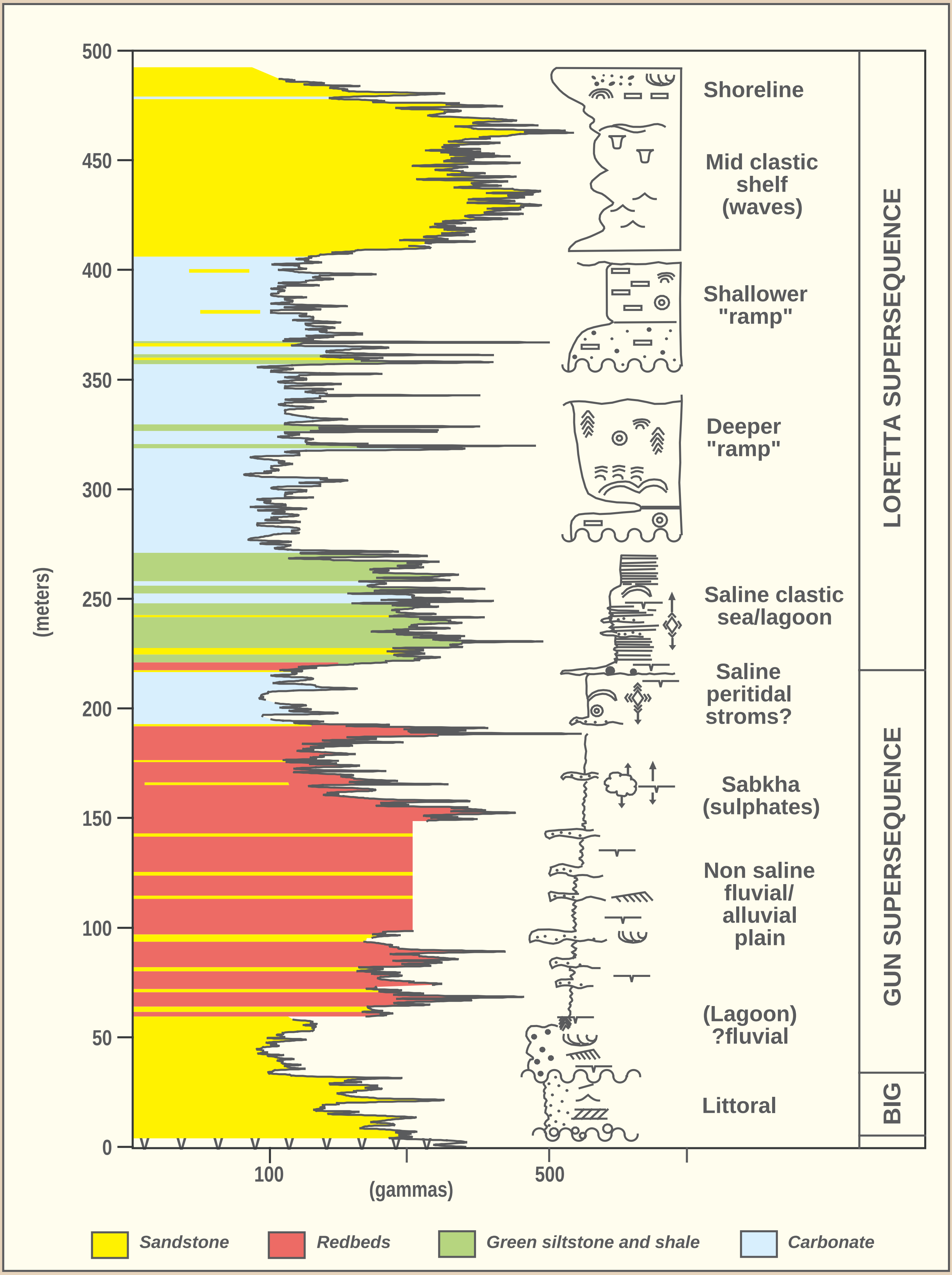

Figure 13 Simplified and generalised gamma ray log for the Big, Gun and lower part of the Loretta Supersequences in the southern McArthur Basin. Main rock types shown by colours to left of gamma log. Dominant facies shown schematically with broad depositional setting indicated.

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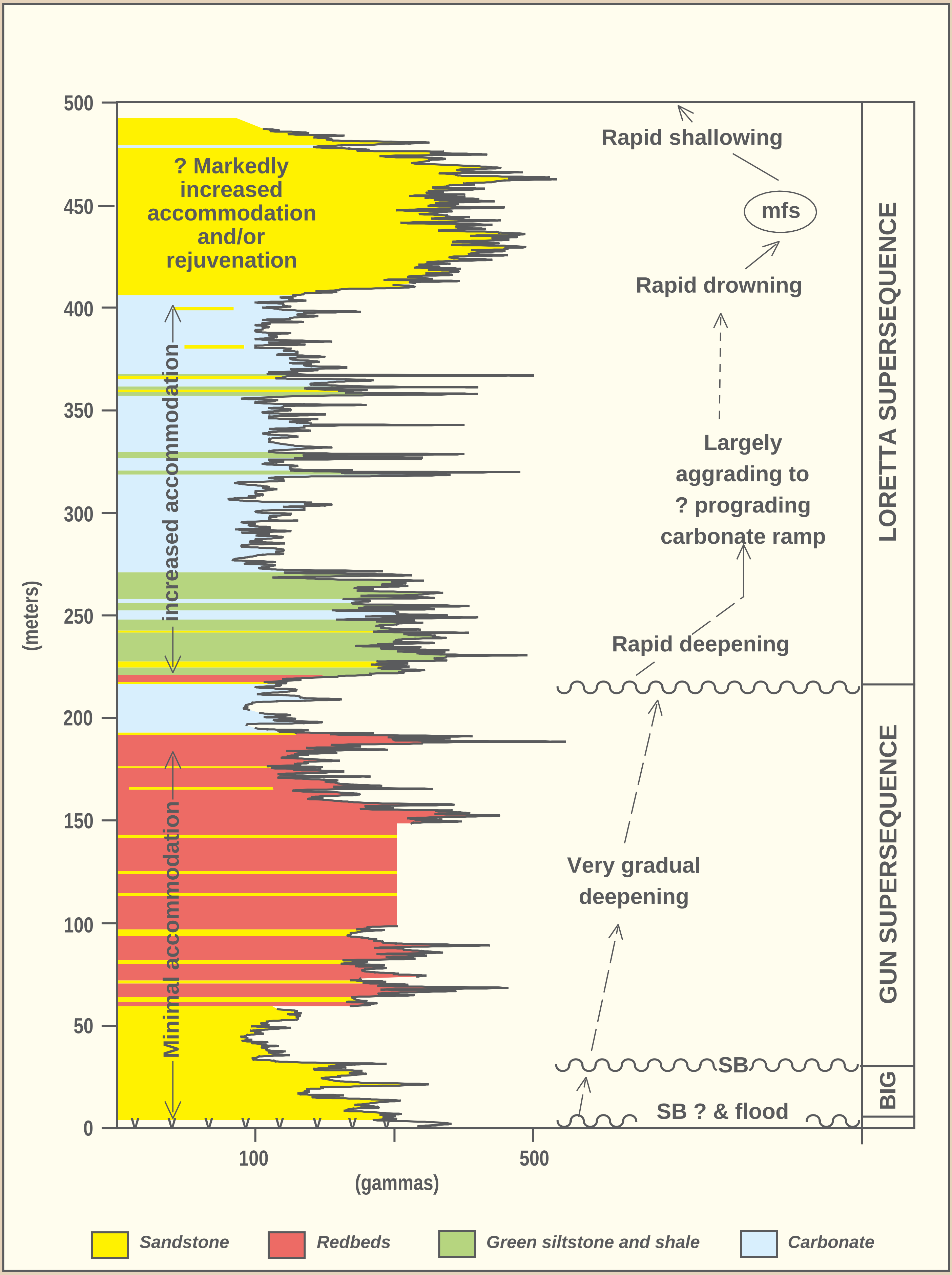

Figure 14 Sedimentological evolution of the Big, Gun and lower part of the Loretta Supersequences in the southern McArthur Basin, gamma log and rock types as shown in Figure 13.

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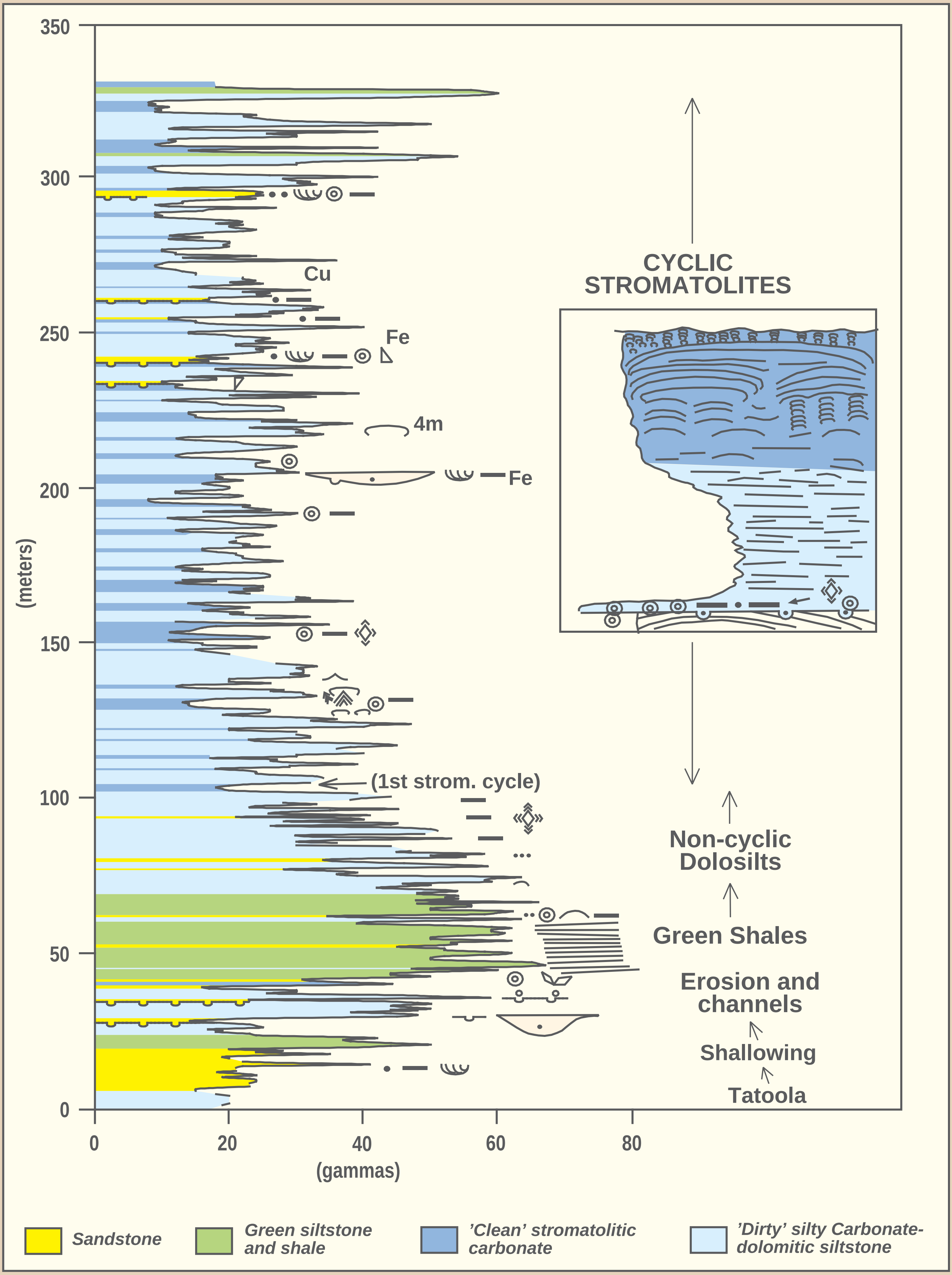

Figure 15 Simplified gamma ray, rock type and facies log of the middle part of the Loretta Supersequence (the Tooganinie Formation) from the southern part of the Mc Arthur Basin.

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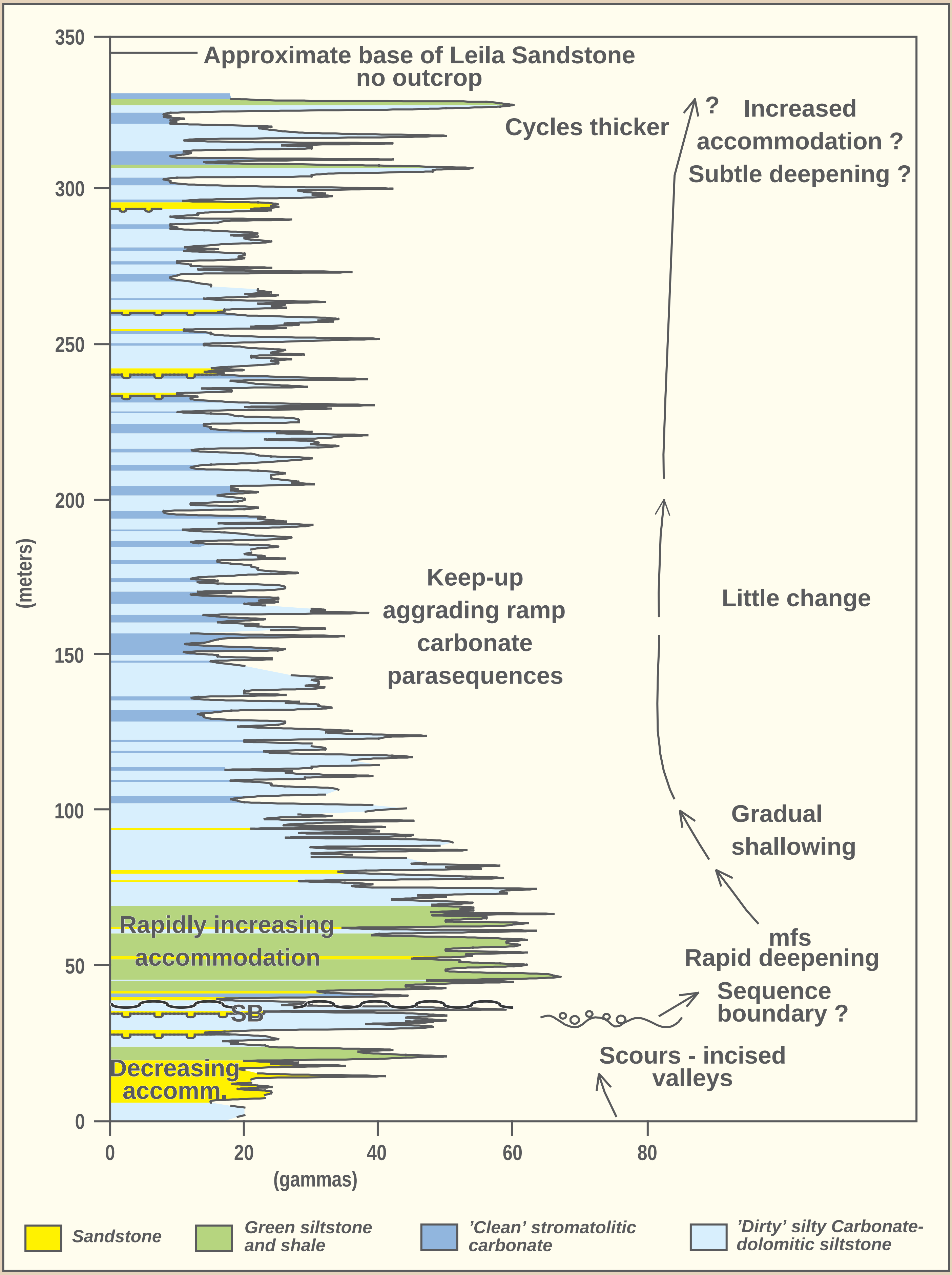

Figure 16 Evolution of the middle part of the Loretta Supersequence (the Tooganine Formation) from the southern part of the McArthur Basin, based on same log as shown in Figure 15.

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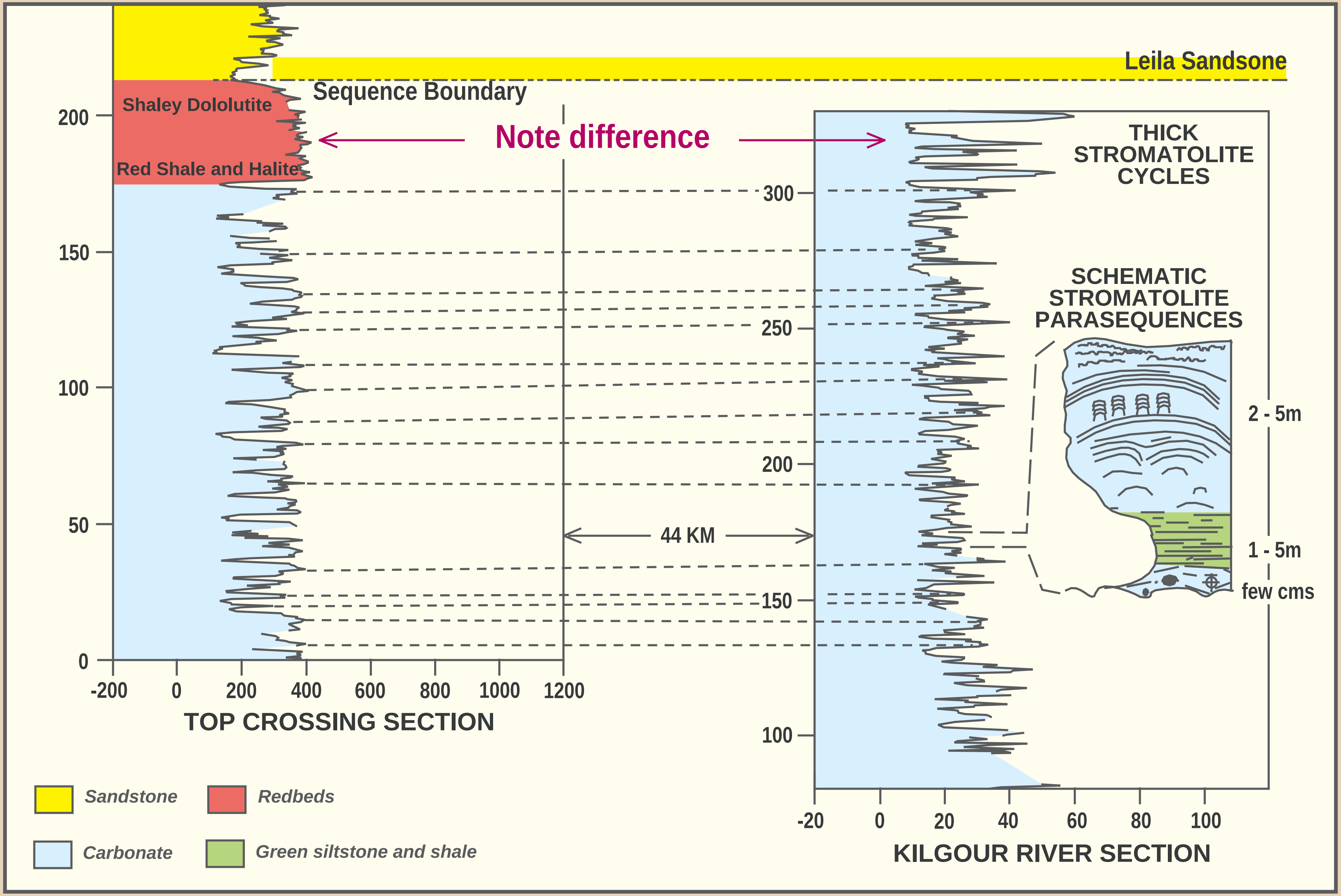

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Figure 17 Tentative detailed correlation of parasequences in the middle Loretta Supersequences (Tooganine Formation). Measured sections about 44km apart and have been correlated using visual pattern matching of respective gamma log curves only. Note: lateral facies differences at very top sections.

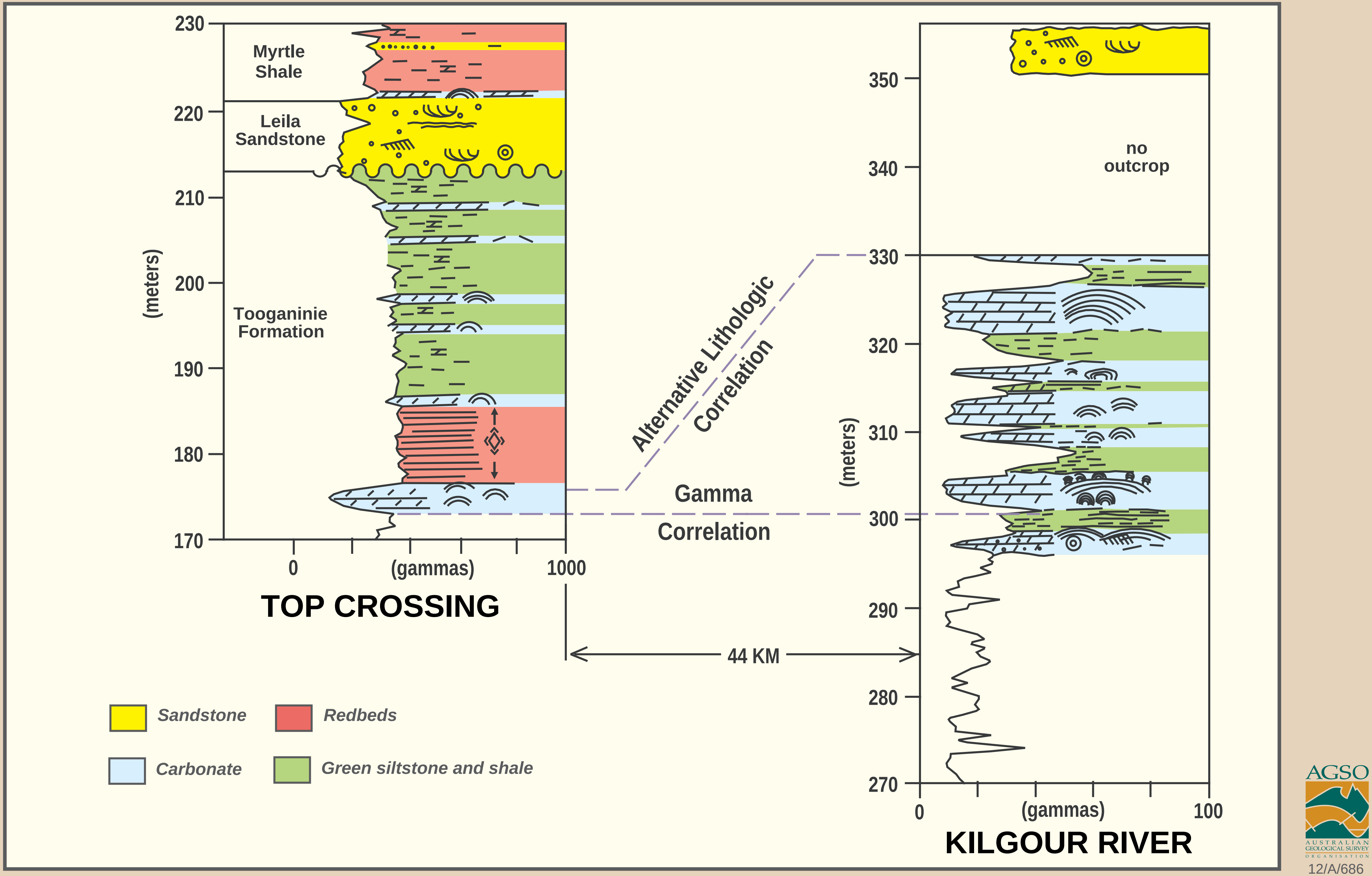

Figure 18 Expanded view of sections shown in Figure 17 showing detailed lateral facies changes at the top of the Loretta Supersequence. Two correlations are shown - The preferred correlation based on matching gamma ray logs from the two localities, and a lithologic correlation.

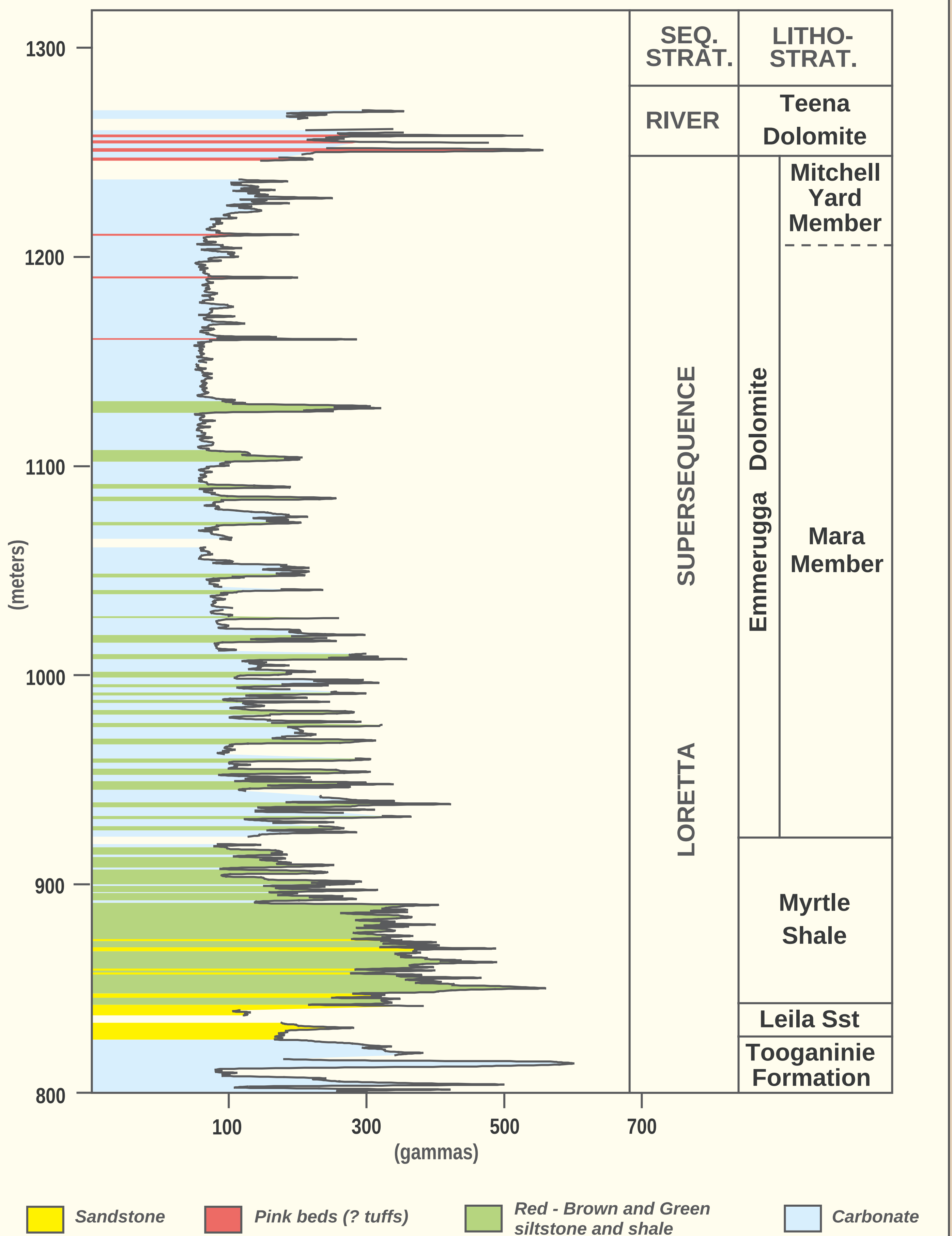

Figure 19 Composite gamma ray curve for the uppermost Loretta Supersequence and lower part of the River Supersequence in the southern part of the McArthur Basin.
Main rock types shown by colours to left of gamma log.

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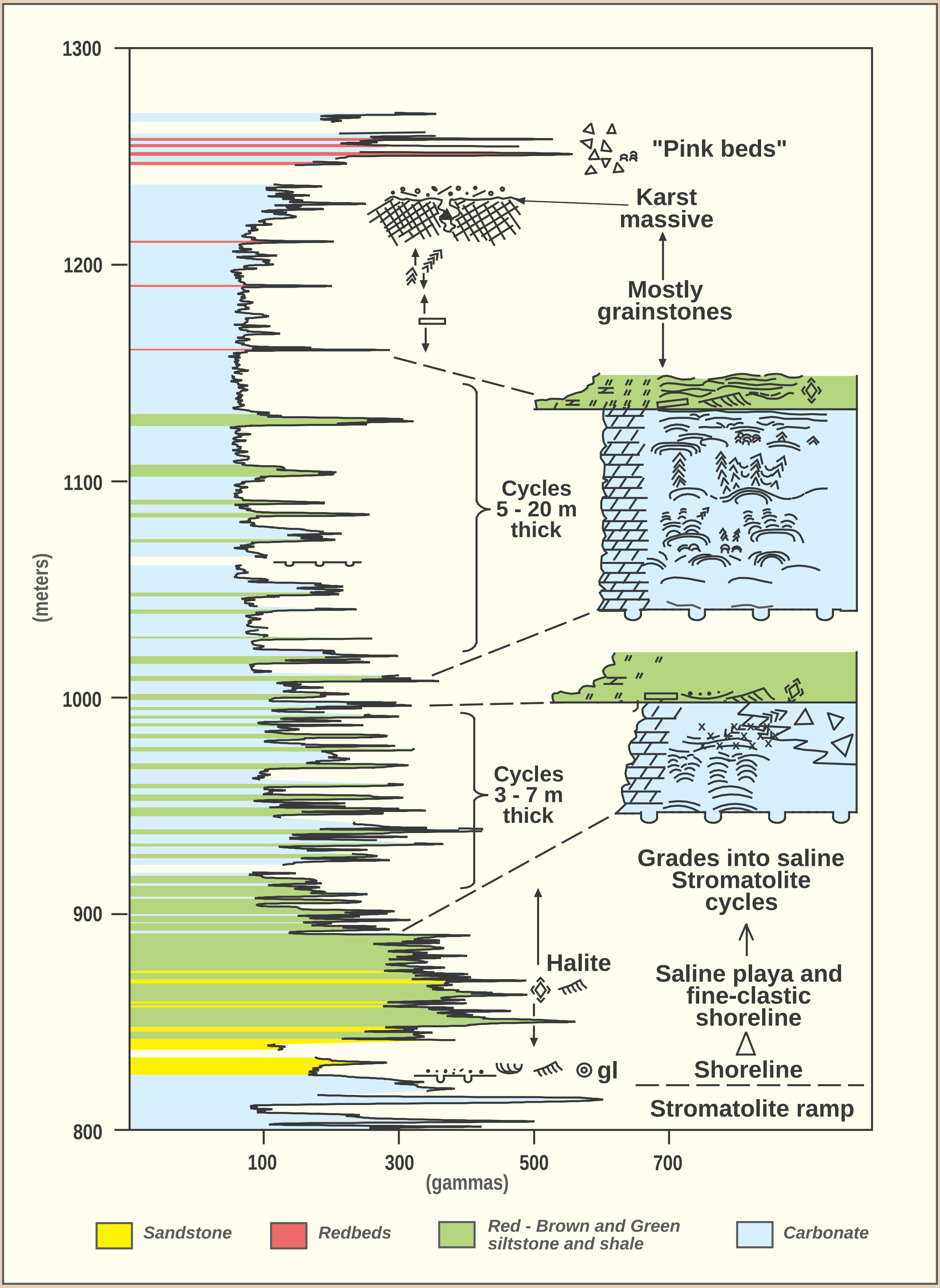

Figure 20 Composite gamma ray curve for the uppermost Loretta Supersequence and lower part of the River Supersequence (as in Figure 19) showing main facies present.

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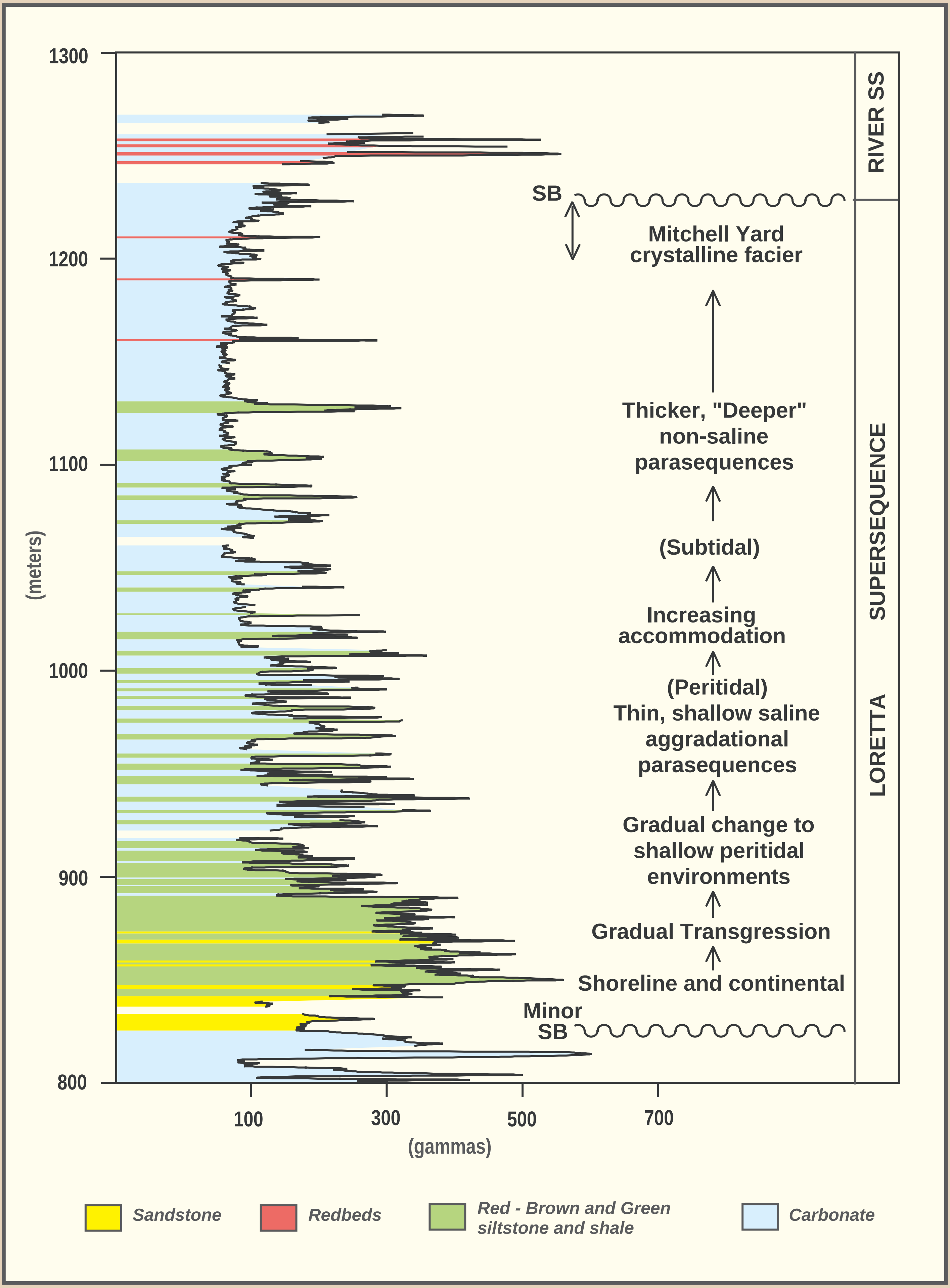

Figure 21 Evolution of depositional environments for the uppermost part of the Loretta Supersequence

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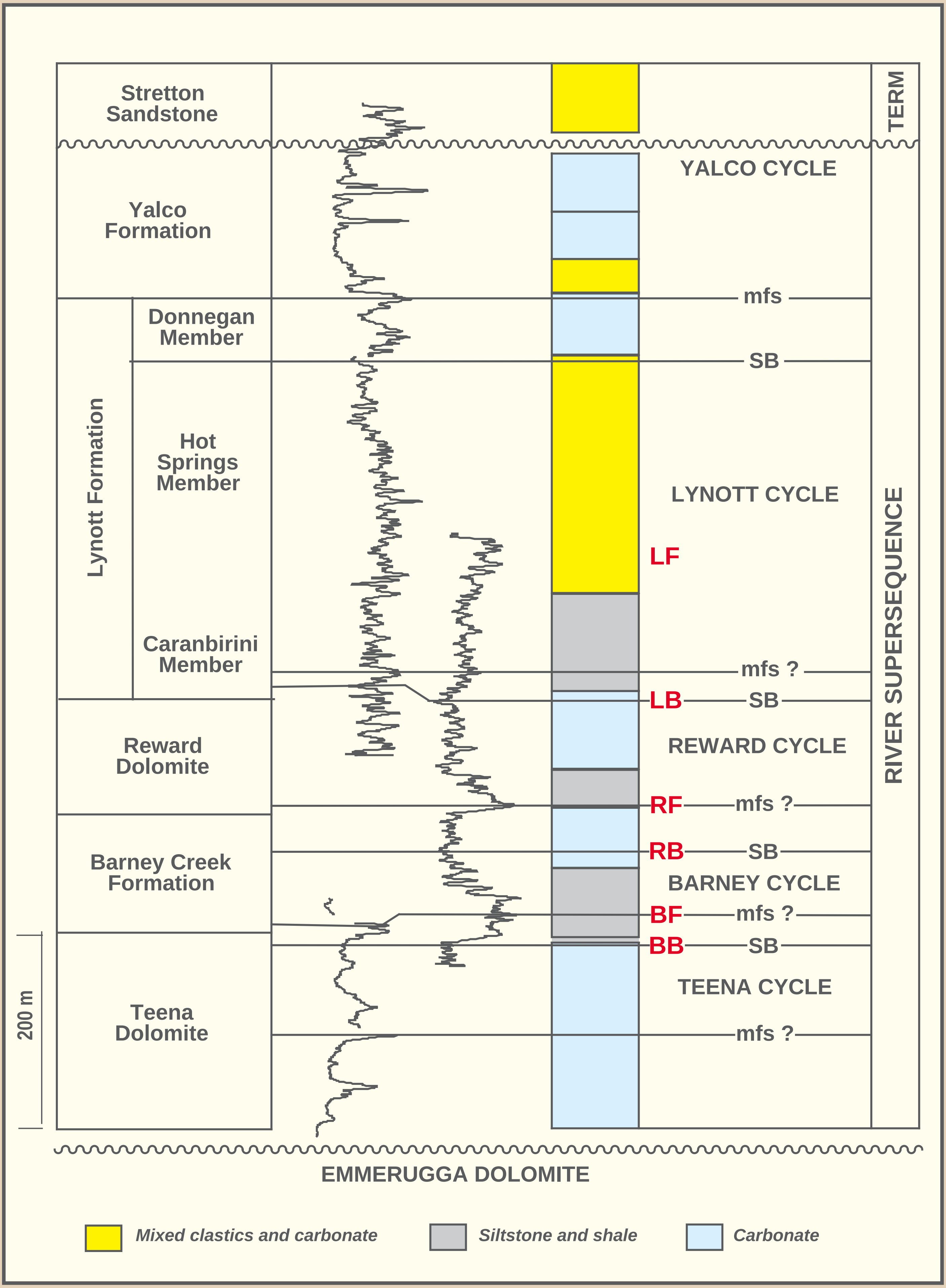

Figure 22 Modified after Southgate et al (1997). Composite gamma ray curve and simplified lithofacies through the River Supersequence in the McArthur Basin. Approximate locations of surfaces identified on cross section in Appendix (eg. BB, BF etc. shown).

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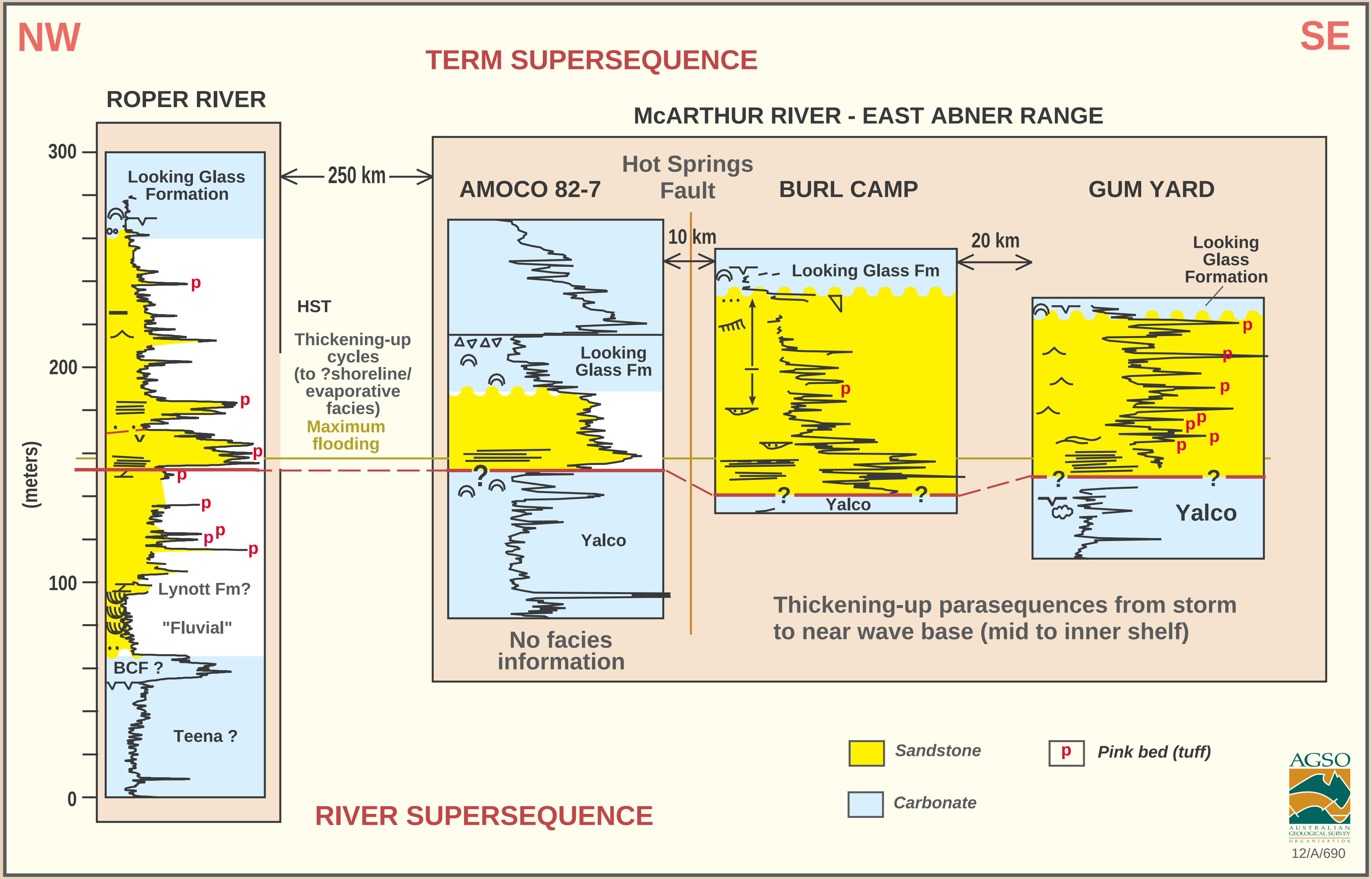

Figure 23 Regional gamma ray log correlations of the Stretton Sandstone.

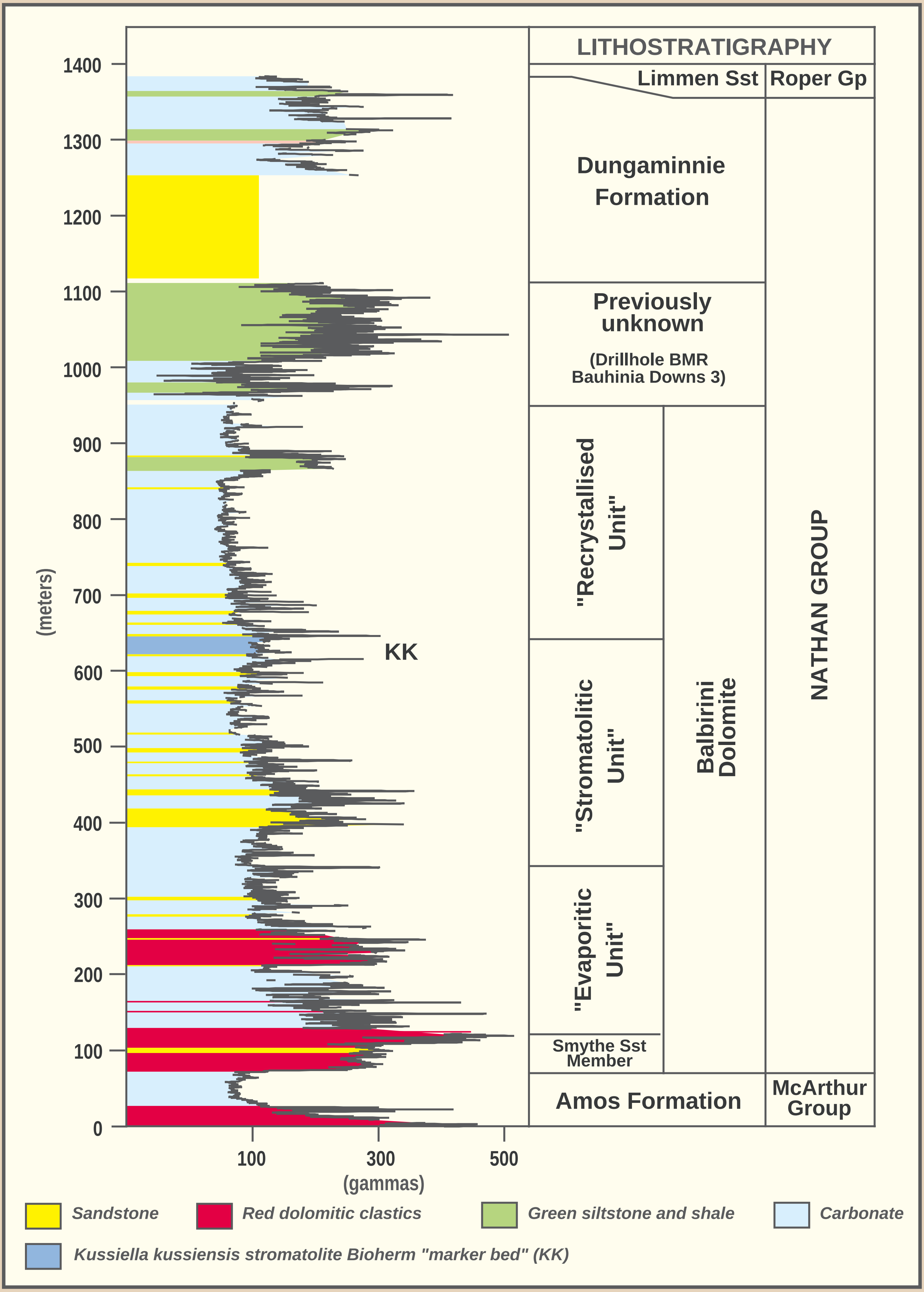

Figure 24 Composite gamma ray curve for the section through the Amos Formation, Balbirini Dolomite and Dungaminnie Formation near Balbirini Homestead.
Previous formal and informal lithostratigraphic subdivisions (after Jackson et al. 1987) in columns on right.

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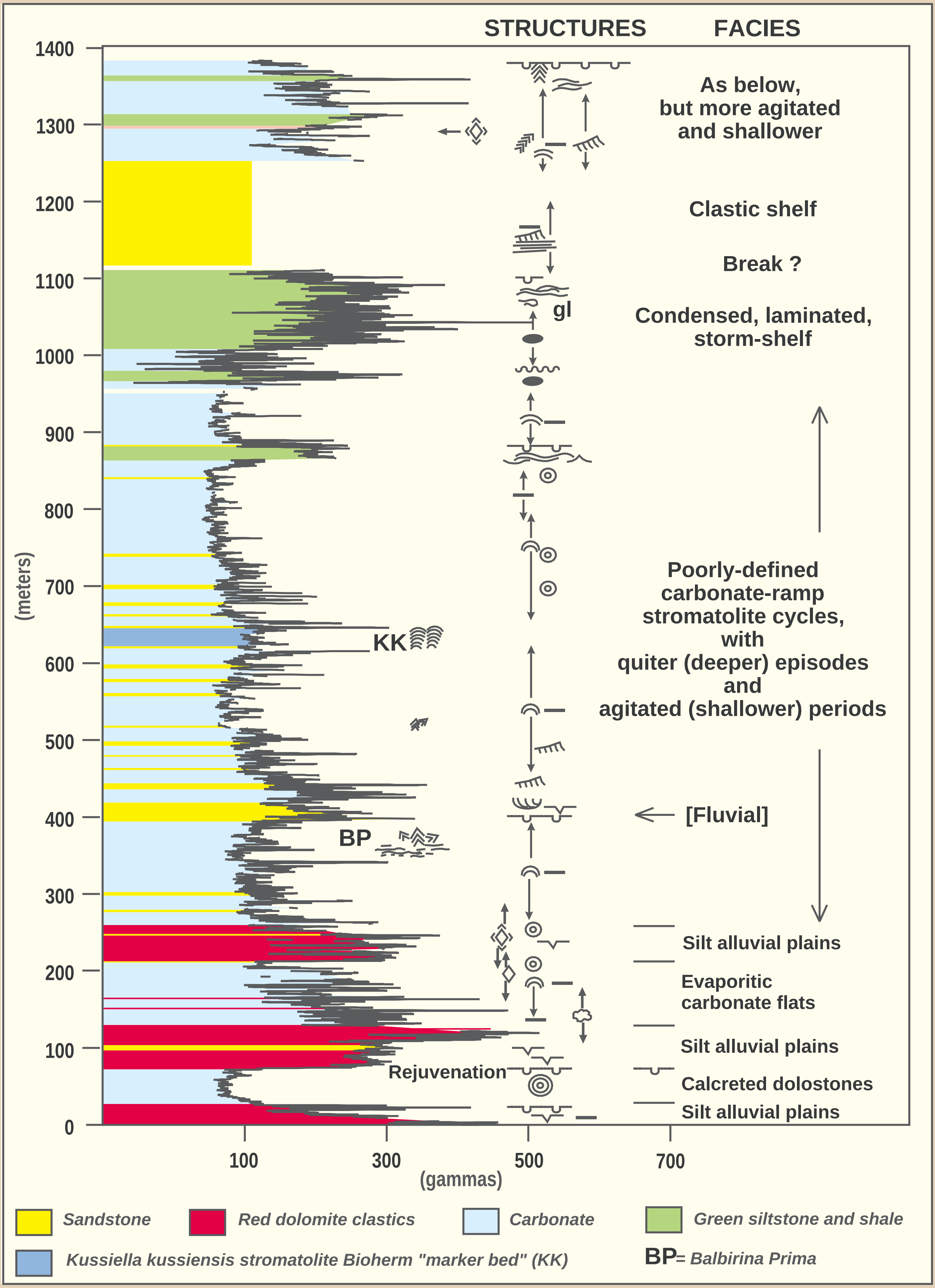

Figure 25 As figure 24, but showing main sedimentary structures and evolution of main facies belts.

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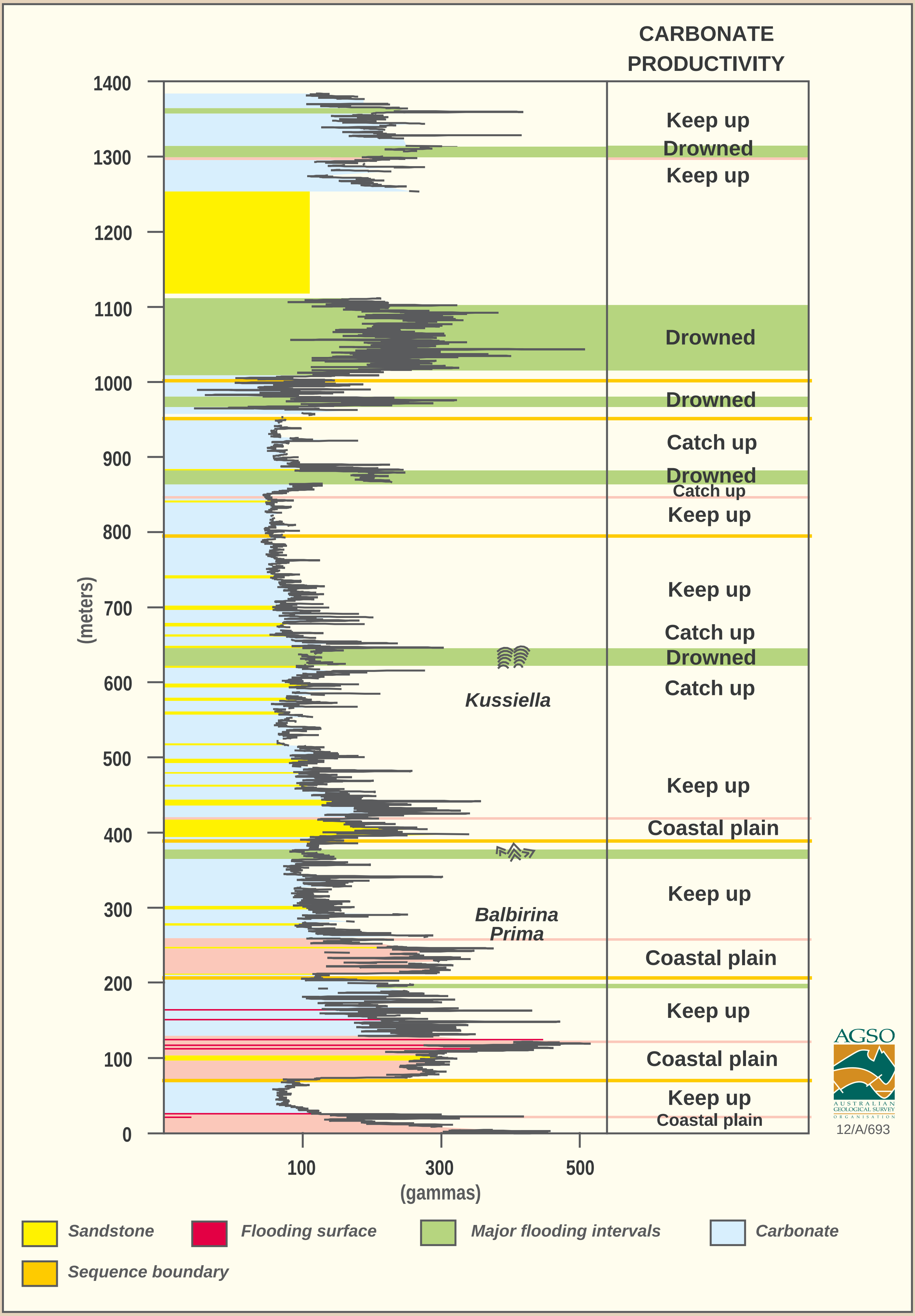


Figure 26 As figure 24, but showing main interpreted accommodation history, as described in text.

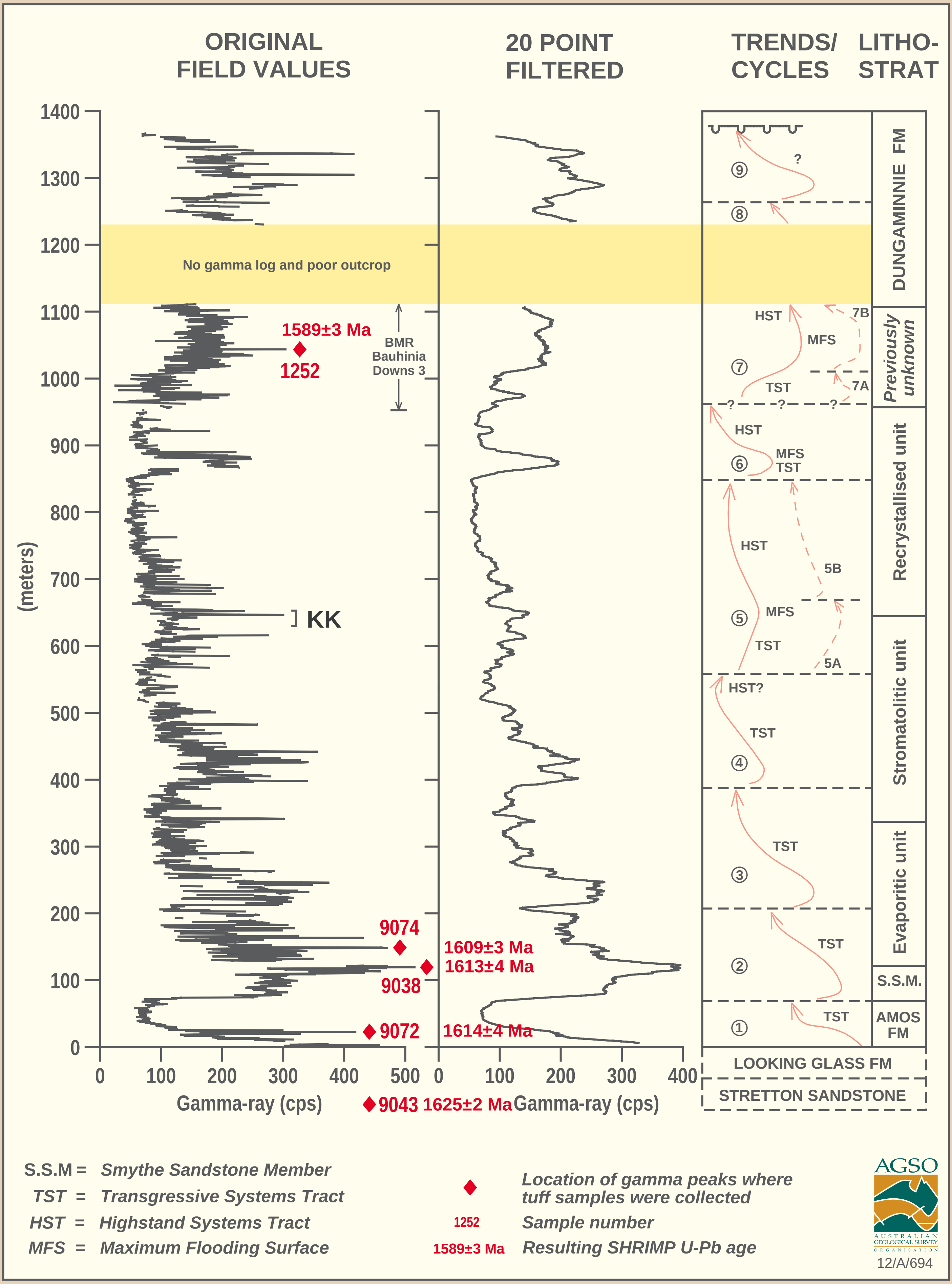


Figure 27 From Jackson and Southgate (2000). Composite gamma ray curves through the Nathan Group. The middle column is smoothed (using a 20-point filtering routine) gamma ray curve, to elucidate and emphasise the broad trends in the log. The right hand column shows our interpretation of the major log trends and breaks with the numbered Cycles as described in the text. Broken lines show alternative subdivisions for Cycles 5 and 7.

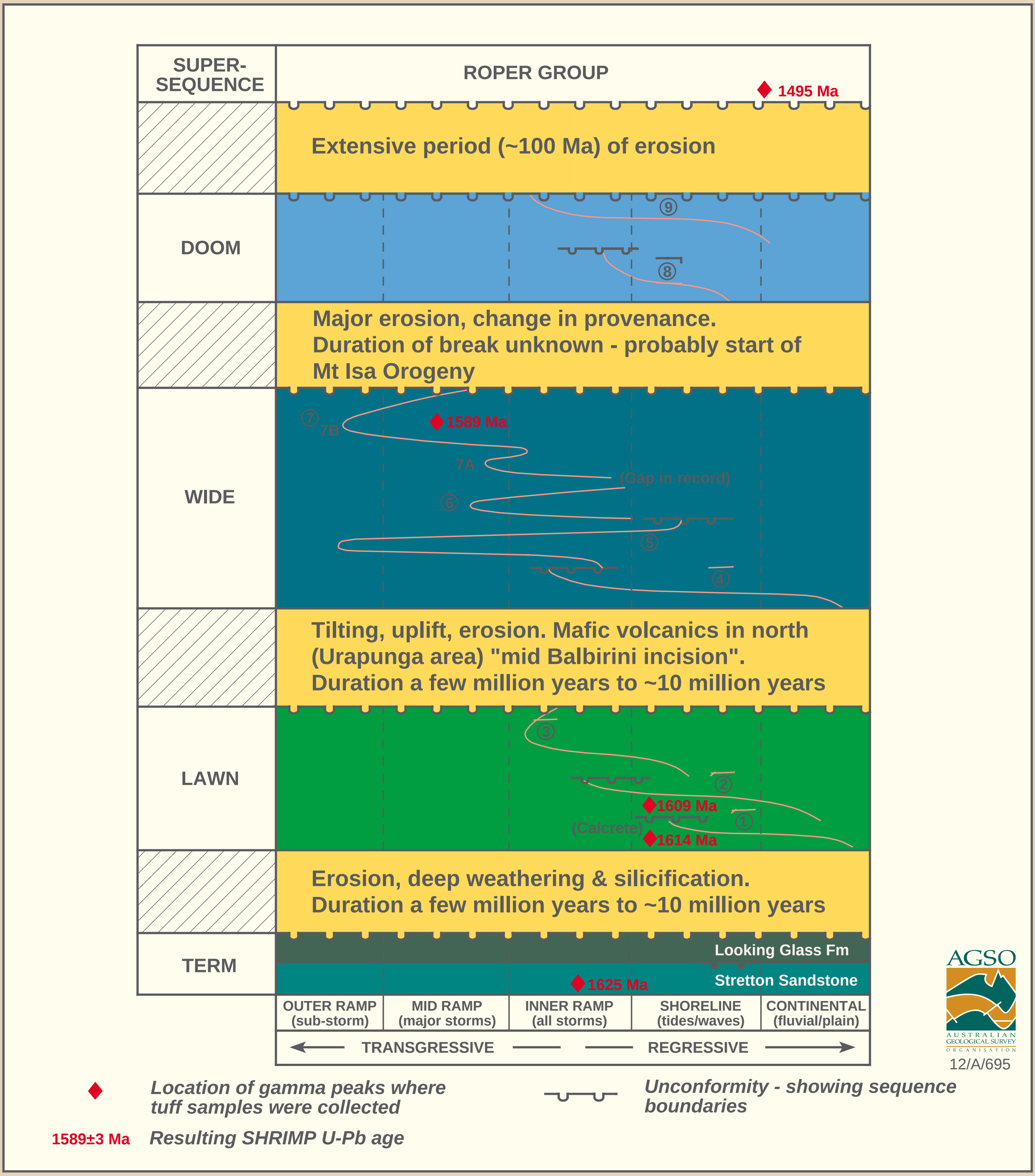
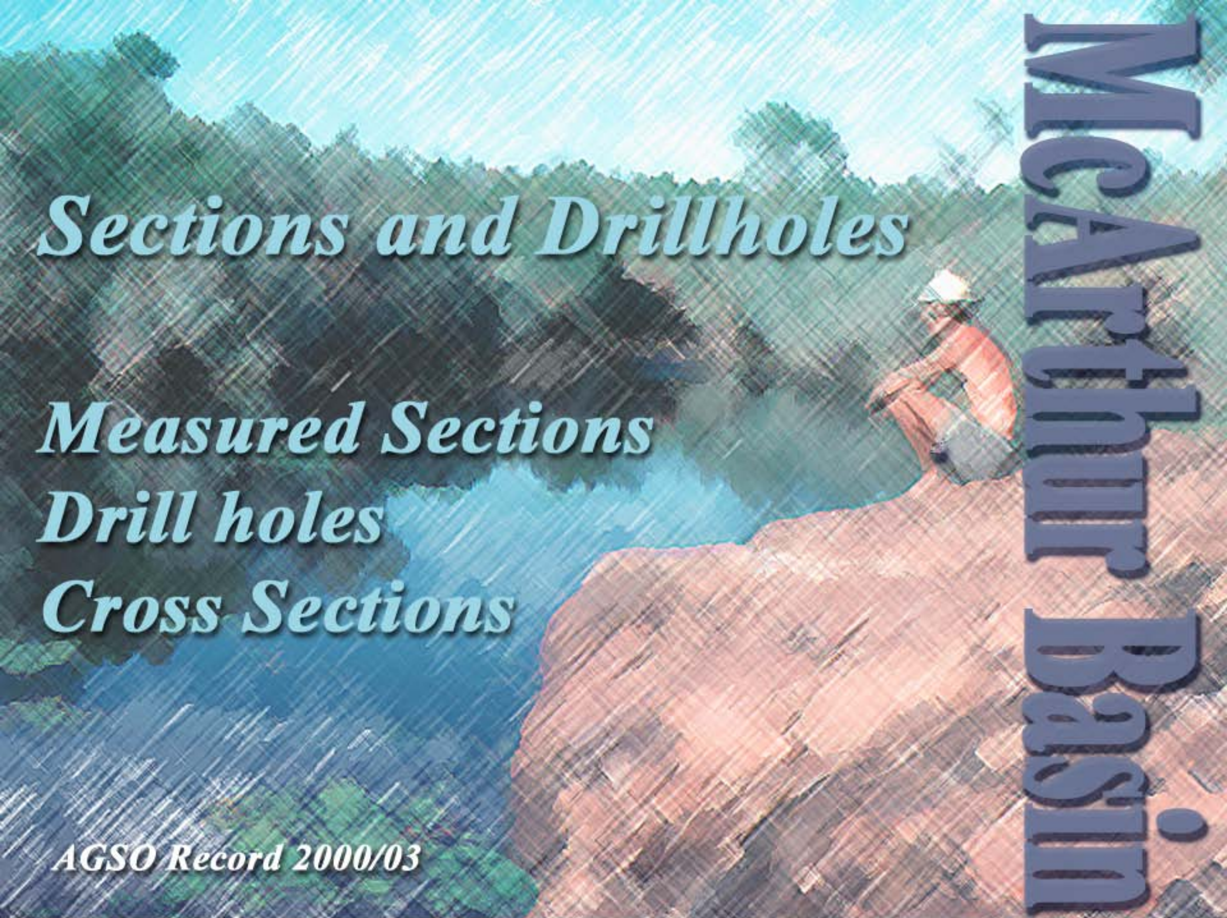
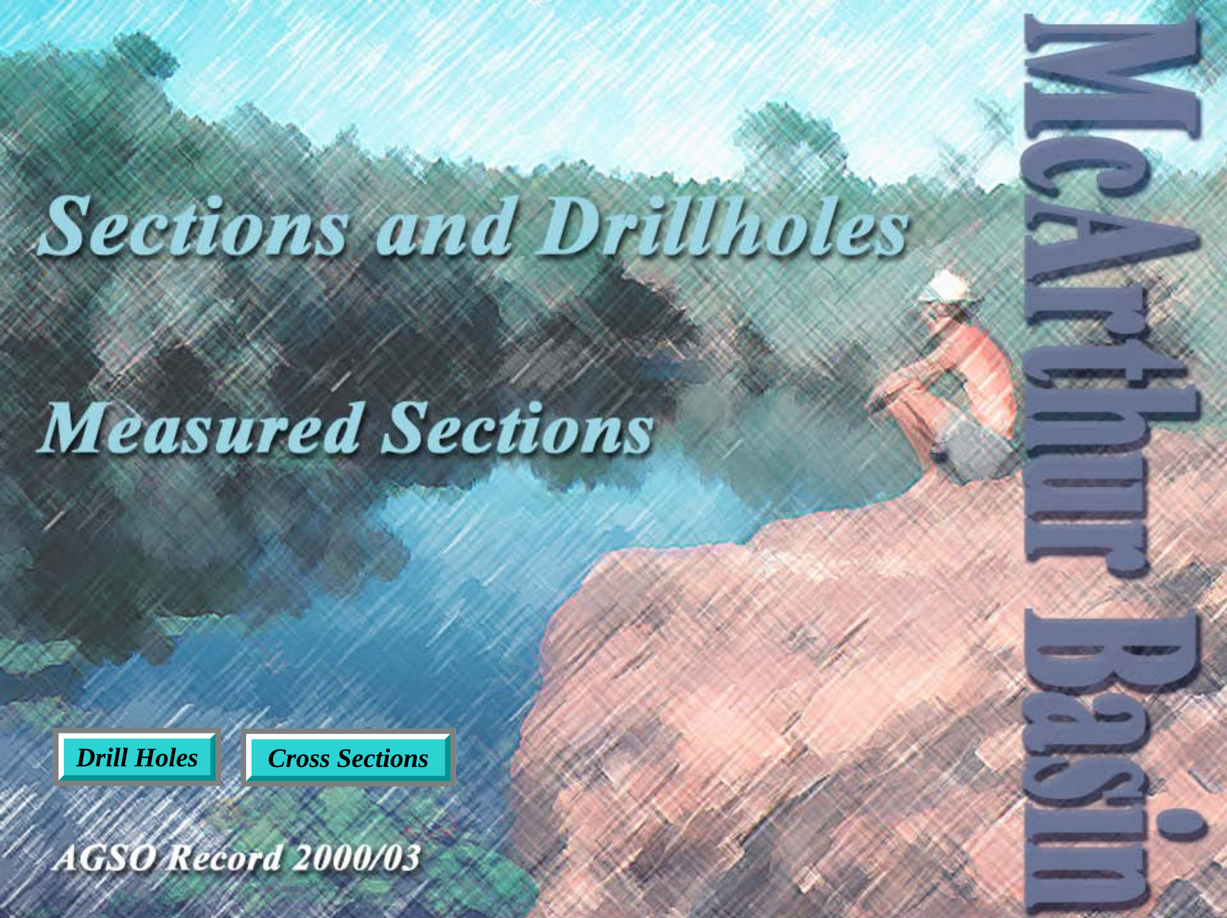


Figure 28 From Jackson and Southgate (2000). Revised evolution of the Nathan Group. Vertical axis is time, which is approximately linear,except at the top where the break between Doom Supersequence and Roper Group should be ten times thicker. Major episodes of deposition are represented by the Supersequences: intervening gaps in the geological record are shown in orange. Red lines show the palaeoenvironmental trends of the lithofacies in the individual cycles. Trends towards the left are transgressive, (ie the facies are deepening), trends towards the right regressive (ie the facies are shoaling).
Note: (a) The overall (large-scale) transgressive nature of cycles 1 to 7.
(b) The dominance of TST's in the Lawn Supersequence, but more complete sequences in the Wide Supersequence.
(c) A marked regressive shift between the Wide and Doom Supersequences, indicating a major change across this supersequence boundary;
(d) Two maximum flooding episodes in the Wide Supersequence which may indicate that the sequence boundary 5/6 is possibly more significant than recognised in the field.


McArthur Basin:
Sections and Drillholes
Measured Sections
Drill holes
Cross Sections
AGSO Record 2000/03


McArthur Basin
Sections and Drillholes
Measured Sections
Drill Holes
Cross Sections
AGSO Record 2000/03

Archie Creek Composite

95PS06, 77/11, 77/12

SCALE 1:1000

Easting: 595600

Northing: 8110300

Data type: Measured Section

Map sheet: Kilgour

Geology: M J Jackson & P N Southgate

Geolog compilation: K Barnett & I Zeilinger

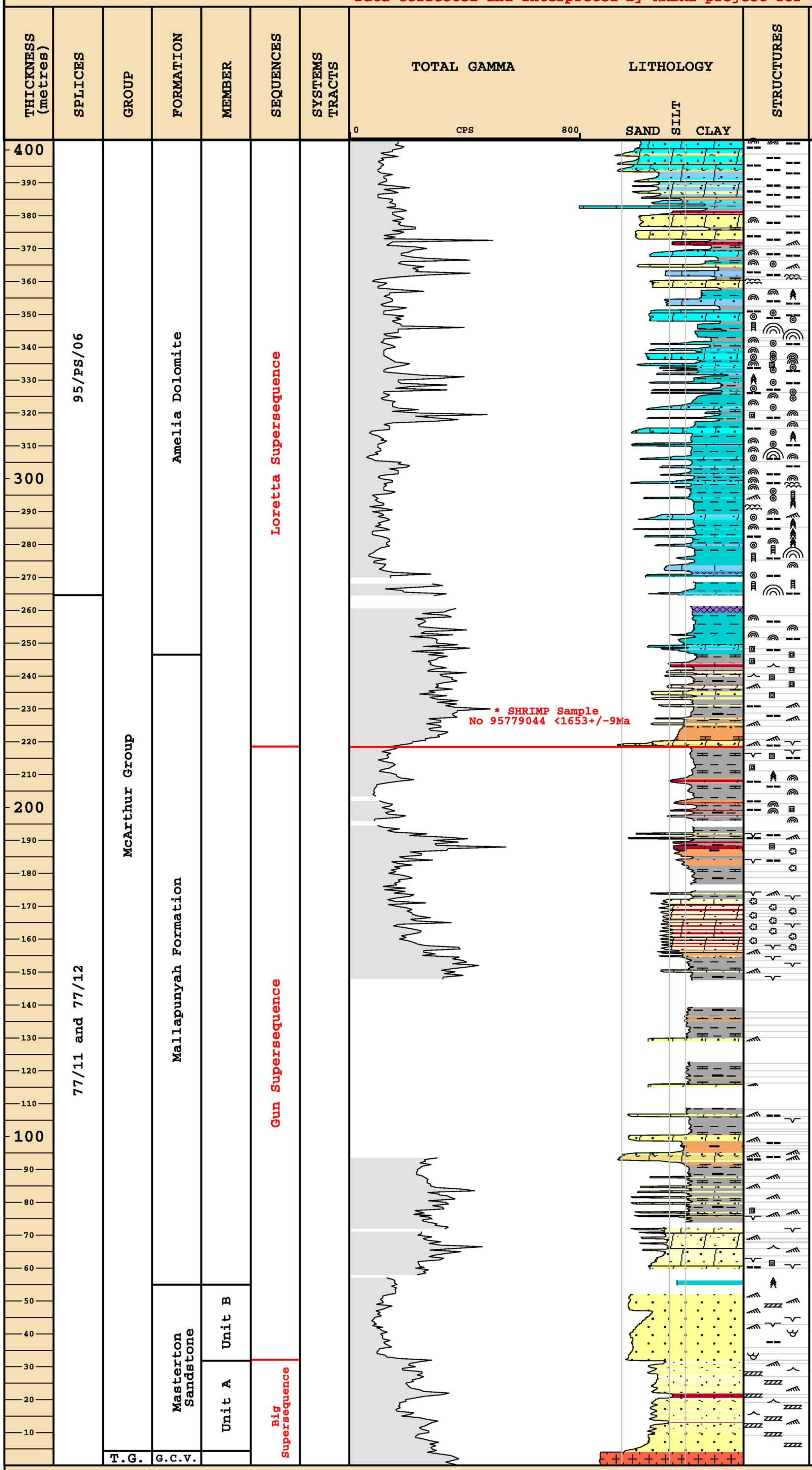
AUSTRALIA

DEPARTMENT OF MINES AND ENERGY

NORTHERN TERRITORY DEPARTMENT OF MINES AND ENERGY

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)



Outcrop / Core Description

358–405m: Predominantly intraclastic sandy dolarenites with interbeddded shaley dololutite/dolomitic mudstone. Quartz sand mostly fine but rare coarse grains. Lower parts of cycles contain stromatolites between 358 and 370 m, but above here stroms are rare & usually of low relief. Bases of cycles marked by intraclast conglomerates on erosion surfaces with up to ~1 m local relief. (Quartz sand present above 358 m)(INTERTIDAL?)

316–358m: As below, similar cyclic sequence of stromatolitic and intraclastic dolostones, but shaley dololutite/ dolomitic mudstone (up to ~50 cm thick) forms base to most cycles. Oolitic dolarenites common. Rare halite casts @ 320 m & 350 m, oncolites @ 340 m. (SUBTIDAL FACIES)

272–316m: Interbedded stromatolitic dololutites and coarser grained dolarenites, forming distinct shoaling cycles around 3–5 m thick. Stromatolitic units comprise laterally–linked domes, low rounded domes & various types of conical forms. Base of cycle is usually marked by an intraclast conglomerate, ooid grainstone or a recessive shaley dololutite bed on a sharp planar surface; top of cycle is usually marked by intraclast (flat – pebble) conglomerate
Rare (few %) medium quartz sand @ 280 m.(PERITIDAL TO SUBTIDAL FACIES)

247–272m: Predominantly stromatolitic dololutite with interbedded sandy dolarenites and dolomitic siltstone. Distinctive pale green chert beds @ 260 & 272 m. Probably cyclic with domal and pseudo–columnar stromatolites grading up into intraclastic dolostones. (Base of section PS/95/06)

(Top of sections 77/11 & 12)

223–247m: Predominantly thin bedded to laminated dolomitic siltstone & mudstone with beds of dolomitic v. fg – medium grained sandstone (commonly 1–5 cms but up to ~10 cms thick). Interval above 230 m is crowded with halite casts and moulds. Bedding parallel and continuous, rare scouring at base of some graded v.fg sandstone beds, rare loading.('HASELGEBIRGE' FACIES)

@220–223m: Dolomitic siltstone/mudstone with desiccation cracks, starved ripples, lenticles of medium sand (MUD FLAT).

219–220m: Planar erosion surface overlain by heamatitic pebbly dolomitic sandstone with exotic clasts.

196–219m: Predominantly stromatolitic dololutite with interbeds of red mudstone, oolitic dolarenite & intraclast conglomerate. Rocks form shoaling cycles a few metres thick. Stromatolites include domal and conical forms.(MOSTLY INTERTIDAL FACIES)

177–194m: Predominantly red brown dolomitic fine sandstone, siltstone & mudstone, common desiccation and halite casts. Small (<1 cm) cauliflower cherts. Two v. coarse grained, pebbly conglomerate beds near top, with cross–bedding, ripples and barite nodules. Large skeletal hopper halite casts @ 190 m.(DRY MUDFLAT & ?INTERTIDAL FACIES)

154–175m: Thinly bedded dolomitic sandstone, sandy dolosiltstone and dololutite with large cauliflower chert nodules.
Stratification disrupted by scouring, desiccation, intraclast bed formation and diagenetic growth of nodules after anhydrite.
(SALINE MUD FLAT FACIES/SABKHA)

115–154m: Section of poor outcrop – gamma ray data not recorded. Rocks as below; predominantly purple/brown dolosiltite to dololutite. Rare fine–medium grained dolomitic sandstone beds with ripples. Desiccation cracks at top.(DRY MUD FLAT FACIES)

74–108m: Predominantly purple/brown muddy dolosiltite to dololutite with numerous thin (few cms) current rippled beds of medium to coarse grained dolomitic sandstone.
Rare desiccation cracks & barite nodules.

@94m: Pebble conglomerate of chert & dolostone pebbles in a coarse dolomitic sandstone.

60–72m: Predominantly fine–medium grained purple dolomitic sandstone grading to sandy dolarenite, rare coarse grained quartz sandstone beds. Thin bedded, with symmetrical & asymmetrical ripples; halite casts & moulds, desiccation cracks. Prominent scoured surfaces in places.(ALLUVIAL/DRY MUD FLAT FACIES)

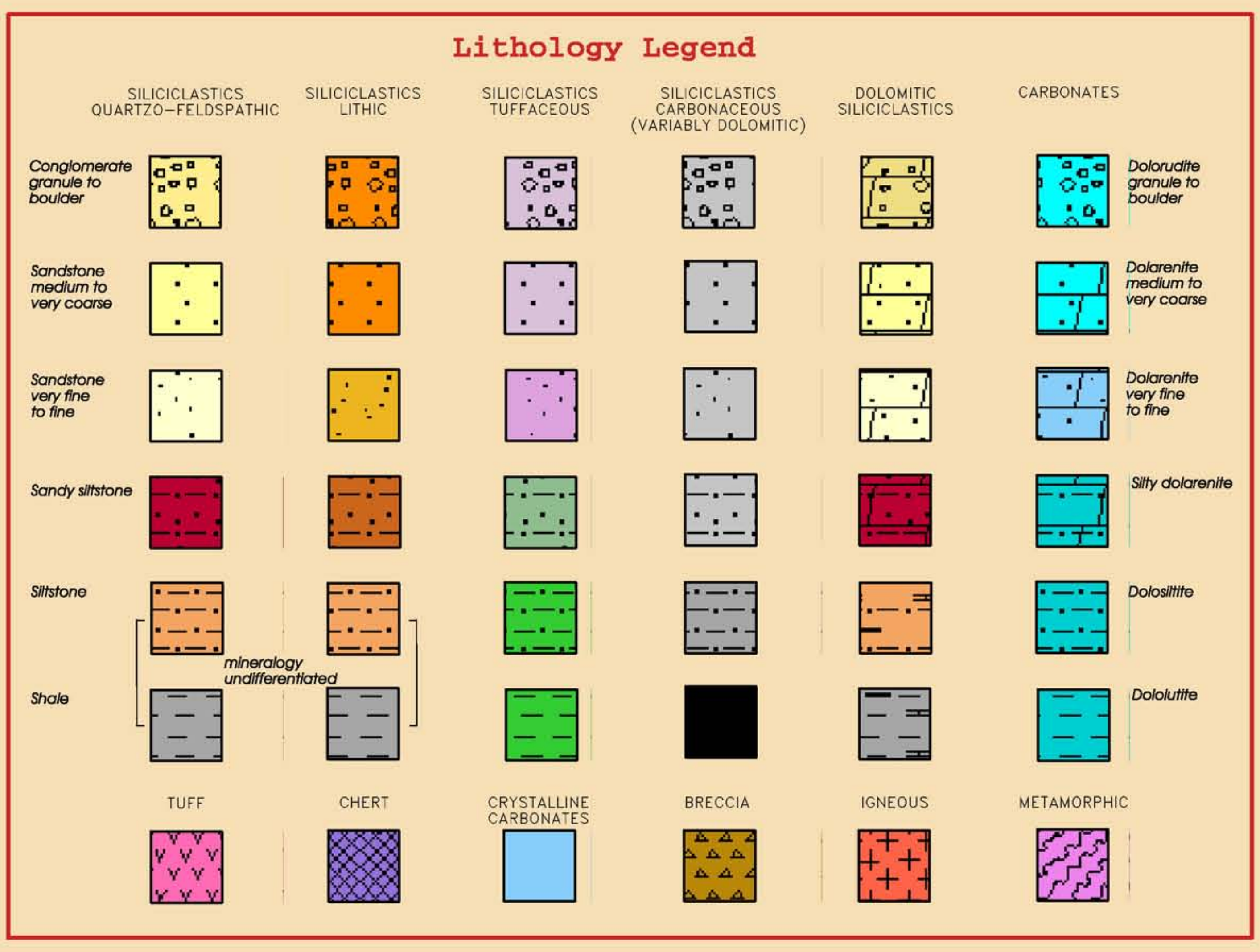
@ 55m: Poorly outcropping chertified branching conical stromatolites.

32–52m: Predominantly fine to coarse grained quartz sandstone. Medium to thick bedded, commonly trough cross–stratified. Ferruginous & cherty mottles & vughs common. Desiccation cracks & planed–off ripples.(FLUVIAL TO SHALLOW MARINE FACIES)

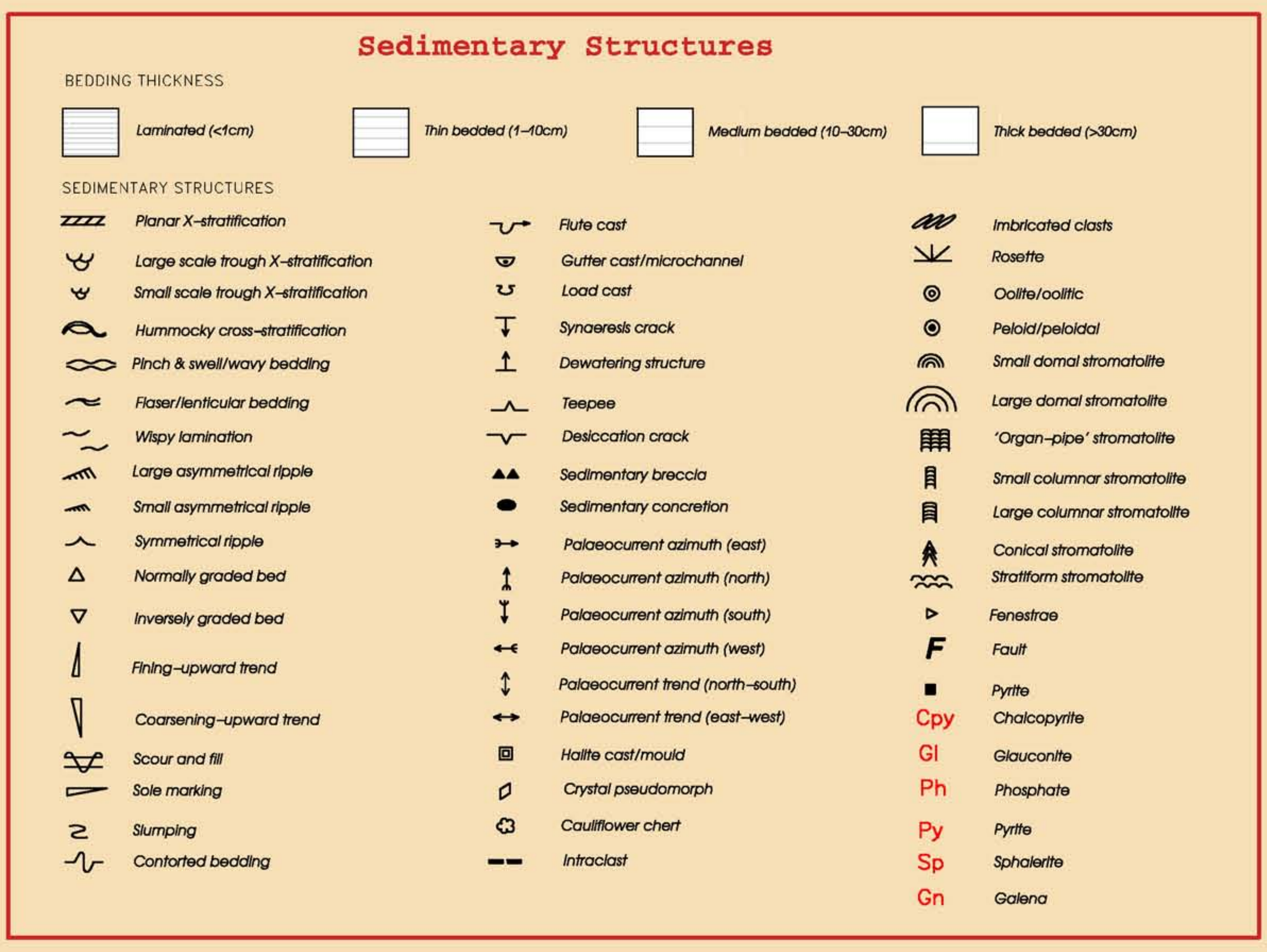
@32m: Sharp erosion surface with about 2 m of incision.
4–32m: Predominantly very fine to fine grained quartz sandstone with rare medium grained intervals; siltstone beds and laminae. Medium to thick–bedded, common low angle planar to wavy cross–stratification. Numerous current ripples. Herringbone cross–stratification.(SHALLOW MARINE FACIES)

0–4m: Purple to red–brown chloritic, vesicular, brecciated igneous rock.

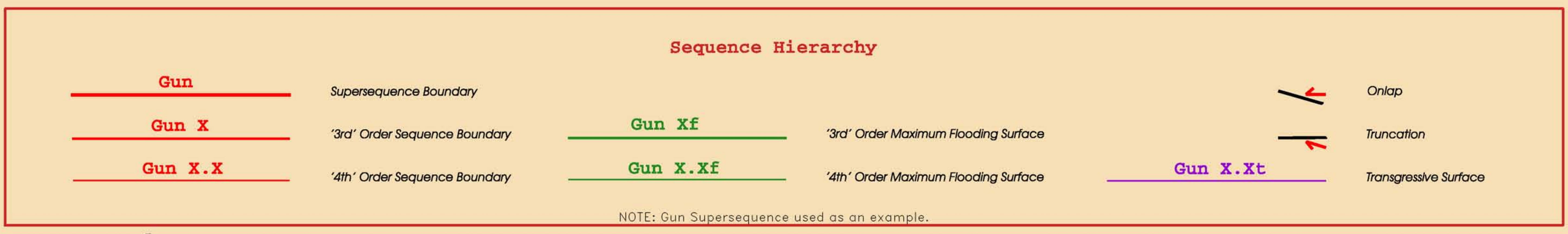
Lithology Legend



Sedimentary Structures



Sequence Hierarchy



NOTE: Gun Supersequence used as an example.

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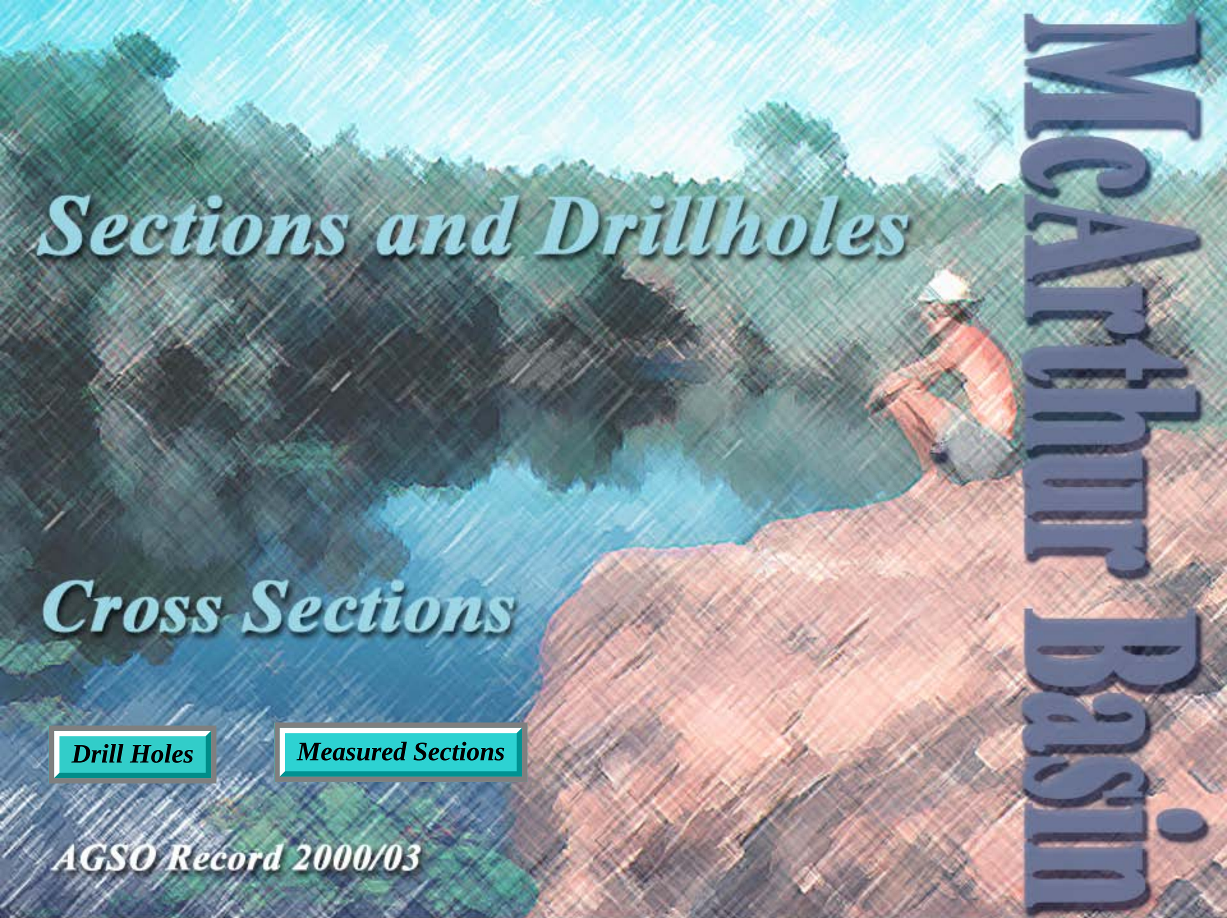
GPO Box 378, Canberra ACT 2601.
Phone 02–62499519, Facsimile 02–62499982

Date: 05–Oct–2000



McArthur Basin

Sections and Drillholes

Cross Sections

Drill Holes

Measured Sections

AGSO Record 2000/03

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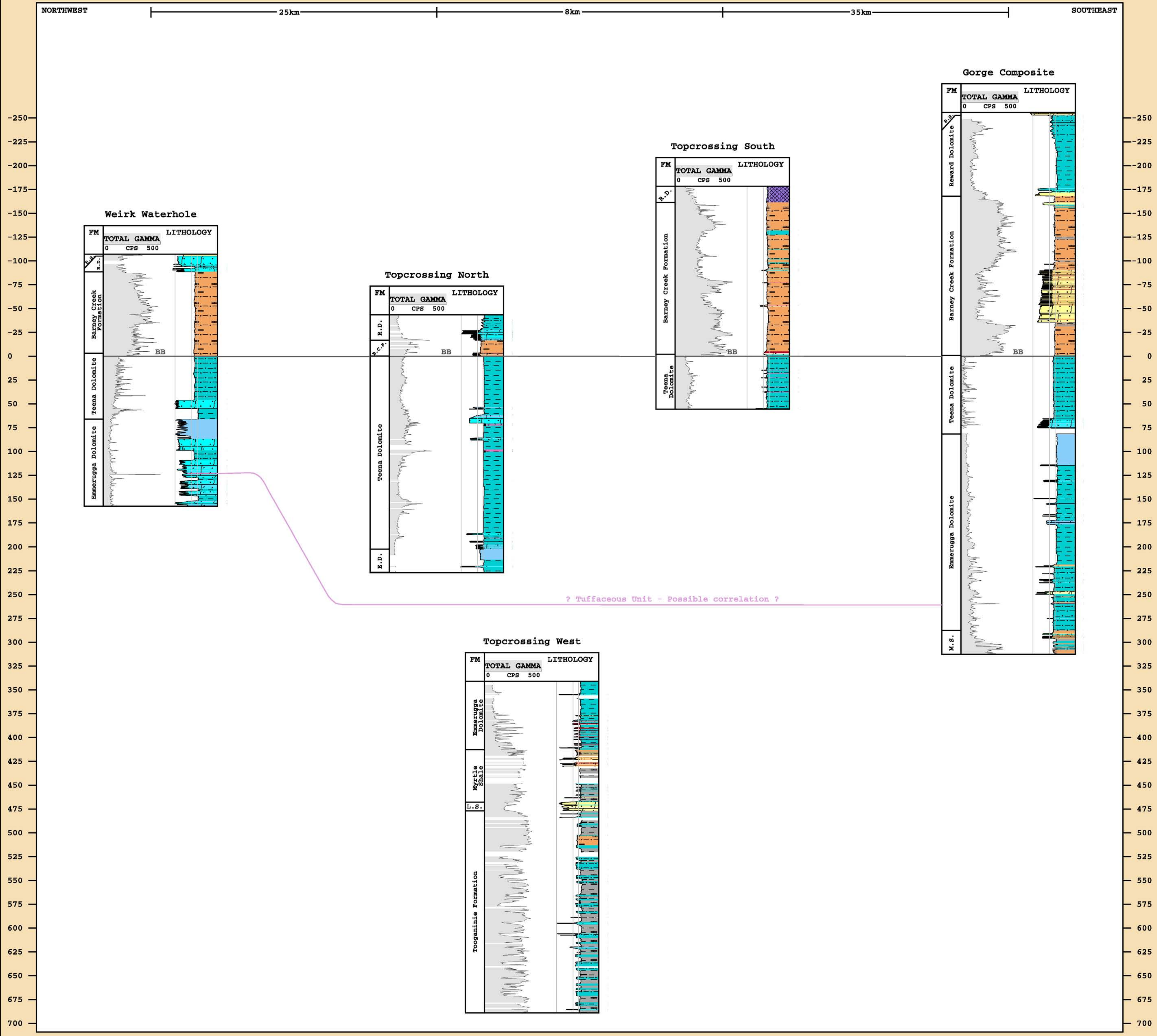


Cross Section 2
Barney B

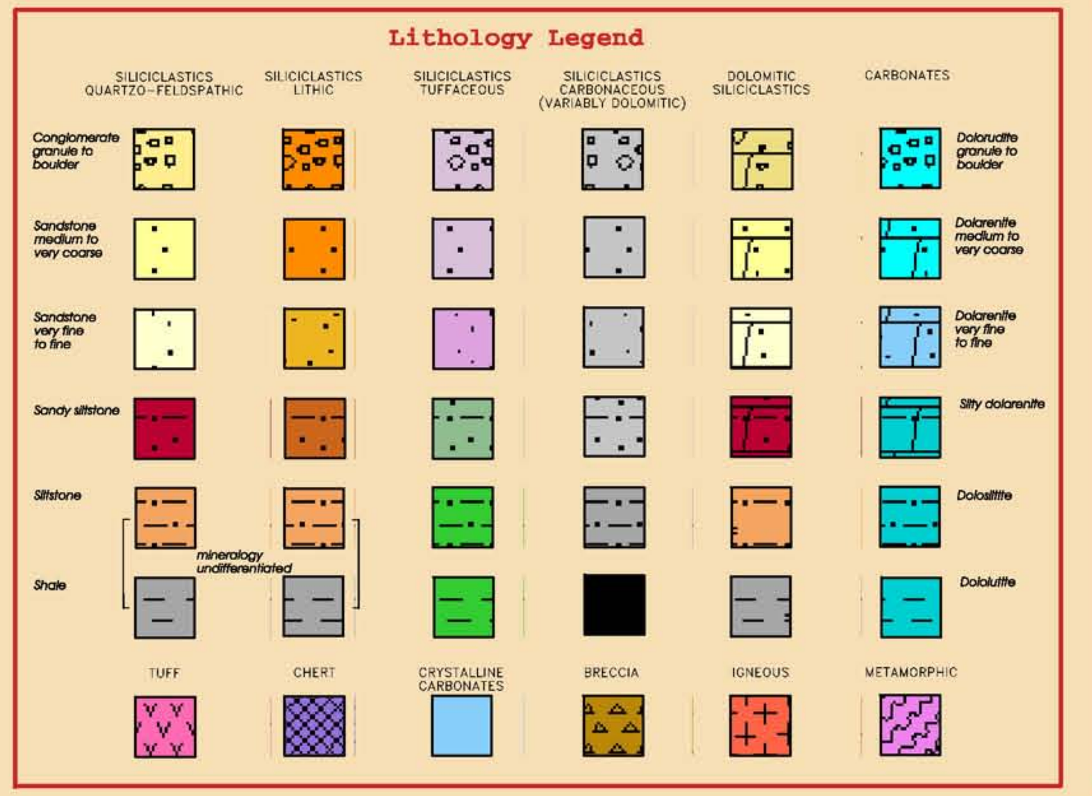
Scale 1:2000

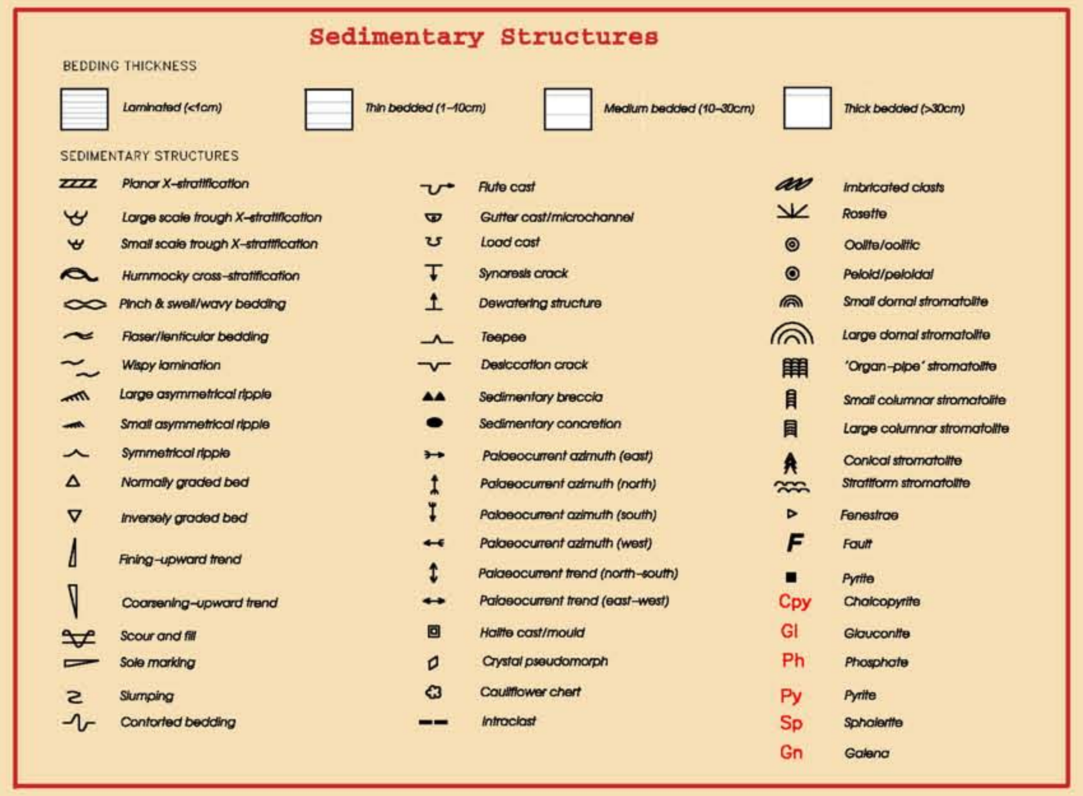
Data Type: Cross Section

Cross Section Interpretation: M J Jackson

Geolog Compilation: K Barnett

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)





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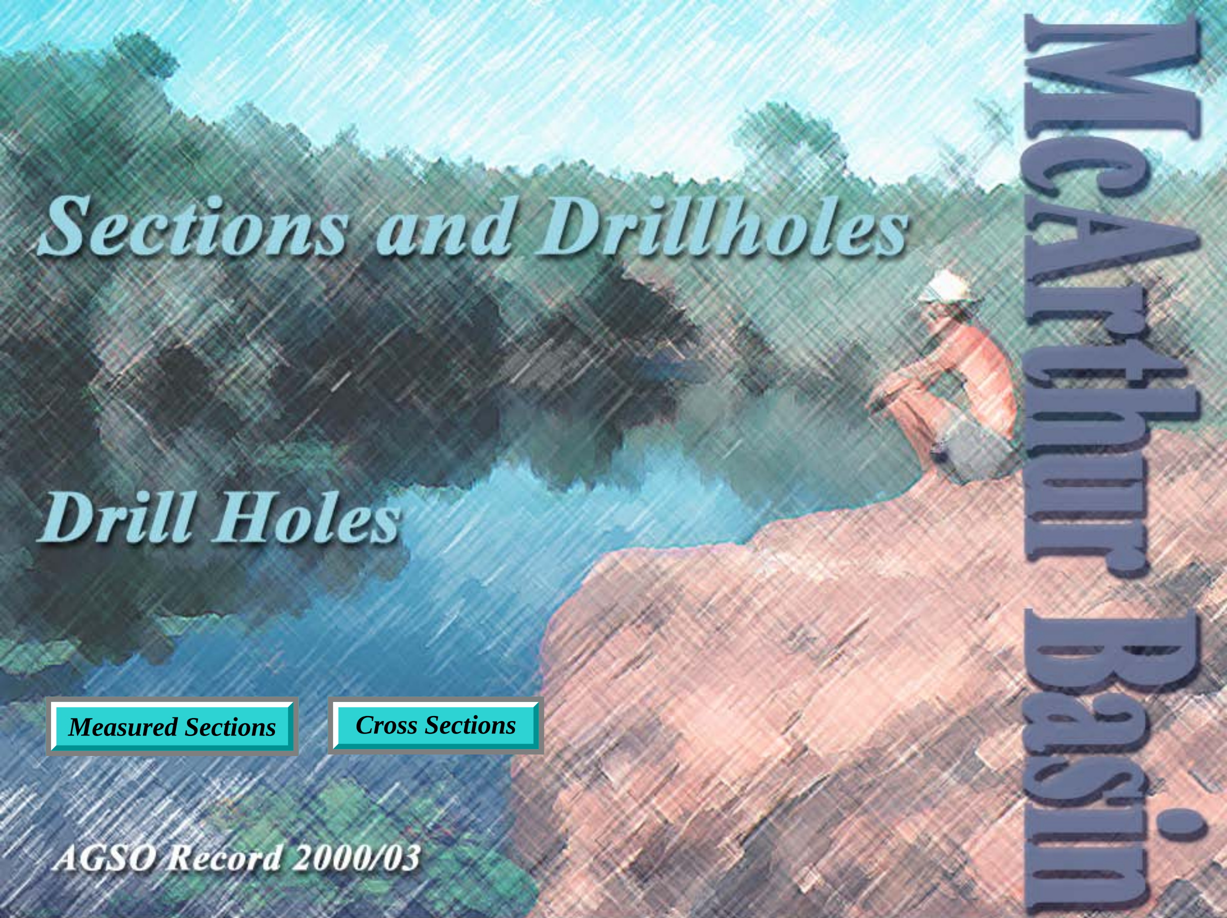
McArthur Basin
Sections and Drillholes
Drill Holes
Measured Sections
Cross Sections
AGSO Record 2000/03

Amelia Basin 4

MIM

SCALE 1:1000

Easting: 621700
Northing: 8160100
Data type: Drill Hole
Map sheet: Glyde
Geology: M J Jackson (based on Sedcon core photographs)
Geolog compilation: K Barnett & I Zeilinger

AUSTRALIA

DEPARTMENT OF MINES AND ENERGY

NORTHERN TERRITORY DEPARTMENT OF MINES AND ENERGY

AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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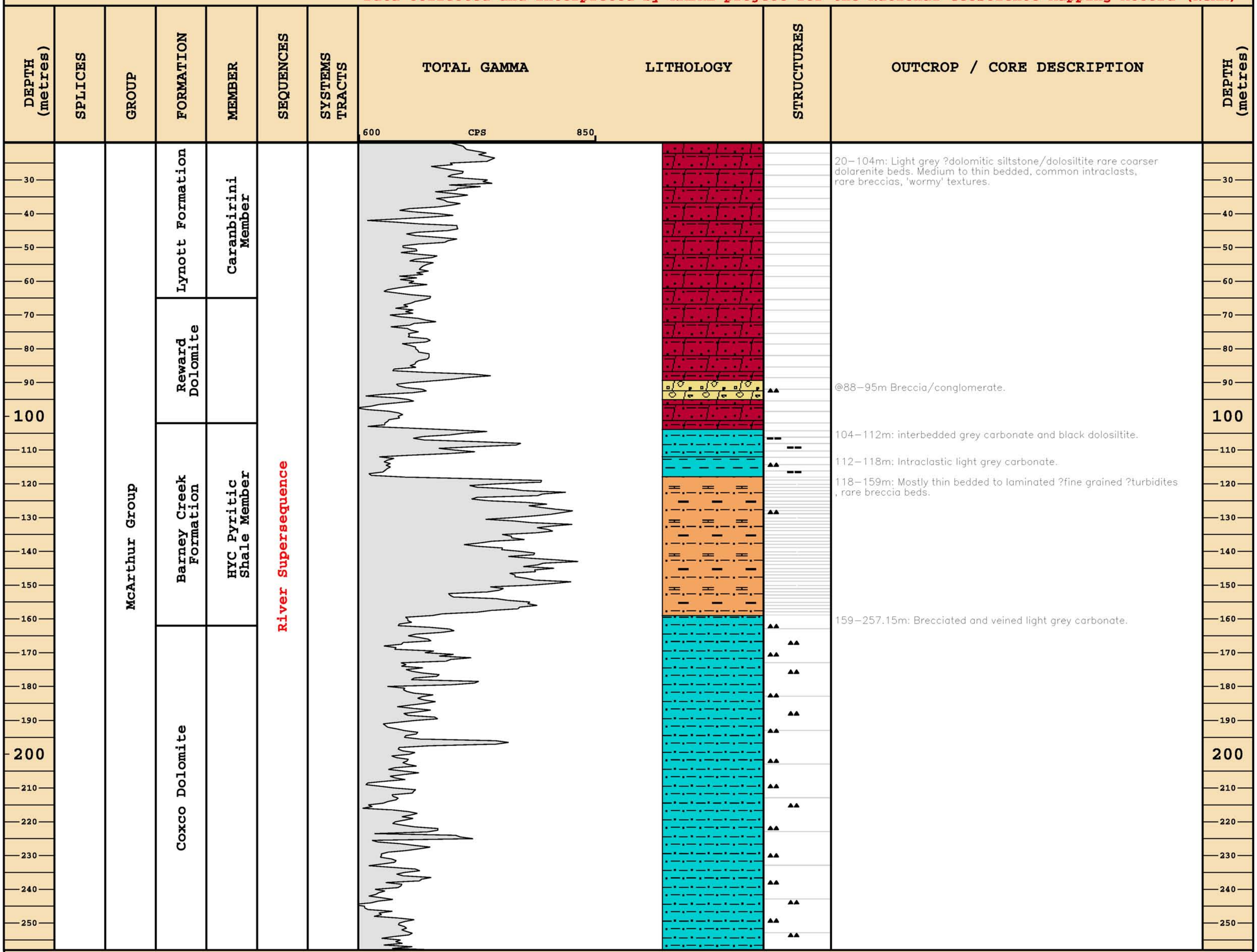
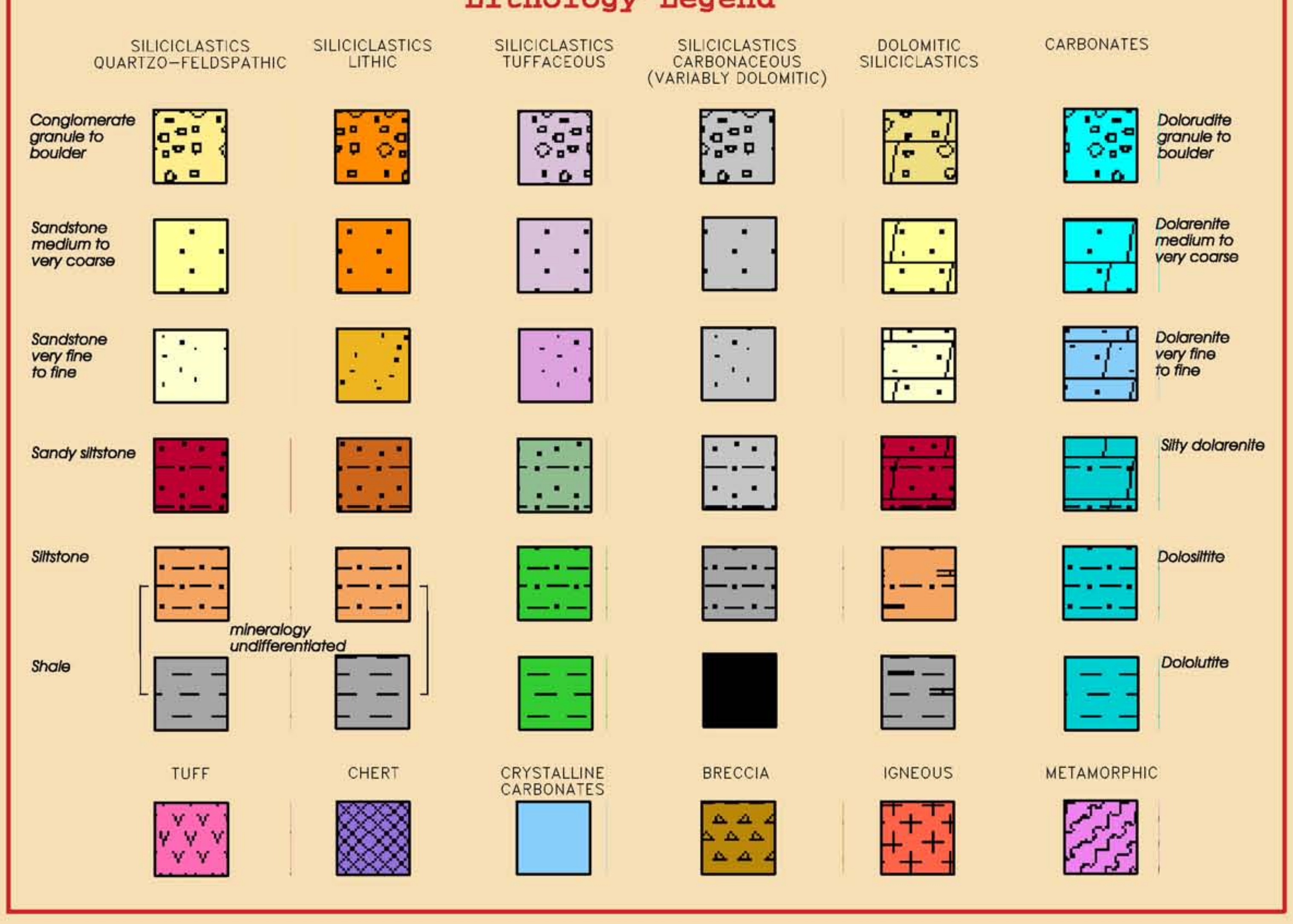
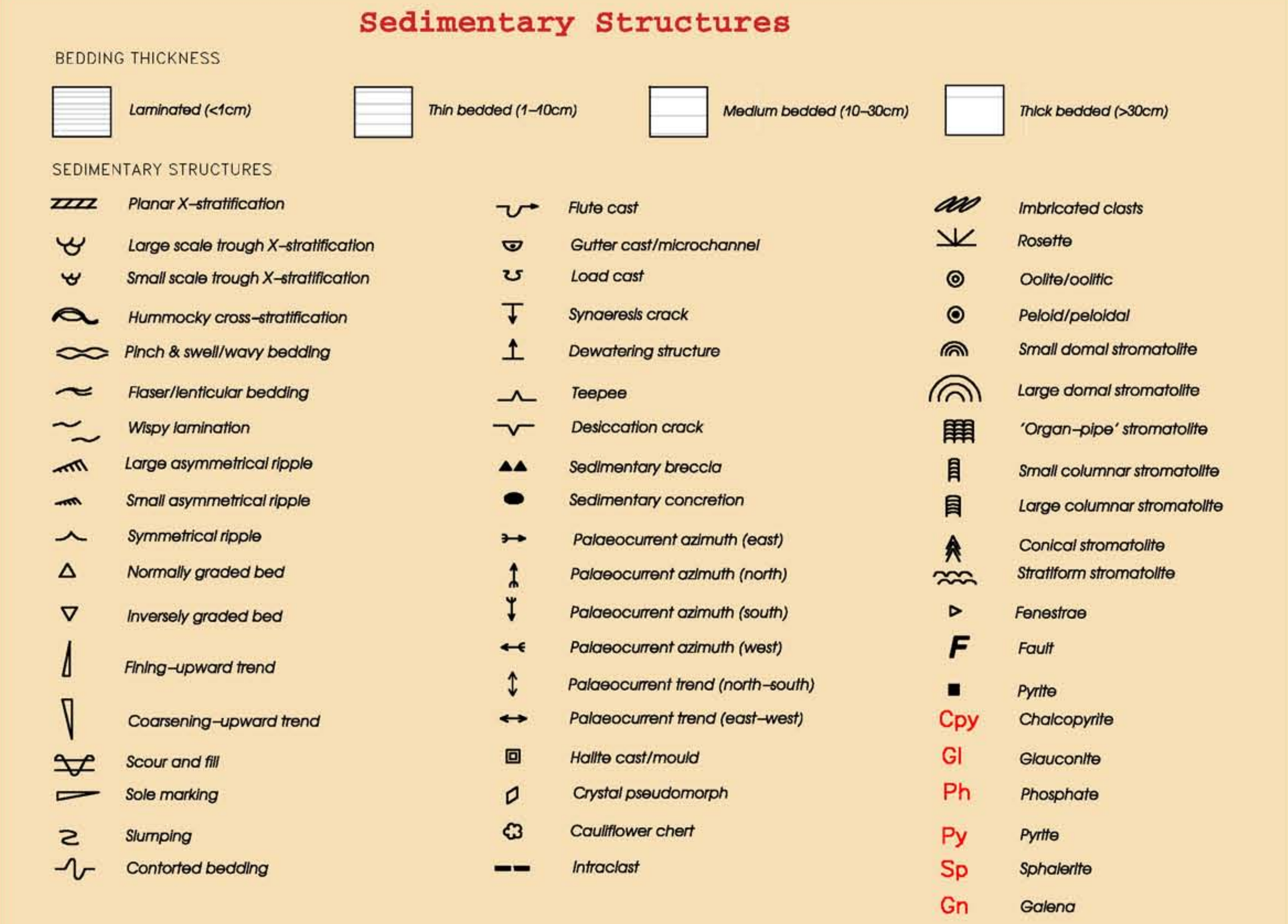


Lithology Legend



Sedimentary Structures



Sequence Hierarchy

NOTE: Gun Supersequence used as an example.

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Phone 02–62499519, Facsimile 02–62499982
Date: 17–Oct–2000

Amelia Basin 5

MIM

SCALE 1:1000

Easting: 622100

Northing: 8157820

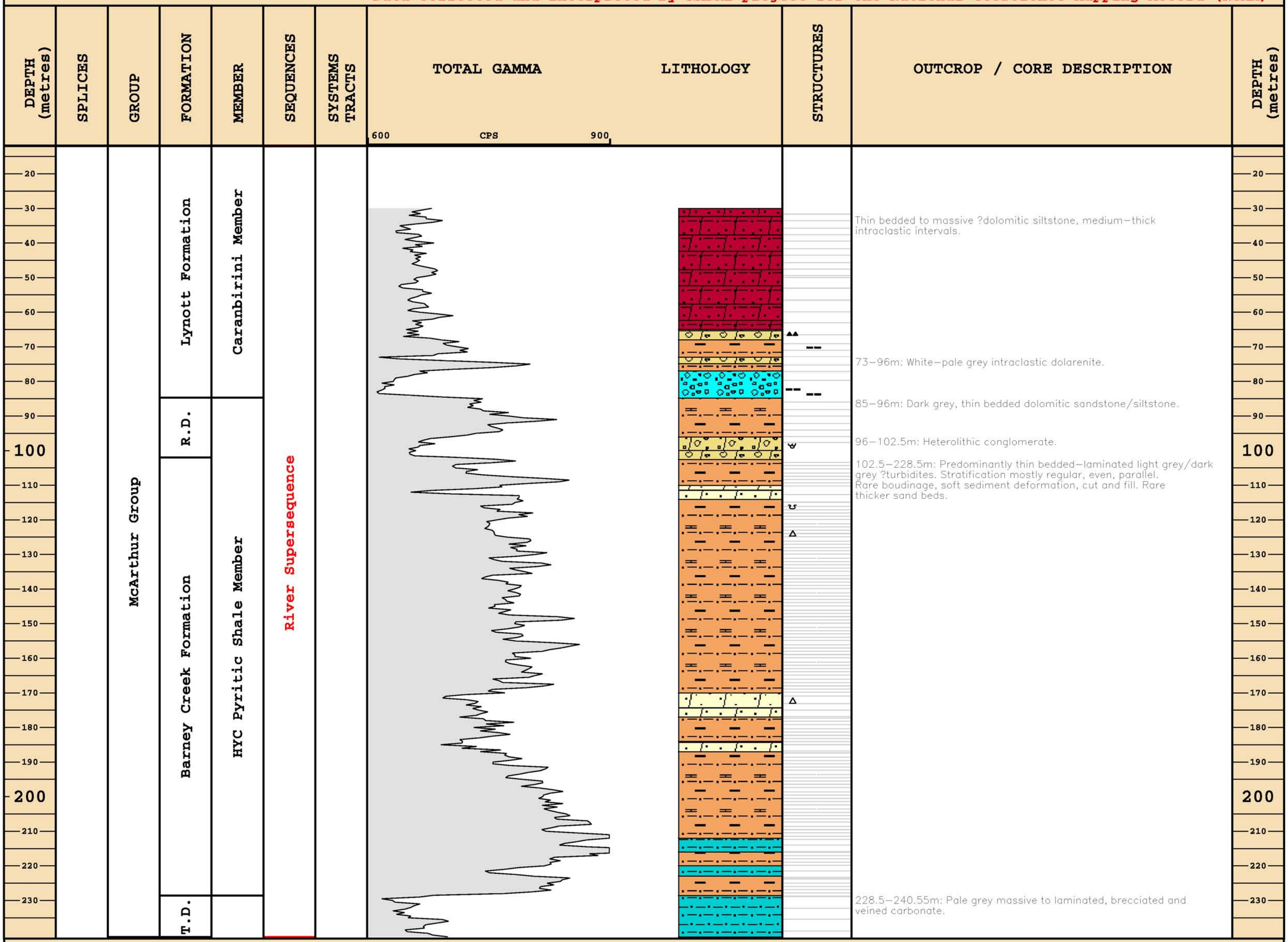
Data type: Drill Hole

Map sheet: Glyde

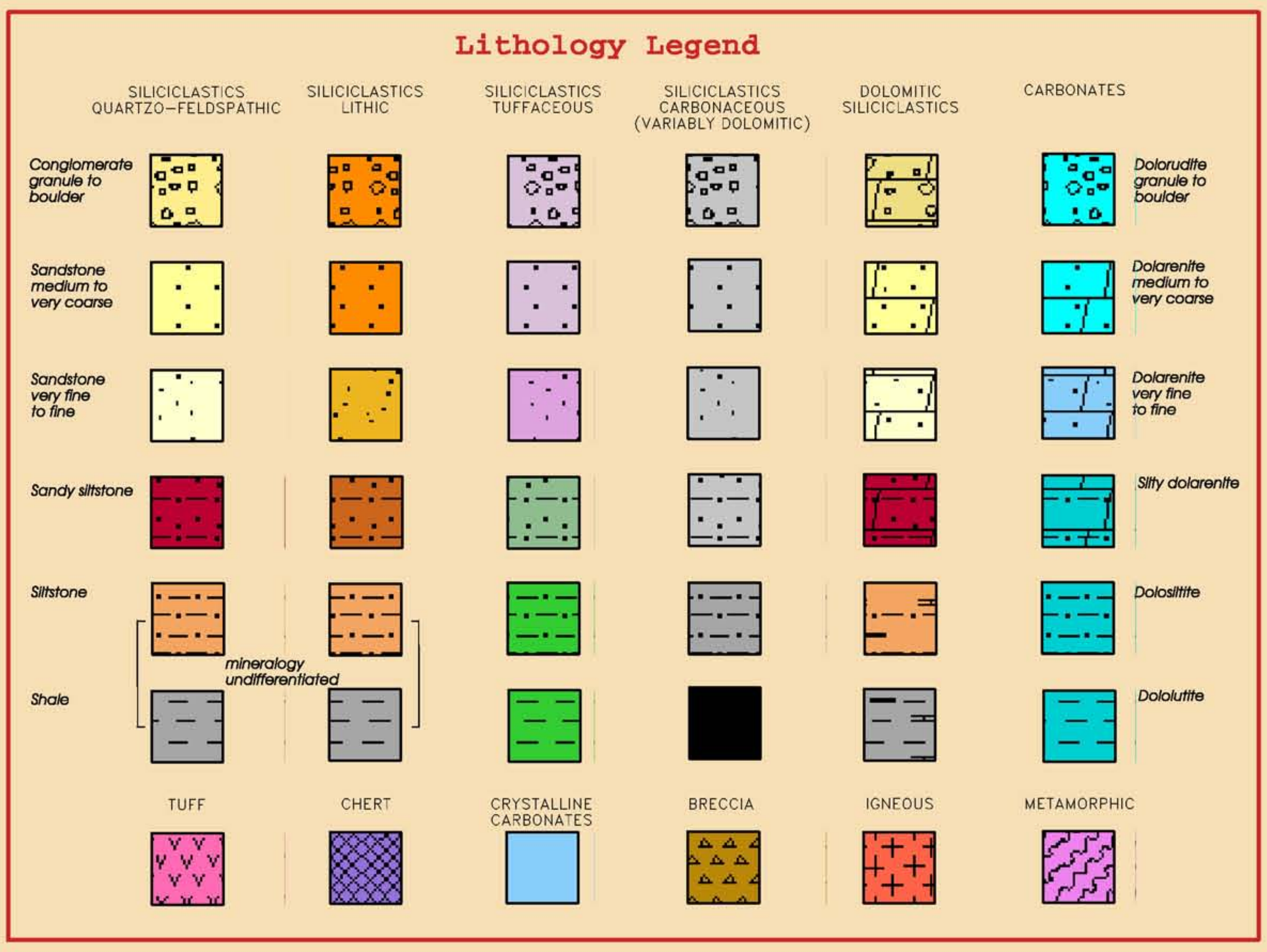
Geology: M J Jackson (based on Sedcon core Photographs)

Geolog compilation: K Barnett & I Zeilinger

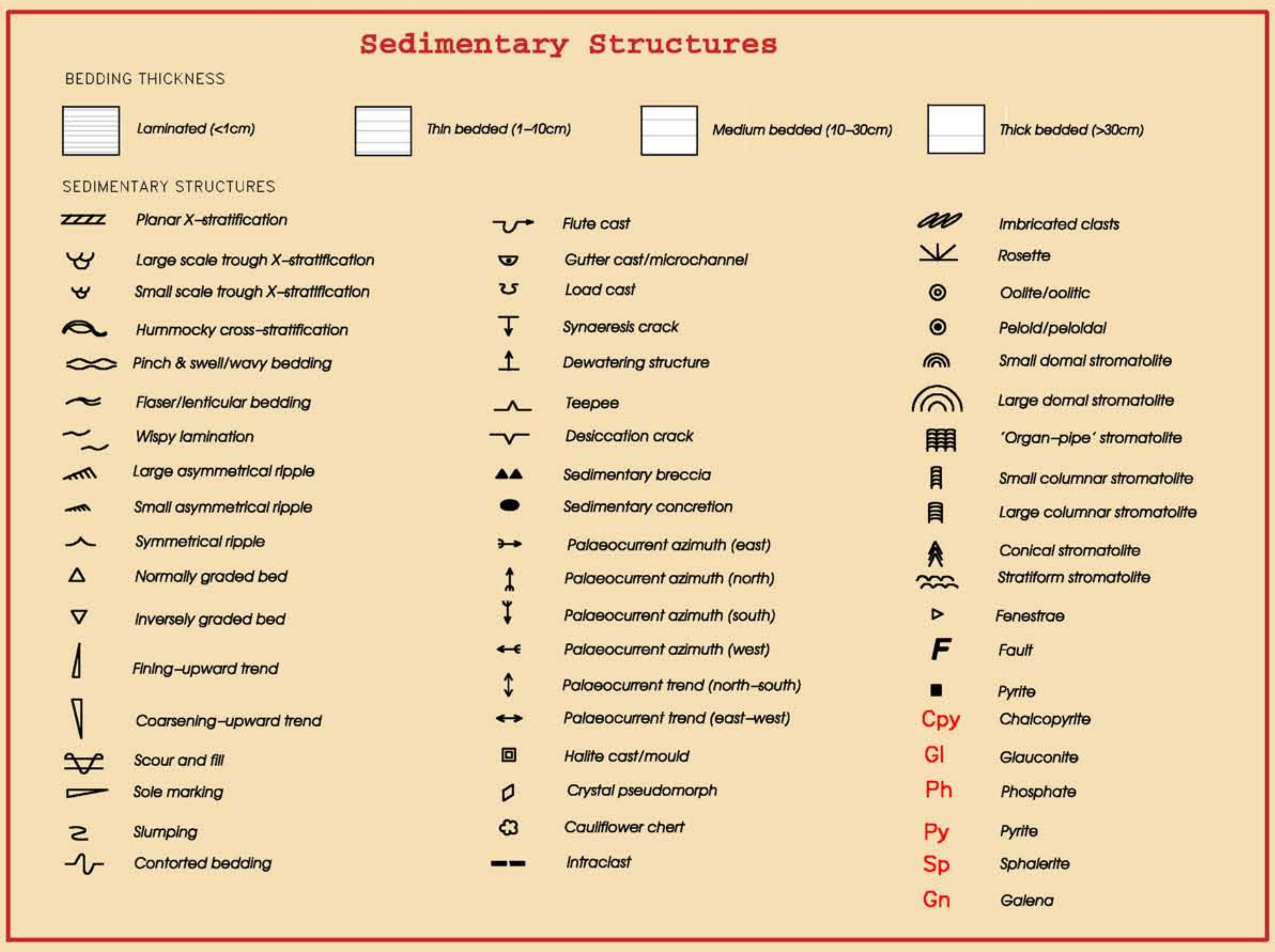
Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)



Lithology Legend



Sedimentary Structures



Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

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Date: 17-Oct-2000

Amelia Basin 6

MIM

SCALE 1:1000

Easting: 620340

Northing: 8158500

Data type: Drill Hole

Map sheet: Glyde

Geology: M J Jackson (based on Sedcon core photographs)

Geolog compilation: K Barnett & I Zeilinger

DEPARTMENT OF MINES AND ENERGY

NORTHERN TERRITORY DEPARTMENT OF MINES AND ENERGY

AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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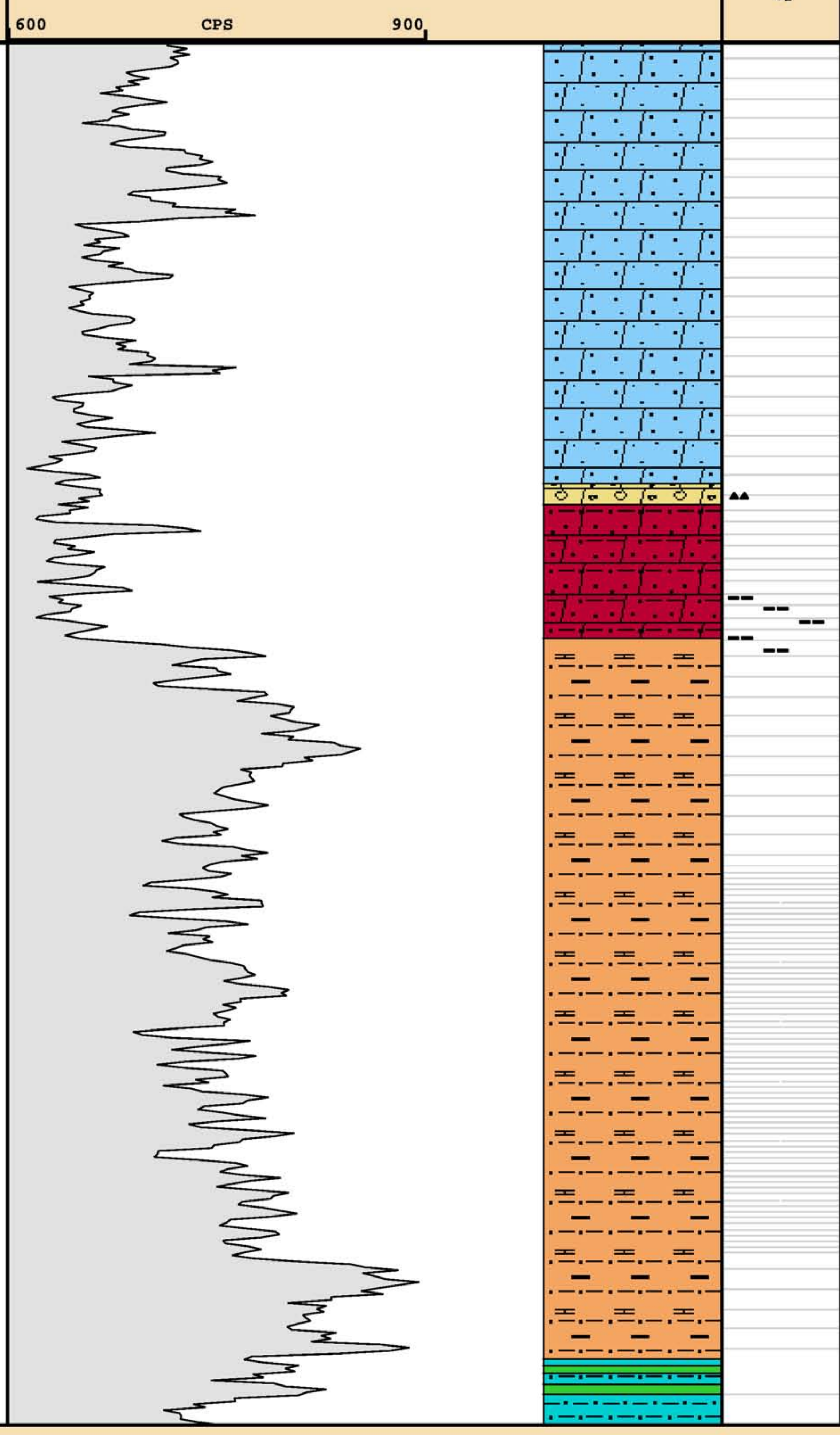
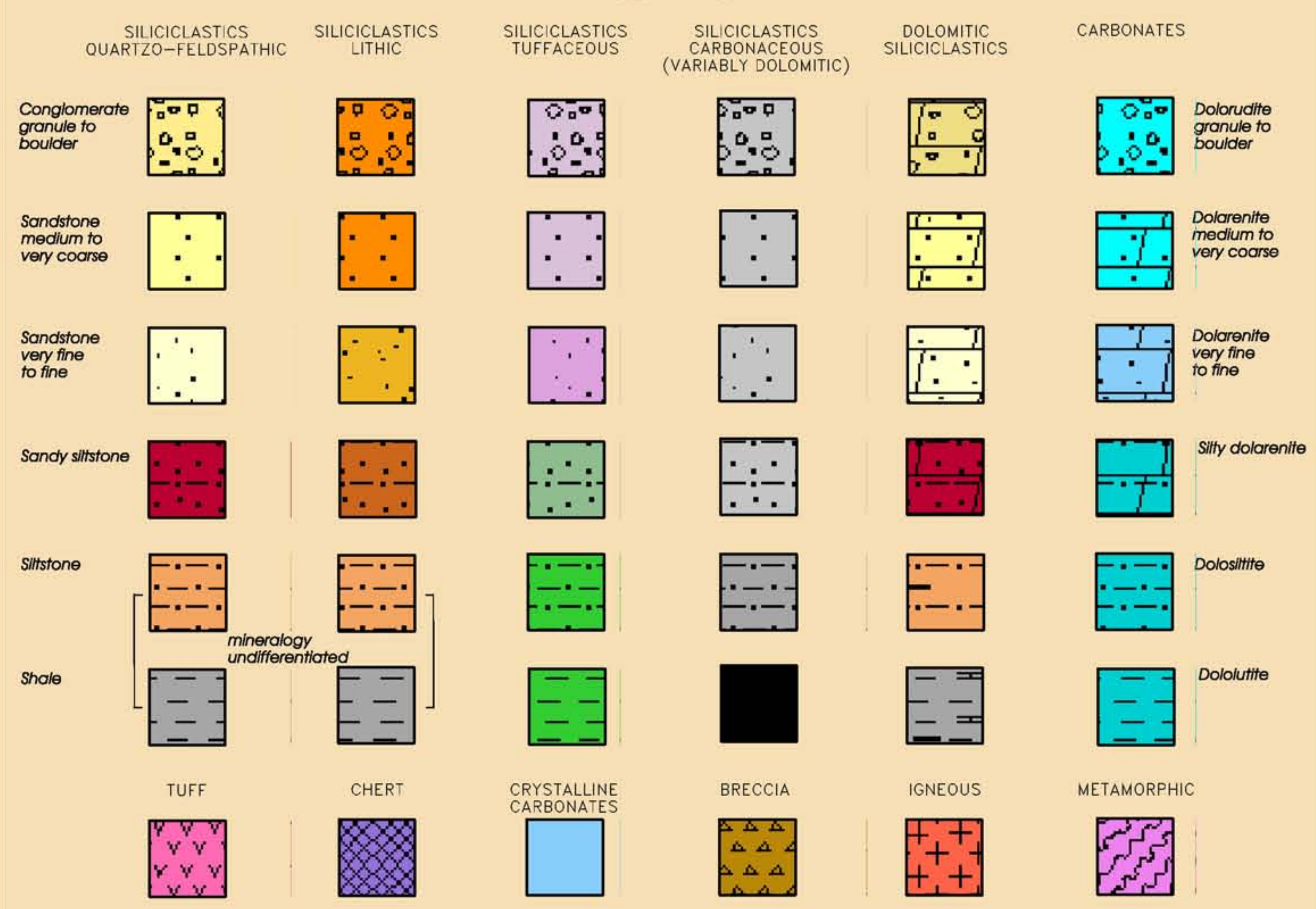
DEPTH (metres)	SPLICES	GROUP	FORMATION	MEMBER	SEQUENCES	SYSTEMS TRACTS	TOTAL GAMMA / LITHOLOGY	STRUCTURES	OUTCROP / CORE DESCRIPTION	DEPTH (metres)
110–200		McArthur Group	Lynott Formation	Caranbirini Member	River Supersequence				102.3–176m: Pale grey ?dolarenites interbedded with dolosiltites thin to medium bedded. 176–179.5m: Heterolithic conglomerate/breccia. 179.5–202m: Thin bedded–laminated, rare breccias & intraclastic intervals.	110–200
200–260			Reward Dolomite						202–240m: Medium to thick bedded. 240–324m: Laminated to thin bedded ?turbidites. Regular, even stratification, rare tuffaceous claystone.	200–260
260–330			Barney Creek Formation	HYC Pyritic Shale Member; W-fold					324–334m: White pale grey carbonate with green mudstone.	260–330
			T.D.							



Lithology Legend



Sedimentary Structures

BEDDING THICKNESS

Laminated (<1cm) · Thin bedded (1–10cm) · Medium bedded (10–30cm) · Thick bedded (>30cm)

SEDIMENTARY STRUCTURES

- Planar X-stratification
- Large scale trough X-stratification
- Small scale trough X-stratification
- Hummocky cross-stratification
- Pinch & swell/wavy bedding
- Flaser/lenticular bedding
- Wispy lamination
- Large asymmetrical ripple
- Small asymmetrical ripple
- Symmetrical ripple
- Normally graded bed
- Inversely graded bed
- Fining-upward trend
- Coarsening-upward trend
- Scour and fill
- Sole marking
- Slumping
- Contorted bedding
- Flute cast
- Gutter cast/microchannel
- Load cast
- Synaeresis crack
- Dewatering structure
- Teepee
- Desiccation crack
- Sedimentary breccia
- Sedimentary concretion
- Palaeocurrent azimuth (east)
- Palaeocurrent azimuth (north)
- Palaeocurrent azimuth (south)
- Palaeocurrent azimuth (west)
- Palaeocurrent trend (north-south)
- Palaeocurrent trend (east-west)
- Halite cast/mould
- Crystal pseudomorph
- Cauliflower chert
- Intraclast
- Imbricated clasts
- Rosette
- Ooilite/oolitic
- Peloid/peloidal
- Small domal stromatolite
- Large domal stromatolite
- 'Organ-pipe' stromatolite
- Small columnar stromatolite
- Large columnar stromatolite
- Conical stromatolite
- Stratiform stromatolite
- Fenestrae
- F Fault
- Pyrite
- Cpy Chalcopyrite
- Gl Glauconite
- Ph Phosphate
- Py Pyrite
- Sp Sphalerite
- Gn Galena

Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

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BMR Bauhinia Downs 3

BMR

SCALE 1:1000

Easting: 586800

Northing: 8160400

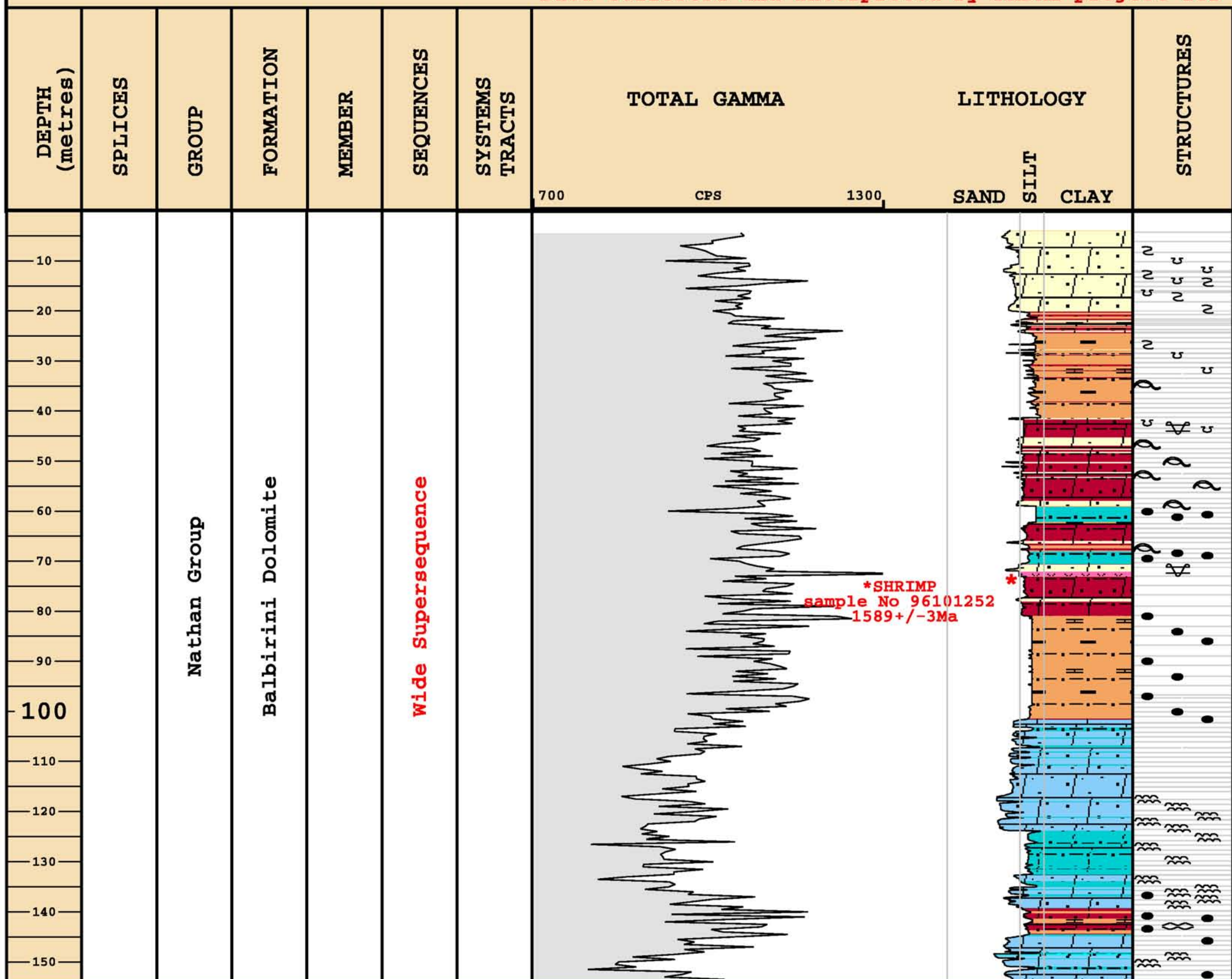
Data type: Drill hole

Map sheet: Mallapunyah

Geology: M J Jackson

Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)



OUTCROP / CORE DESCRIPTION

134–150m: Pale grey v.fg. dolomitic sandstone with dolomitic siltstone beds commonly 3–5 cm thick; scours & loads common & extensive soft–sediment bedding disruption. Grainsize and bed thickness gradually increase upwards.

(gradational contact)
113–134m: Similar to above, but finer grained and more regularly bedded. Predominantly grey–green dolomitic siltstone with thin v.fg. sandstone laminae & lenses. Parallel, even bedded, mm–scale soft sediment deformation. Rare low–angle wavy (hcs) lamination.

(gradational contact)
73–113m: Green dolomitic siltstone – v.fg. sandstone with numerous ~1 cm thick, fine grained, glauconitic sandstone beds. Parallel, laminated to thin bedded, common scouring at bases of beds, rare loading.
Small wavy ripples and low–angle undulating lamination (hcs)

Two intervals distinctly more dolomitic with well formed crystalline carbonate concretions up to several cms across (83–86, 92–95m)

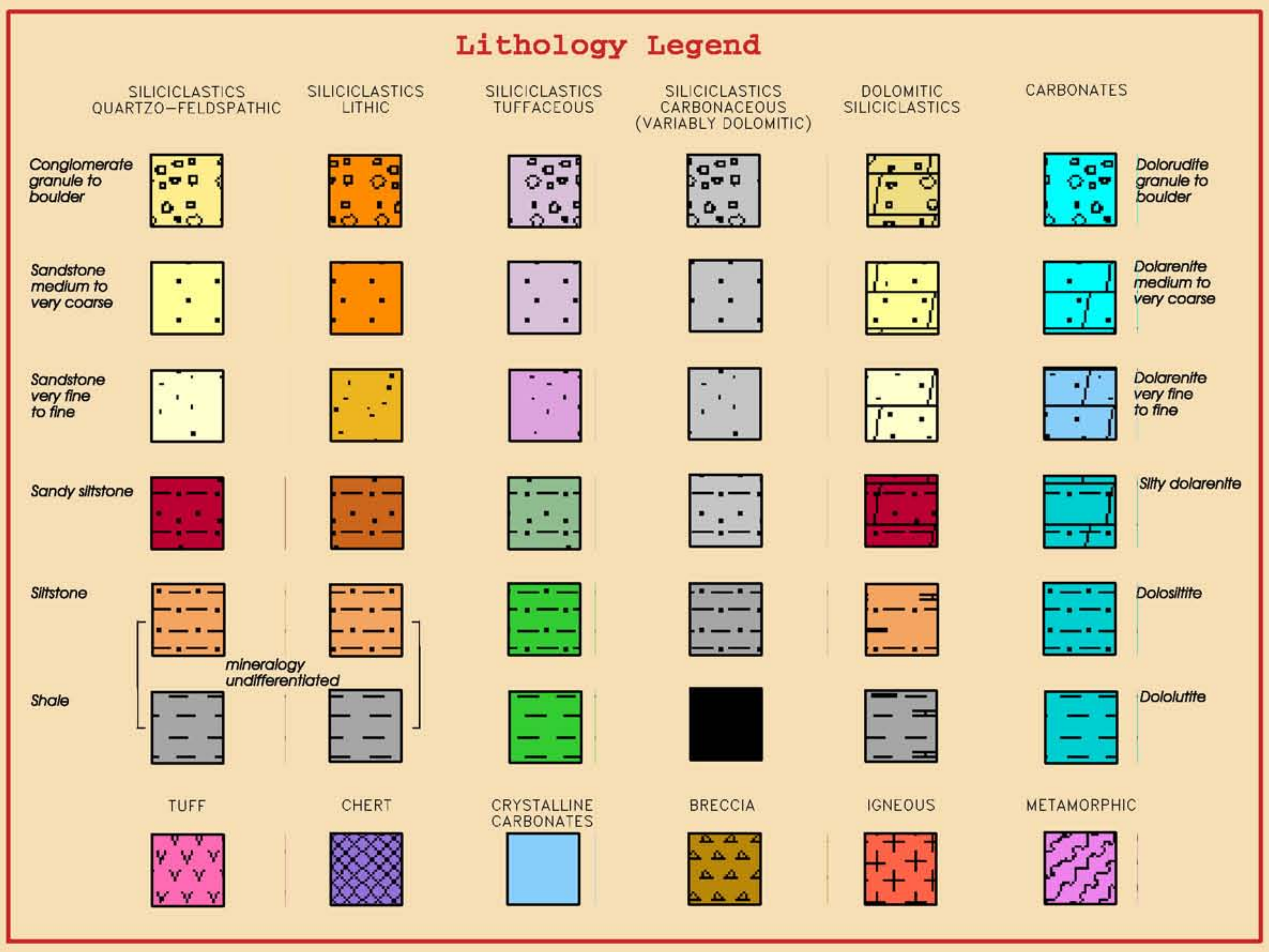
81–83m: Scoured surfaces mantled by pink grains (tuffaceous?)

53–73m: Predominantly red–brown dolomitic siltstone with numerous pale green carbonate concretions.

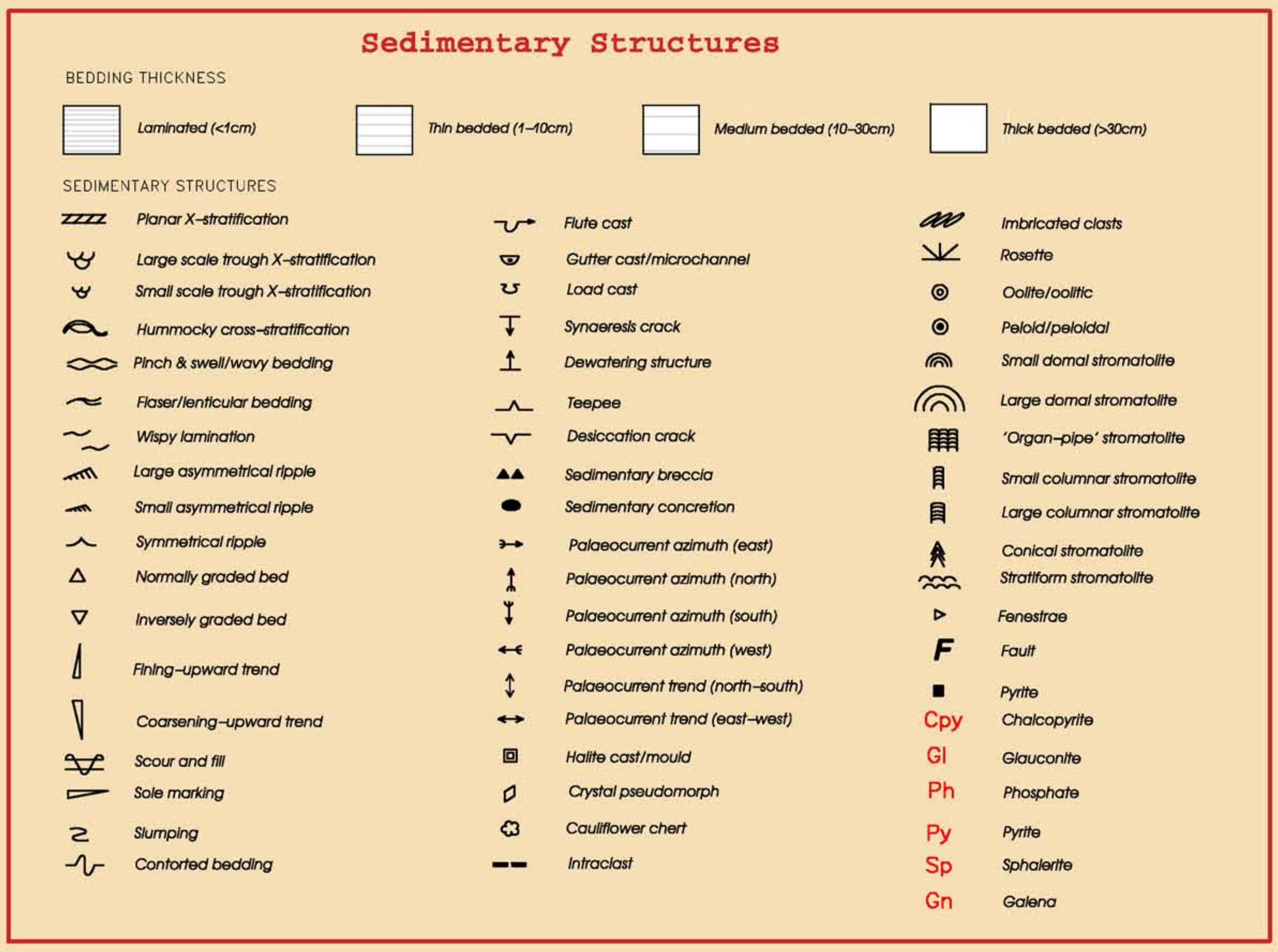
gradational contact
0–53m: Predominantly light grey crystalline carbonate (f–g dolarenite to dololutite) with laminae & beds of green–brown dolomitic mudstone. Carbonates are laminated (often crinkly) and are probably stromatolitic. Rare intraclasts. Some intervals contain well developed carbonate concretions (especially 9–15m). Intervals 10–35m and 40–53m: are probably cyclic, with green dolomudstone defining cycle boundaries.

Predominantly green dolosiltstone.

Lithology Legend



Sedimentary Structures



Sequence Hierarchy

NOTE: Gun Supersequence used as an example.

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Bingbong 2

AO (AUST) Pty Ltd

SCALE 1:1000

Easting: 603700

Northing: 8253900

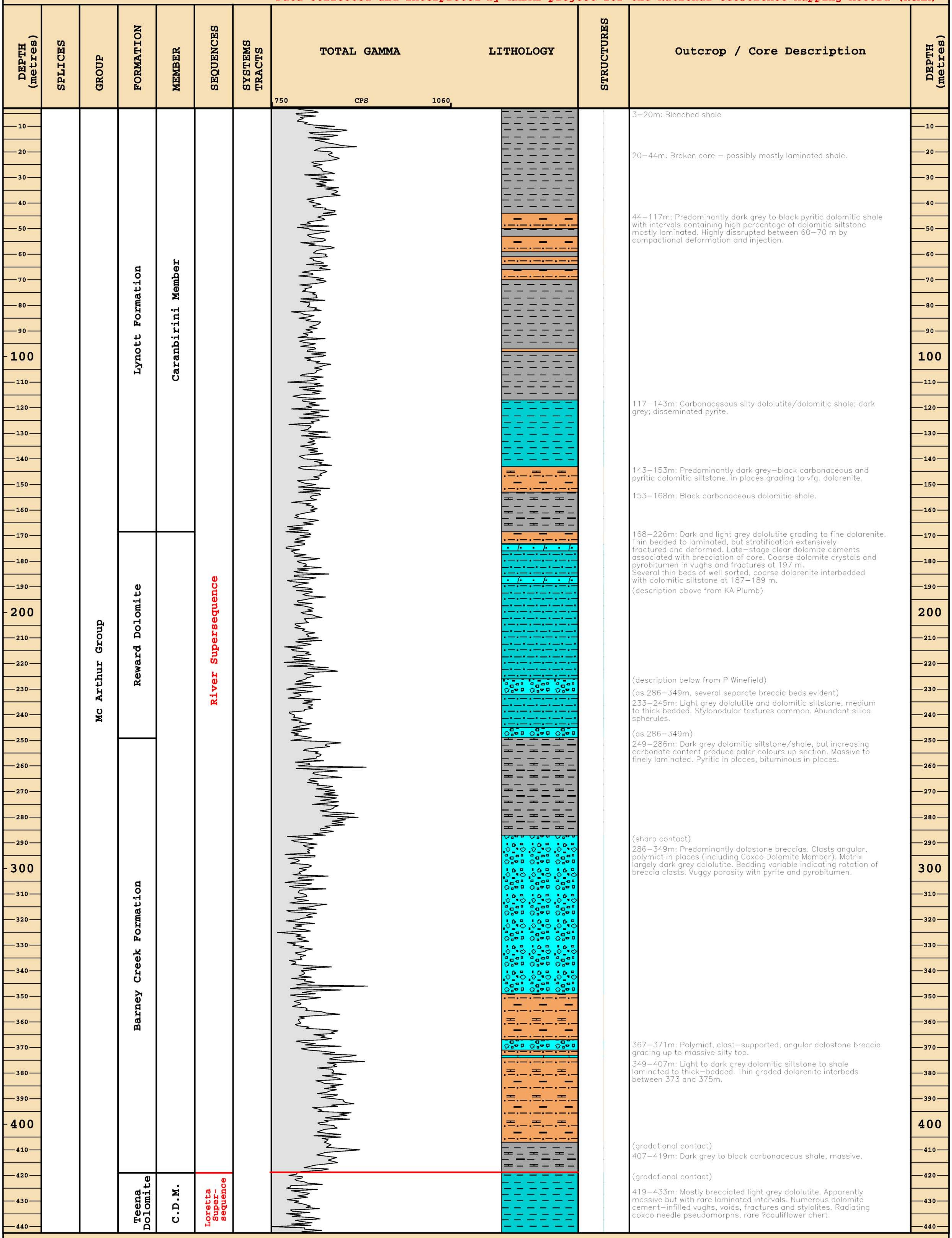
Data type: Drill Hole

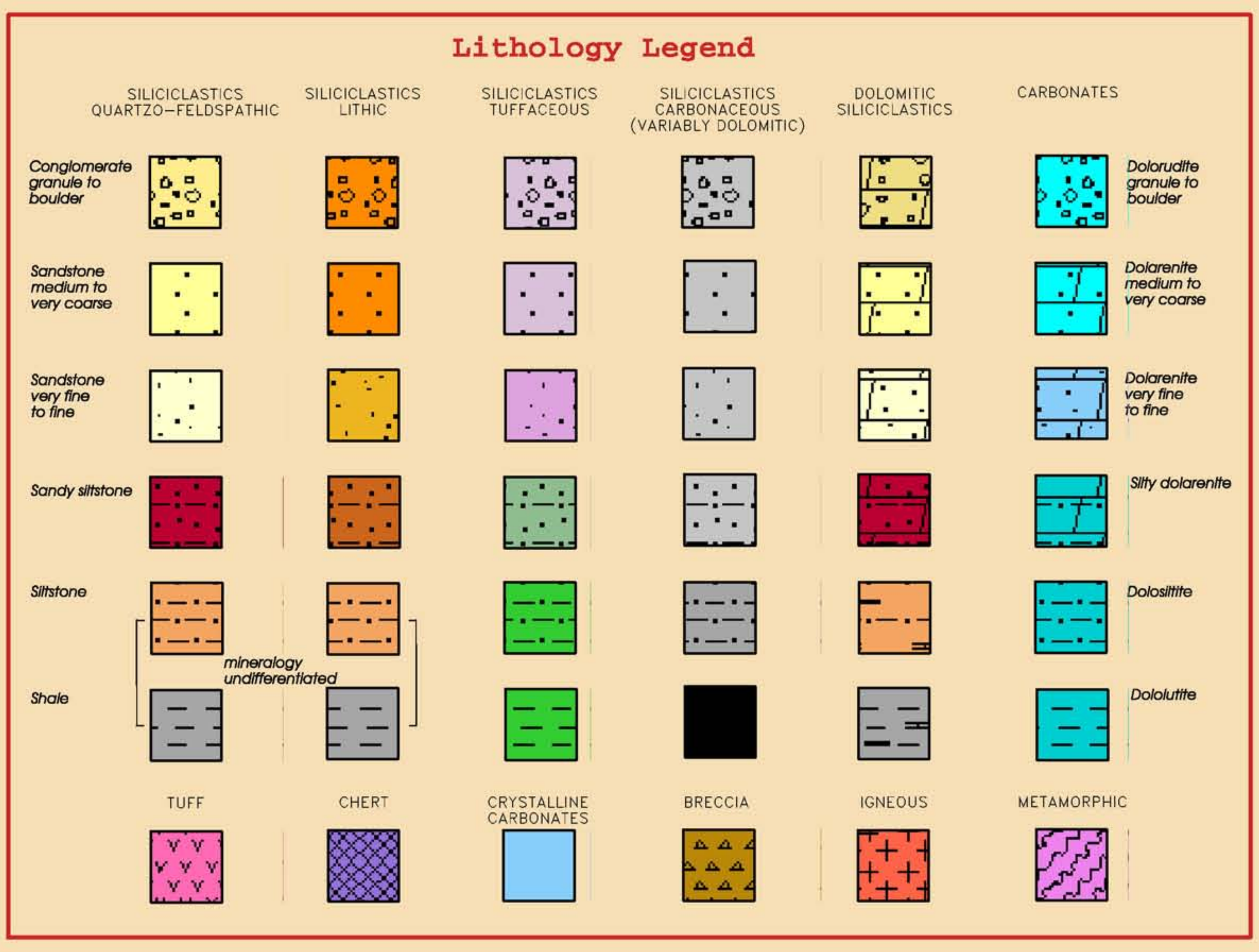
Map sheet: Bing Bong

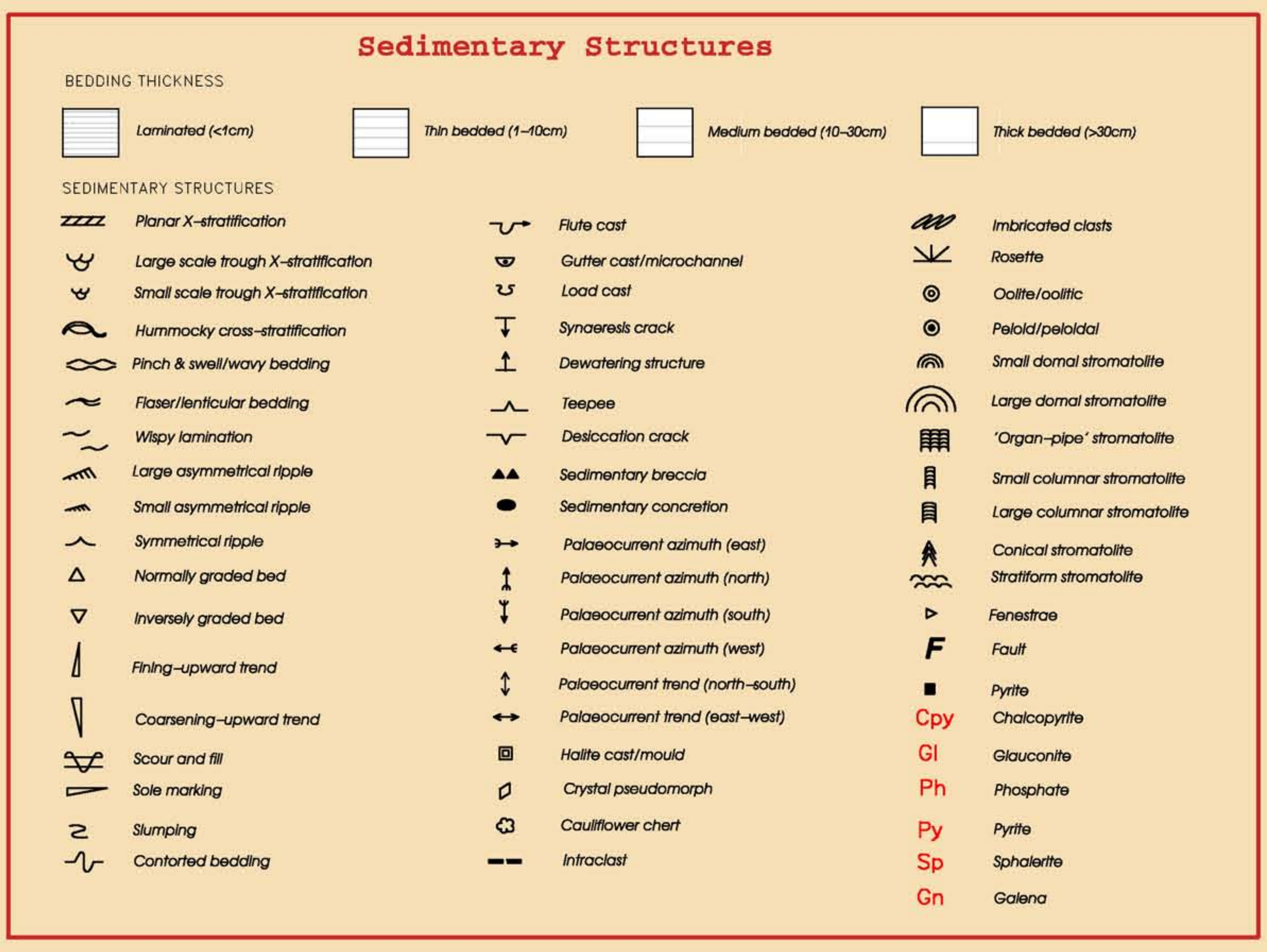
Geology: J Jackson (based on Haines et al, 1993 Mount Young notes)

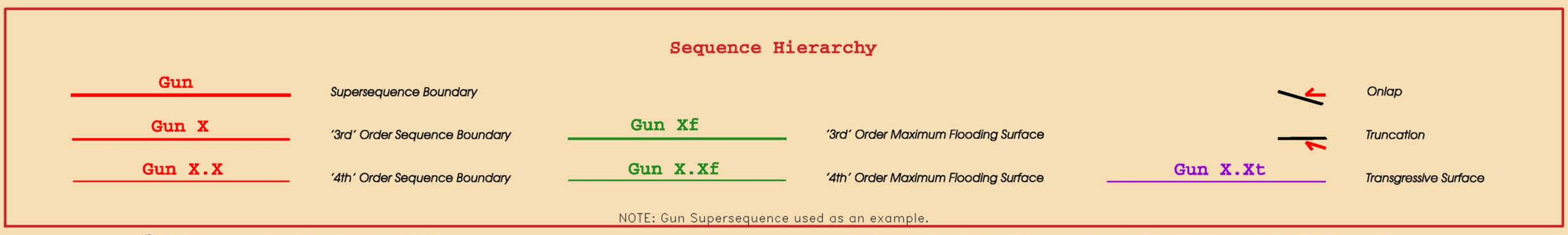
Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)









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Date: 17–Oct–2000

Emu 11

MIM

SCALE 1:1000

Easting: 613910

Northing: 8186492

Data type: Drill Hole

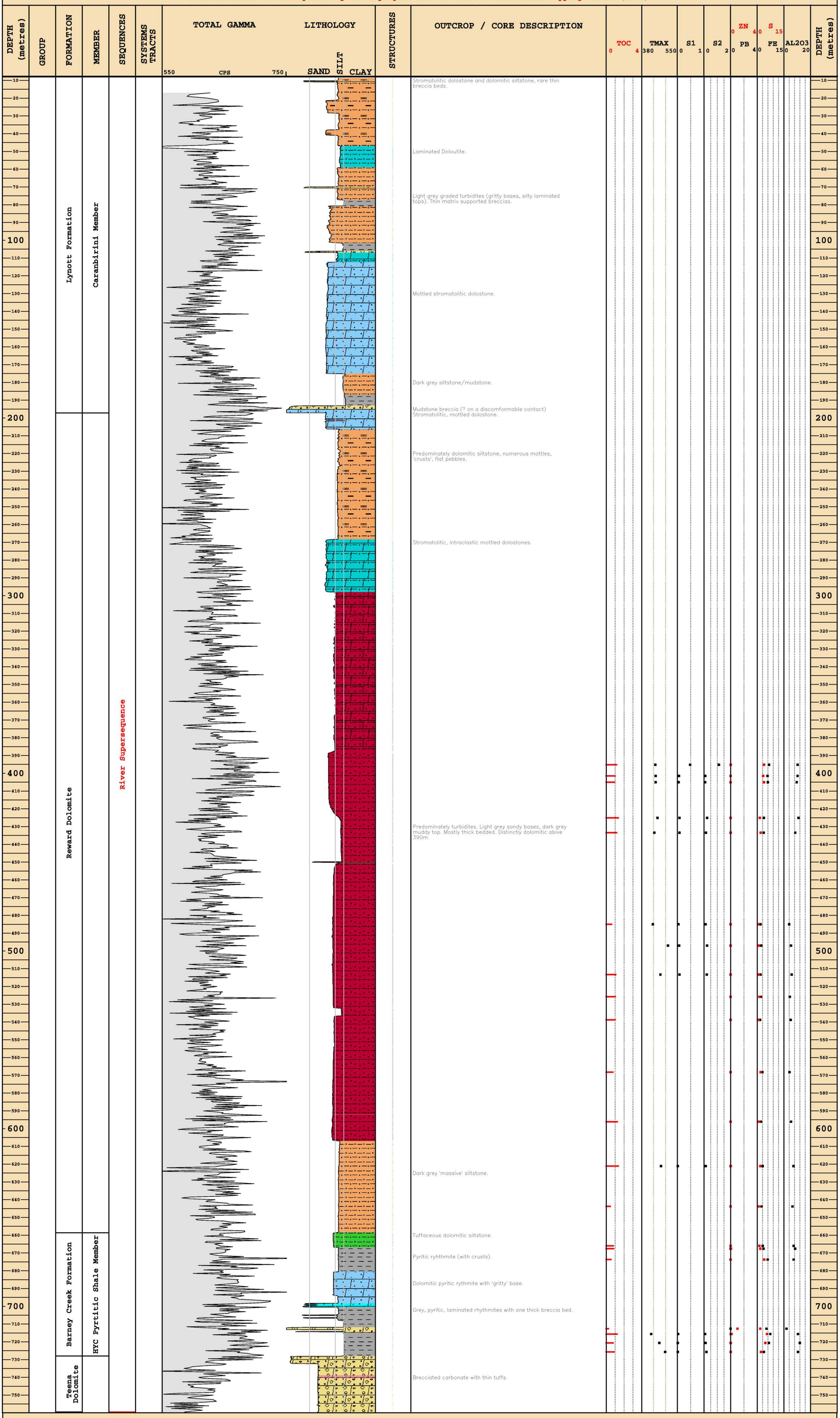
Map sheet: Borroloola

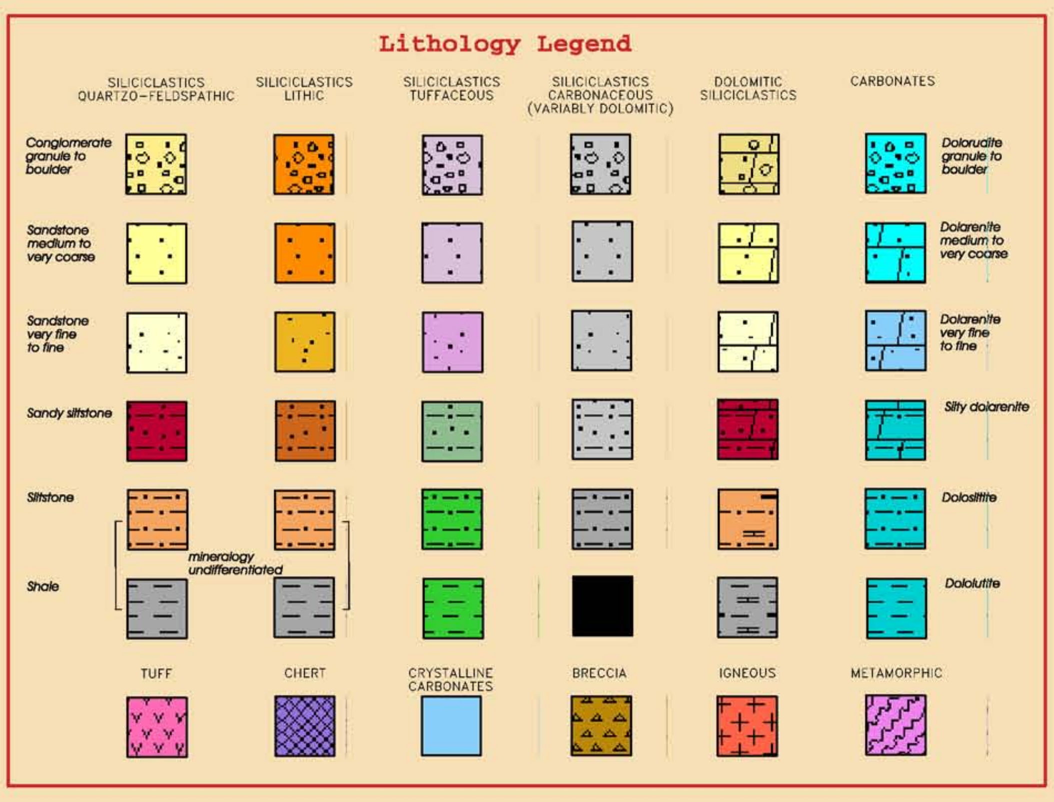
Geology: J Jackson (based on company lithologic log)

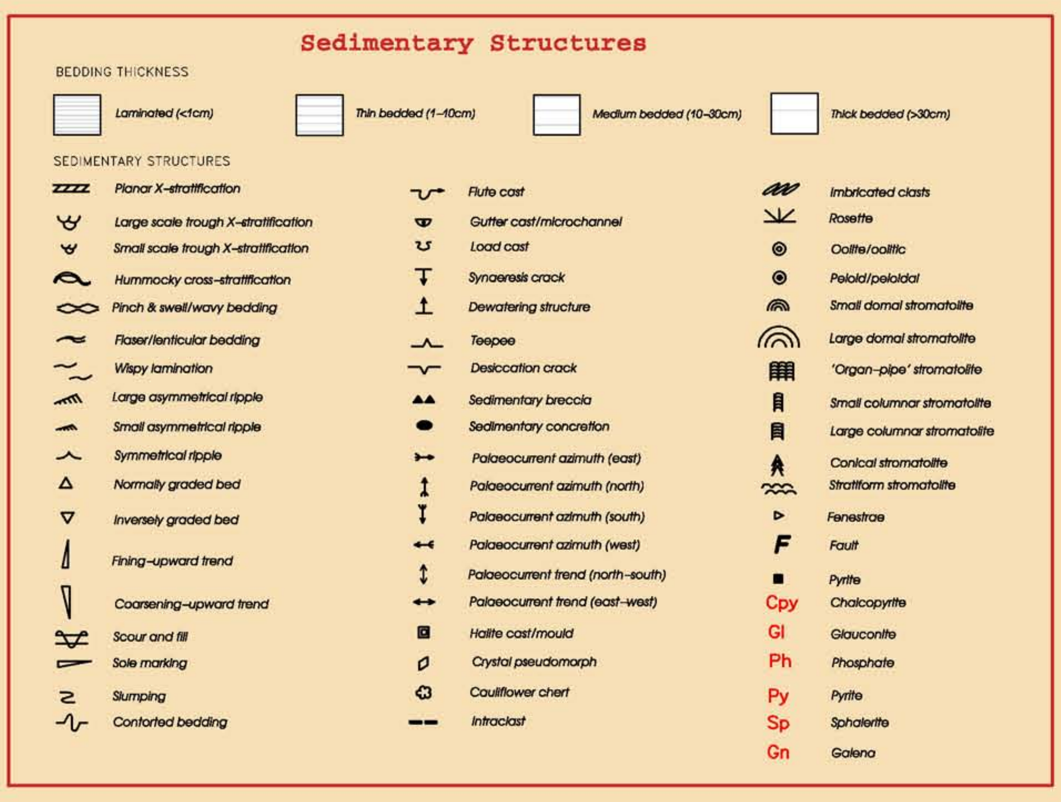
Geolog compilation: K Barnett & I Zeilinger

AUSTRALIA
DEPARTMENT OF MINES AND ENERGY
AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)







Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

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Emu 13

MIM

SCALE 1:1000

Easting: 616571

Northing: 8186340

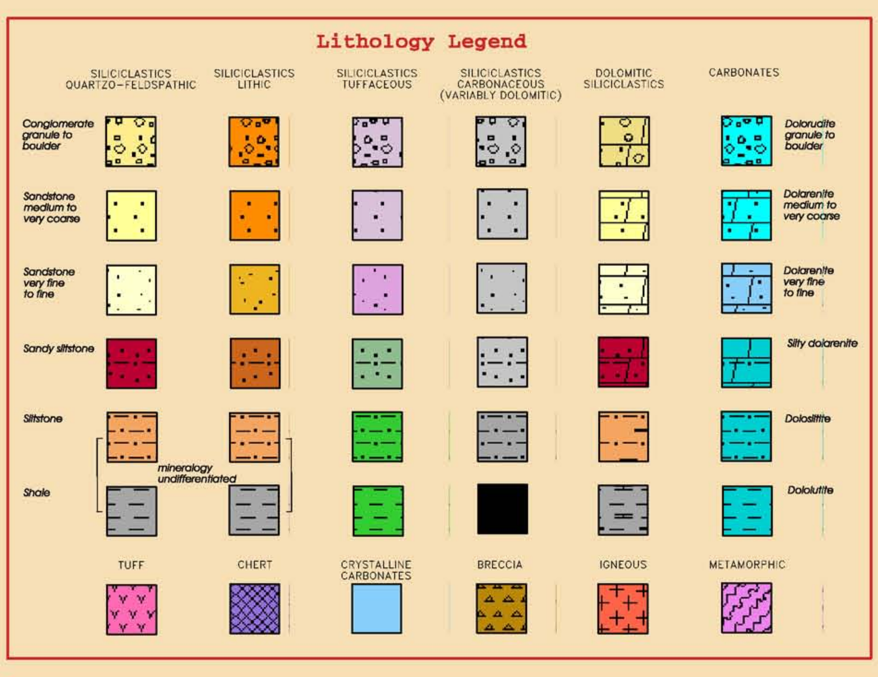
Data type: Drill Hole

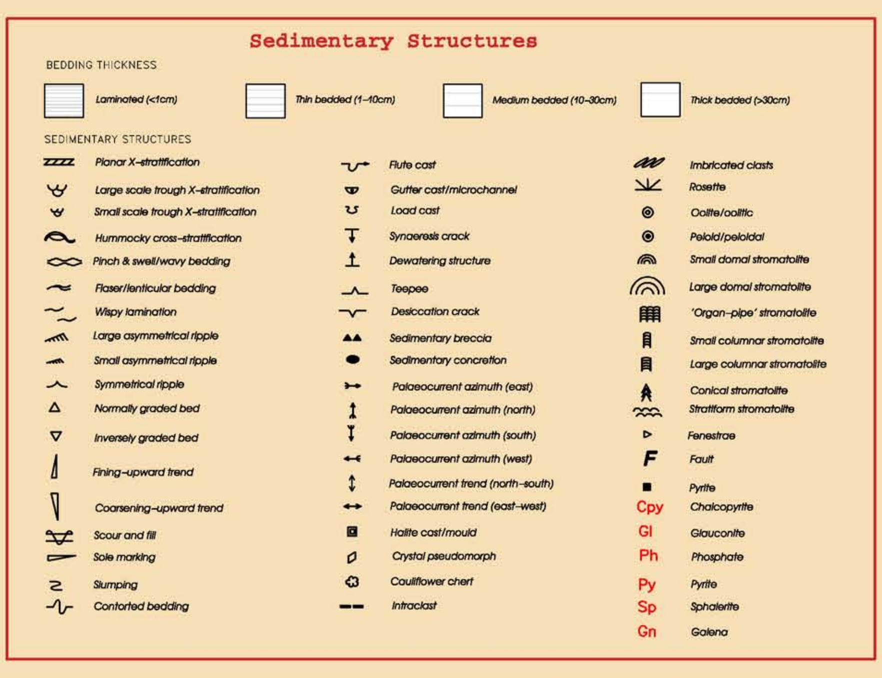
Map sheet: Borroloola

Geology: J Jackson (based on company Lithologic log)

Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)





Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

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Emu 9

MIM

SCALE 1:1000

Easting: 615561

Northing: 8186162

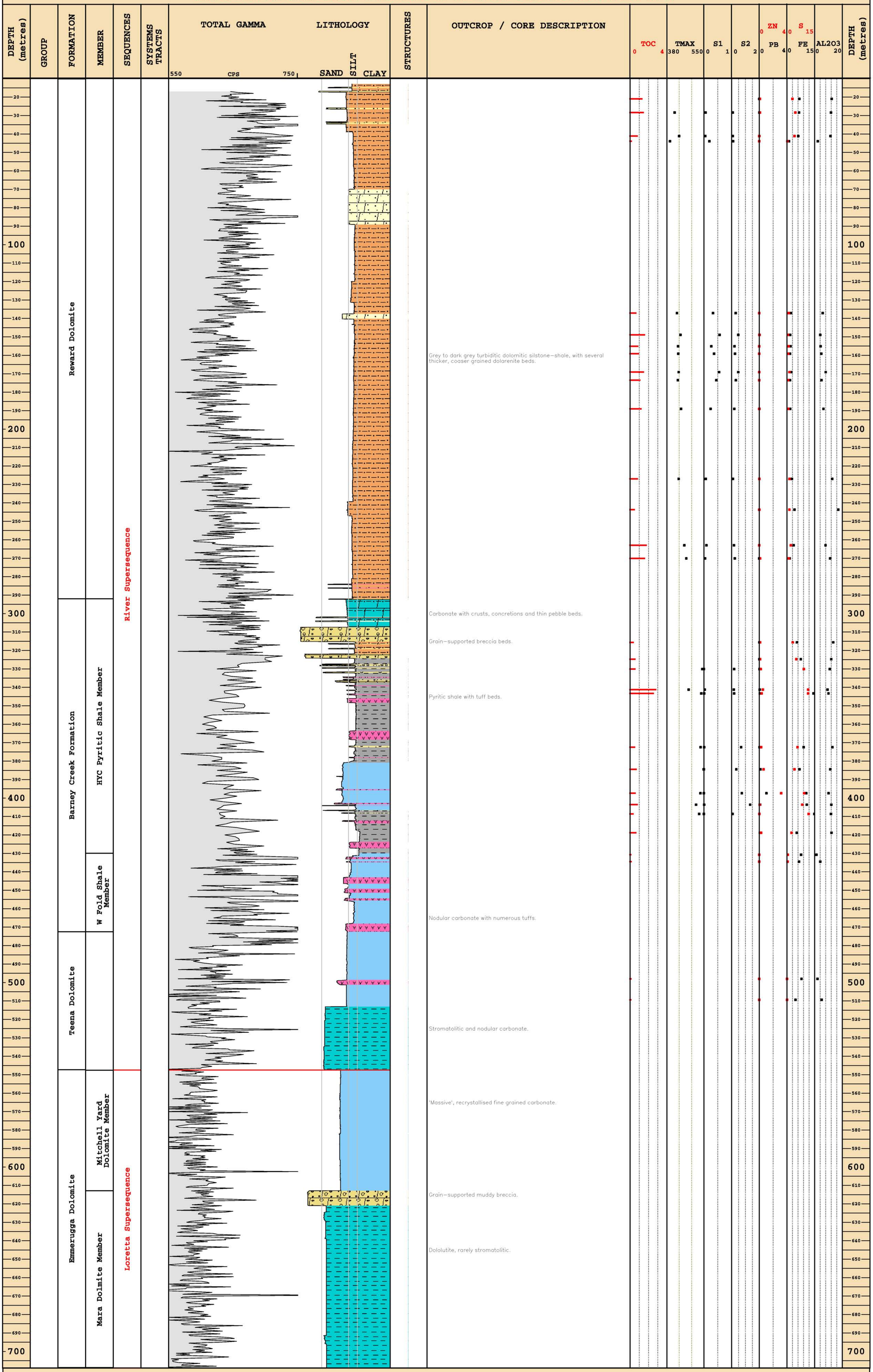
Data type: Drill Hole

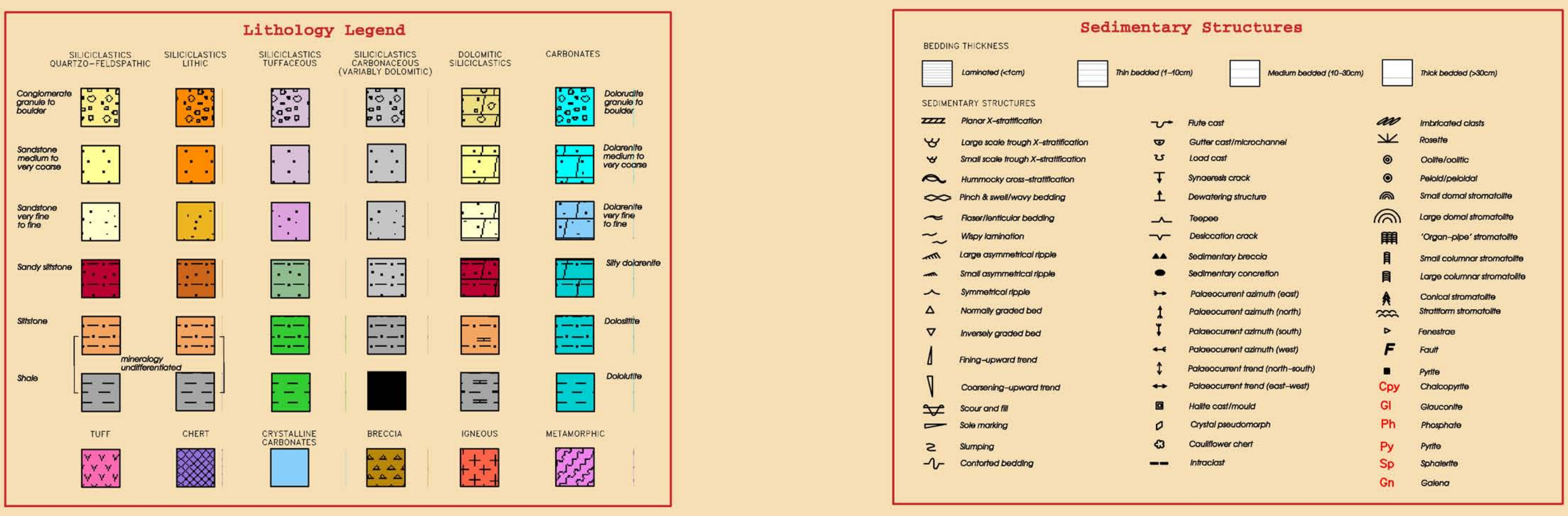
Map sheet: Borroloola

Geology: M J Jackson (based on 1993 Sedcon log)

Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)





Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

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I20/32s

MIM

SCALE 1:1000

Easting: 617488

Northing: 8182443

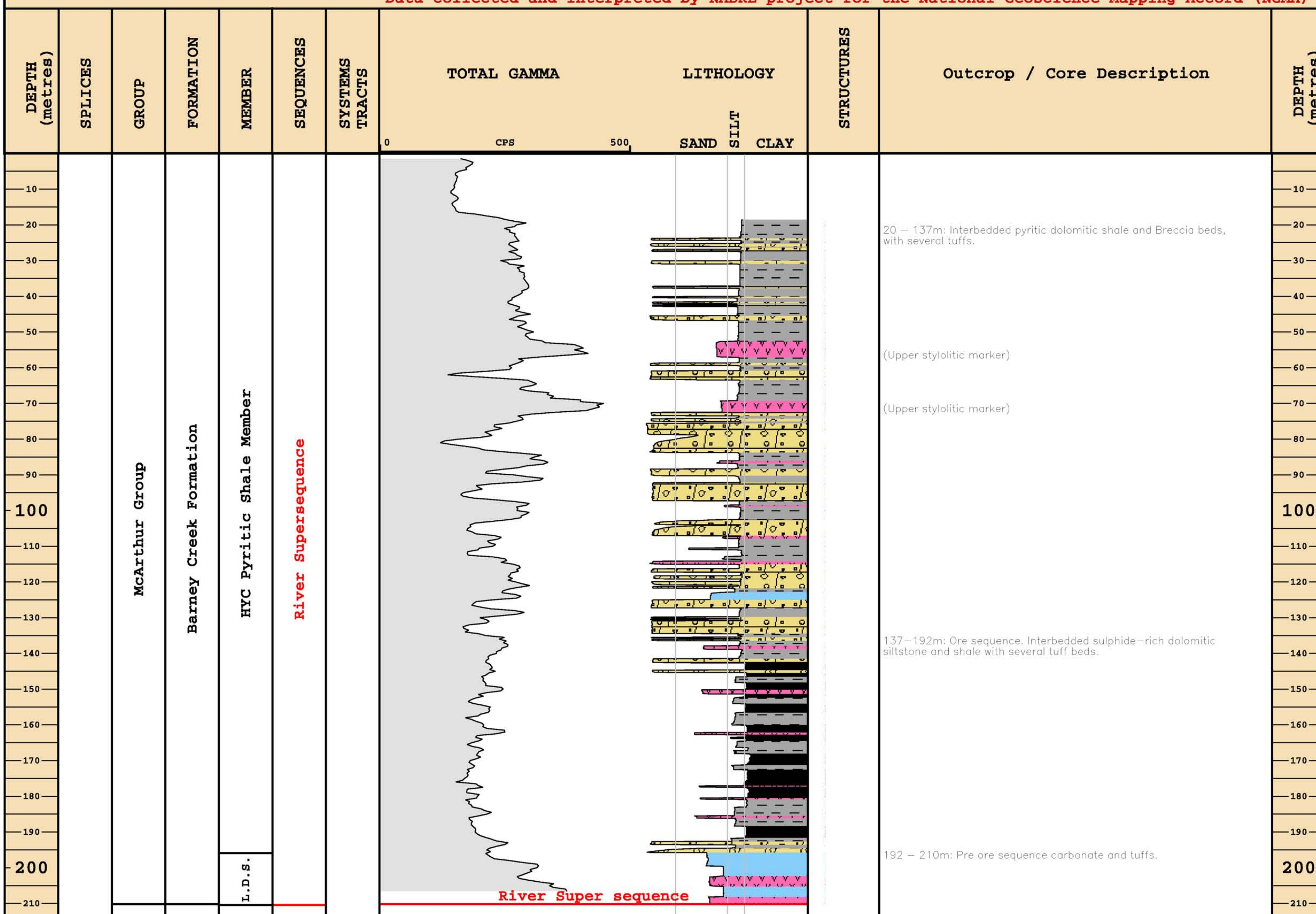
Data type: Drill Hole

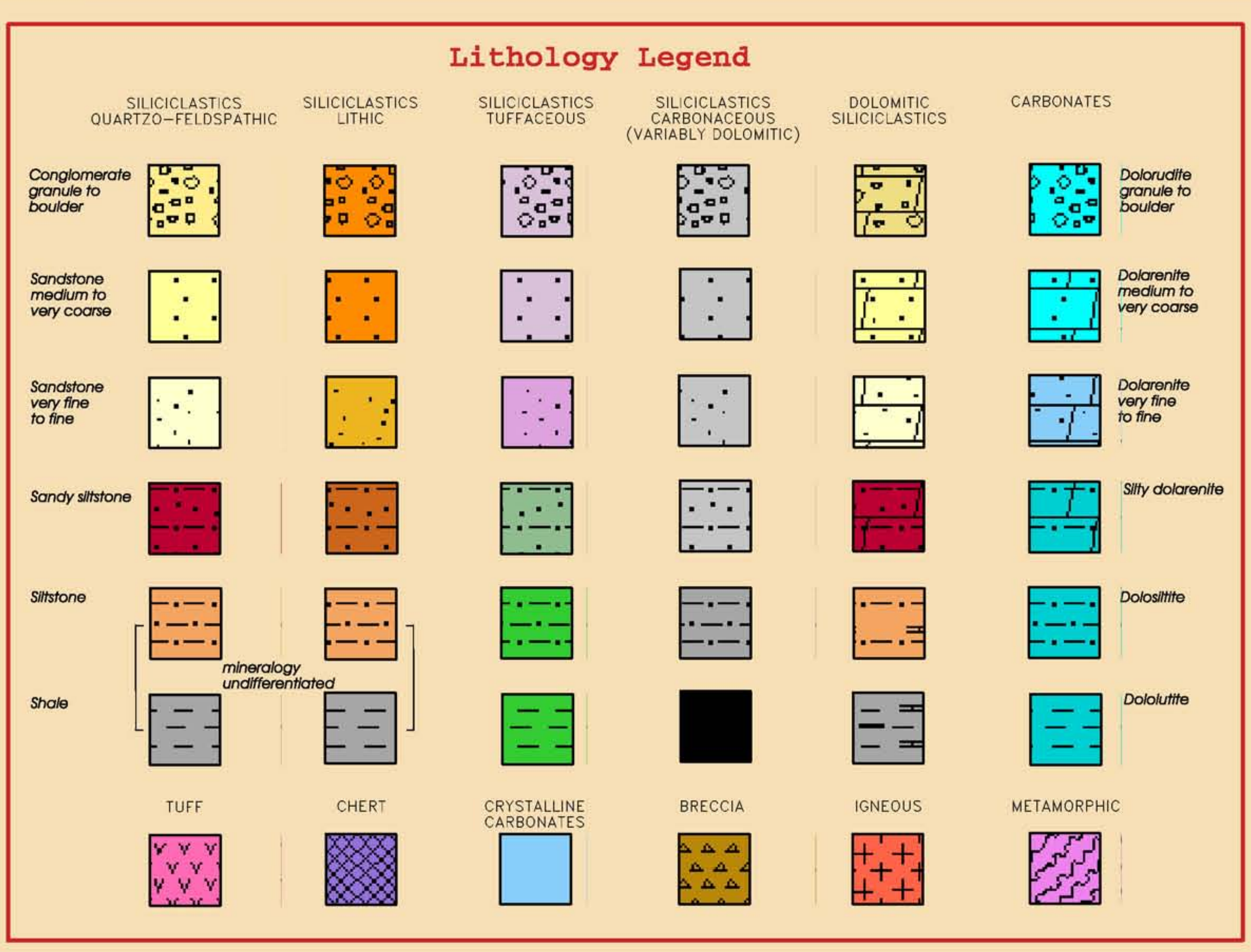
Map sheet: Borroloola

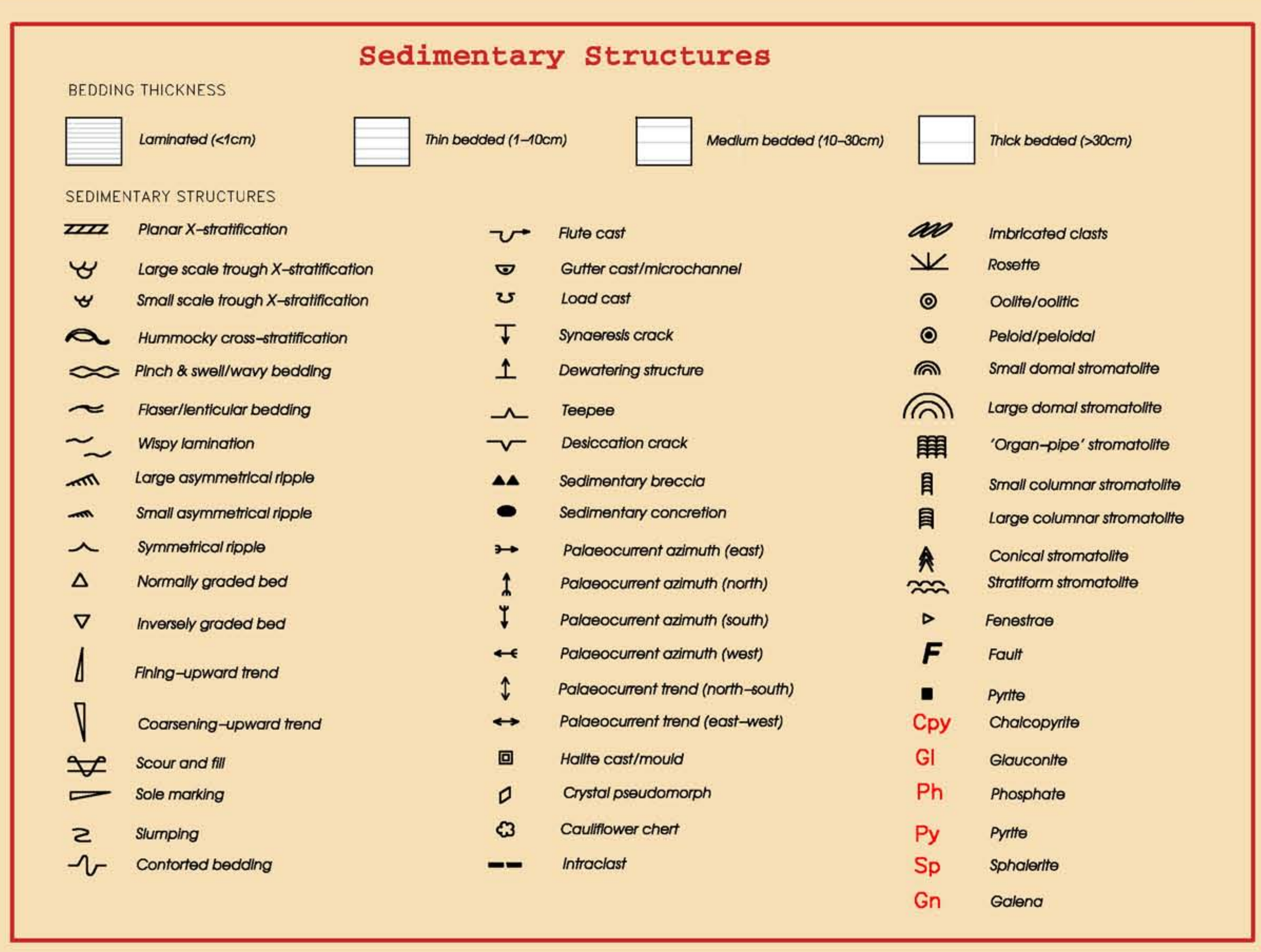
Geology: M J Jackson (based on company lithologic log)

Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)







Sequence Hierarchy

Label	Meaning	Label	Meaning	Label	Meaning
Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

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I22/55

MIM

SCALE 1:1000

Easting: 617506

Northing: 8182666

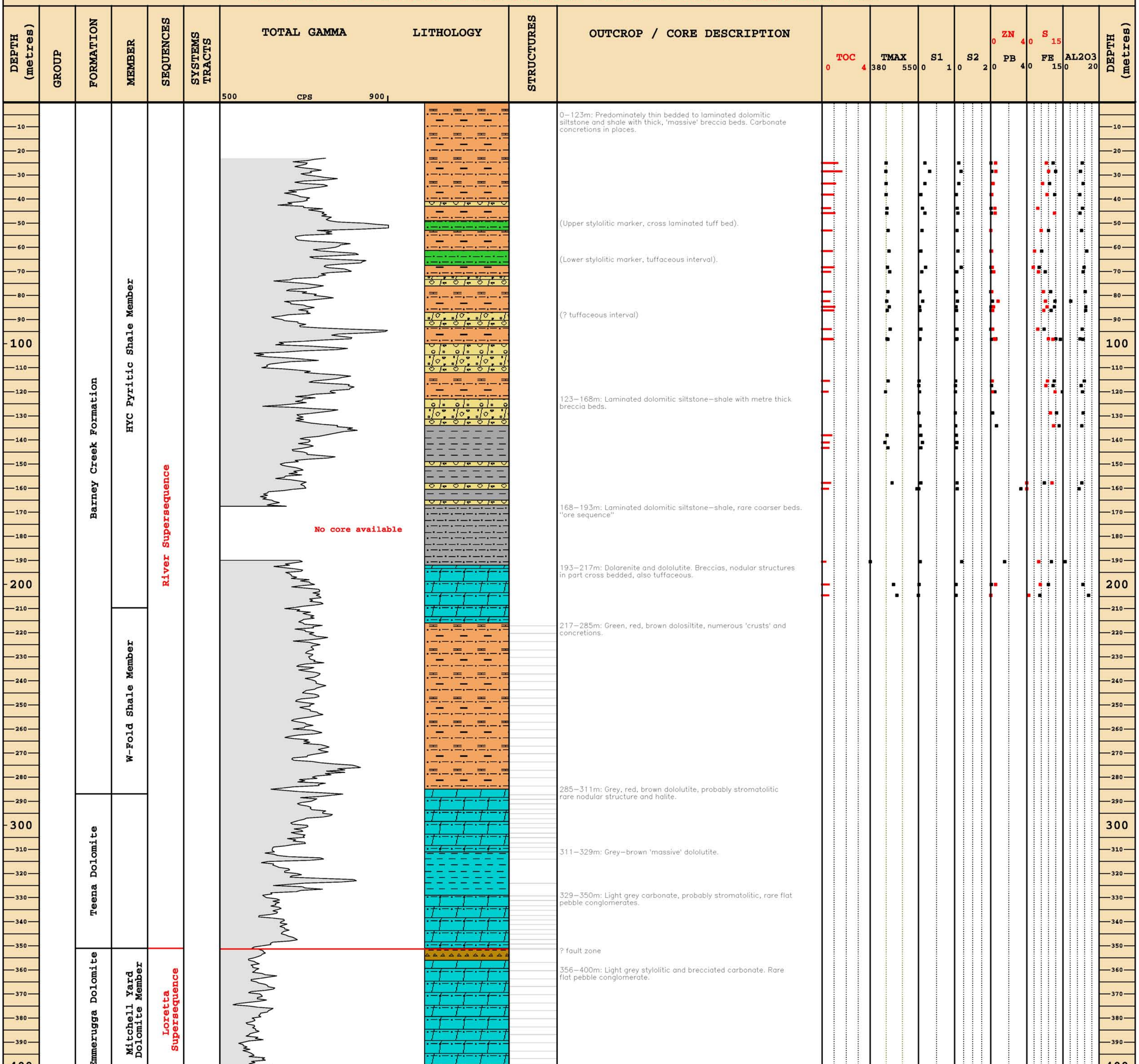
Data type: Drill Hole

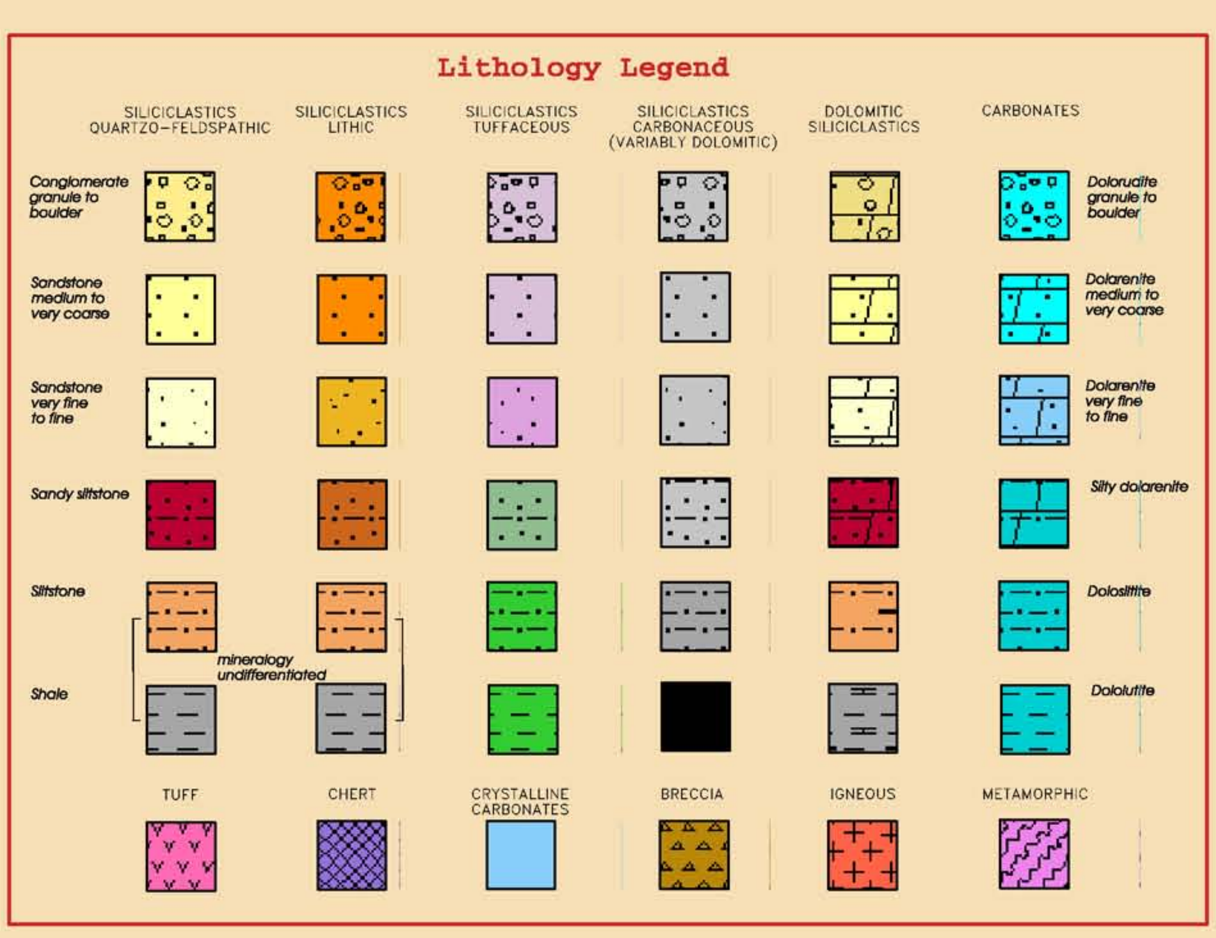
Map sheet: Borroloola

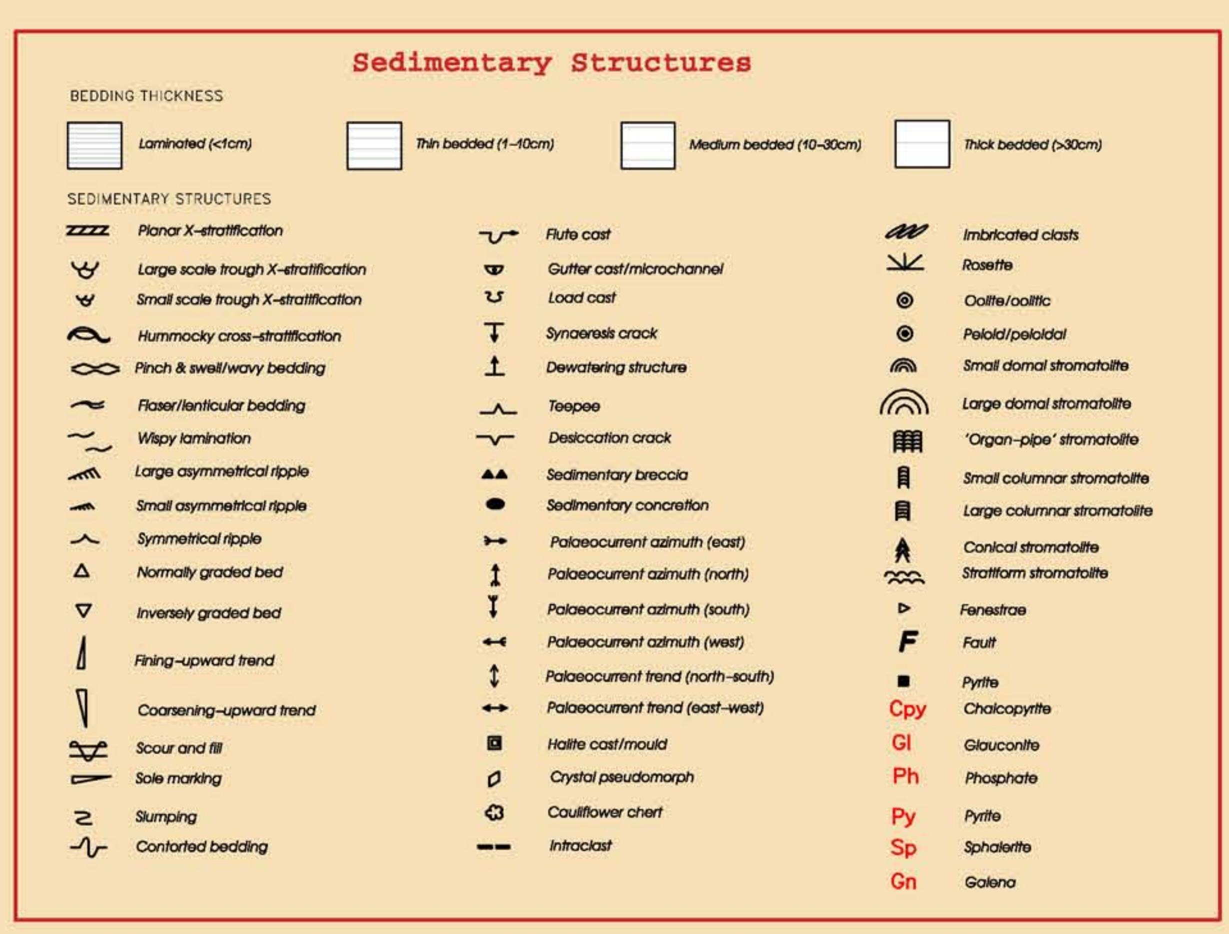
Geology: M J Jackson (based on M K Neudert 1993 log)

Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)







Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

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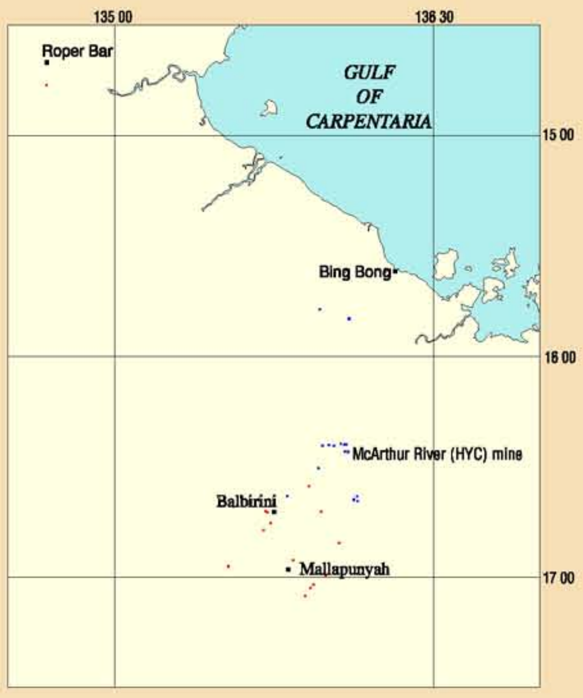
Phone 02–62499519, Facsimile 02–62499982

Date: 18–Oct–2000



Lynott West 3

MIM

SCALE 1:1000

Easting: 610678

Northing: 8185465

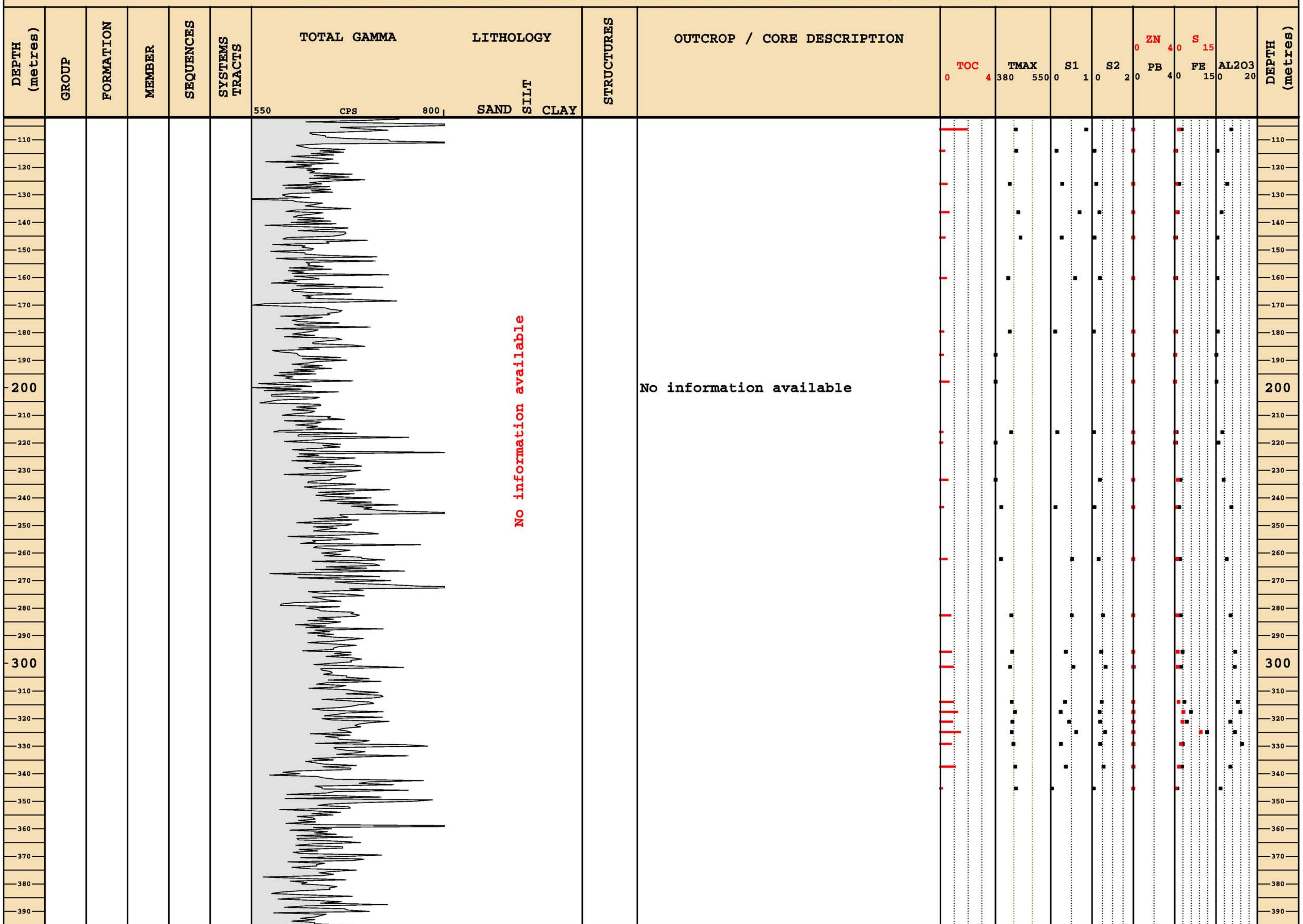
Data type: Drill Hole

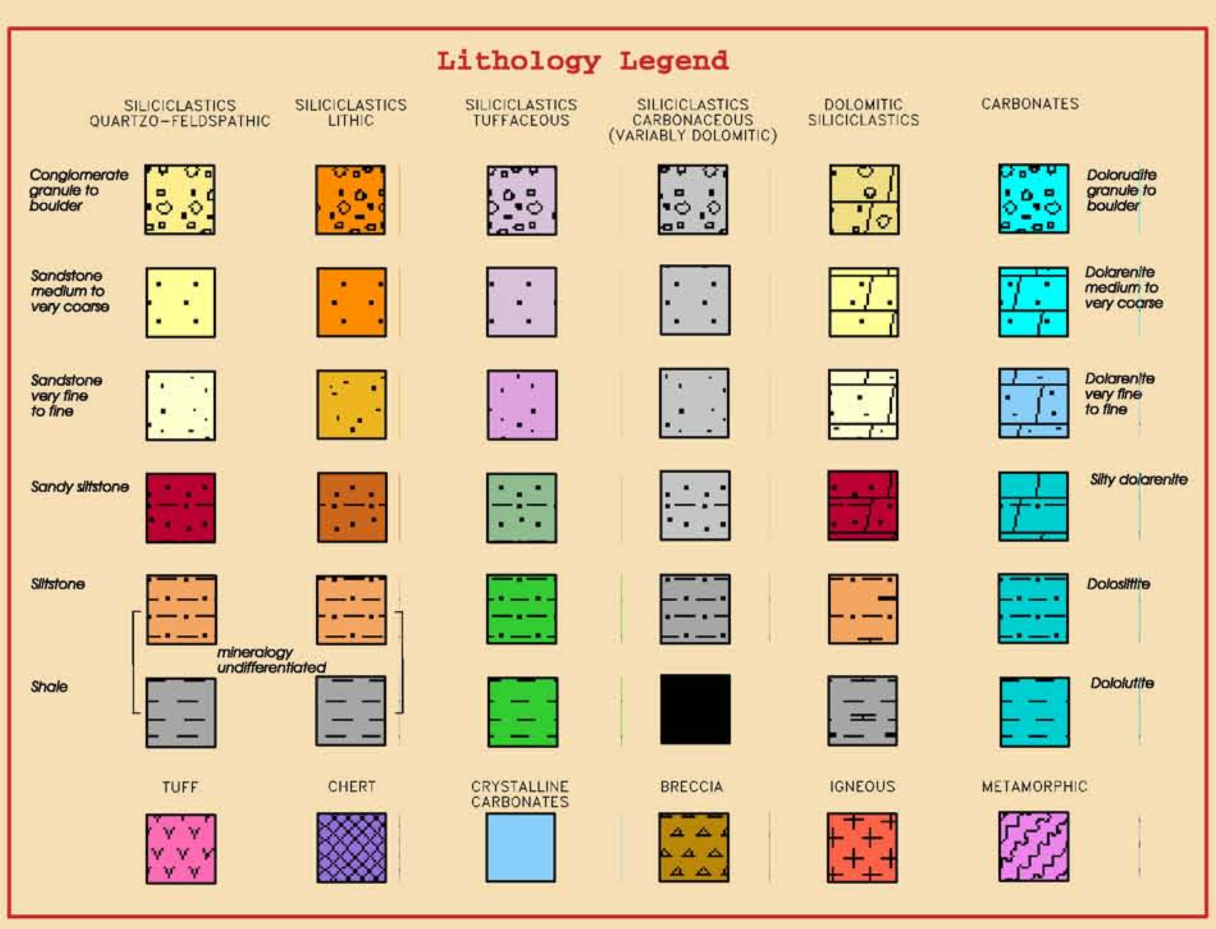
Map sheet: Borroloola

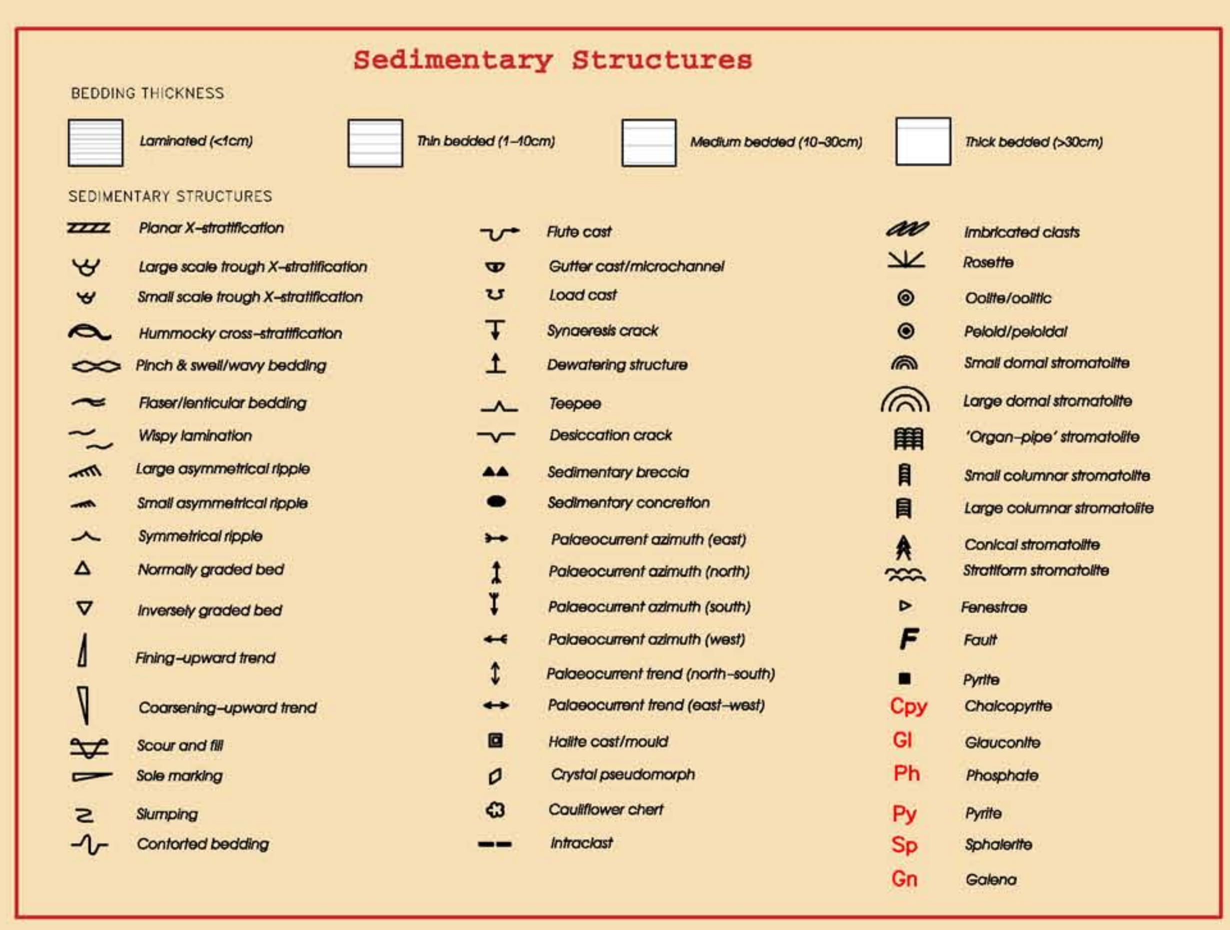
Geology: M J Jackson (None available gamma log only)

Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)







Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

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Date: 18-Oct-2000 11:42:38

Lynott West 4

MIM

SCALE 1:1000

Easting: 604830

Northing: 8185559

Data type: Drill Hole

Map sheet: Batten

Geology: (None available, gamma log only)

Geolog compilation: K Barnett & I Zeilinger

AUSTRALIA

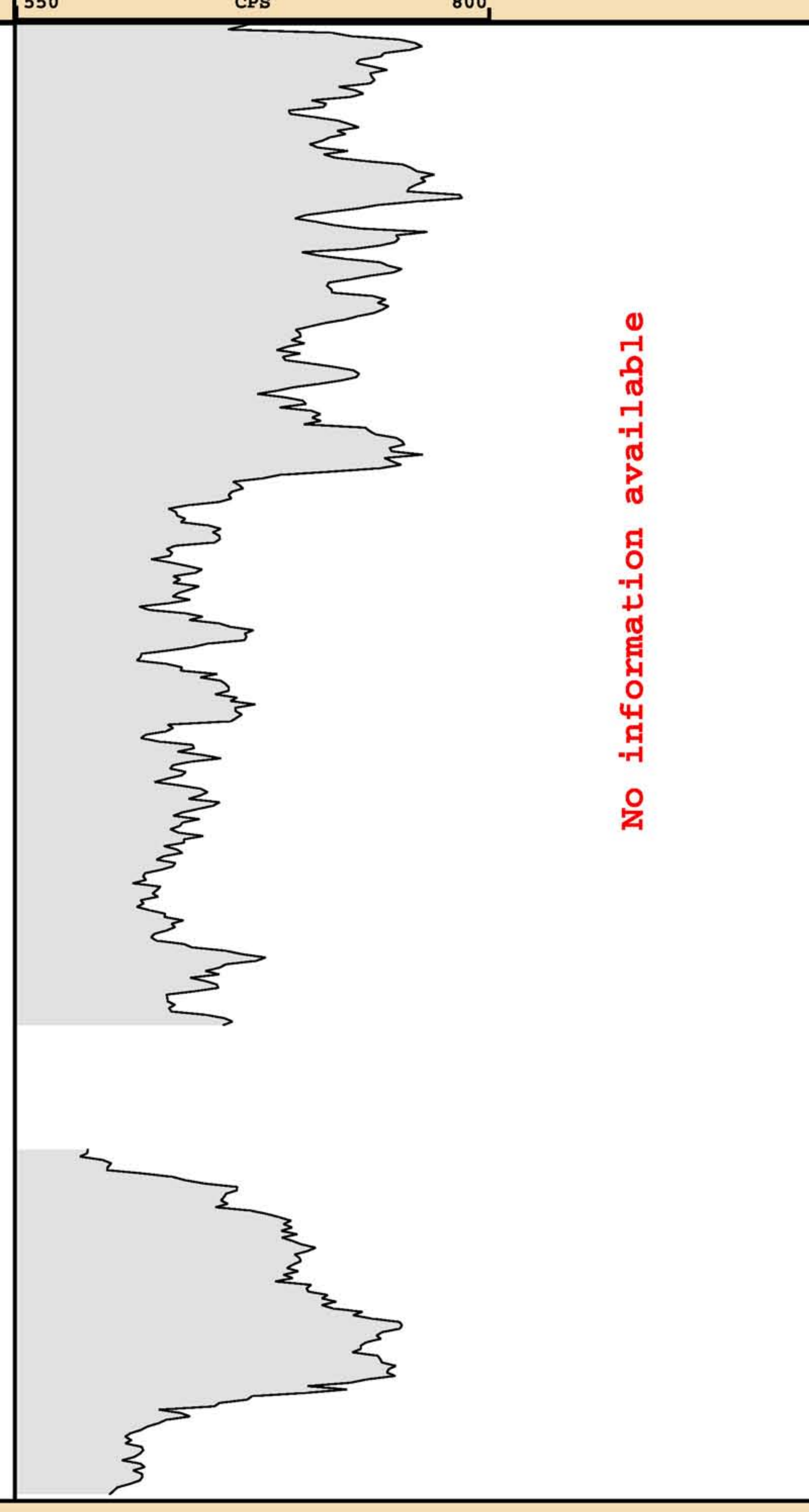
DEPARTMENT OF MINES AND ENERGY

NORTHERN TERRITORY DEPARTMENT OF MINES AND ENERGY

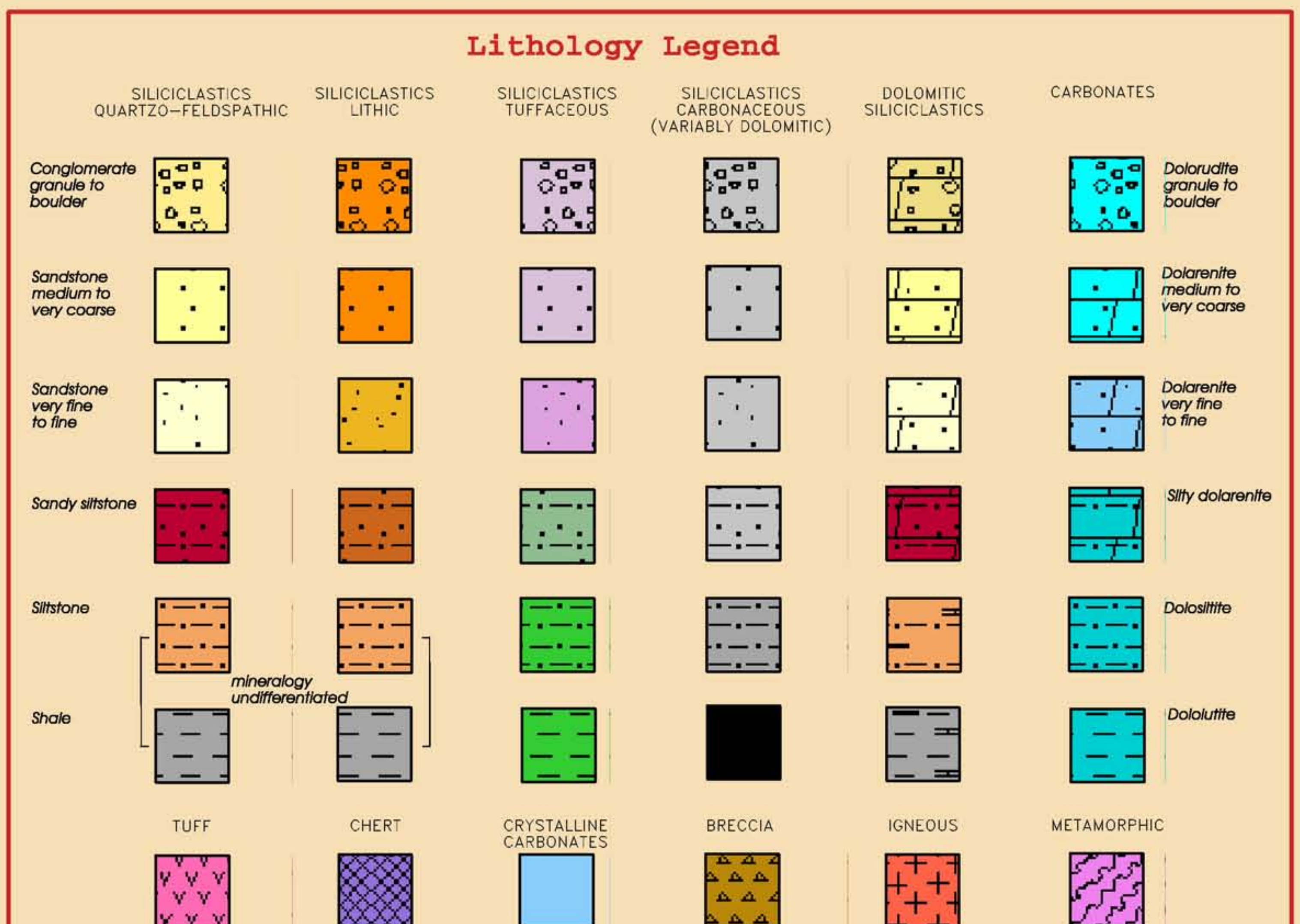
AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)

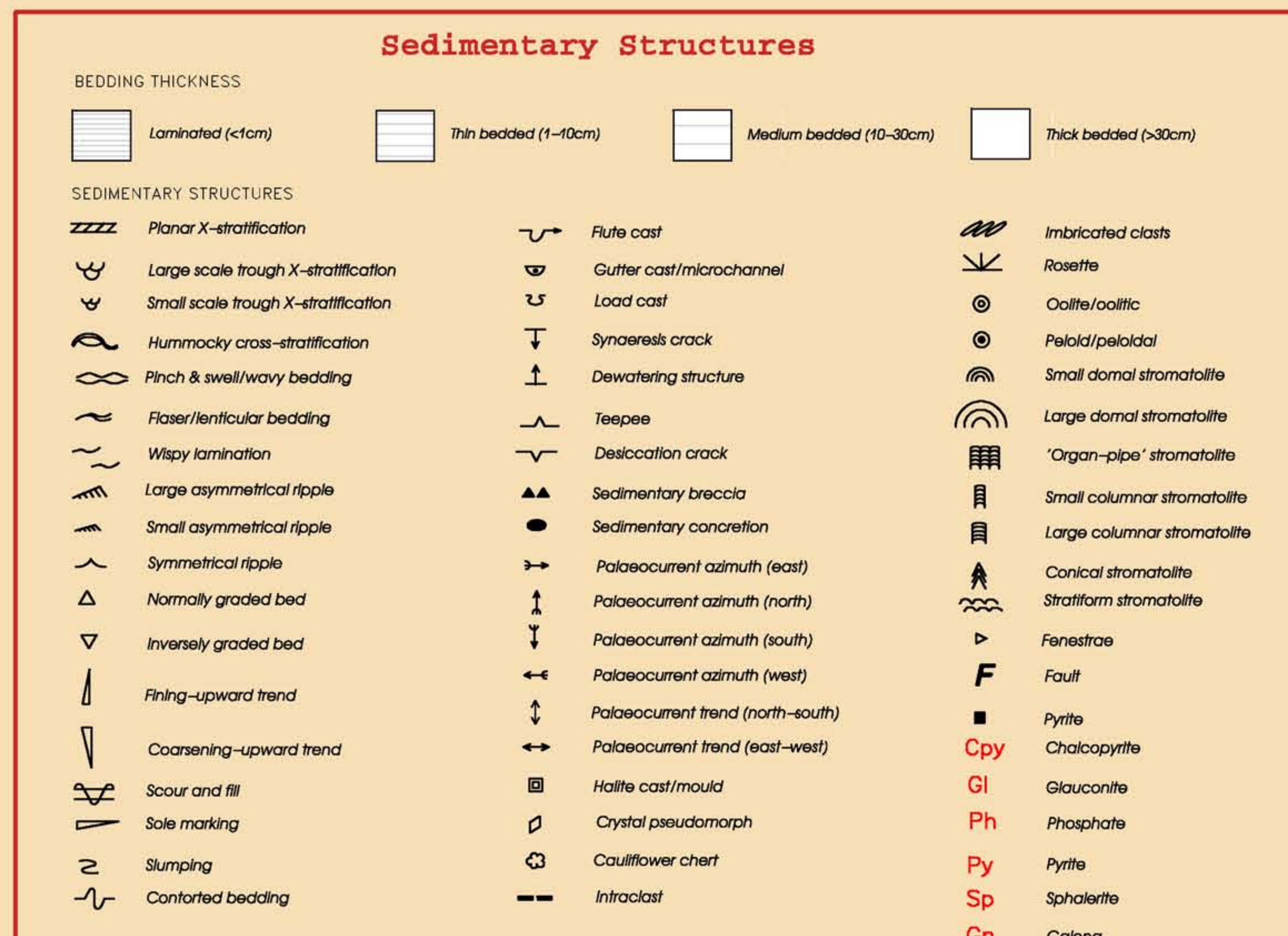
DEPTH (metres)	SPLICES	GROUP	FORMATION	MEMBER	SEQUENCES	SYSTEMS TRACTS	TOTAL GAMMA	LITHOLOGY	STRUCTURES	OUTCROP / CORE DESCRIPTION	DEPTH (metres)
130–340							550 CPS 800 (curve)	No information available		No information available	130–340



Lithology Legend



Sedimentary Structures



Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

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Lynott West 5

MIM

SCALE 1:1000

Easting: 607884

Northing: 8186136

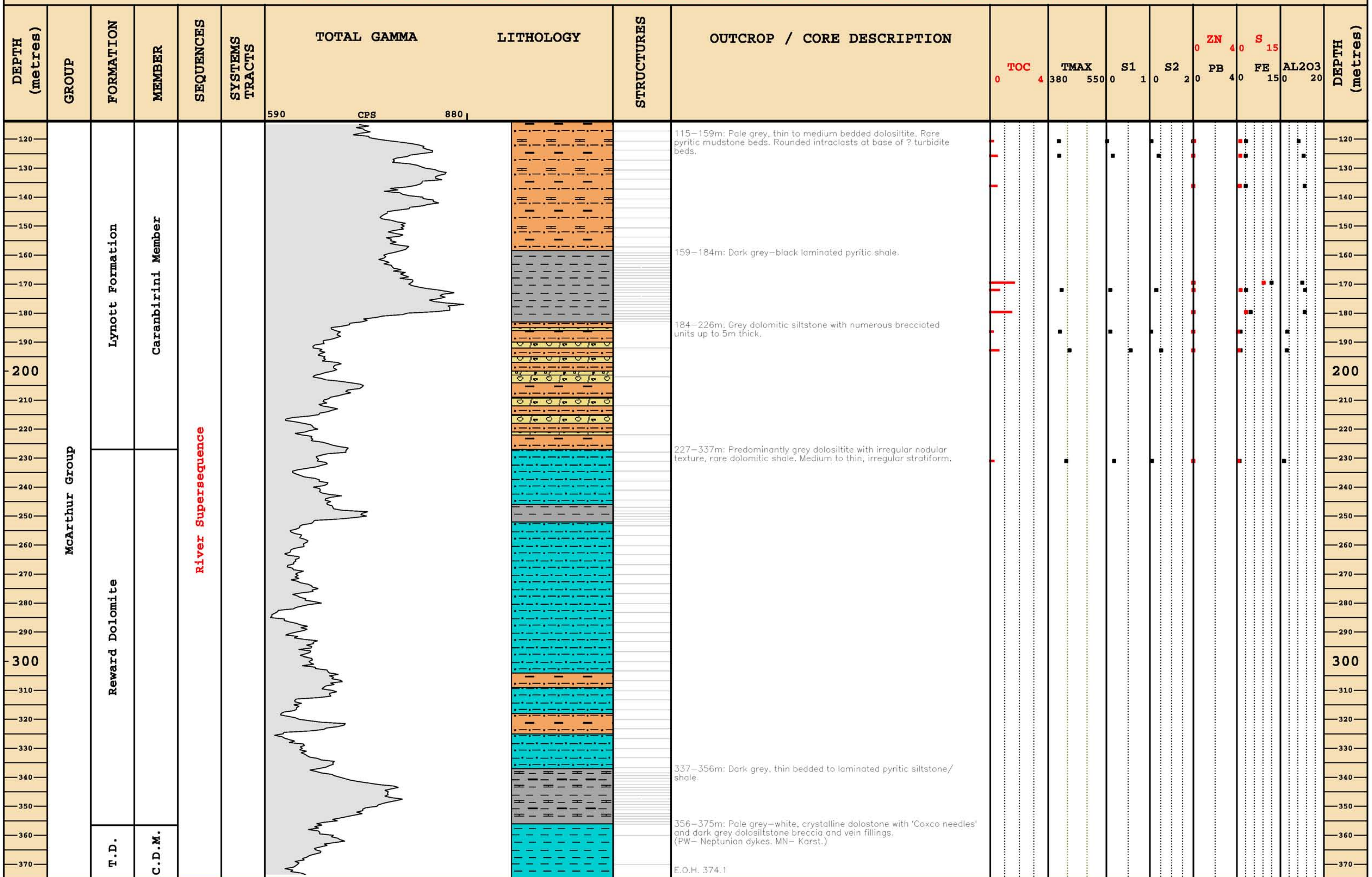
Data type: Drill Hole

Map sheet: Borroloola

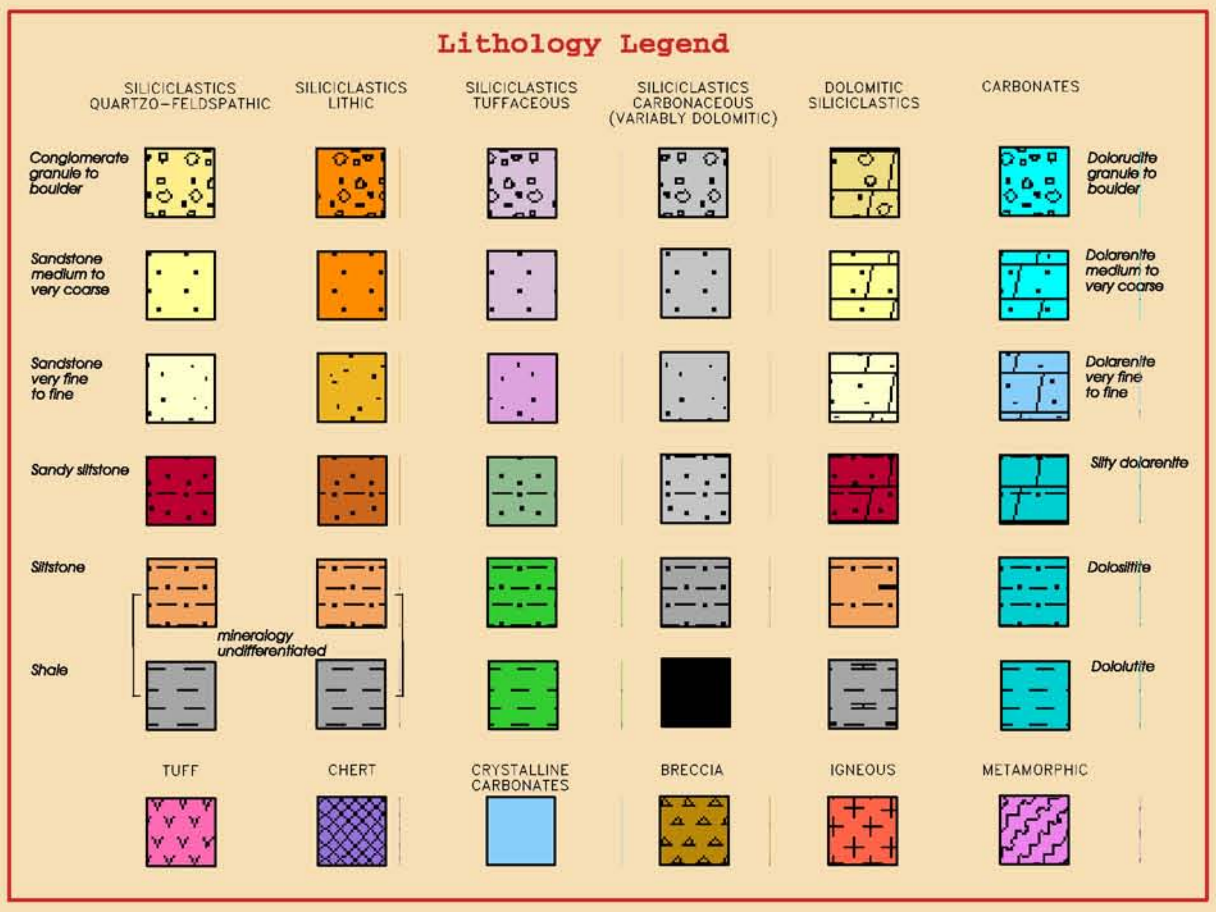
Geology: M J Jackson & P N Southgate

Geolog compilation: K Barnett I Zeilinger

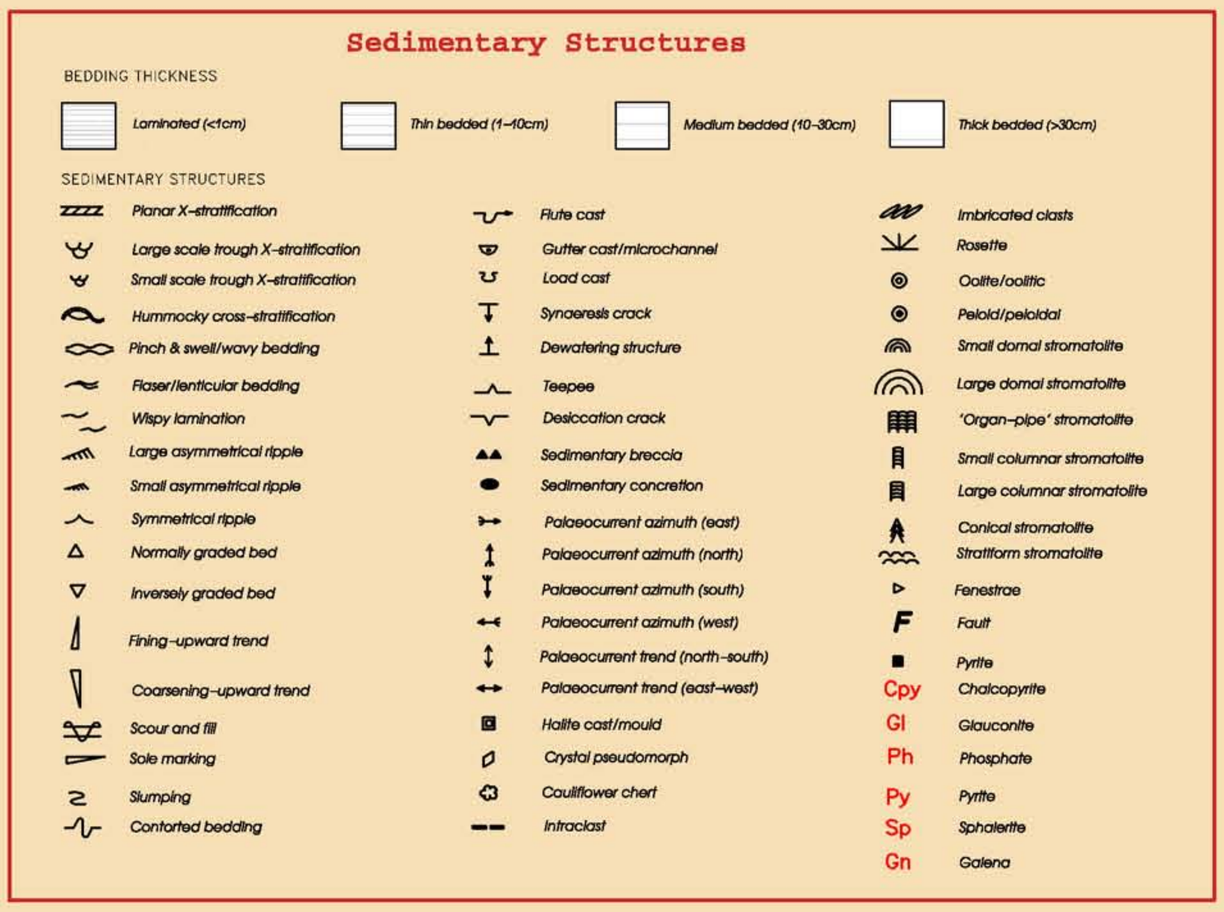
Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)



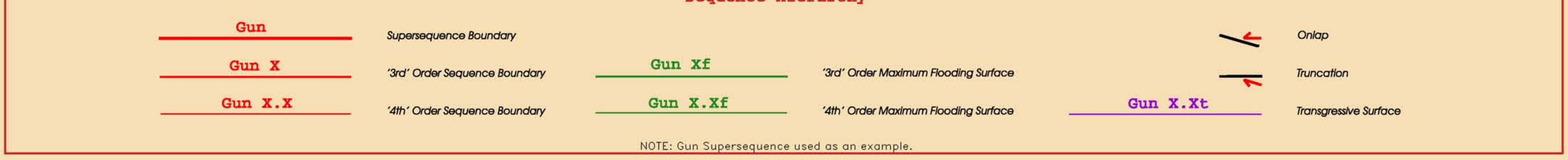
Lithology Legend



Sedimentary Structures



Sequence Hierarchy



Copies of this figure may be obtained as a CD ROM product AGSO Record 2000/03 from:
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Phone 02–62499519, Facsimile 02–62499982

Date: 19–Oct–2000

McA10

BHP

SCALE 1:1000

Easting: 602718

Northing: 8174487

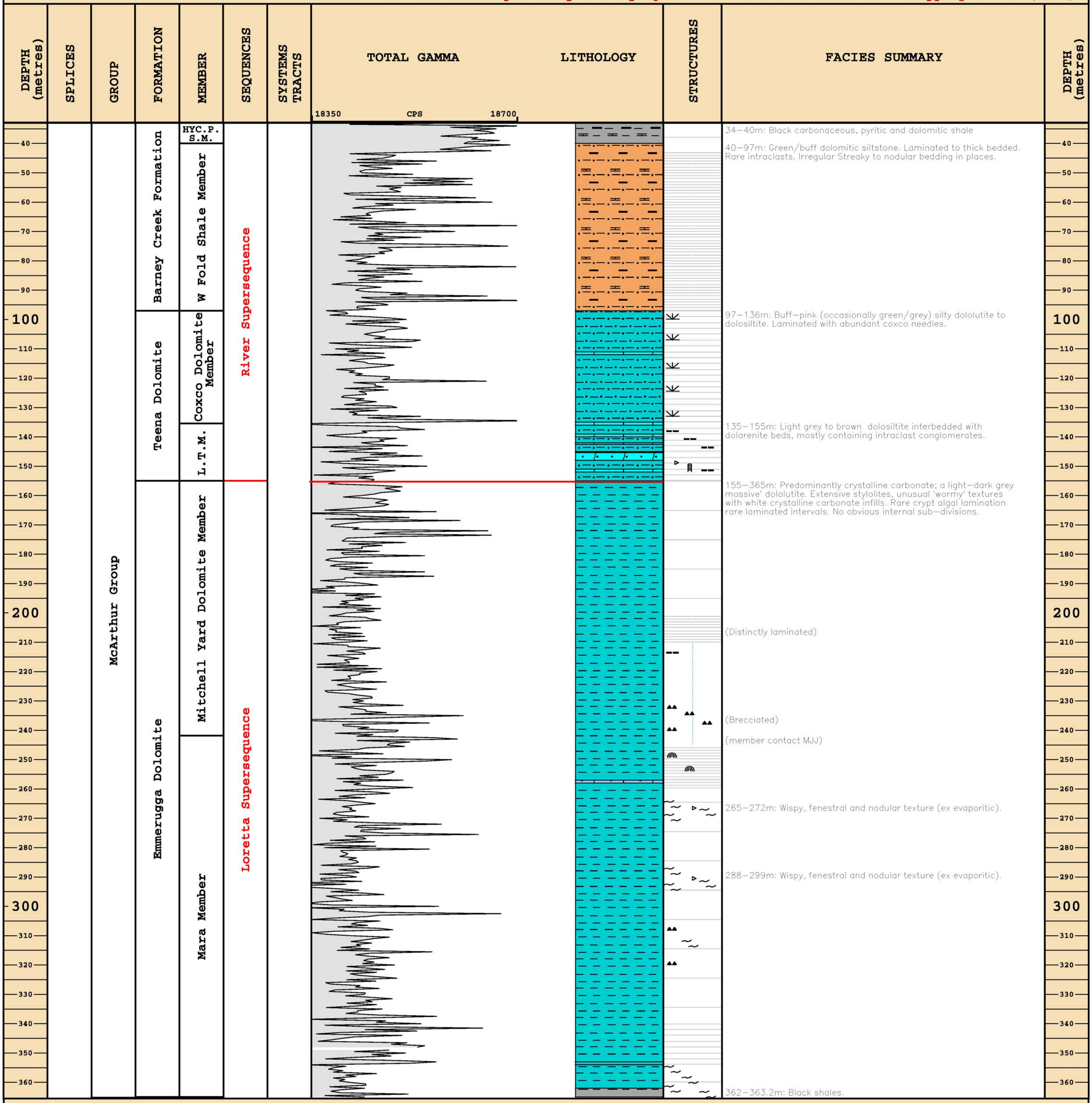
Data type: Drill Hole

Map sheet: Mallapunyah

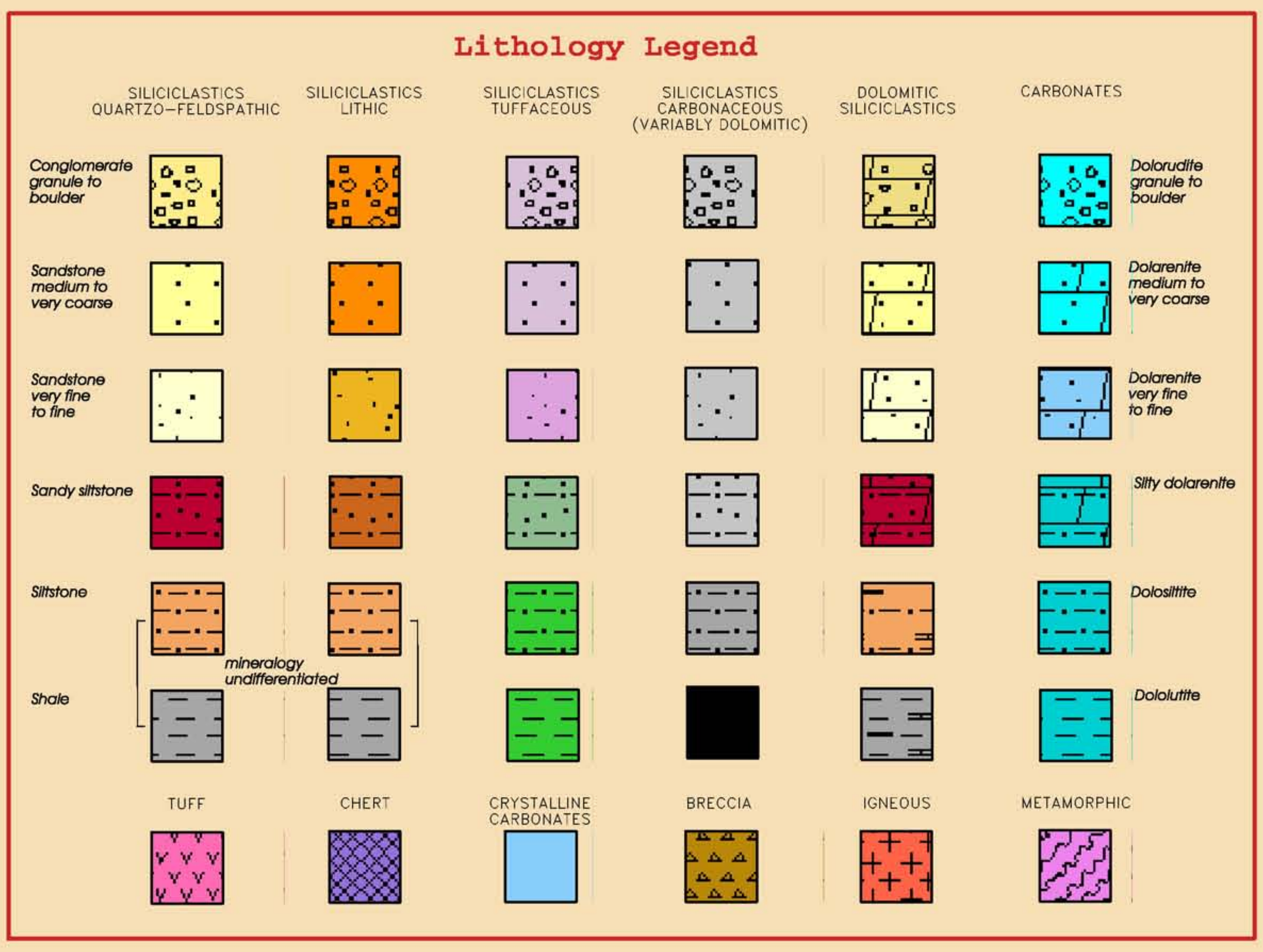
Geology: P R Winefield (University of Tasmania) & M J Jackson

Geolog compilation: K Barnett & I Zeilinger

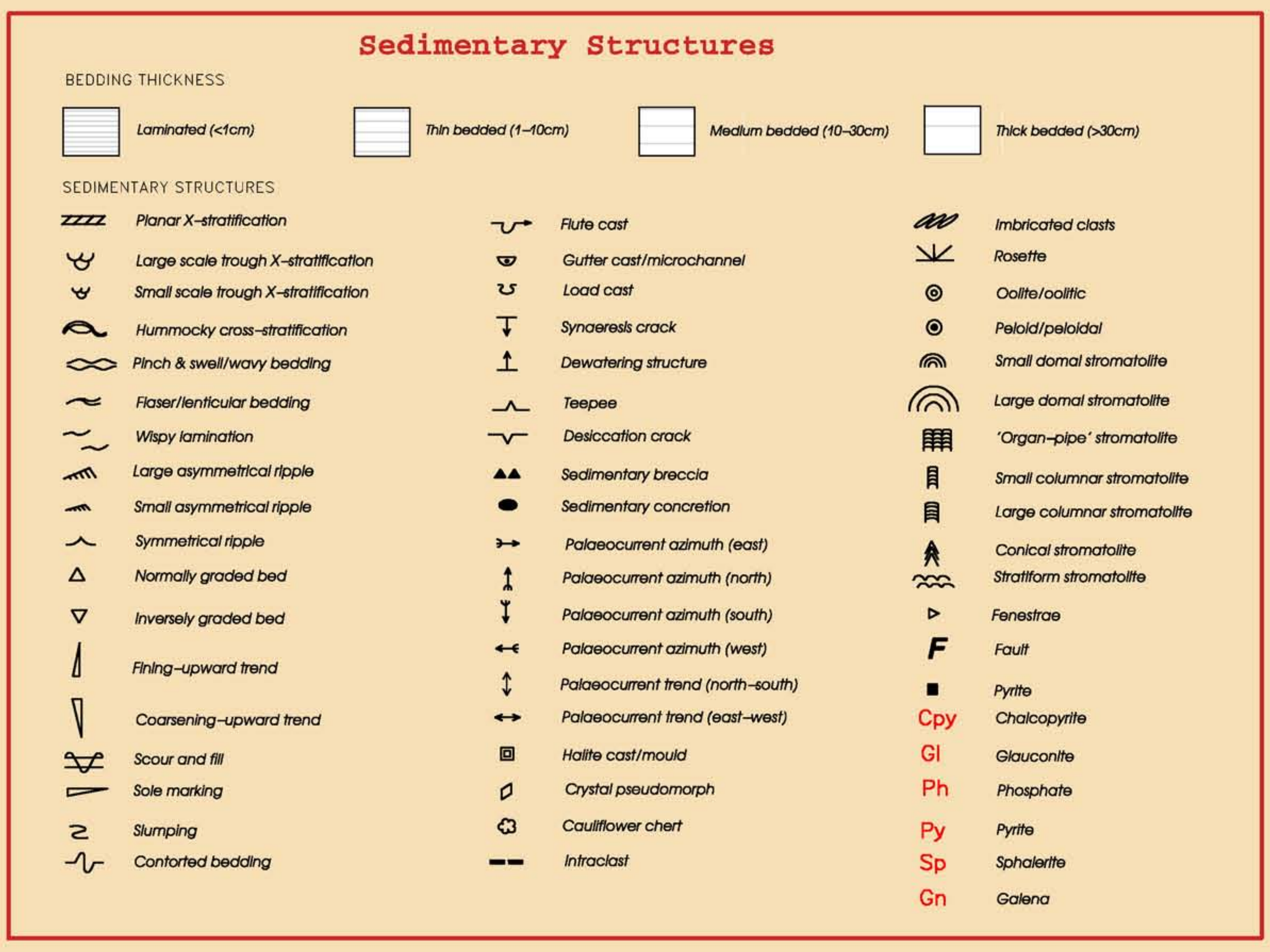
Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)



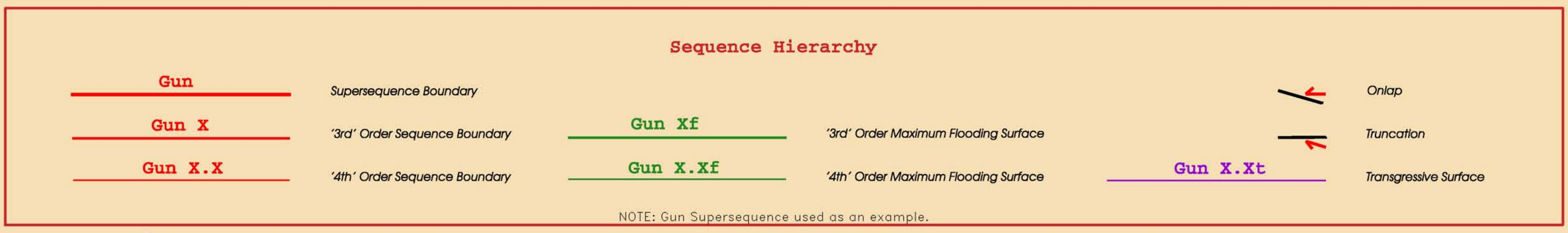
Lithology Legend



Sedimentary Structures



Sequence Hierarchy



Copies of this figure may be obtained as a CD ROM product AGSO Record 2000/03 from:
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Phone 02–62499519, Facsimile 02–62499982 Date: 19–Oct–2000

McA5

BHP

SCALE 1:1000

Easting: 618440

Northing: 8249240

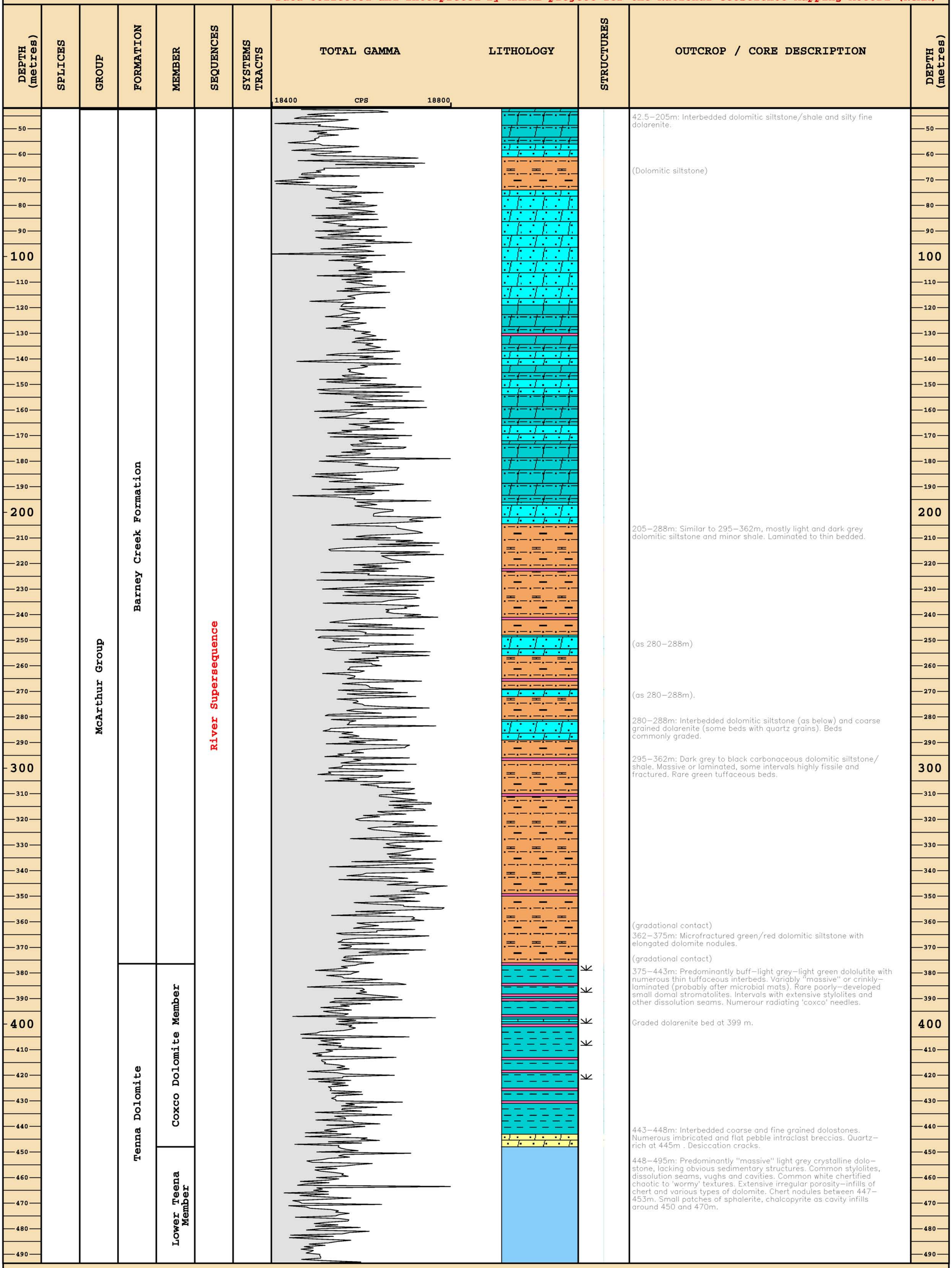
Data type: Drill Hole

Map sheet: Bing Bong

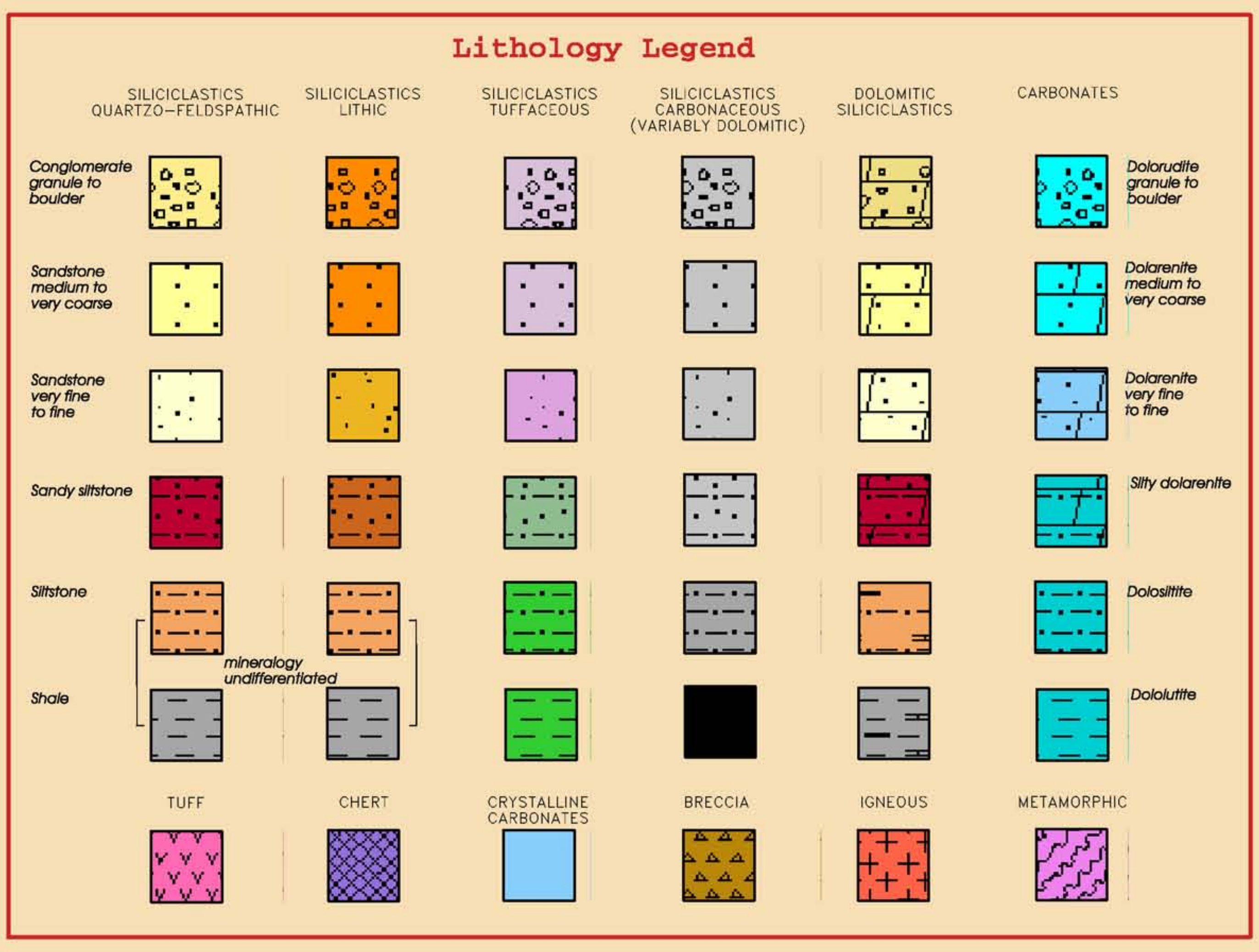
Geology: P R Winefield (University of Tasmania)

Geolog compilation: K Barnett & I Zeilinger

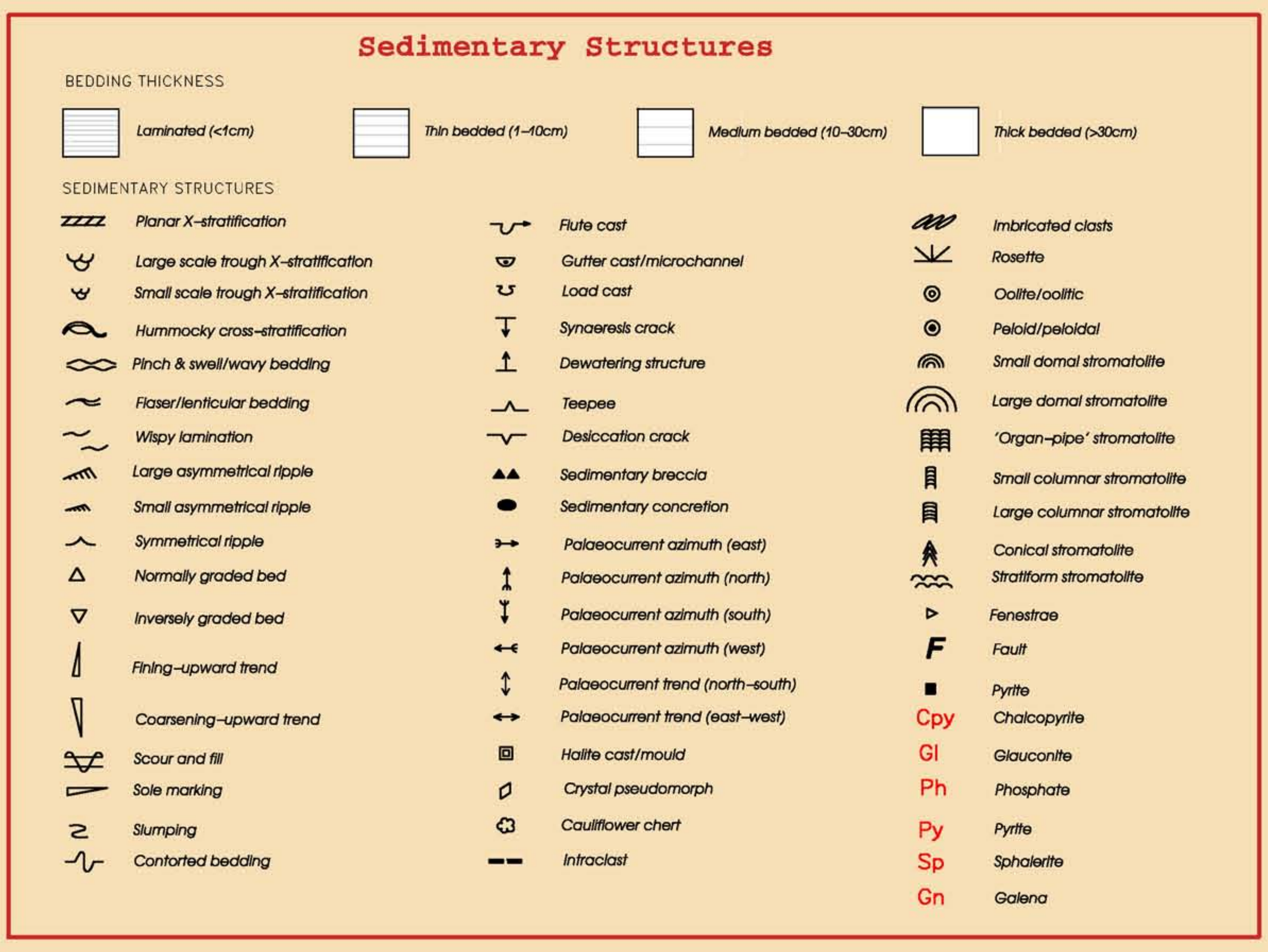
Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)



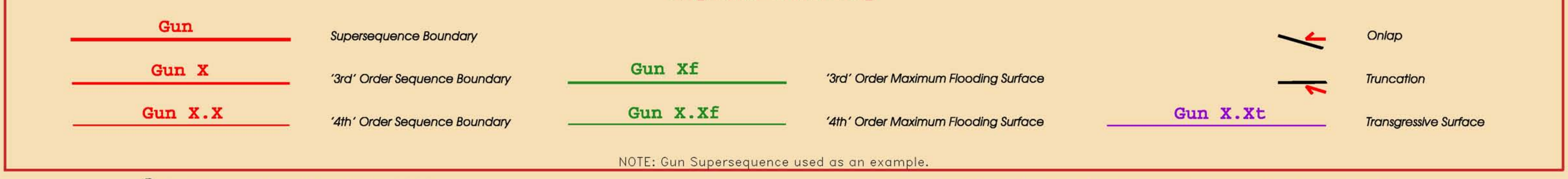
Lithology Legend



Sedimentary Structures



Sequence Hierarchy



NOTE: Gun Supersequence used as an example.

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Balbirini Composite

96JJ01A, 96JJ01B, 96JJ01C, BMR Bauhinia Downs 3, 77/06, 96JJ02

SCALE 1:1000

Easting: 578722

Northing: 8146484

Data type: Measured Section

Map sheet: Mallapunyah

Geology: M J Jackson & P N Southgate

Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)

Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

AGSO has tried to make the information in this product as accurate as possible. However, it does not guarantee that the information is totally accurate or complete. Therefore, you should not rely solely on this information when making a commercial decision.

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Burl Camp-Stretton

96JJ07

SCALE 1:1000

AUSTRALIA

Easting: 603900

Northing: 8152500

Data type: Measured section

Map sheet: Mallapunyah

Geology: M J Jackson & P N Southgate

Geolog compilation: K Barnett & I Zeilinger

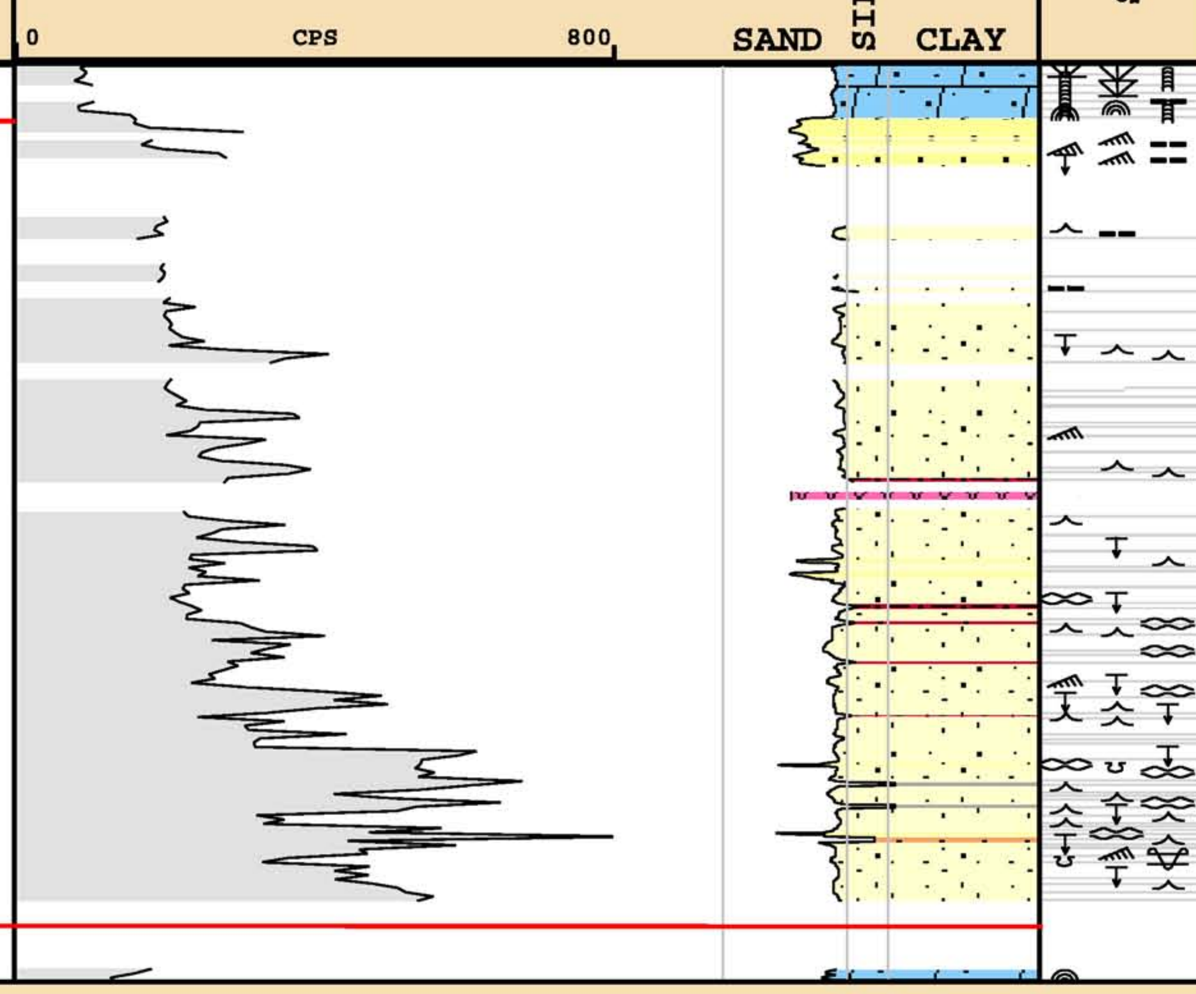
DEPARTMENT OF MINES AND ENERGY

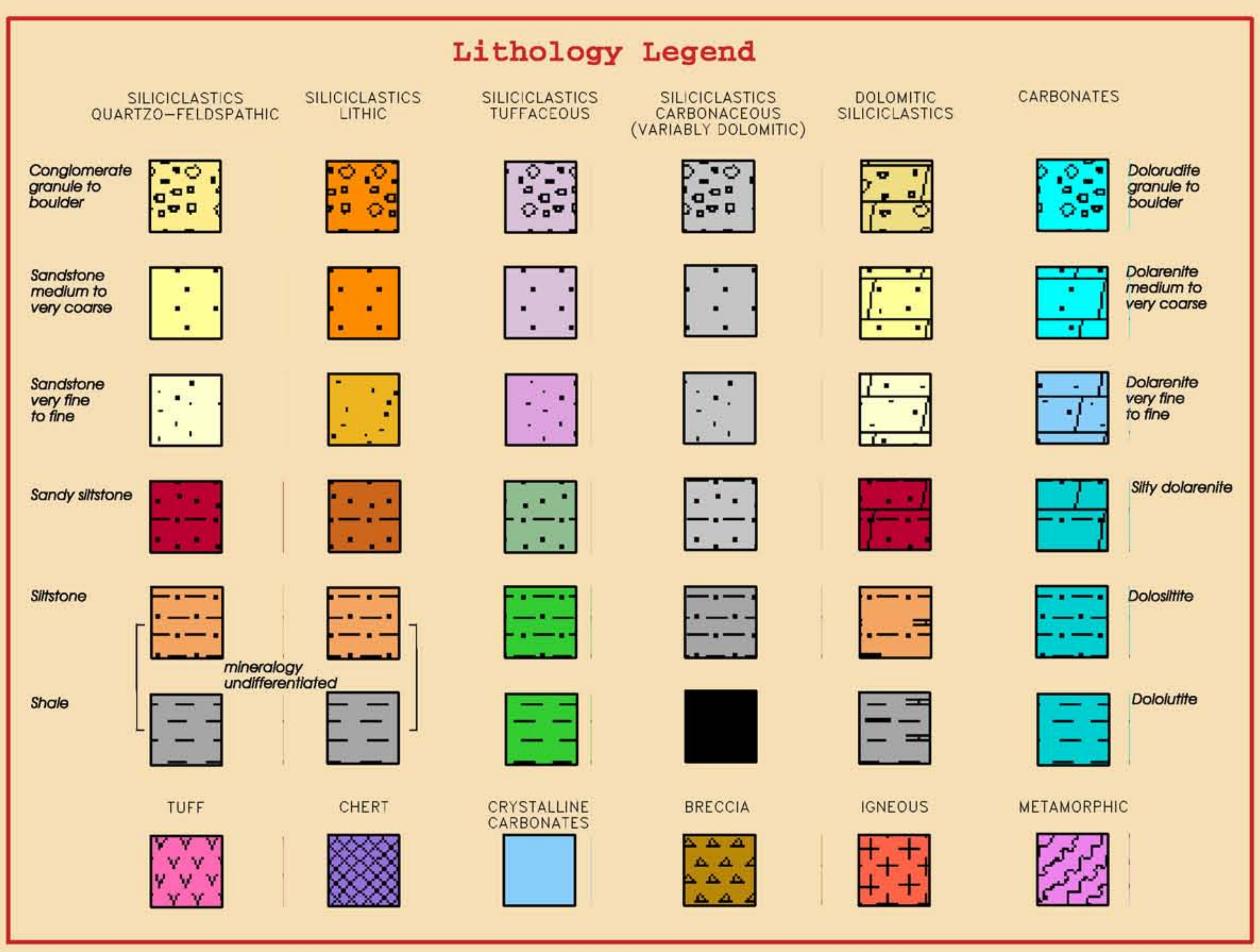
NORTHERN TERRITORY DEPARTMENT OF MINES AND ENERGY

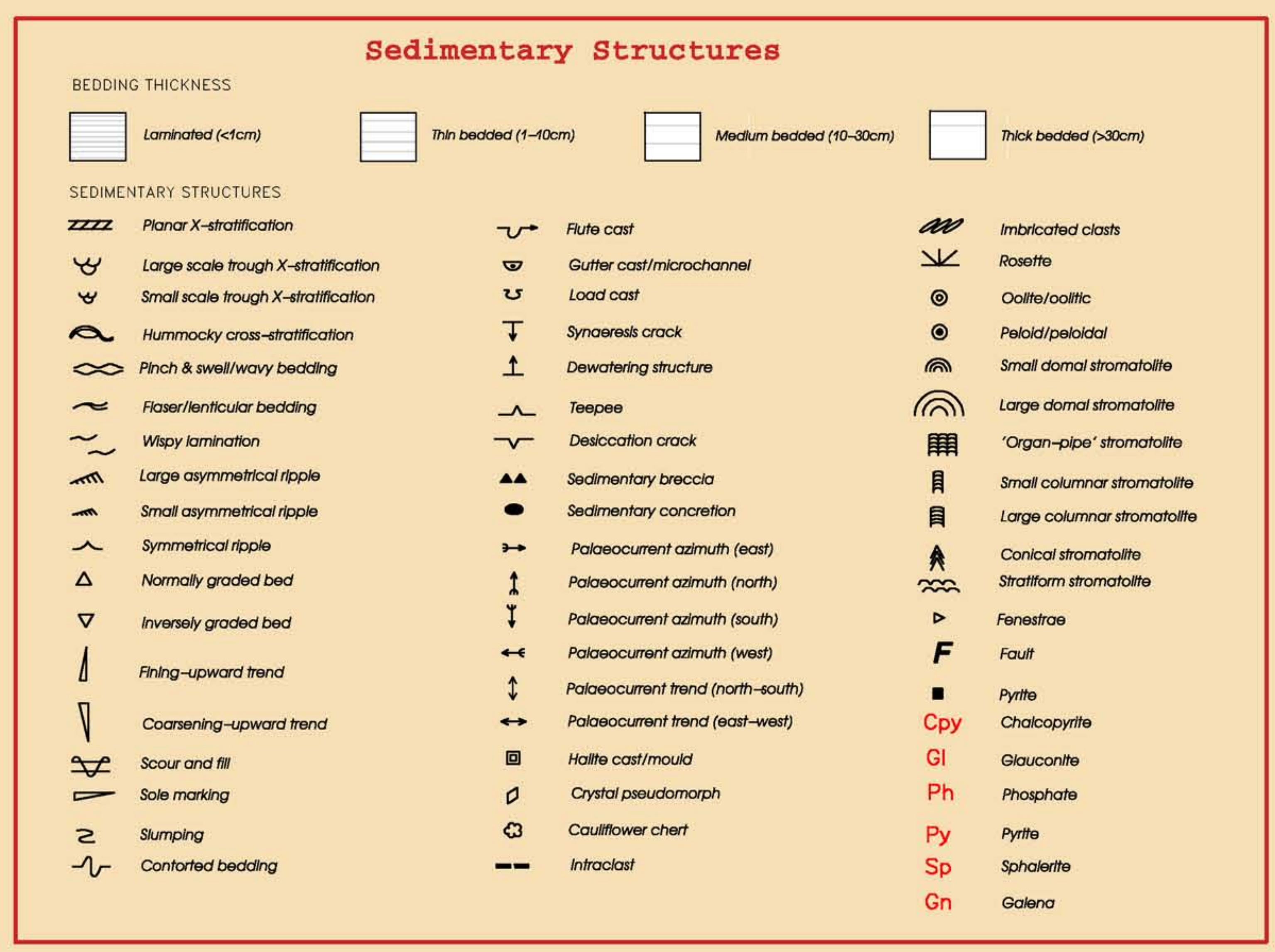
AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

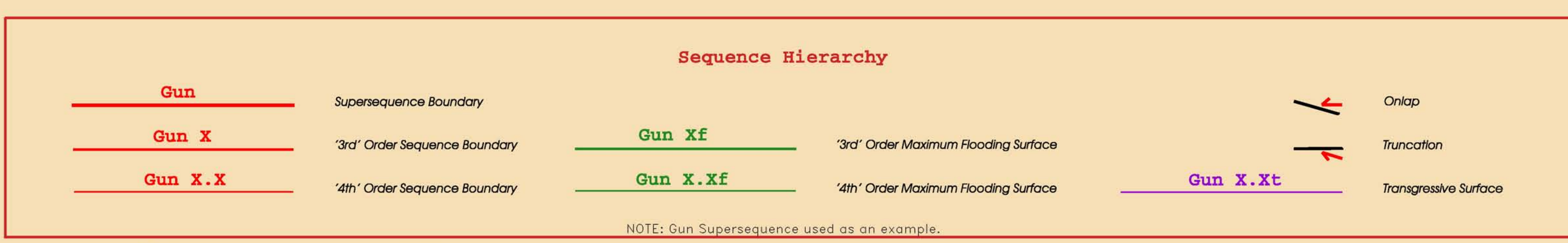
Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)

THICKNESS (metres)	SPLICES	GROUP	FORMATION	MEMBER	SEQUENCES	SYSTEMS TRACTS	TOTAL GAMMA / LITHOLOGY	STRUCTURES	OUTCROP / CORE DESCRIPTION	THICKNESS (metres)
100	96/JJ/07	McArthur Group	L.G.F.		Term Supersequence				102–108m: Cherty carbonates, intraclasts, clast rosettes, domal and columnar stromatolites – sharp planar contact at 101 m. 80–102m: Mostly fine grained grading to medium grained. Bedding medium to thick. Numerous current ripples & ball impressions.	100
90–10			Stretton Sandstone						9–80m: Pale green very fine grained quartz sandstone with thin interbeds of siltstone/mudstone. Stratification continuous, regular, parallel to undulatory. Rare more resistant sharp–based fine to medium grained beds with clast impressions & wave ripples. Low–angle wave & current ripples common, occasional preservation of clay drapes, numerous syneresis cracks. @56m: Two reworked pink beds with interval wavy–lamination and load–casts on base. Rare surface markings – prod & scrape and 'armoured sandstone balls'. @ 48m: Three thick beds, each about 50 cm thick (vfg to medium). Possible thickening up cycles between 25–50 m, mostly 2–4 m thick. Pinch & swell common, some thicker beds form shallow channels @17m: 30 cm siltstone interval overlain by medium to coarse sandstone bed.	90–10
			Y.F.		R.S.				0–2m: Cherty dolostone with small domal stromatolites.	









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Phone 02–62499519, Facsimile 02–62499982 Date: 19–Oct–2000

Gorge Composite

97/PW_KP/1, 96/PW_KP/1, 97/PW_KP/2

SCALE 1:1000

Easting: 606149

Northing: 8120265

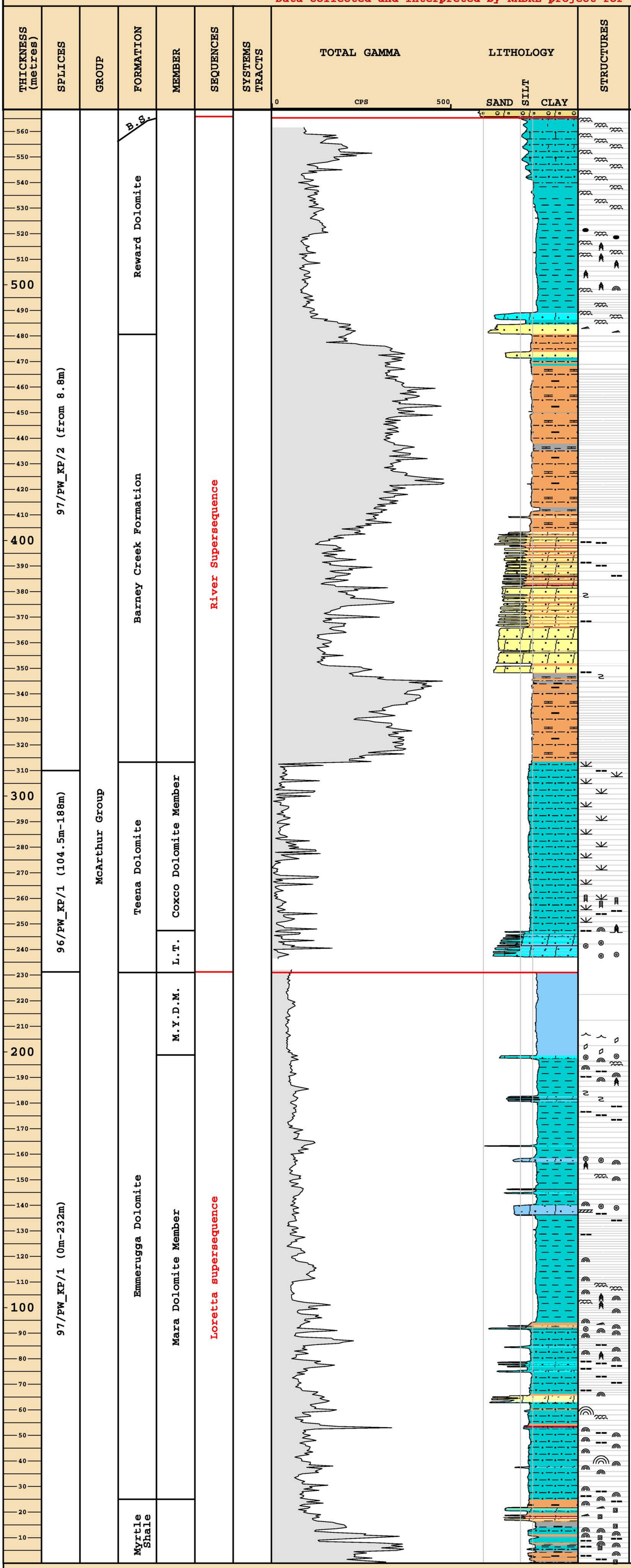
Data type: Measured Section

Map sheet: Mallapunyah

Geology: P Winefield (University of Tasmania)

Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)



Outcrop / Core Description

566–568.5m: conglomerate contains clasts from underlying units.

489–566m: Light–pink to purple dololutite and vfg dolarenite. Laminated to thin bedded (1–100 cms) stratification wavy after stromatolites – small low domes and irregular, peaked cuspate forms.

481–489m: Medium–coarse quartz sandstone and dolarenite with current ripples, interbeds of silicified dololutite.

403–481m: Laminated to thinly bedded dolomitic siltstone–dololutite. Mostly planar parallel laminated, rarely wavy. Rare intervals with thicker stratification. Rare beds of very fine grained dolarenite grading up into siltstone.

365–403m: Interbedded coarse grained dolarenite and dolomitic siltstone/dololutite. Beds commonly 10–15 cms thick. Large angular clasts of finer facies present in thicker dolarenite beds. Rare soft–sediment bedding disruption. Imbricated (40 cms thick) clast conglomerate at 398 m.

348–365m: Three 'massive' units of coarse grained dolarenite/dolomitic sandstone separated by thin intervals of dolomitic silt–stone/dololutite. Only structures present are large brecciated clasts

Sharp contact at 348m.

313–348m: Laminated to very thinly bedded dololutite and dolomitic siltstone. Bedding mostly planar–parallel but wavy in places. Rare intervals with bedding distortion.

(thin bedded with normally graded siltstone beds)

[sharp contact at 313m]

247–313m: Pale pink–purple massive to finely laminated dolostone with abundant radiating acicular 'coxco needles'. Intervals with brecciation, intervals with columnar/plumose stromatolites. Numerous Neptunian dykes.
Red silty fracture infillings present around 300m

237–250m: Interbedded coarse ooid grainstones and dolomitic siltstone. Imbricated flat pebble breccia with possible teepee overlain by domal and conical stromatolites at top. Numerous cross cutting dykes.

[nominal gap–correlation not certain]

205–234m: 'Massive' crystalline grey dolostone. Diffuse lamination in places (planar to irregular).

199–205m: Red ferruginous dolostone with large vughs and veins infilled with large dolomite crystals.
187–199m: Pink grey dolostone with large (1m high) conophyton and linked domal and columnar stromatolites with a 1m thick medium grained, sandy, ooid grainstone at top.

163–187m: Predominantly laminated to thinly bedded dololutite, apparently devoid of stromatolites, rare intraclasts. Several beds of quartz–rich pelloid grainstones @ 181–183m.

(dolarenite with rounded quartz pebbles)
65–163m: Similar to 24–63m; tan–grey dololutite with silicified stratiform stromatolites and low relief linked domes; rare cuspate to conical forms. Several intervals rich in intraclast conglomerates. (1m ooid grainstone bed)

(Thick prominent beds of cross–bedded ooid grainstones.)

(Poor outcrop)

(non–silicified conical stromatolites)

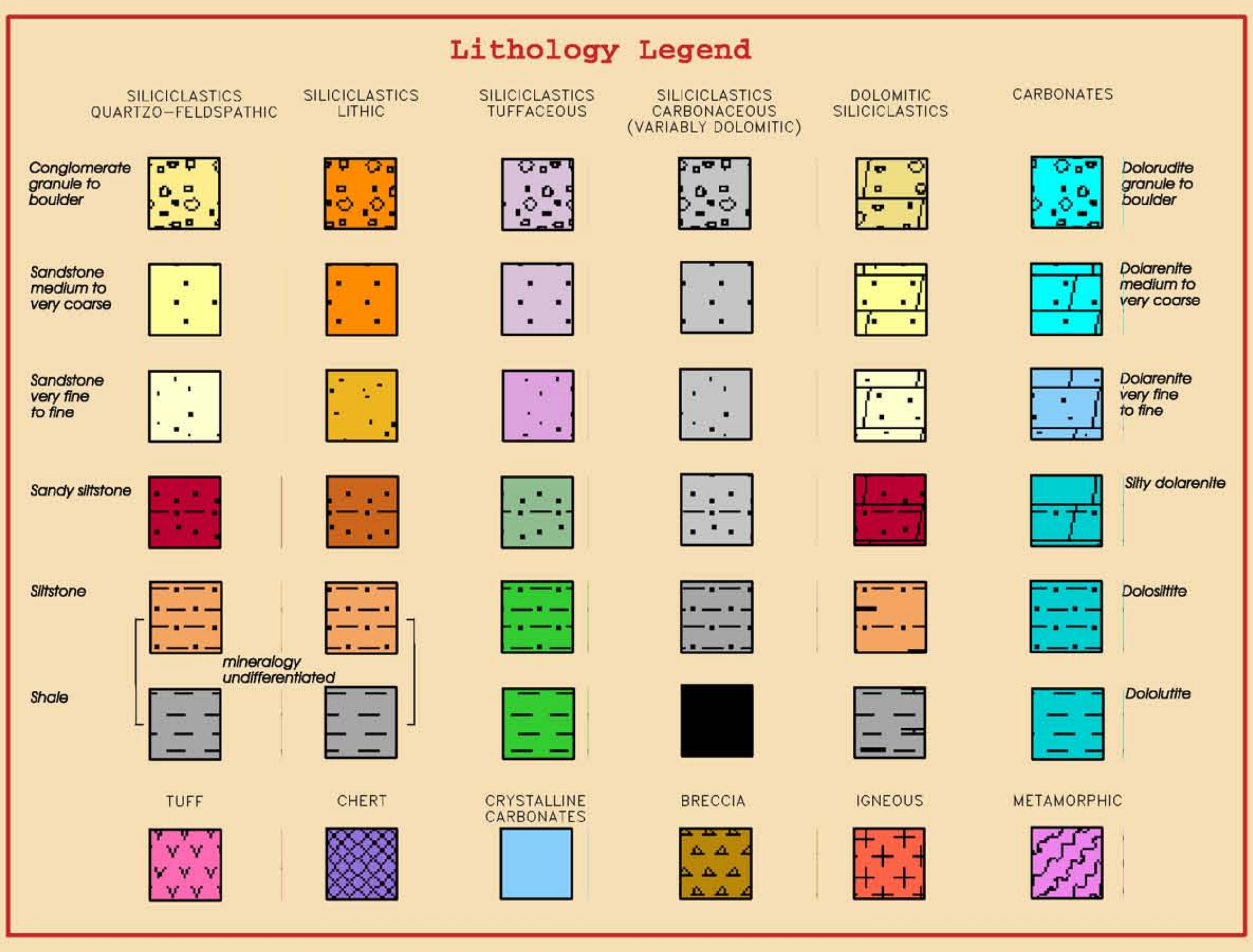
(30 cm thick coarse–grained ooid grainstone)

63–65m: Med–v.crs grained dolomitic sandstone
24–63m: Predominantly stromatolitic dololutite, comprising linked and isolated low domal forms. Stromatolites are commonly silicified.

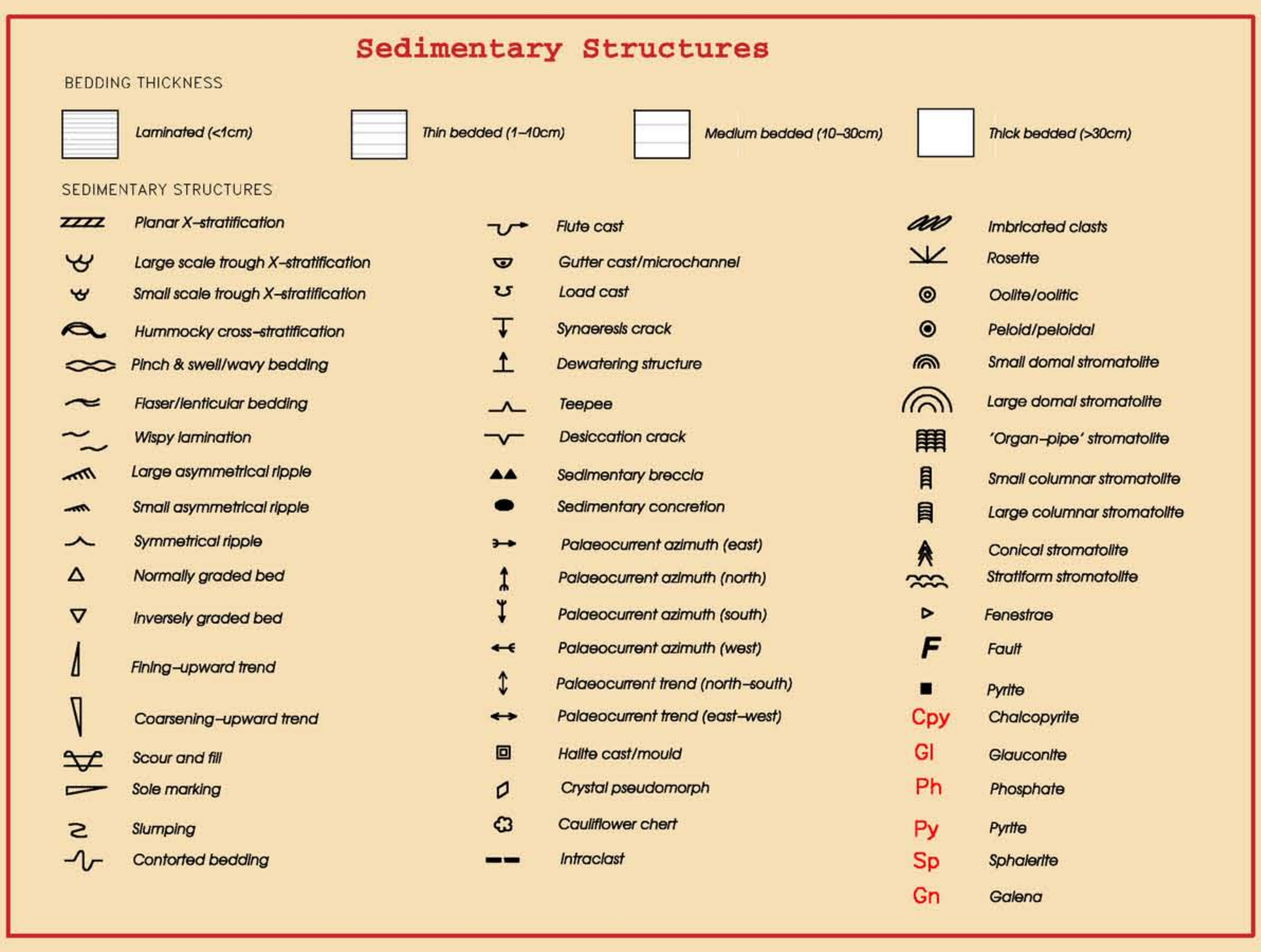
(thin bed of fine grained dolomitic sandstone)

0–24m: Interbedded red dolomitic siltstone/shale and grey–tan stromatolitic dololutite. Red beds are laminated and occasionally rippled and brecciated and contain halite casts and moulds. Stromatolites are mostly laterally linked, low to moderate relief domes, but irregularly silicified stratiform varieties also present. Several beds of fine grained rippled dolomitic sandstone at top.

Lithology Legend



Sedimentary Structures



Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

Copies of this figure may be obtained as a CD ROM product AGSO Record 2000/03 from:
Australian Geological Survey Organisation Sales Centre, GPO Box 378, Canberra ACT 2601.
Phone 02-62499519, Facsimile 02-62499982

Date: 18-Oct-2000

Gum Yard-Stretton

96JJ06

SCALE 1:1000

Easting: 612975

Northing: 81350645

Data type: Measured Section

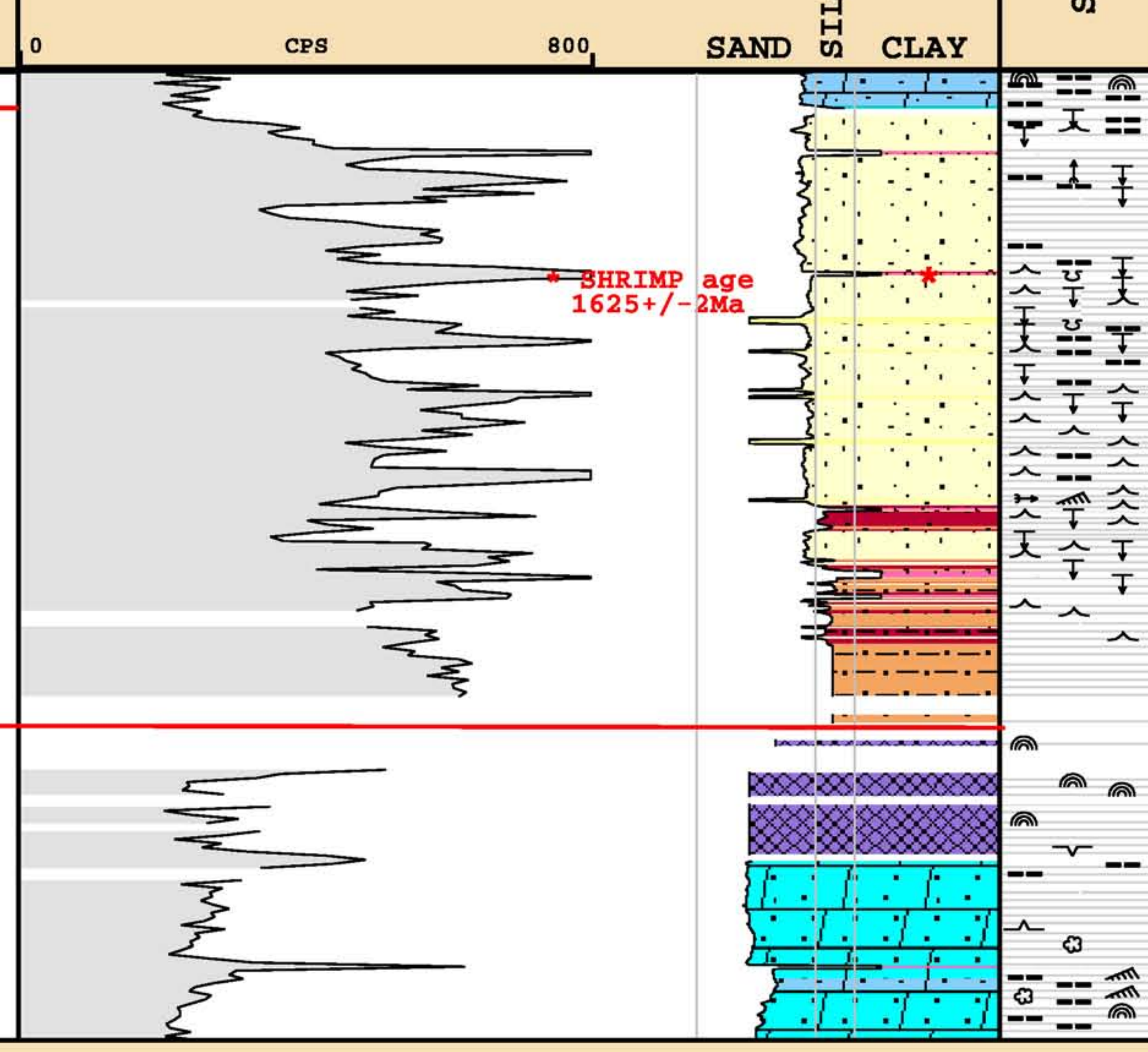
Map sheet: Glyde

Geology: M J Jackson & P N Southgate

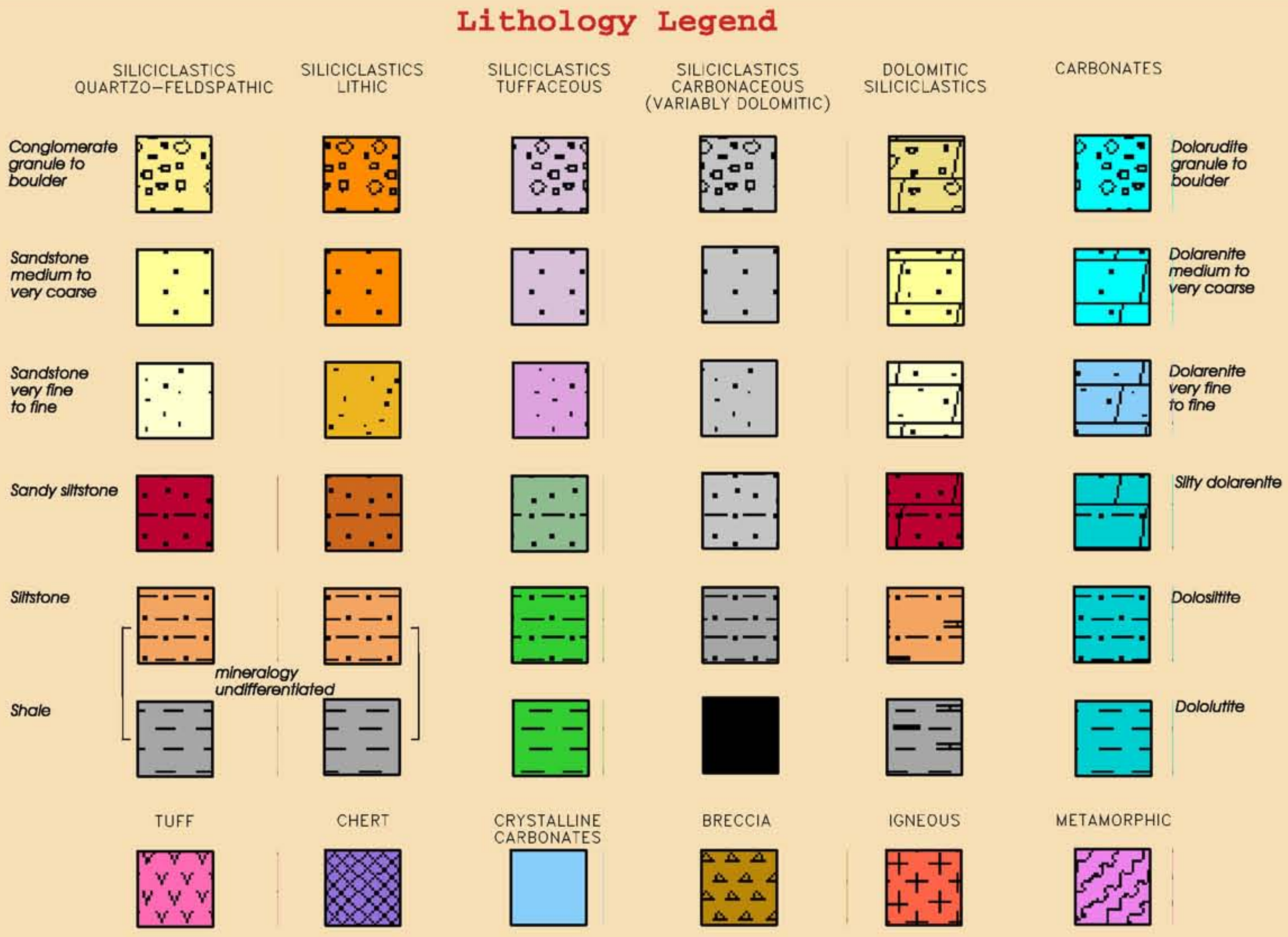
Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)

THICKNESS (metres)	SPLICES	GROUP	FORMATION	MEMBER	SEQUENCES	SYSTEMS TRACTS	TOTAL GAMMA / LITHOLOGY	STRUCTURES	OUTCROP / CORE DESCRIPTION	THICKNESS (metres)
110–40	96/JJ/06	McArthur Group	L.G.F.; Stretton Sandstone		Term Supersequence				114–118m: Chertified intraclastic & stromatolitic dolostone. 114m: Sharp contact with < 5 m erosional relief. 66–114m: Predominantly very fine grained quartz sandstone. Flaggy to fissile with continuous regular parallel to gently undulatory stratification (mostly <2 cm thick). Rare sharp-based thicker beds of fine to medium quartz sandstone with interference rippled tops & internally low-angle wave ripple lamination. Numerous rounded clasts impressions & syneresis cracks. Several sharply-defined pink beds (tuffaceous) between 10–50 cm thick. Upper 5 m is thicker bedded. 48–66m: Predominantly siltstone to vfg sandstone with several pink beds (3–30 cm thick). Parallel to wavy low-angle laminated. Wave ripples & synerersis cracks. 40–48m: Green-purple siltstone, fissile papery shale cleavage, parallel continuous laminated, no current structures.	110–40
40–0			Yalco Formation		River Supersequence				24–39m: Grey-white chert, extensively replaced carbonate rock. Laminated but with probable desiccation cracks @ 25 m and low domal stromatolites. 0–23m: Grey intraclastic & stromatololitic dolostones, irregularly replaced by chert. Dolostones mostly medium to coarse grained dolarenites. Mostly thin bedded to laminated. Poorly preserved low domal stromatolites, irregular current & interference ripples. 30 cm white chert bed @ 10 m (originally tuffaceous?). Small irregular nodules (?replaced sulphate evaporites).	40–0



Lithology Legend



Sedimentary Structures

BEDDING THICKNESS

Laminated (<1cm) · Thin bedded (1–10cm) · Medium bedded (10–30cm) · Thick bedded (>30cm)

SEDIMENTARY STRUCTURES

Planar X-stratification; Large scale trough X-stratification; Small scale trough X-stratification; Hummocky cross-stratification; Pinch & swell/wavy bedding; Flaser/lenticular bedding; Wispy lamination; Large asymmetrical ripple; Small asymmetrical ripple; Symmetrical ripple; Normally graded bed; Inversely graded bed; Fining-upward trend; Coarsening-upward trend; Scour and fill; Sole marking; Slumping; Contorted bedding

Flute cast; Gutter cast/microchannel; Load cast; Synaeresis crack; Dewatering structure; Teepee; Desiccation crack; Sedimentary breccia; Sedimentary concretion; Palaeocurrent azimuth (east); Palaeocurrent azimuth (north); Palaeocurrent azimuth (south); Palaeocurrent azimuth (west); Palaeocurrent trend (north-south); Palaeocurrent trend (east-west); Halite cast/mould; Crystal pseudomorph; Cauliflower chert; Intraclast

Imbricated clasts; Rosette; Ooilite/oolitic; Peloid/peloidal; Small domal stromatolite; Large domal stromatolite; 'Organ-pipe' stromatolite; Small columnar stromatolite; Large columnar stromatolite; Conical stromatolite; Stratiform stromatolite; Fenestrae; F Fault; Pyrite; Cpy Chalcopyrite; Gl Glauconite; Ph Phosphate; Py Pyrite; Sp Sphalerite; Gn Galena

Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

Copies of this figure may be obtained as a CD ROM product AGSO Record 2000/03 from:
Australian Geological Survey Organisation Sales Centre, GPO Box 378, Canberra ACT 2601.
Phone 02-62499519, Facsimile 02-62499982 Date: 19-Oct-2000

Kilgour-Tatoola

77/09

SCALE 1:1000

Easting: 598500

Northing: 8114700

Data type: Measured Section

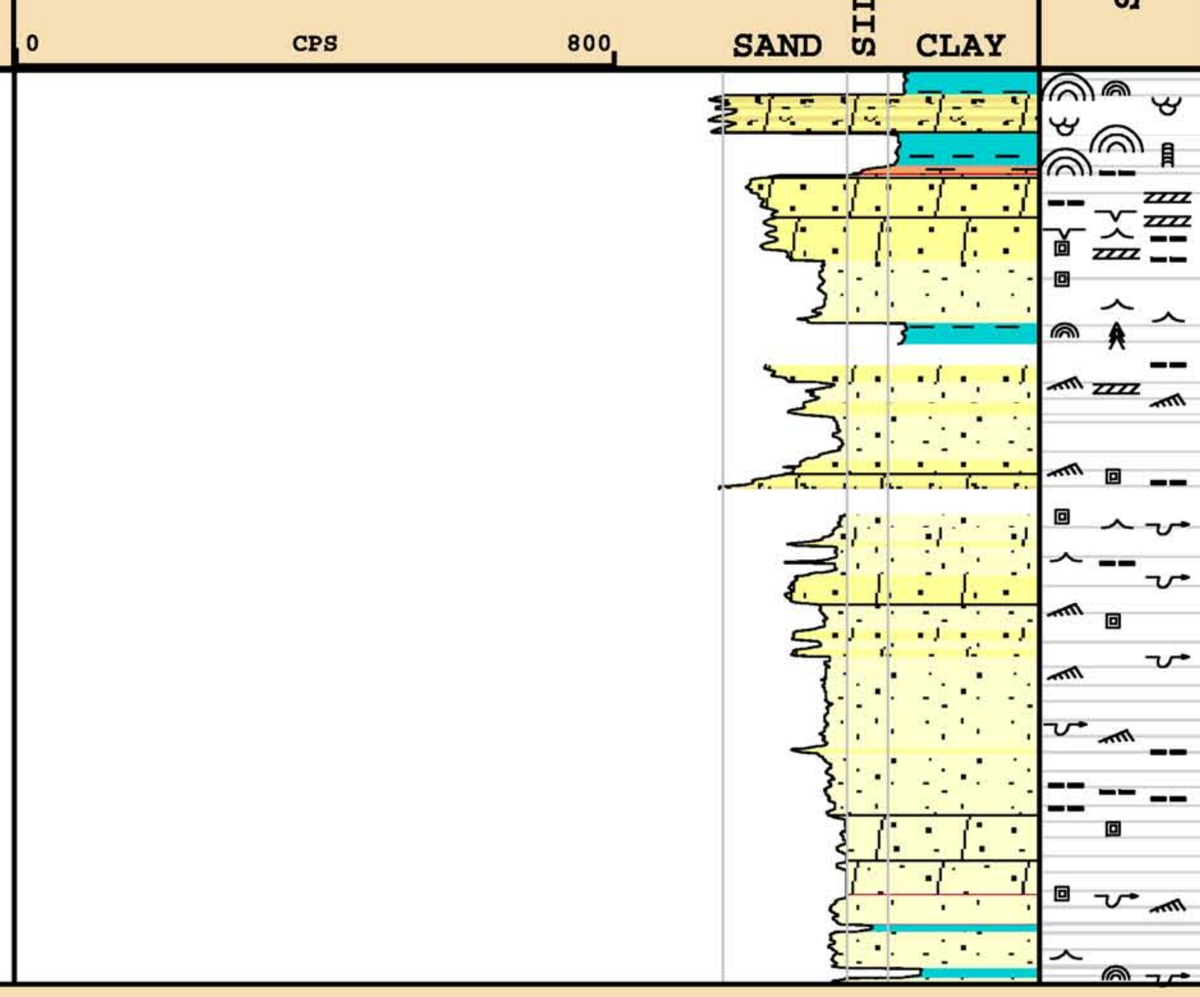
Map sheet: Kilgour

Geology: J Jackson & P Southgate

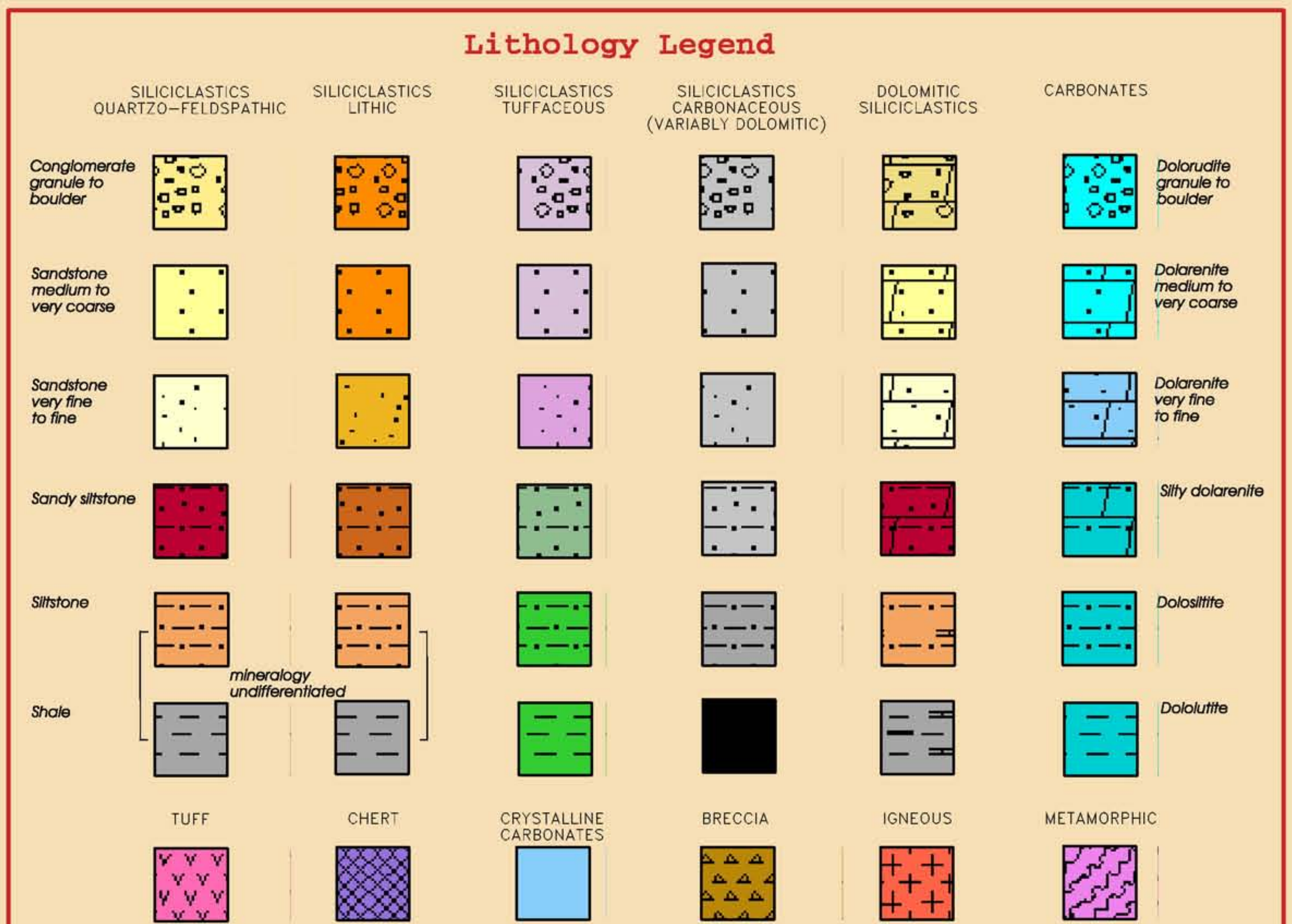
Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)

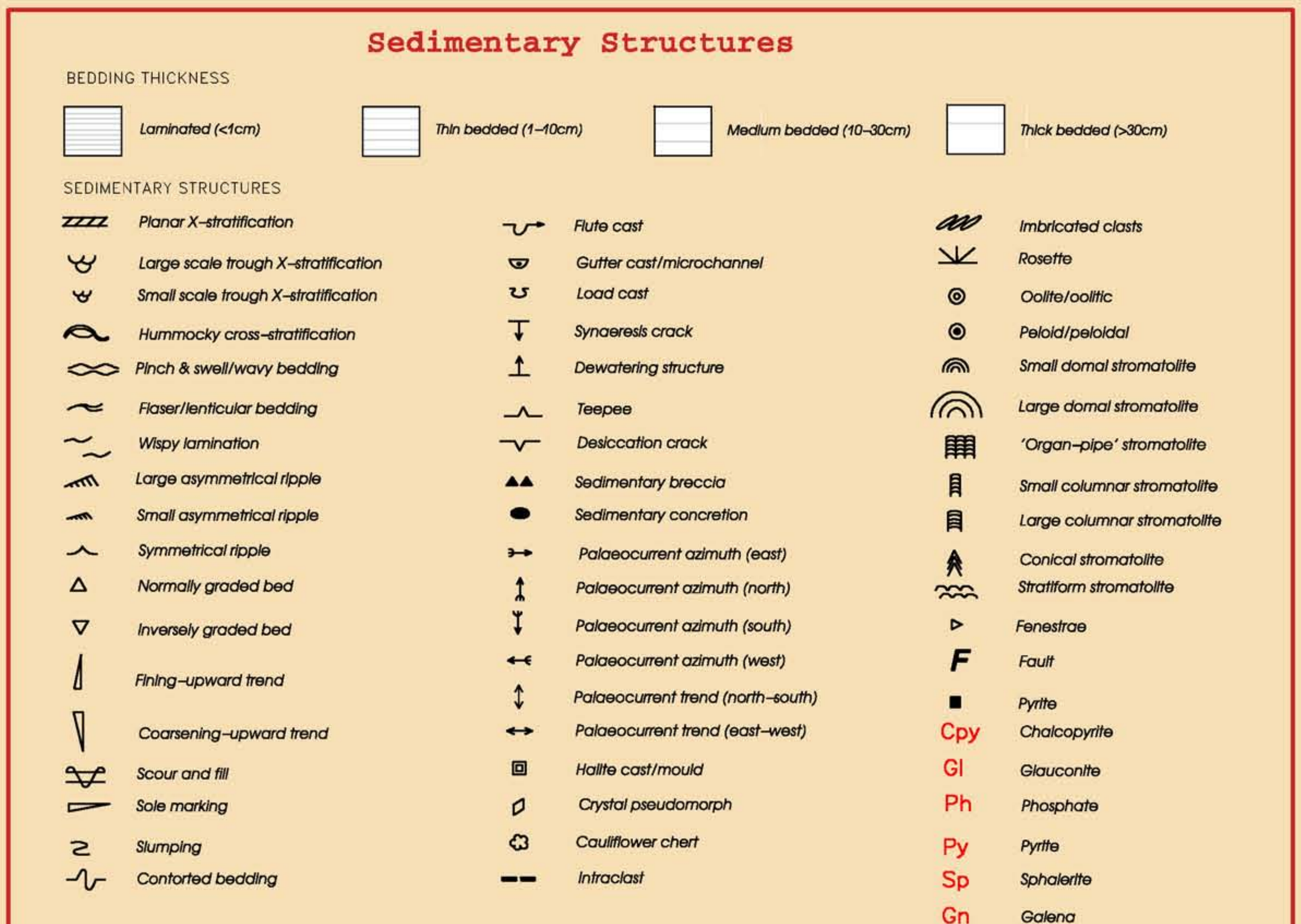
THICKNESS (metres)	SPLICES	GROUP	FORMATION	MEMBER	SEQUENCES	SYSTEMS TRACTS	TOTAL GAMMA / LITHOLOGY	STRUCTURES	OUTCROP / CORE DESCRIPTION	THICKNESS (metres)
0–100	77/09	McArthur Group	T.F. / Tatoola Sandstone		Loretta Supersequence				95–107m: Interbedded stromatolitic dololutite and very coarse-grained, pebbly dolomitic sandstone. 85–95m: Medium grained dolomitic sandstone that coarsens up to coarse cross-bedded sandstone with intraclasts and rare desiccation-cracked mudstone layers. 78–85m: (as 0–72m) 72–78m: Poorly outcropping stromatolitic dololutite with domal and conical forms. 0–72m: Predominantly very fine-fine grained quartz sandstone, but with medium grained and dolomitic intervals. Mostly thin bedded, distinctly flaggy. Numerous low-amplitude current and wave ripples, and surface markings (including prod, groove, scrape and rounded clast impressions). Halite casts and moulds also common.	0–100



Lithology Legend



Sedimentary Structures



Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

Copies of this figure may be obtained as a CD ROM product AGSO Record 2000/03 from:
Australian Geological Survey Organisation Sales Centre, GPO Box 378, Canberra ACT 2601.
Phone 02-62499519, Facsimile 02-62499982 Date: 05-Oct-2000

Mallapunyah Creek-Tatoola

96JJ08

SCALE 1:1000

AUSTRALIA

Easting: 589600

Northing: 8128400

Data type: Measured section

Map sheet: Mallapunyah

Geology: M J Jackson & P N Southgate

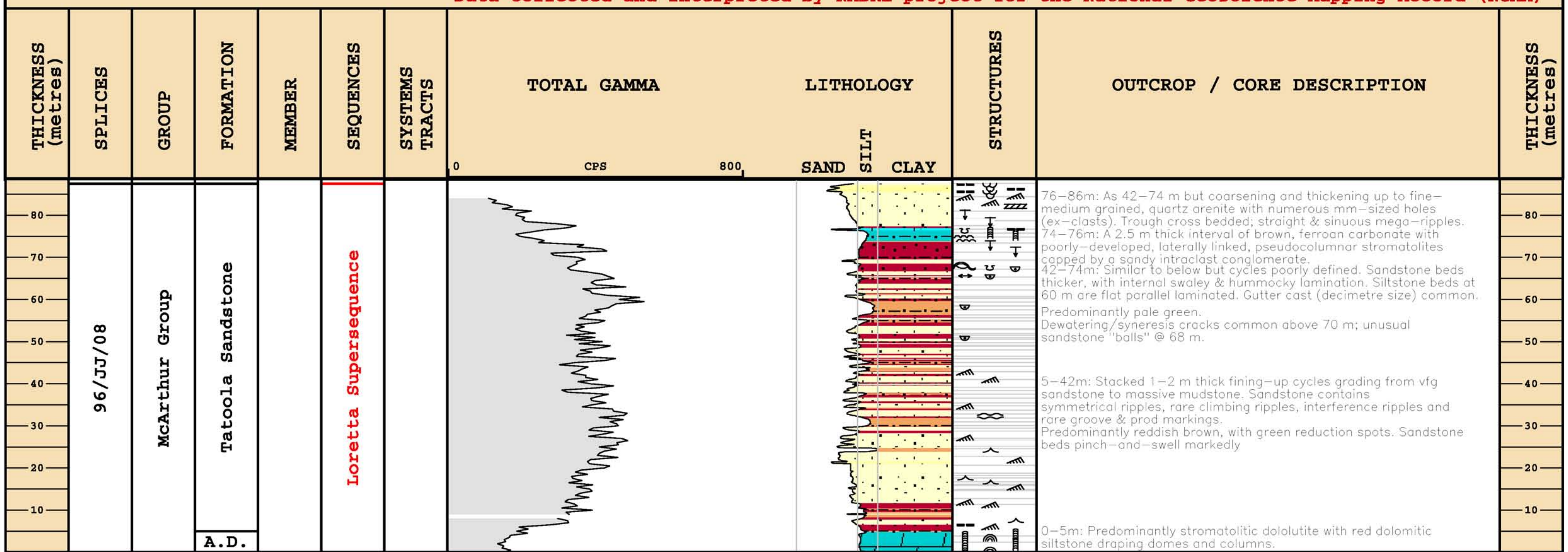
Geolog compilation: K Barnett & I Zeilinger

DEPARTMENT OF MINES AND ENERGY

NORTHERN TERRITORY DEPARTMENT OF MINES AND ENERGY

AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)



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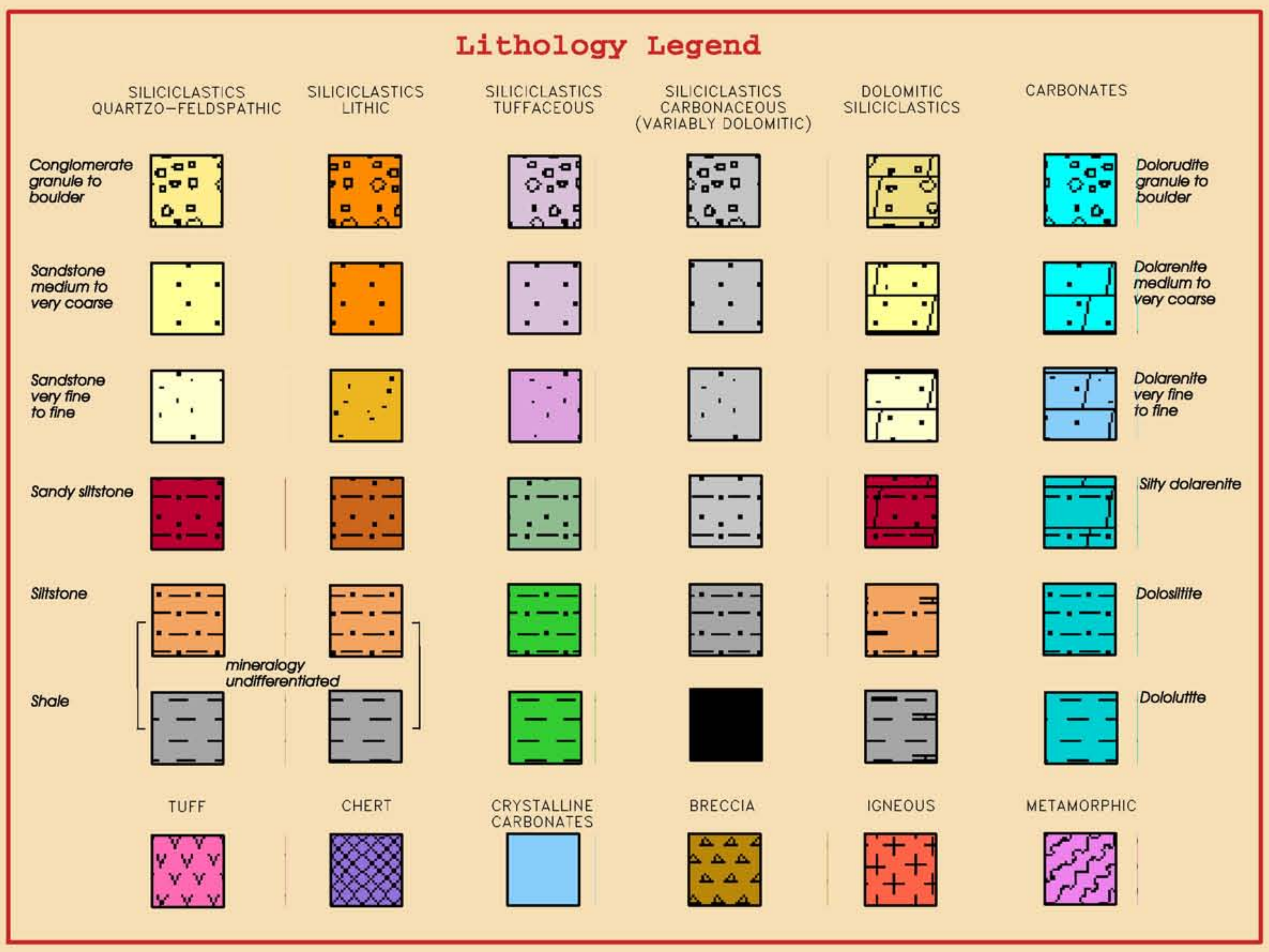
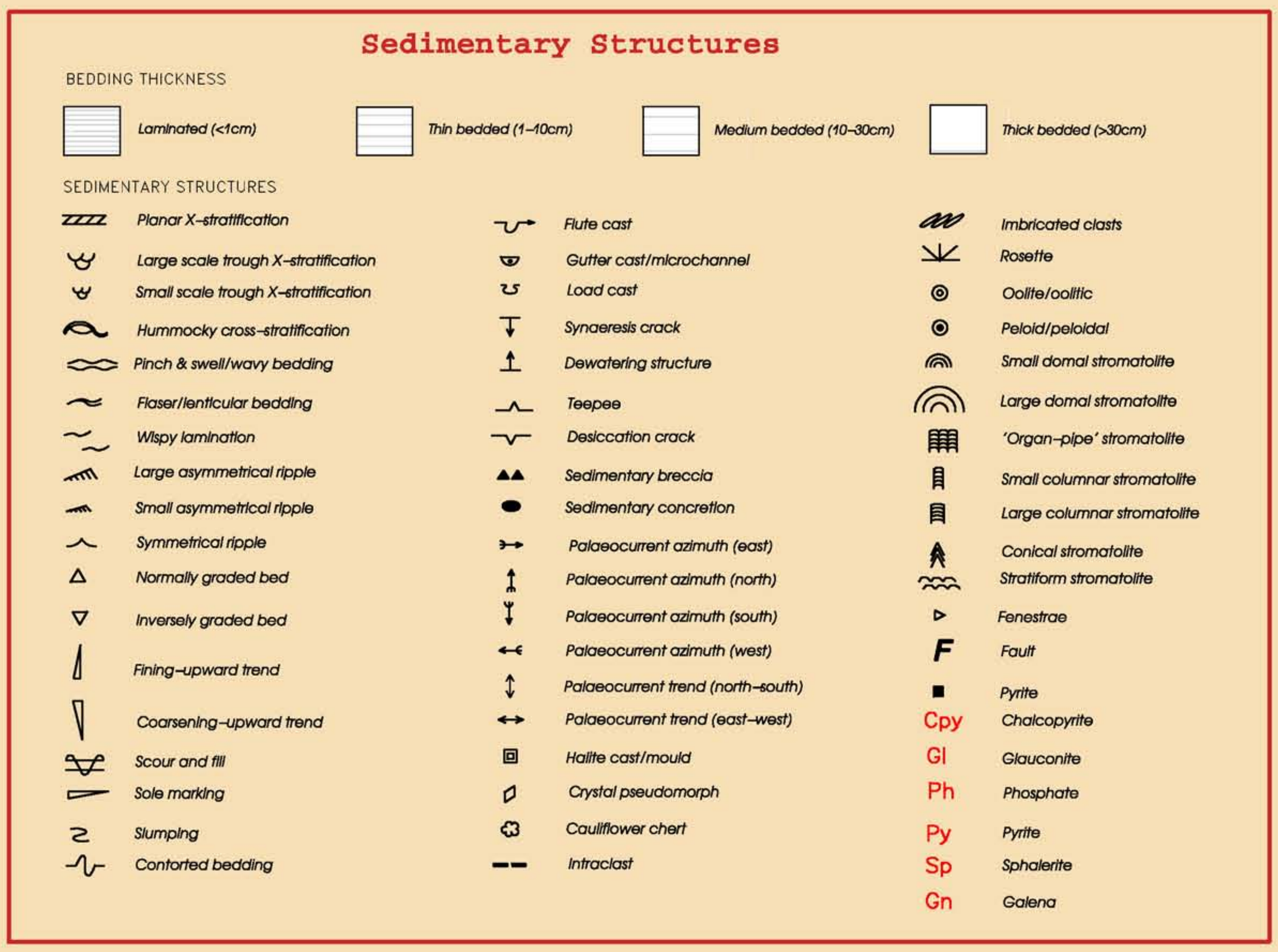
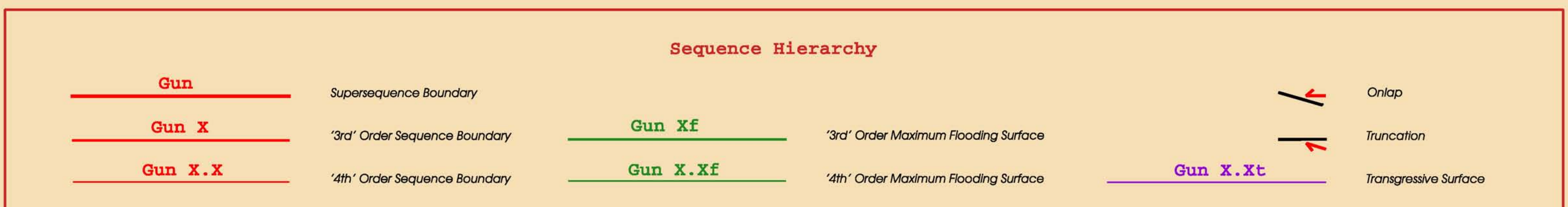


Sedimentary Structures



Sequence Hierarchy



NOTE: Gun Supersequence used as an example.

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Date: 05–Oct–2000

Mid Kilgour Composite

95PS07, 96JJ05

SCALE 1:1000

Easting: 598600

Northing: 8114900

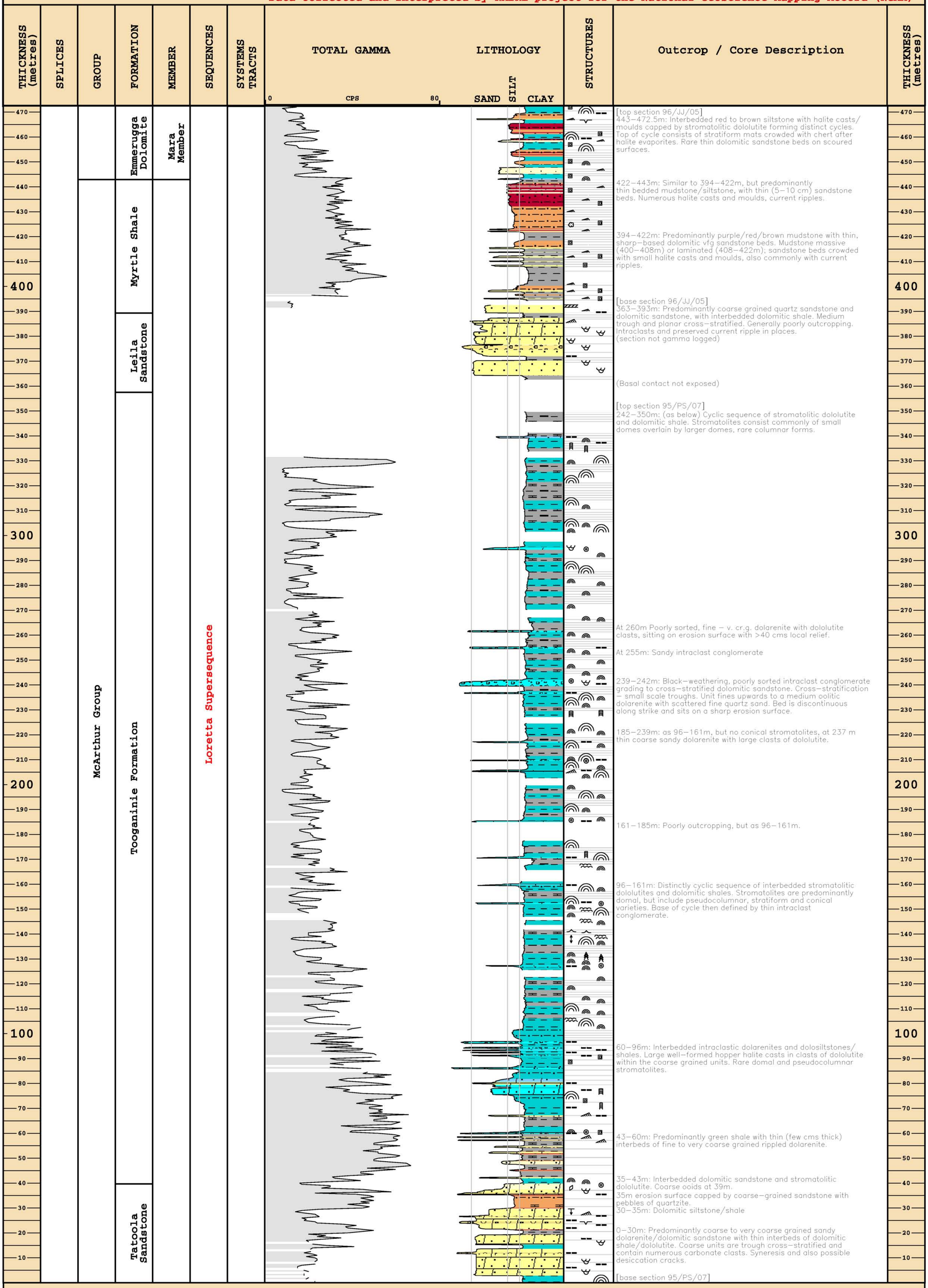
Data type: Measured Section

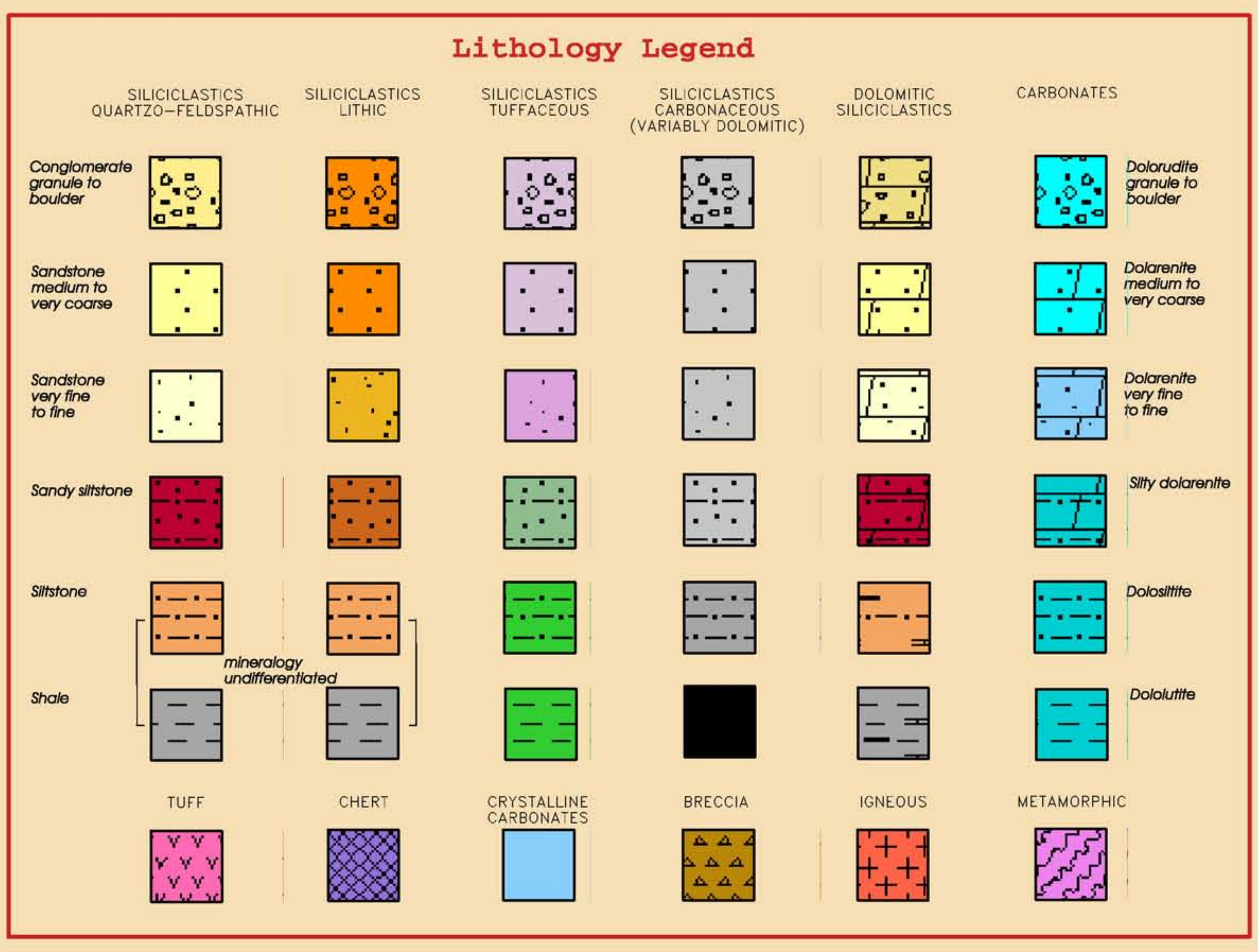
Map sheet: Kilgour

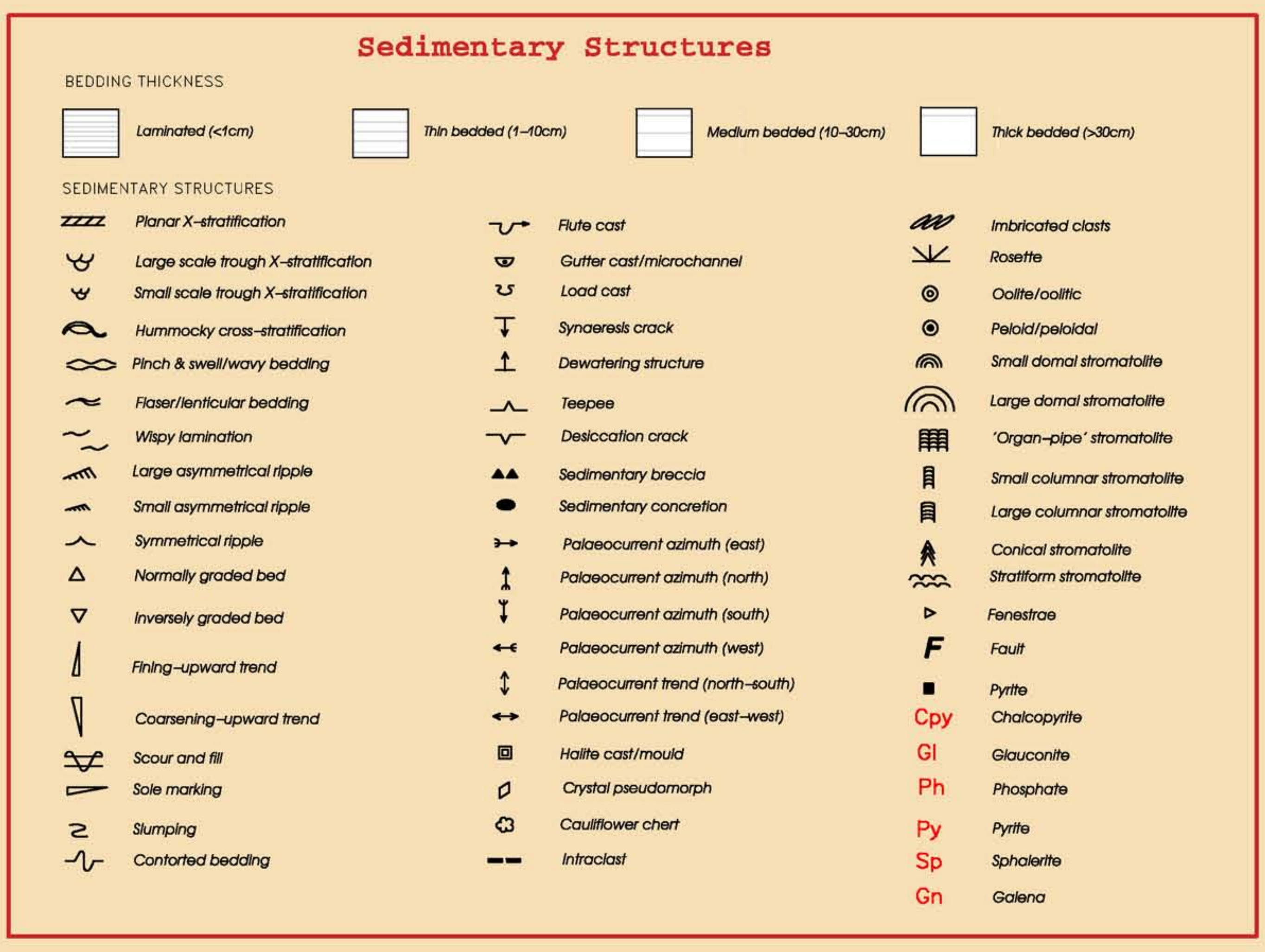
Geology: M J Jackson & P N Southgate

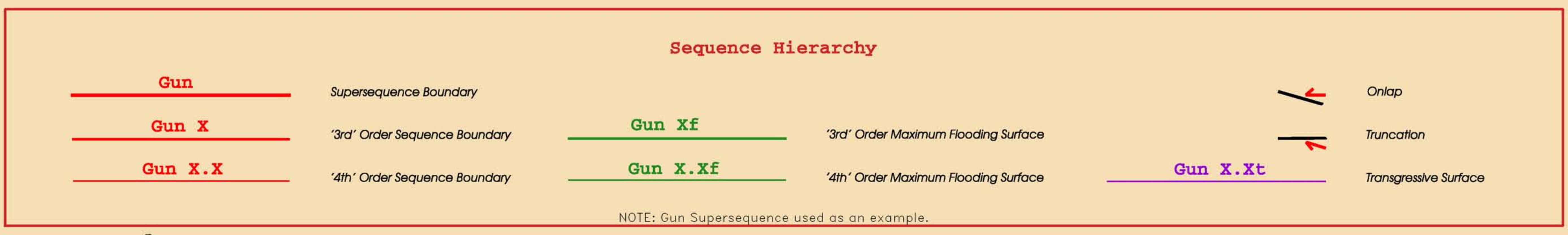
Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)









Copies of this figure may be obtained as a CD ROM product
AGSO Record 2000/03 from:
Australian Geological Survey Organisation Sales Centre,
GPO Box 378, Canberra ACT 2601.
Phone 02–62499519, Facsimile 02–62499982 Date: 05–Oct–2000

Mount Birch Composite

SCALE 1:1000

Easting: 469095

Northing: 8365848

Data type: Measured Section

Map sheet: Urapunga

Geology: J Jackson & P Southgate

Geolog compilation: K Barnett & I Zeilinger

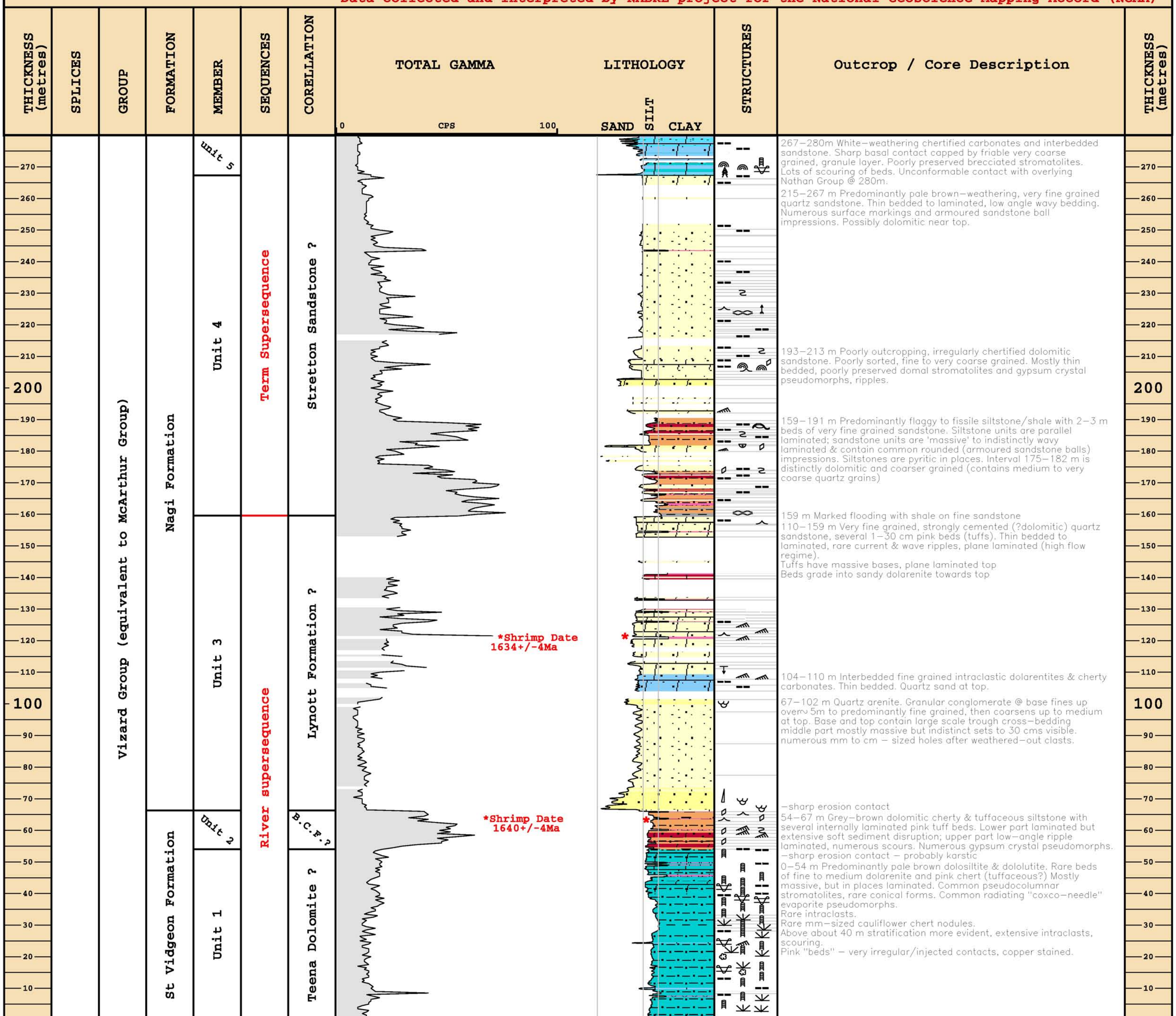
AUSTRALIA

DEPARTMENT OF MINES AND ENERGY

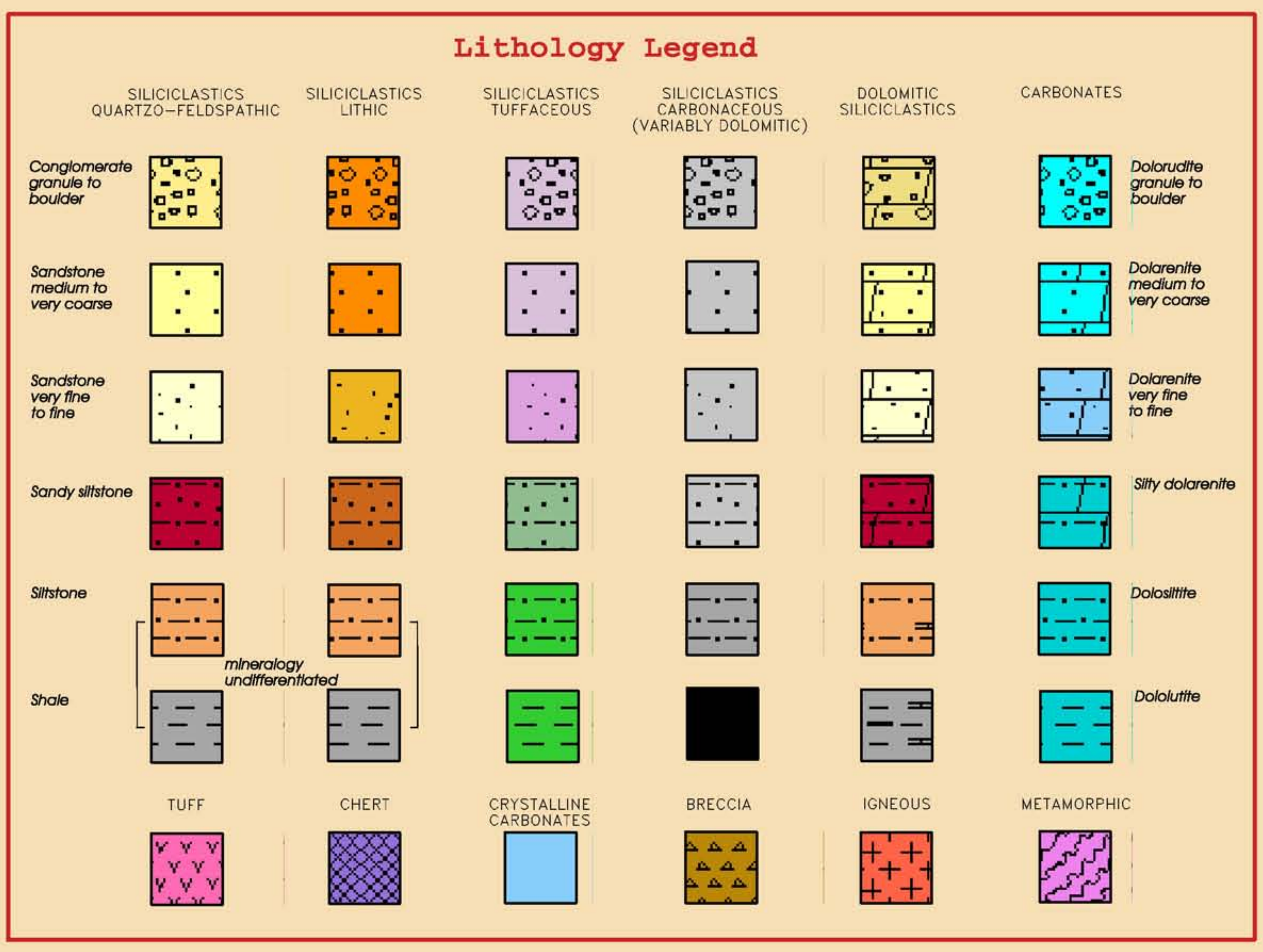
NORTHERN TERRITORY · DEPARTMENT OF MINES AND ENERGY

AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

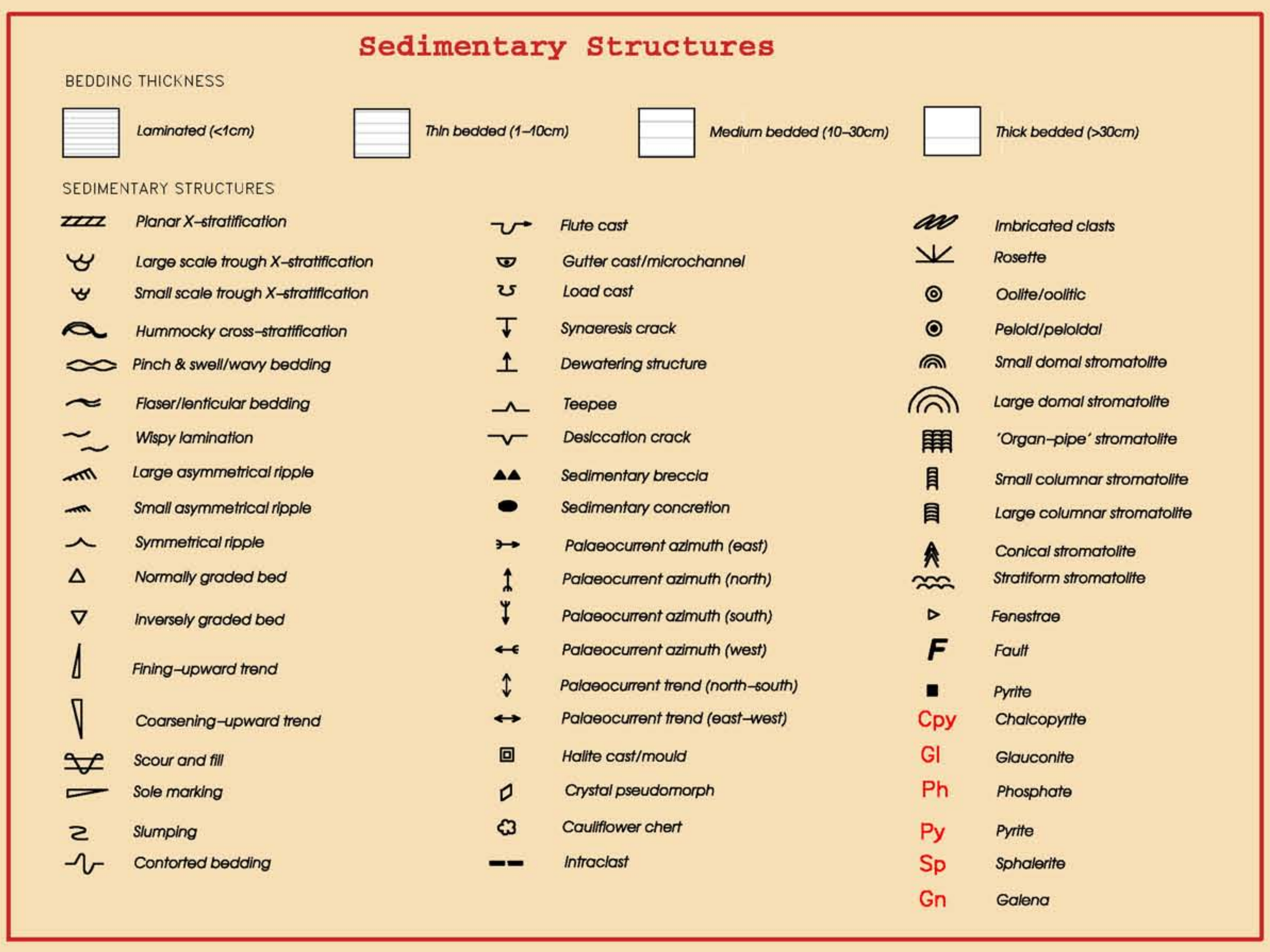
Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)



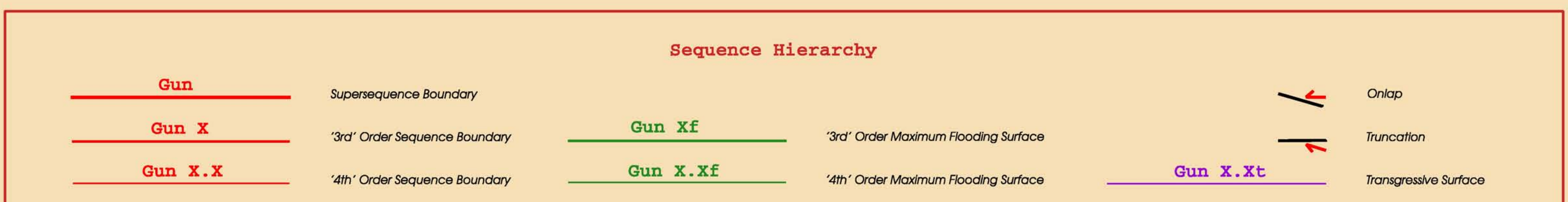
Lithology Legend



Sedimentary Structures



Sequence Hierarchy



NOTE: Gun Supersequence used as an example.

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Australian Geological Survey Organisation Sales Centre,
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Phone 02–62499519, Facsimile 02–62499982 Date: 19–Oct–2000

Top Crossing North

TopC_N

SCALE 1:1000

Easting: 576850

Northing: 8152300

Data type: Measured Section

Map sheet: Mallapunyah

Geology: P R Winefield (University of Tasmania) & S A Abbott (NTGS)

Geolog compilation: K Barnett & I Zeilinger

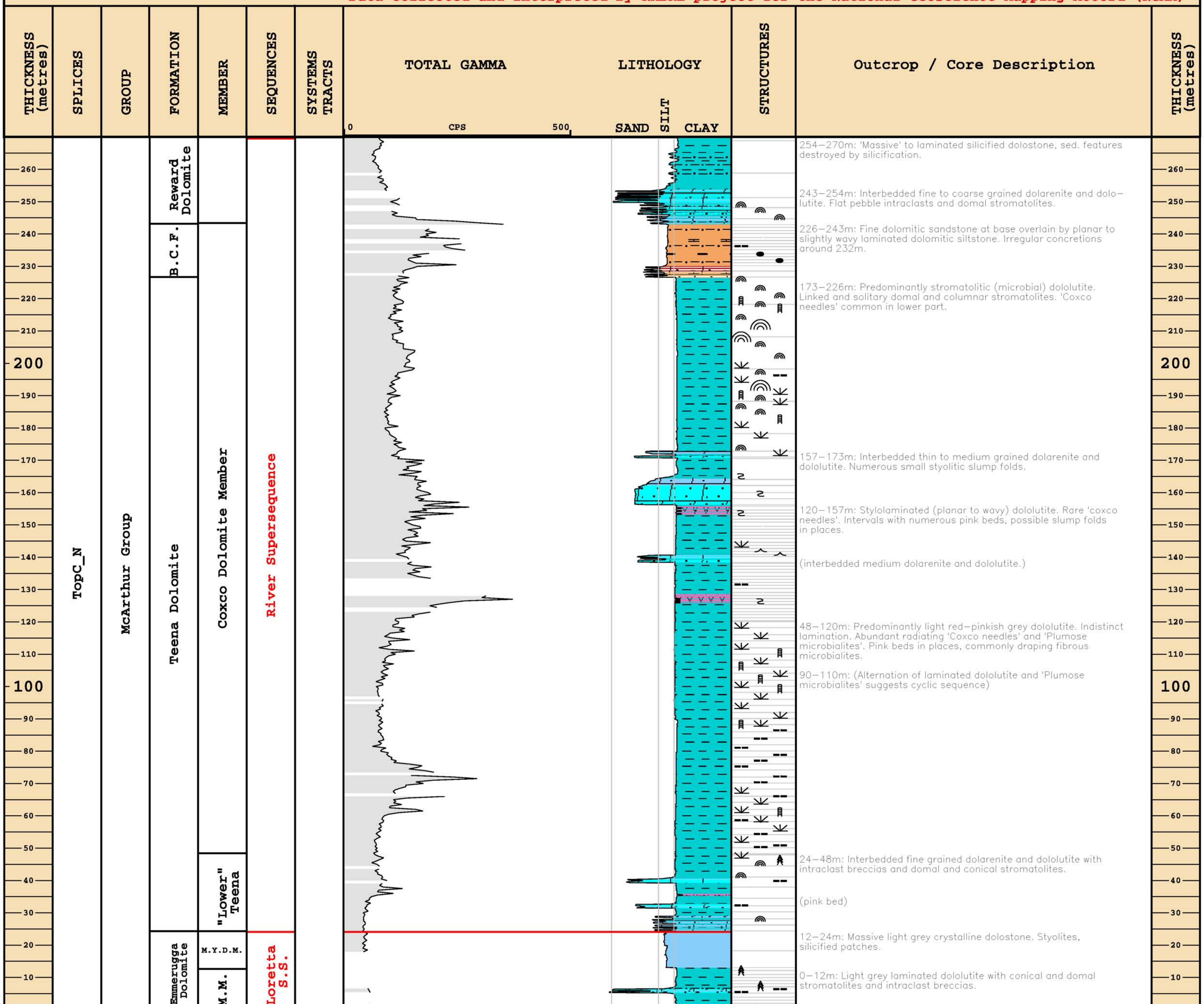
AUSTRALIA

DEPARTMENT OF MINES AND ENERGY

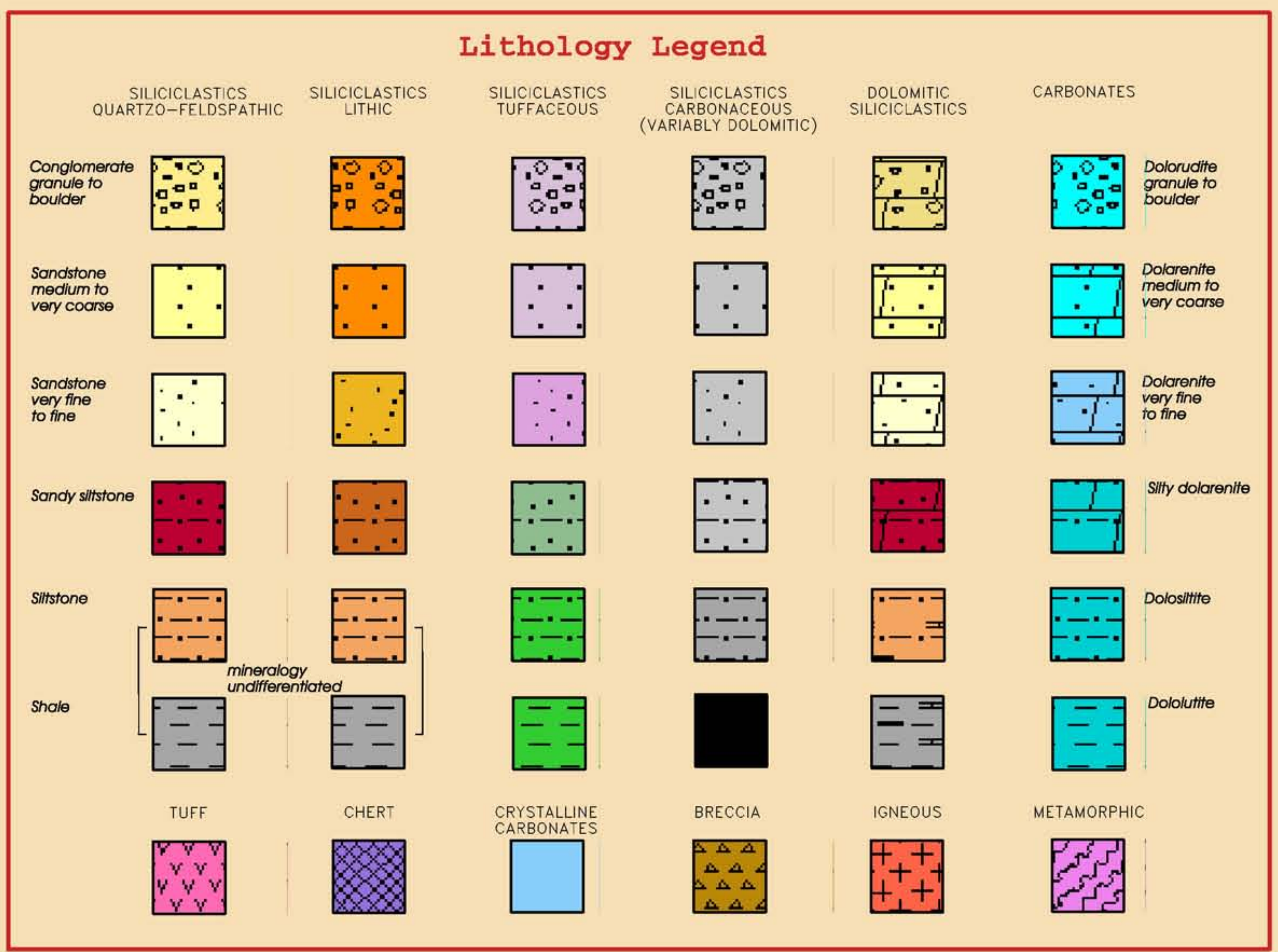
NORTHERN TERRITORY · DEPARTMENT OF MINES AND ENERGY

AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

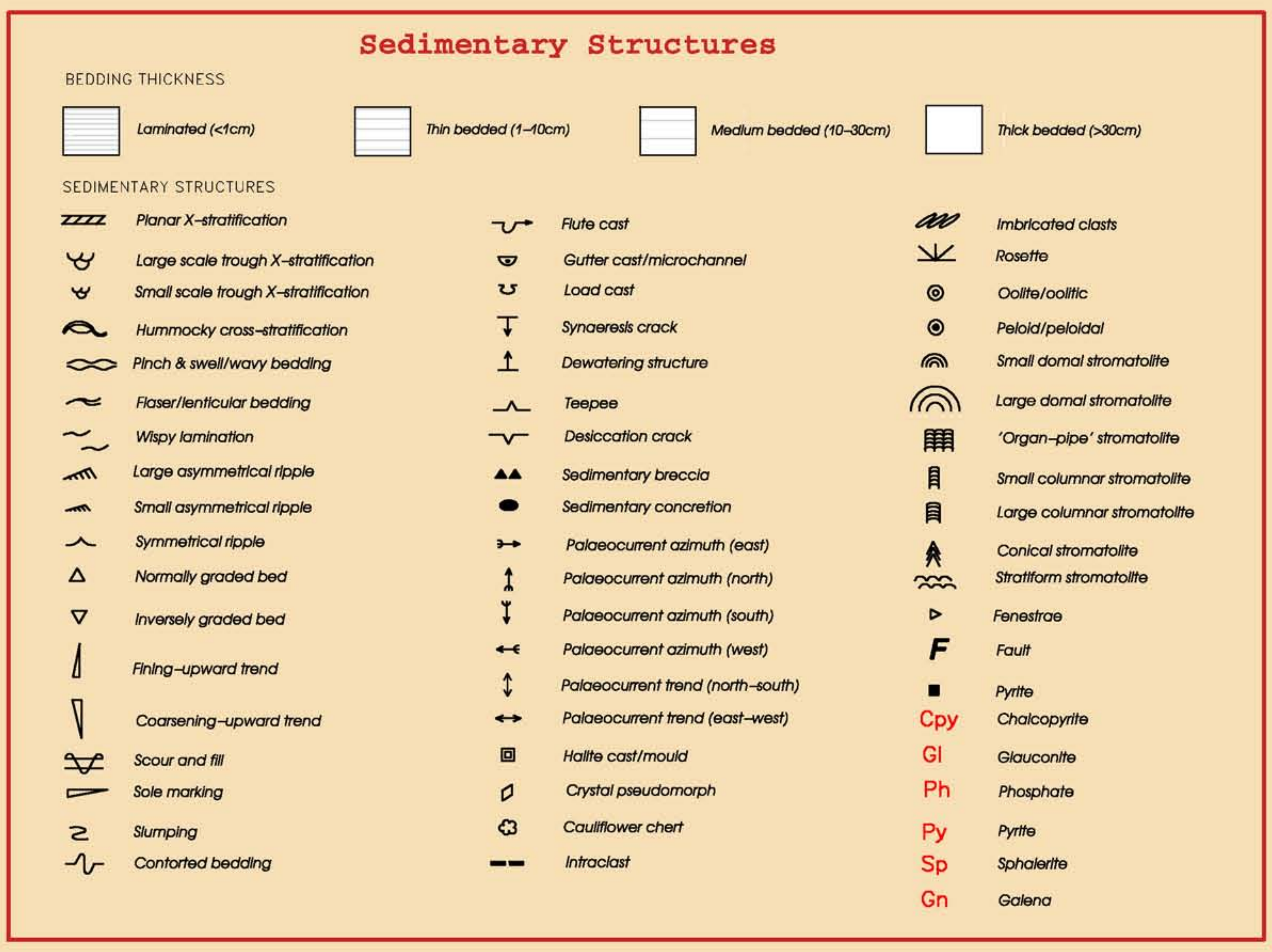
Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)



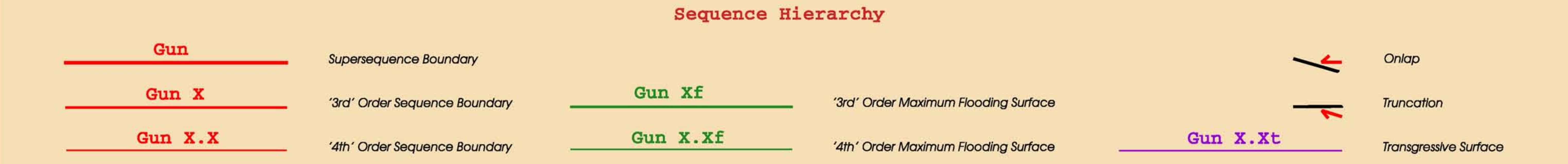
Lithology Legend



Sedimentary Structures



Sequence Hierarchy



Copies of this figure may be obtained as a CD ROM product AGSO Record 2000/03 from:
Australian Geological Survey Organisation Sales Centre,
GPO Box 378, Canberra ACT 2601.
Phone 02–62499519, Facsimile 02–62499982 Date: 19–Oct–2000

Top Crossing South

TopC_S

SCALE 1:1000

Easting: 574926

Northing: 8143531

Data type: Measured Section

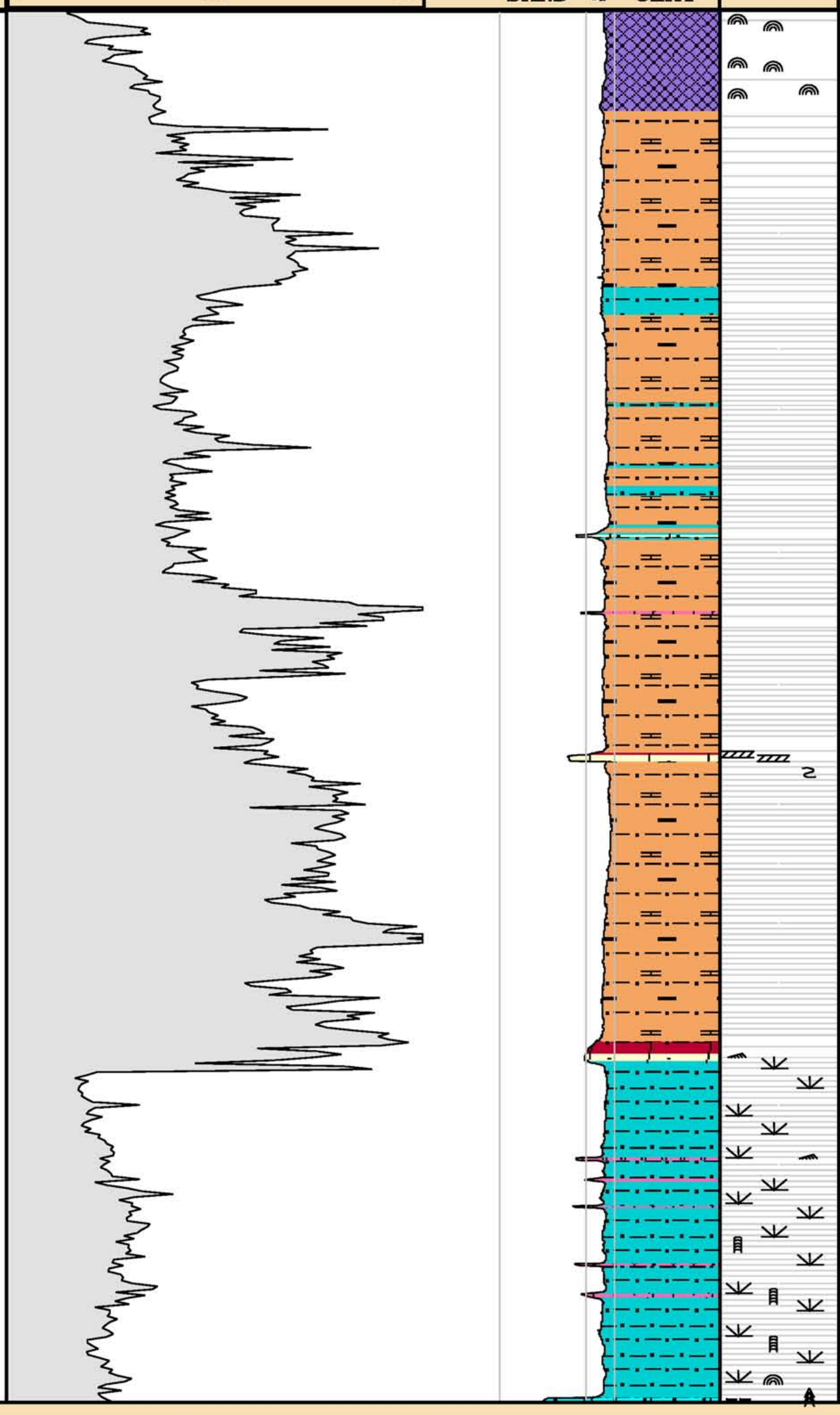
Map sheet: Mallapunyah

Geology: P R Winefield (University of Tasmania)

Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)

THICKNESS (metres)	SPLICES	GROUP	FORMATION	MEMBER	SEQUENCES	SYSTEMS TRACTS	TOTAL GAMMA / LITHOLOGY	STRUCTURES	OUTCROP / CORE DESCRIPTION	THICKNESS (metres)
0–230	TopC_S	McArthur Group	R.D. (top); Barney Creek Formation; Teena Dolomite	Coxco Dolomite Member; L.T.	River Supersequence		0 CPS 500; SAND SILT CLAY			0–230



218–234m: Silicified dolostones (very poor outcrop) with probable domal stromatolites

57–218m: Thinly laminated to thinly bedded, dark brown dololutite and dolomitic siltstone. Rare intervals slightly coarser grained with planar cross-lamination.

Several 10–20 cm 'massive' beds of light grey dololutite.

5 cm bed of carbonaceous dolomitic siltstone.

(pink bed)

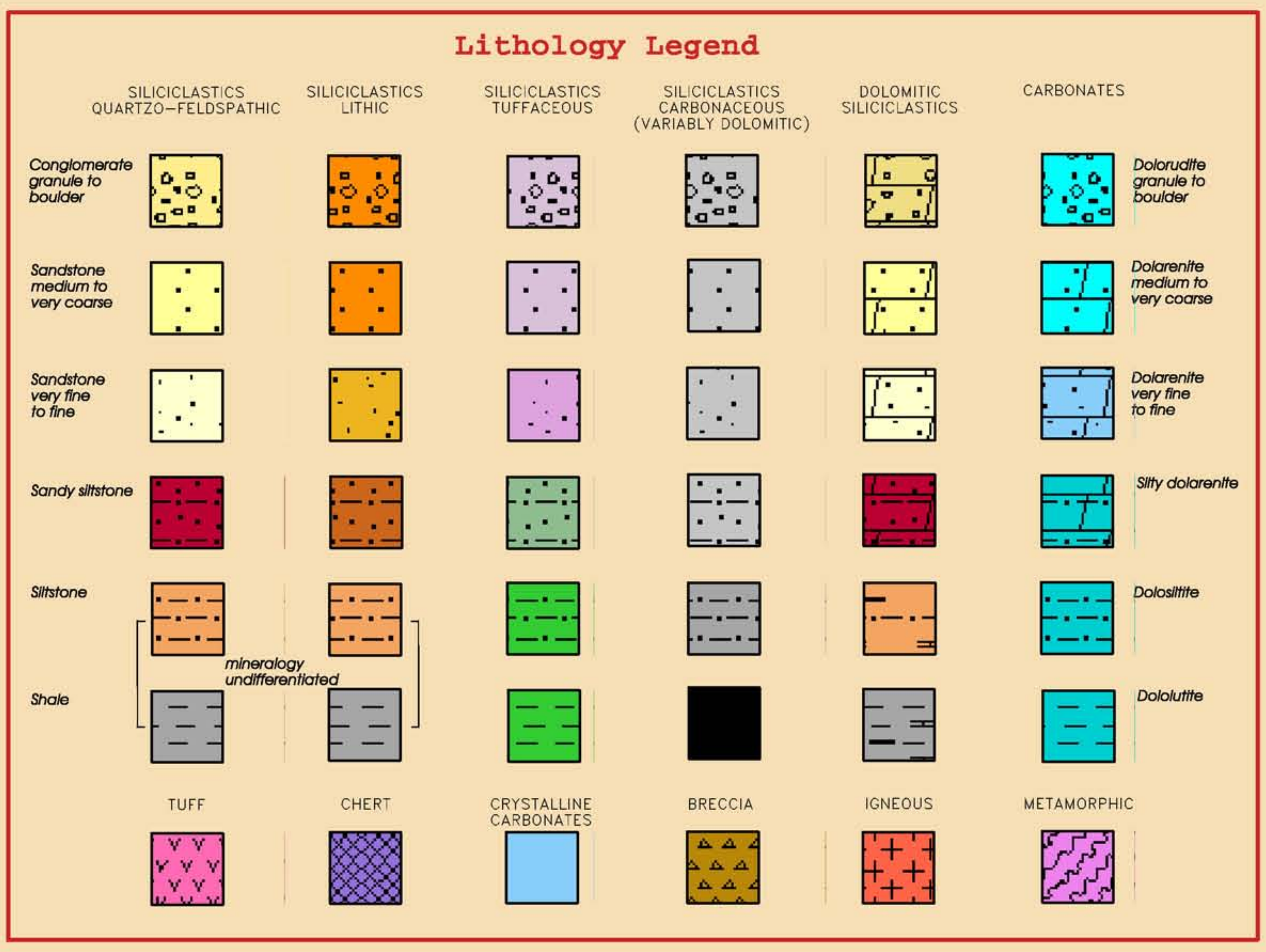
several thin beds of vfg dolarenite

(sharp contact)

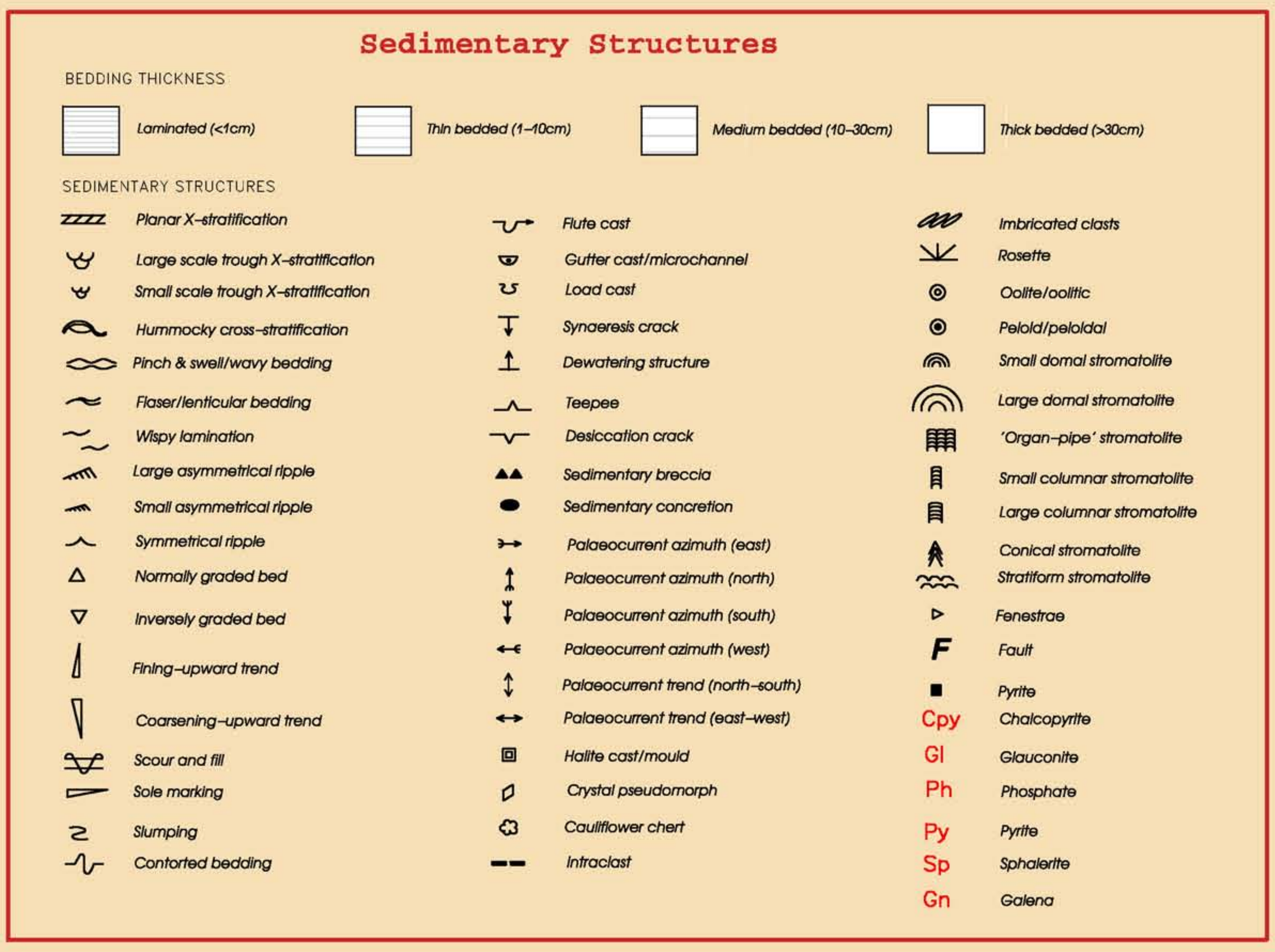
2–57m: Predominantly tan to light grey, stromatolitic dololutite with abundant 'Coxco needles'. Several pink-weathering beds, in places with internal lamination, draped over stromatolite columnar/mounds. Irregularly coarsely crystalline and silicified vughy in upper 3 m.

0–2m: Intraclast conglomerate and stromatolitic dololutite

Lithology Legend



Sedimentary Structures



Sequence Hierarchy

Gun	*Supersequence Boundary*				*Onlap*
Gun X	*'3rd' Order Sequence Boundary*	Gun Xf	*'3rd' Order Maximum Flooding Surface*		*Truncation*
Gun X.X	*'4th' Order Sequence Boundary*	Gun X.Xf	*'4th' Order Maximum Flooding Surface*	Gun X.Xt	*Transgressive Surface*

NOTE: Gun Supersequence used as an example.

Copies of this figure may be obtained as a CD ROM product
AGSO Record 2000/03 from:
Australian Geological Survey Organisation Sales Centre,
GPO Box 378, Canberra ACT 2601.
Phone 02-62499519, Facsimile 02-62499982 Date: 19-Oct-2000

Top Crossing West

96/JJ/10, 96/JJ/04

SCALE 1:1000

Easting: 575900

Northing: 8153000

Data type: Measured Section

Map sheet: Malapunyah

Geology: S Abbott (NTGS), M J Jackson & P N Southgate

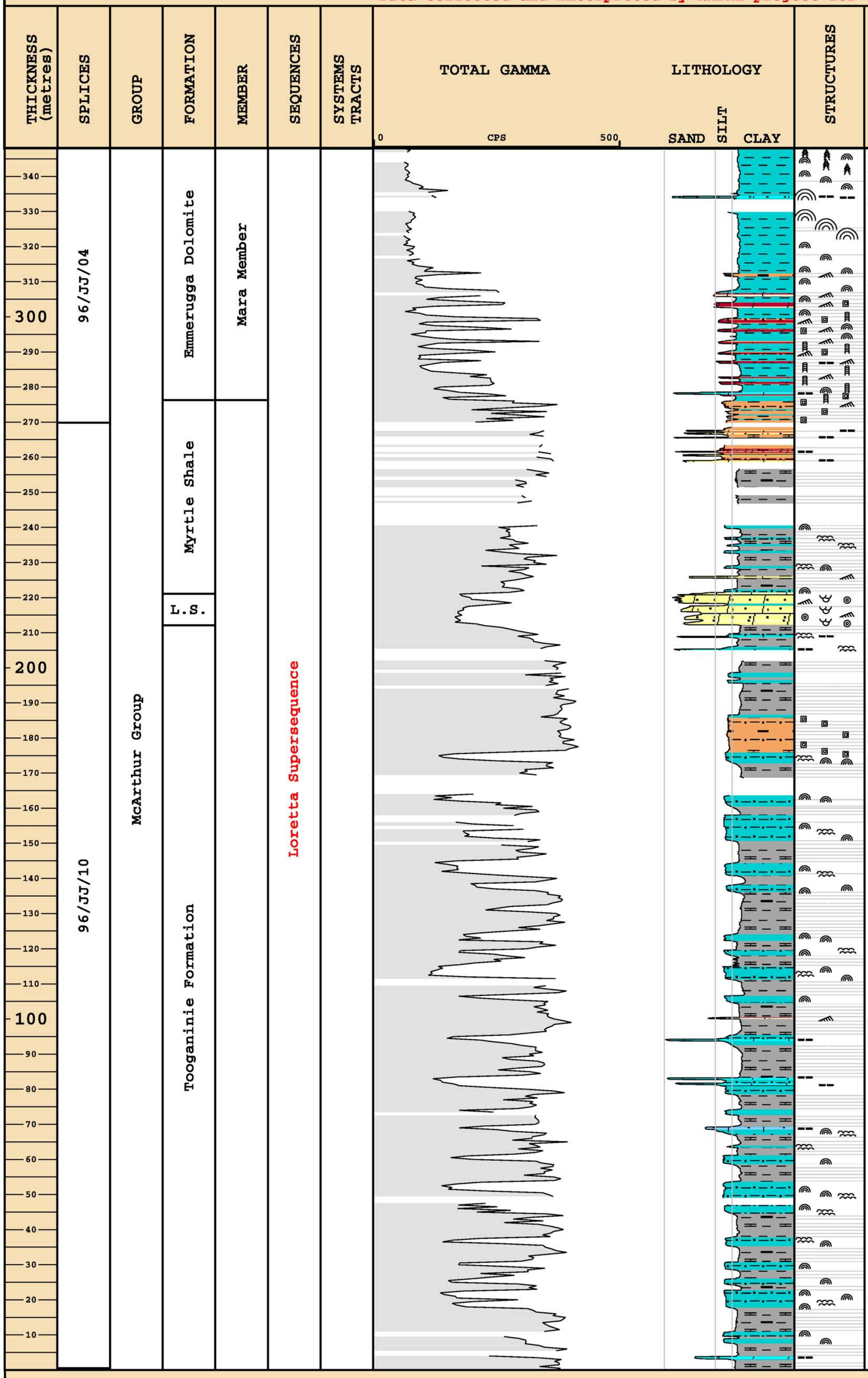
Geolog compilation: K Barnett & I Zeilinger

DEPARTMENT OF MINES AND ENERGY

NORTHERN TERRITORY DEPARTMENT OF MINES AND ENERGY

AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)



OUTCROP / CORE DESCRIPTION

312–348m: Dark grey stromatolitic dolostone with irregular to nodular dark grey to black chert. Stromatolites dominantly small and large domes, but branched conical forms above 340 m.
No obvious cycles, mostly medium to thick bedded, flat pebble intraclast conglomerate @ 334 m.

276–312m: Interbedded grey stromatolitic dololutites and red/brown dolomitic siltstone/silty dolostone. These form distinct cycles with stromatolitic bases and silty top. Stromatolites include laterally–linked columnar/pseudocolumnar forms and small domes with over–hanging margins; tops of stromatolitic units contain sucrosic chert after halite and large skeletal halite hopper & pagoda pseudomorphs. Silty units contain intraclasts, numerous halite hopper pseudomorphs and current ripples.

270–276m: Interbedded red dolomitic siltstone/mudstone and grey shaley dololutite. Thin bedded to laminated. Graded beds, ripples, numerous halite casts and moulds.

258–268m: Red dolomitic siltstone/shale interbedded with intraclast breccias.

222–256m: Laminated muddy dololutite – dolomitic shale. Dololutite beds generally poorly exposed, but contain small stratiform and domal stromatolites.

@ 226m: Fine grained quartz sandstone bed (3 cm thick).
@ 222m: Stromatolitic dololutite resting on sharp upper contact of sandstone
212–221m: Medium to coarse grained oolitic dolarenite interbedded with dolomitic quartz sandstone. Large–scale trough cross–bedding, numerous current ripples. Thin interval of dolomitic shale
@ 212m: Sharp erosional contact at base of sandstone.
186–212m: Predominantly shaley dololutite–dolomitic shale, with thin more resistant beds of dololutite with stratiform stromatolites and intraclast beds.

176–186m: Interlaminated to thinly interbedded dololutite and dolomitic siltstone. Halite casts/moulds common on bedding surfaces.

0–176m: Alternating units of stromatolitic dololutite and laminated shaley dololutite/dolomitic shale. Stromatolitic units contain stratiform and large rounded domal forms, rare intraclast breccias and dolarentite beds. Shaley units are laminated to massive and devoid of obvious sedimentary structures. Probably consists of cycles with shaley bases and stromatolitic tops.

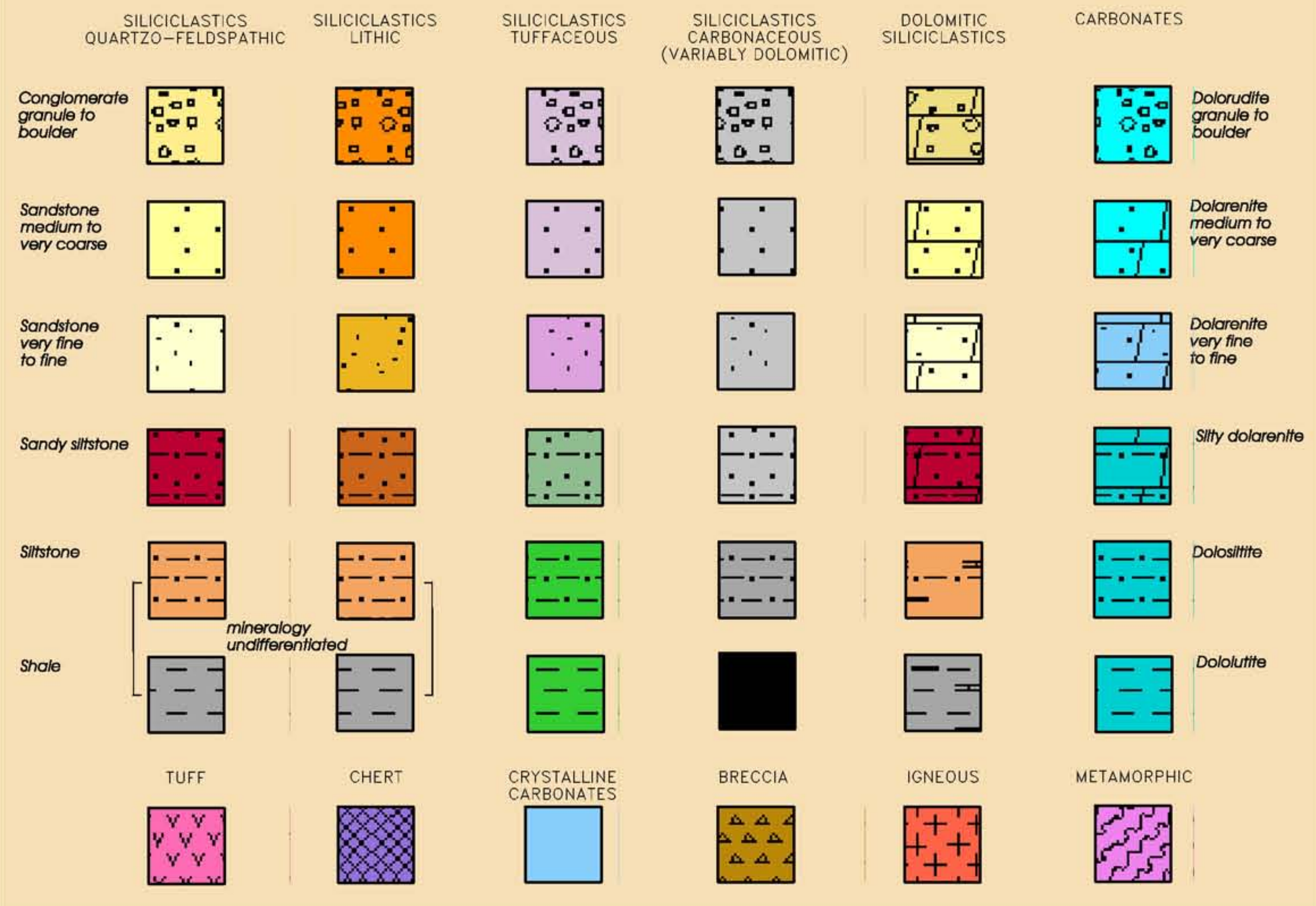
@ 100m: Rippled sandy dolarenite (with quartz sand)

@ 82 & 95m: Beds of intraclastic dolostones.

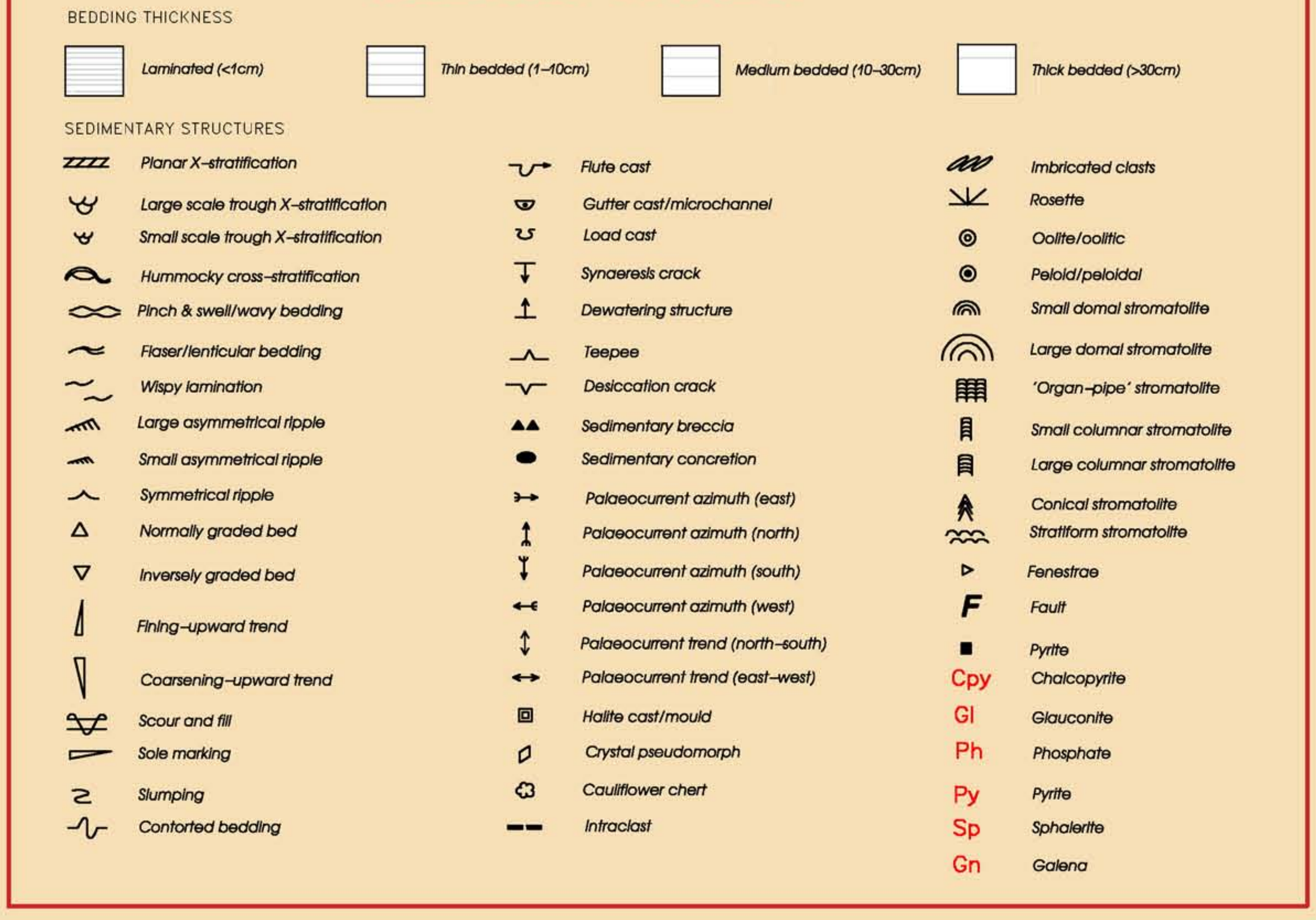
15–20m: Pinkish coloured dolostone (?tuffaceous?)

(base of formation not exposed)

Lithology Legend



Sedimentary Structures



Sequence Hierarchy

NOTE: Gun Supersequence used as an example.

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Australian Geological Survey Organisation Sales Centre,
GPO Box 378, Canberra ACT 2601.
Phone 02–62499519, Facsimile 02–62499982

Date: 19–Oct–2000

Weirk Waterhole

97/PW_WE/1

SCALE 1:1000

Easting: 557302

Northing: 8125391

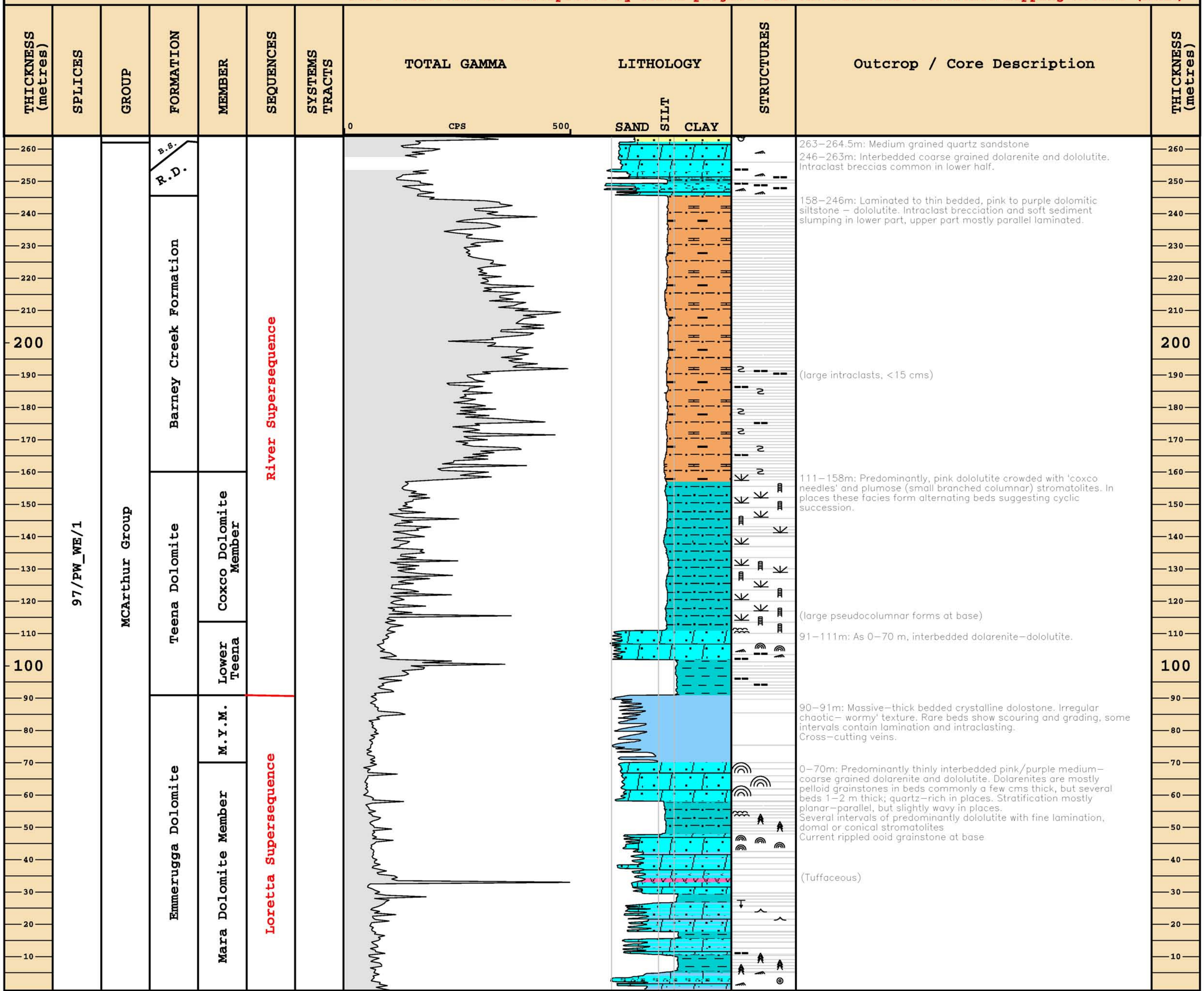
Data type: Measured Section

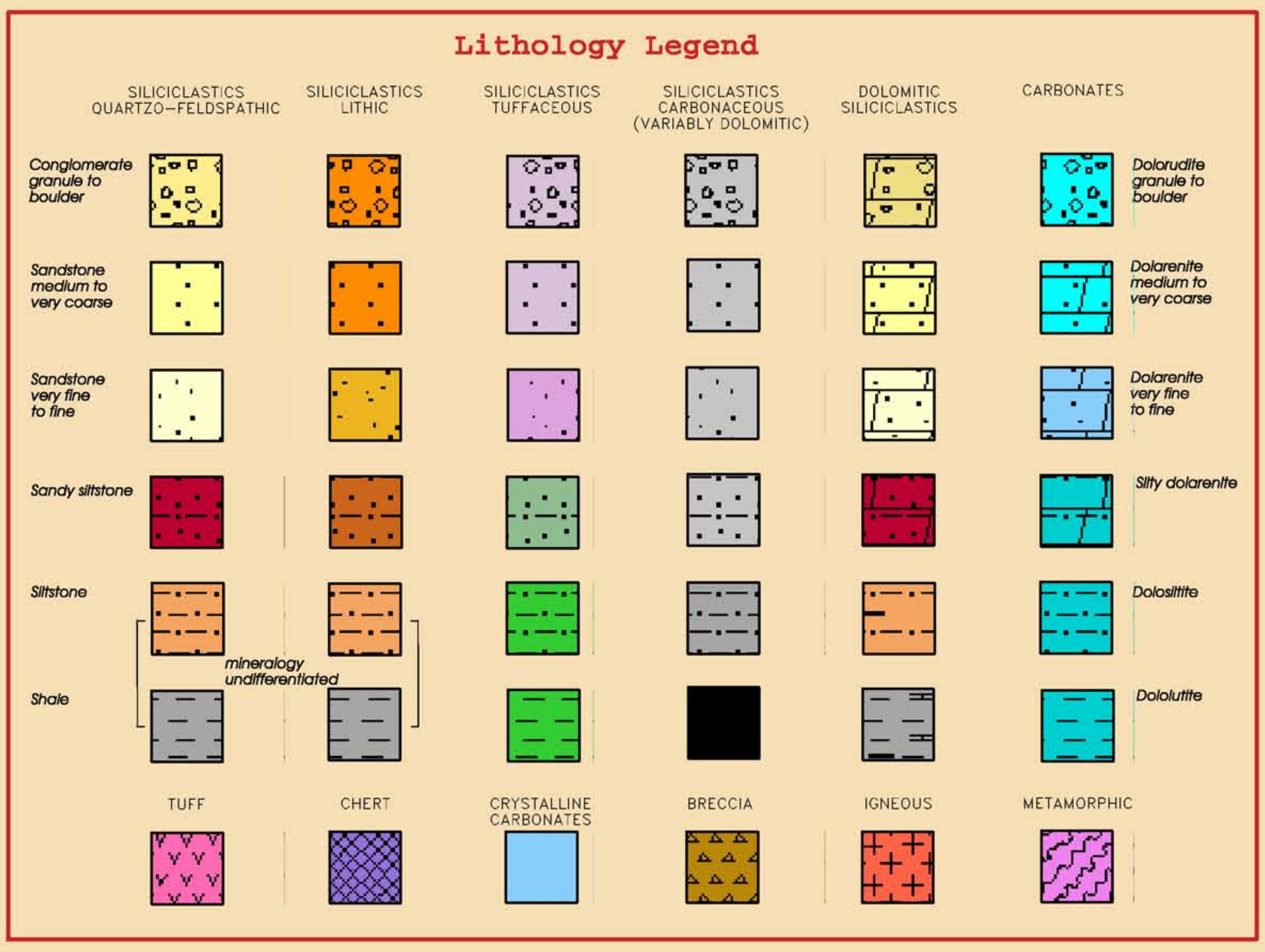
Map sheet: Mallapunyah

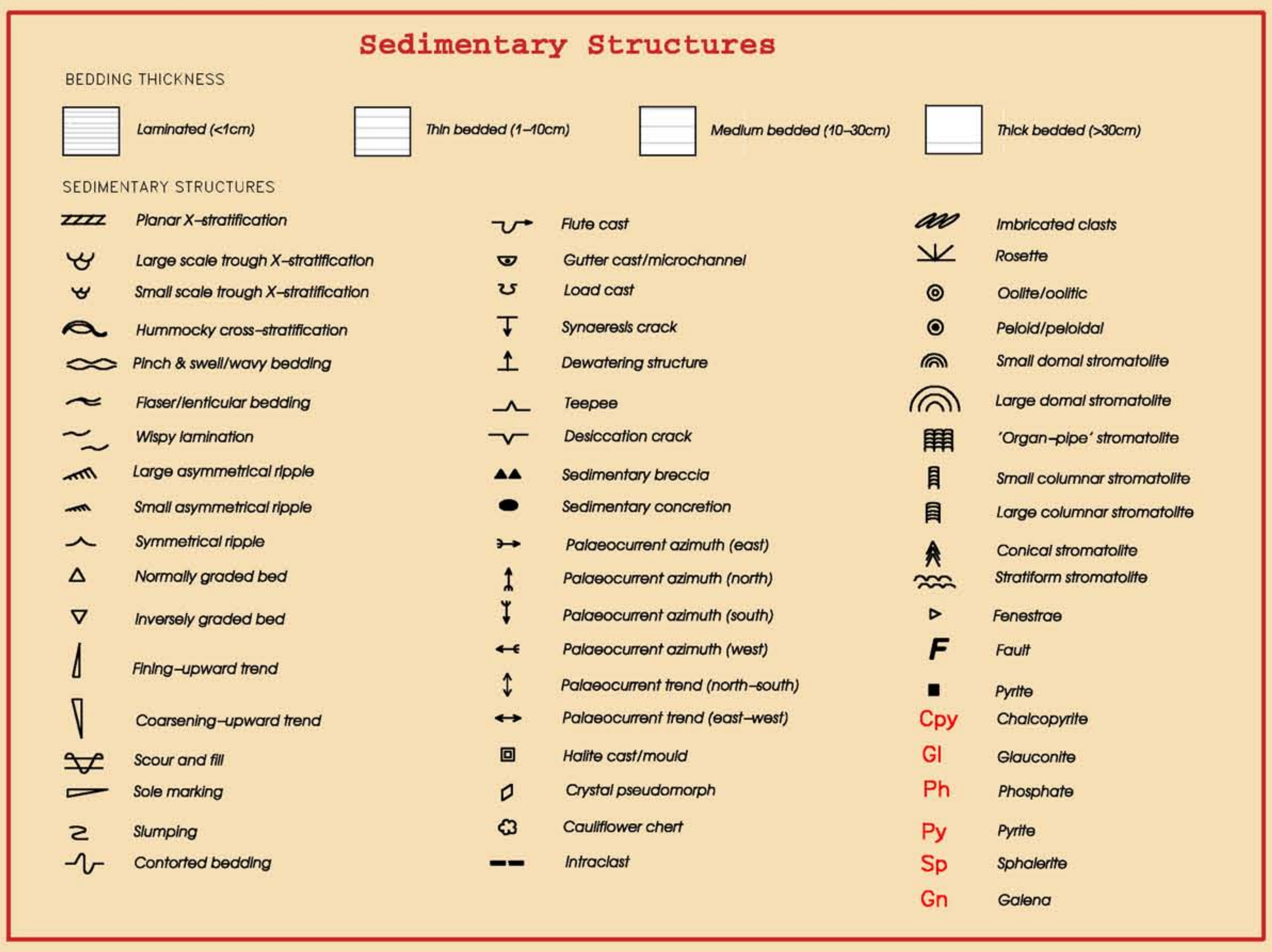
Geology: P R Winefield (University of Tasmania)

Geolog compilation: K Barnett & I Zeilinger

Data collected and interpreted by NABRE project for the National Geoscience Mapping Accord (NGMA)







Sequence Hierarchy

Gun	Supersequence Boundary				Onlap
Gun X	'3rd' Order Sequence Boundary	Gun Xf	'3rd' Order Maximum Flooding Surface		Truncation
Gun X.X	'4th' Order Sequence Boundary	Gun X.Xf	'4th' Order Maximum Flooding Surface	Gun X.Xt	Transgressive Surface

NOTE: Gun Supersequence used as an example.

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Australian Geological Survey Organisation Sales Centre,
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Phone 02–62499519, Facsimile 02–62499982 Date: 19–Oct–2000

Yellow Water Bore

96/JJ/03a, 96/JJ/03b

SCALE 1:1000

Easting: 597792

Northing: 8165471

Data type: Measured Section

Map sheet: Mallapunyah

Geology: M J Jackson & P N Southgate

Geolog compilation: K Barnett & I Zeilinger

AUSTRALIA

DEPARTMENT OF MINES AND ENERGY

NORTHERN TERRITORY DEPARTMENT OF MINES AND ENERGY

AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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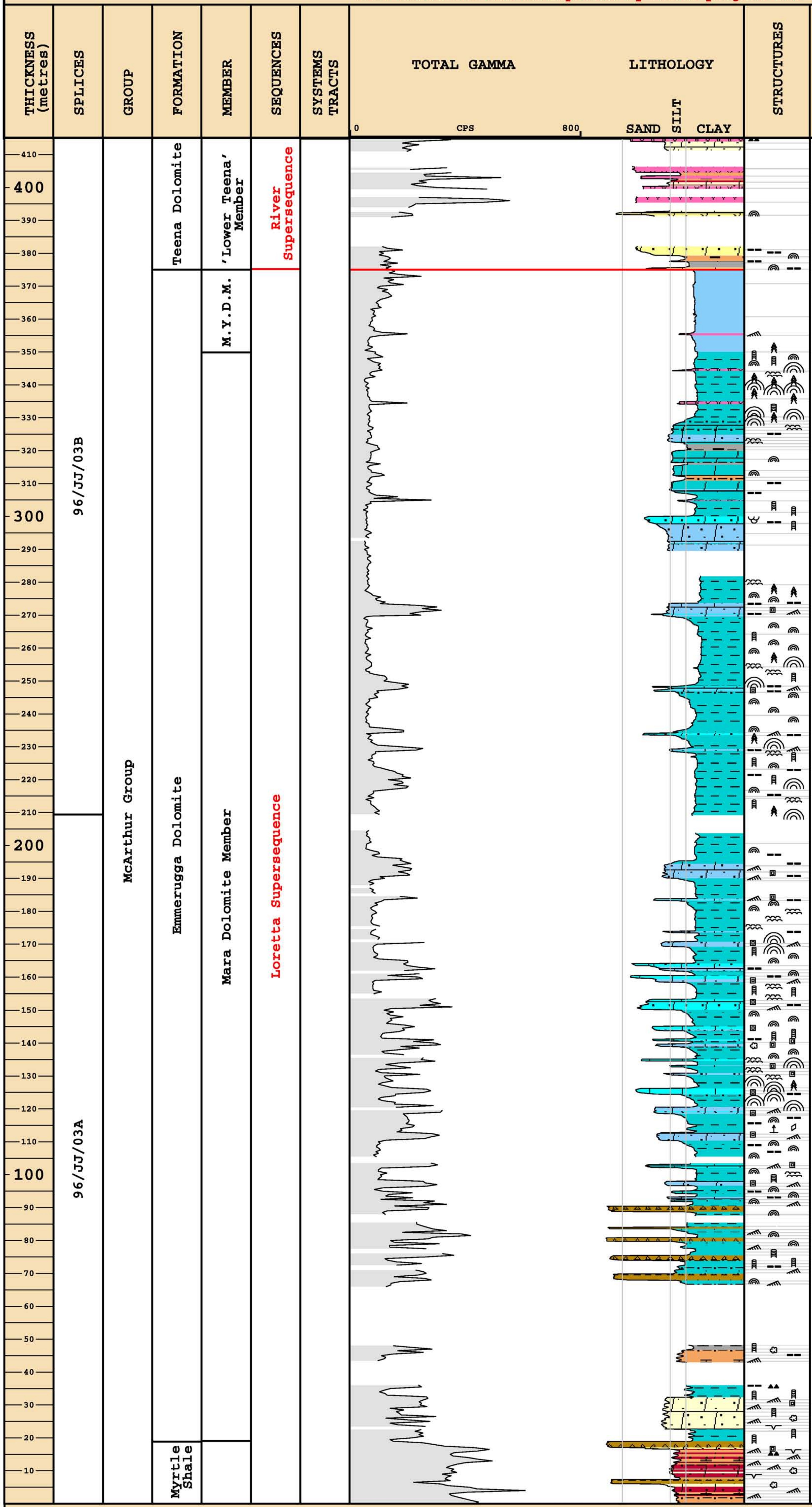


Outcrop / Core Description

390–420m: As 375–382 m but with extensive red–pink chertified, brecciated ?dolosiltstone in beds up to 1 m thick (tuffaceous unit).

(transferred section 200 m to SW)

375–382m: Intraclastic and stromatolitic sandy dolarenites, containing sub–rounded to well–rounded quartz sand (to 2 mm diameter).

350–375m: Dark grey crystalline dolostone devoid of any sedimentary structures, 'massive'. Upper 13 m cut by ?karstic infillings of brecciated & contorted red–pink chertified dolosiltstone (?tuffaceous), not shown on log.

(laminated dolosiltstone)

325–350m: Grey crystalline dolostone with large low relief domal and conical stromatolite bioherms. Rare beds of pink dolosiltstone (?tuffaceous)

300–325m: Similar to 290–300 m, but finer grained, sedimentary structures are less obvious but include domal stromatolites and rare intraclasts.

290–300m: Mostly grey crystalline dolostone. (probably originally fine–medium grained dolarenites). Sedimentary structures are indistinct, but include columnar stromatolites, intraclasts and large scale trough cross–stratification near top.

165–280m: Cyclic carbonate sequence similar to 90–165 m, but cycles much thicker (5–25 m). Lower part of cycle predominantly grey stromatolitic dololutite with variable irregular chert replacement. Stromatolites include stratiform mats, low small domal, large domal (up to 60 cm across), pseudocolumnar, columnar and conical forms. Conical stroms range from mm–sized, laterally linked forms up to large symmetrical and asymmetrical, upright to leaning forms that occur in 2–3m thick resistant biostromes. Upper part of cycle is usually less than 3 m thick. It consists of tan to pale brown dolosiltstone – v.fg dolarenite with rare quartz grain. Rocks are commonly ripple laminated with scours, halite casts and intraclasts.

No outcrop

90–165m: Cyclic sequence of interbedded stromatolitic dololutites and ripple laminated dolarenites. Cycles commonly 3–5 m thick; low part contains stratiform, pseudocolumnar and low domal stromatolites this grades up into very fine to medium grained dolarenite with numerous small current ripples, halite casts & moulds, common scouring.
Stromatolite domes rounded, 10–80 cm diameter, commonly mantled with dolarenite. Rare conical forms on sides of domes.

67–90m: Interstratified dolostones and breccias. Dolostones – mostly fine grained dolarenite and dolomitic mudstone, commonly rippled. Breccias consist of broken up pieces of dolostones, few mm to many cms in size.
Stratiform and pseudocolumnar stromatolites.

No outcrop

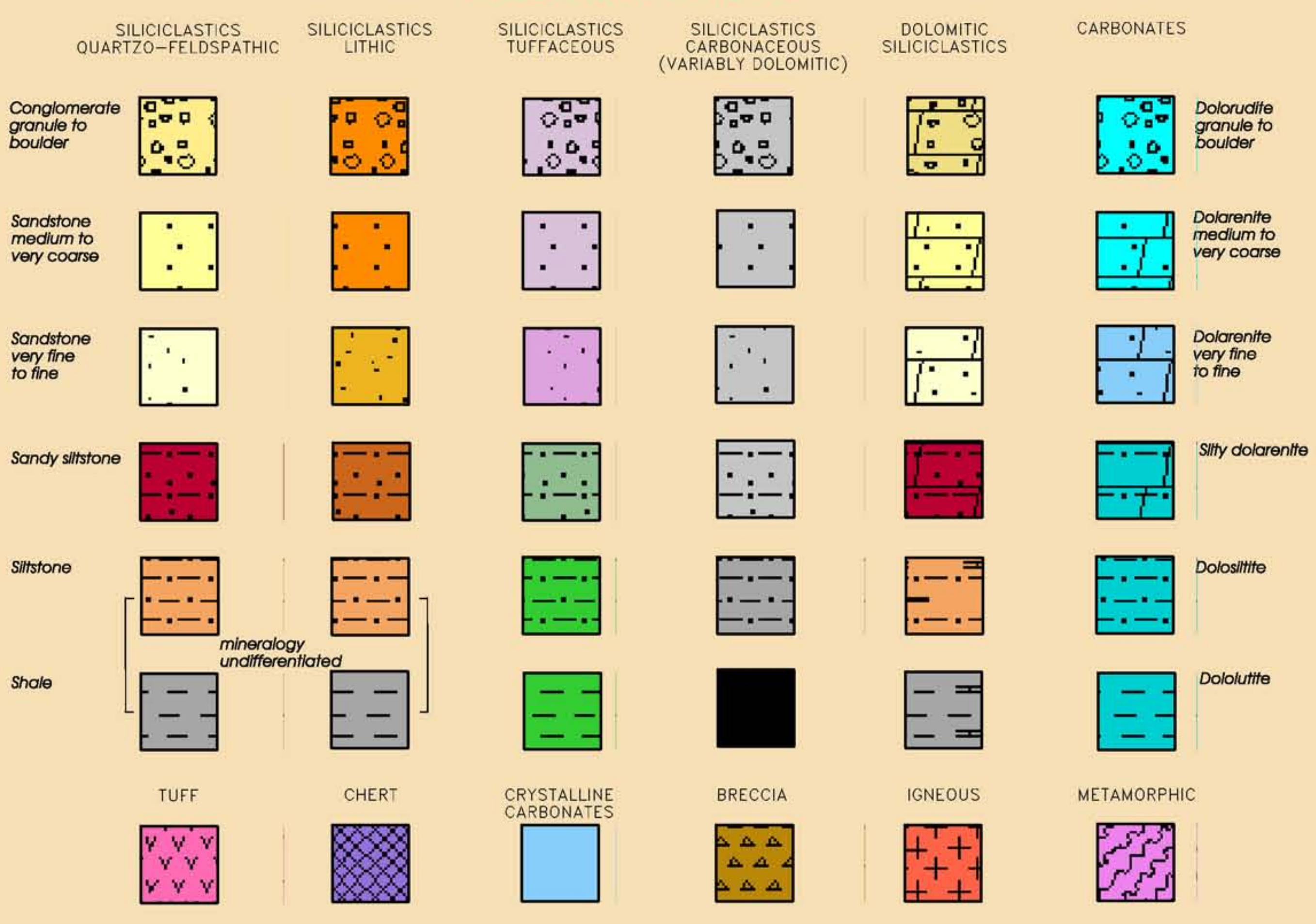
43–48m: Grey & red dolomitic siltstone and mudstone, with ripples, pseudocolumnar stromatolites and rare evaporite pseudomorphs.

No outcrop

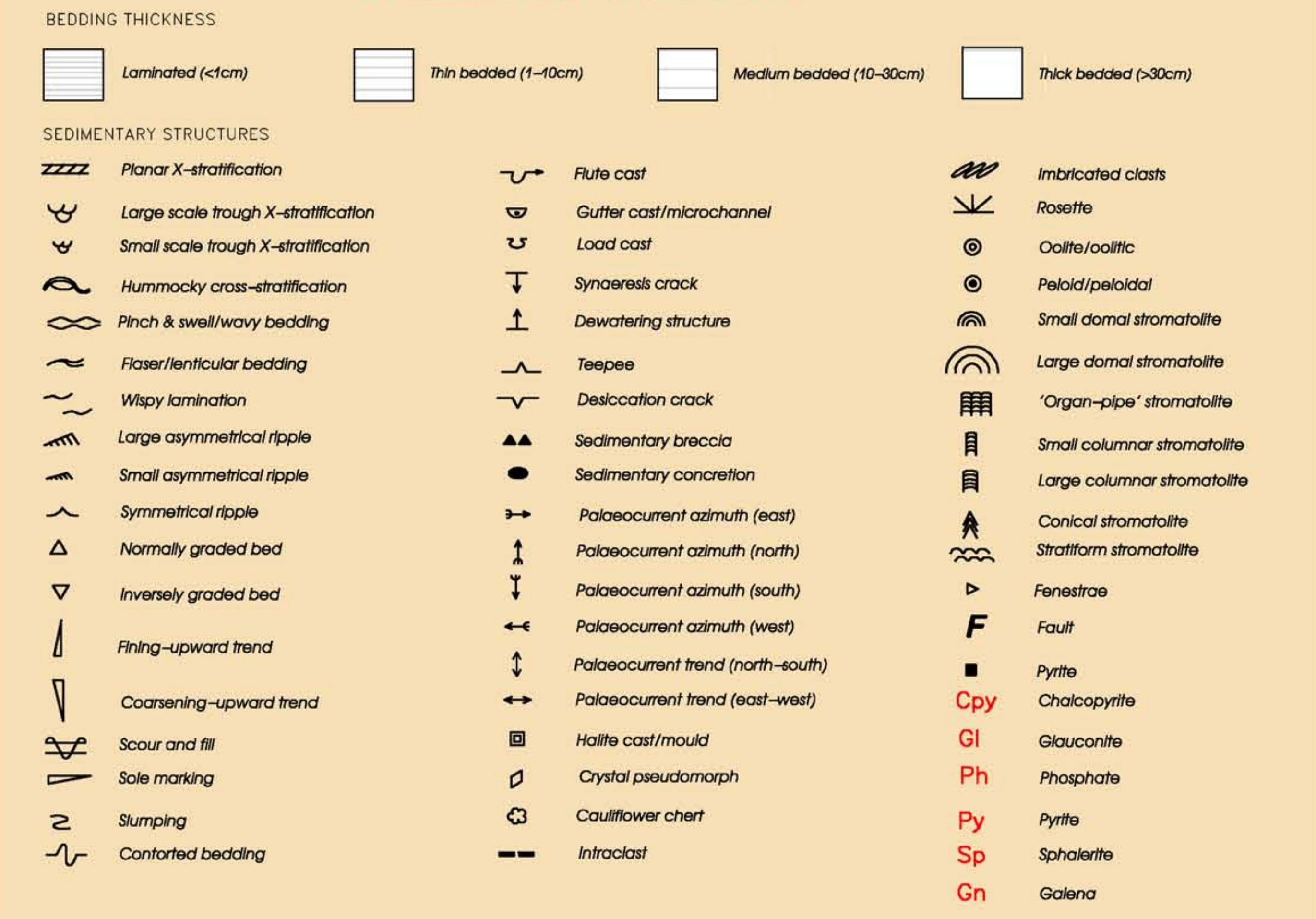
18–35m: Grey stromatolitic dololutite and fine grained dolomitic sandstone. Pseudocolumnar and stratiform stromatolites dominant. Rare desiccation and halite casts. Some beds incipiently brecciated.

0–18m: Red–brown, grey and yellow fine to very fine grained dolarenite, dolosiltstone and mudstone. Current ripples, halite casts and moulds, desiccation cracks and sucrosic chert laminae (after evaporites).
Thin bedded to laminated commonly brecciated.

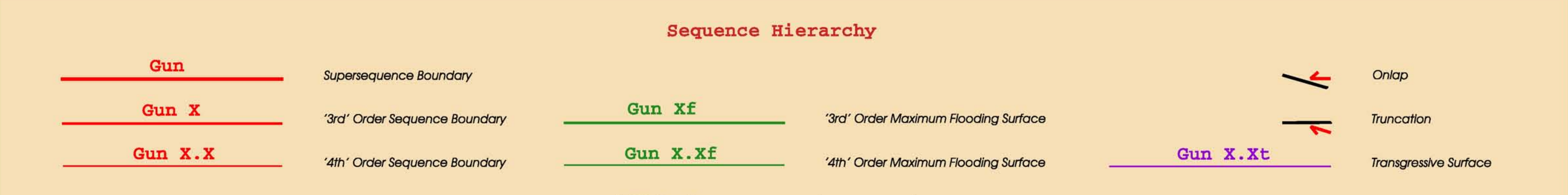
Lithology Legend



Sedimentary Structures



Sequence Hierarchy



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Date: 05–Oct–2000