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GEOLOGY OF THE PROTEROZOIC ROCKS OF NORTHERN AUSTRALIA

by

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INTRODUCTION

This paper describes the Kimberley to Mount Isa region between latitudes 11°S and 22°S, and longitudes 123°E and 141°E. Exposures of Proterozoic rocks total about 650 000 km^2, in a belt which follows the coast, and extends up to 500 km inland. The inland part of the region is covered by Phanerozoic basins.

The region contains several major mineral deposits: Mount Isa lead-zinc-copper; Hilton and McArthur River lead-zinc; Mary Kathleen, Rum Jungle, Ranger, Nabarlek, Koongarra, and Jabiluka uranium; Yampi Sound, Frances Creek, Constance Range, and Roper River iron. The early gold discoveries in the Katherine-Darwin and East Kimberley regions provided much of the impetus for development of the region. The region also encompasses the large Phanerozoic deposits of bauxite at Gove and Mitchell Plateau, manganese at Groote Eylandt, and phosphate in northwest Queensland. The value of mineral production in the region greatly exceeds that of the pastoral industry, and will increase in importance as new deposits come into production. Mining has provided the locus for development of almost all of the major towns, and has stimulated the pastoral, agricultural, and secondary industries.

The area has a monsoonal climate, with a wet summer. Mean annual rainfall ranges from 1600 mm around Darwin to 400 mm inland, around Halls Creek and Mount Isa. Along the coast average daily maximum temperatures range from about 32°C in January to 29°C in July, while inland the range is from about 38°C in January to 26°C in July.

The Kimberley to Mount Isa region contains Precambrian rocks ranging in age from Archaean, right through the Proterozoic, to the base of the Cambrian. The area was largely stabilized by the end of the Lower Proterozoic (except for the Carpentarian Mount Isa Orogenic Domain in the east) and was then covered by a succession of Carpentarian, Adelaidean, and younger mildly deformed platform cover rocks.

This paper summarizes two decades of regional geological mapping by the Bureau of Mineral Resources and the Geological Surveys of Queensland and Western Australia. Geological Sheets, at the scale of 1:250 000, are available for the whole area (see Sheet index on Fig. 1 (in map folder). Remapping at 1:100 000 scale has begun in the Mount Isa/Cloncurry/ Westmoreland region and the Katherine-Darwin region. Comprehensive syntheses of the geology of many areas have not yet been published and the remapping has shown that some modification of published work is necessary; this paper incorporates considerable unpublished work. Detailed stratigraphic tables and correlation charts are presented as a key to interrelationships between 1:250 000 Sheet areas; readers may refer to the maps and Explanatory Notes for more data where necessary.

MAJOR TECTONIC ELEMENTS

The Kimberley to Mount Isa Region encompasses the North Australian Orogenic Province and overlying North Australian Platform Cover of the Tectonic Map of Australia and New Guinea (GSA, 1971), together with some older (Rum Jungle) and younger (Mount Isa) domains

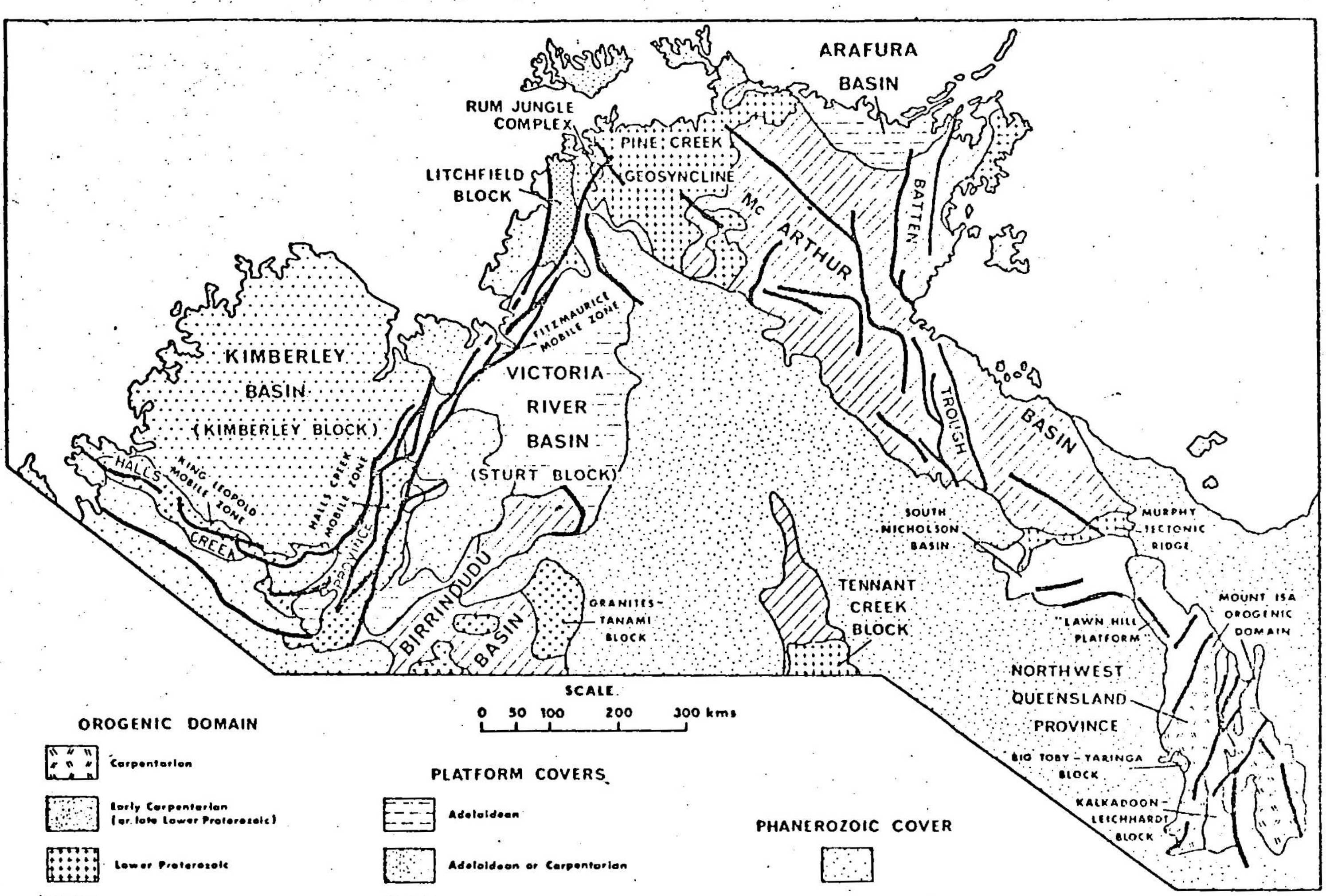

Figure 2. Principal Proterozoic tectonic elements

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belonging to the West and Central Australian Orogenic Provinces, respectively. (The Granites/Tanami and Tennant Creek Orogenic Domains are discussed elsewhere in this volume). All these units are overlain by elements of the Central Australian Platform Cover.

The principal tectonic elements of the region are shown in Figure 2.

The oldest established rocks are in the Rum Jungle Complex and adjoining Litchfield Block, where Archaean metasediments, granites, and gneisses are unconformably overlain by the* Lower Proterozoic Pine Creek Geosyncline succession. The Litchfield Block is also intruded by extensive late Lower Proterozoic granites.

The Pine Creek Geosyncline (Walpole et al., 1968) is a large inlier of Lower Proterozoic low-grade to high-grade metasediments and dolerite intrusives. The major tectonic elements of the geosyncline are revised following the work of Smart, et al. (1974) (Fig. 4). The full extent of the geosyncline is obscured by cover of younger basins; similar rocks in basement inliers of eastern Arnhem Land, Murphy Tectonic Ridge, and the Big Toby/Yaringa Block, are possibly continuous with the geosyncline in the subsurface. The Tennant Creek Block also includes similar rocks. Post-tectonic granites and acid volcanics, emplaced within the geosyncline during the late Lower Proterozoic and early Carpentarian, are assigned to transitional tectonism (GSA, 1971).

* BMR has recently decided to use Nullaginian (Dunn et al., 1966) in place of Lower Proterozoic.

The Halls Creek Province (Daniels & Horwitz, 1969) contains metasediments and metavolcanics of the Halls Creek Group, and Lower Proterozoic plutonic intrusive and metamorphic rocks of the Lamboo Complex (Dow & Gemuts, 1969; Gellatly et al., 1968). The Halls Creek Group may be of Archaean age, but the main metamorphism occurred during the Lower Proterozoic, at a similar time to that of the Pine Creek Geosyncline. The younger late and post-tectonic granites and acid volcanics of the Lamboo Complex represent transitional tectonism (GSA, 1971). The Granites/Tanami Block (Blake & Hodgson, 1974) is probably a continuation of the province.

Exposures of the Halls Creek Province are now confined to inliers within two linear zones of repeated localized deformation, the Halls Creek and King Leopold Mobile Zones (Traves, 1955). The Halls Creek Mobile Zone is the East Kimberlay Geosuture of Rod (1966). Both Traves and Rod extended the zone northwards to the area of the Litchfield Block, west of Darwin. The mobile zones were active from at least the Lower Proterozoic to the end of the Palaeozoic, and during this long period of time they bounded the stable Kimberley and Sturt Blocks and controlled development of various sedimentary basins. The Halls Creek Province was originally more extensive than its present outcrop and there is no firm evidence that the mobile zones exercised any control on the original development of the province (Dow & Gemuts, 1969). The Halls Creek Province and Halls Creek Mobile Zone are distinct features which should not be confused; the mobile zones, as described, are younger than the province.

The Fitzmaurice Mobile Zone was defined by Sweet, et al., (1973a) as the area within which the Adelaidean Fitzmaurice Group occurs; it lies within the Halls Creek Mobile Zone of Traves (1955).

The oldest member of the North Australian Platform Cover is the late Lower Proterozoic Kimberley Basin, which was developed on the Kimberley Block and adjoining Halls Creek and King Leopold Mobile Zones. The succession rests unconformably on the rocks of the Halls Creek Province and has been largely eroded from the mobile zones during subsequent deformation and uplift. Away from the mobile zones deformation is very mild.

The major unit of the North Australian Platform Cover is the McArthur Basin, within which the Carpentarian Tawallah and McArthur Groups, and the Adelaidean or Carpentarian Roper Group, and their stratigraphic equivalents (Fig. 7), were deposited. The basin is bounded by the Murphy Tectonic Ridge in the southeast and the Pine Creek Geosyncline in the northwest, and unconformably overlies the rocks within them. To the north, south, and east the basin extends beneath younger cover or the sea; the subsurface limits are unknown. The rocks in the basin were mildly to moderately deformed during the Adelaidean.

The Northwest Queensland Province, to the southeast of the Murphy Tectonic Ridge, contains stratigraphic equivalents of the McArthur Basin region and locally extends into the Northern Territory. The main unit in the province is the Mount Isa Orogenic Domain (GSA, 1971) which contains more intensely deformed and metamorphosed equivalents of the Carpentarian McArthur and Tawallah Groups. The Mount Isa domain contains the Eastern and Western 'Geosynclines' of (Carter et al., 1961) separated by a tectonic welt of basement rocks, the Kalkadoon-Leichhardt Block (Derrick et al., in prep.), containing granitic and acid volcanic rocks which may be related to the transitional domains beneath the McArthur Basin. In the northwest the Western 'Geosyncline' passes into less deformed equivalents, provisionally called the 'Lawn Hill Platform', a part of the North Australian Platform Cover (GSA, 1971). Other Lower Proterozoic basement inliers occur in the Big Toby/Yaringa Block and Murphy Tectonic Ridge. The mildly deformed South Nicholson Basin contains the South Nicholson Group, a correlative of the Roper Group of the McArthur Basin, and post-dates the main deformation of the underlying 'Lawn Hill Platform' and adjacent Mount Isa domain.

The Carpentarian Limbunya Group and Mount Parker Sandstone/Bungle Bungle Dolomite sequences are almost certainly continuous with the Birrindudu Group, with which they correlate (Blake & Hodgson, 1974), and so are included within the Birrindudu Basin on the Sturt Block.

The oldest representative of the Central Australian Platform Cover in the region is the very mildly deformed Adelaidean Victoria River Basin which developed on the Sturt Block, and is defined here (after I.P. Sweet, pers. comm.) as containing the Wattie, Bullita, Tolmer, and Auvergne Groups, the Bullo River Sandstone, Stubb and Wondoan Hill Formations, and Helicopter Siltstone and Wade Creek Sandstone sequence (Fig. 6). The thicker, more deformed, and partly equivalent, Fitzmaurice and Carr Boyd Groups were deposited in the adjoining Fitzmaurice/Halls Creek Mobile Zone; they do not belong to the basin. The Victoria River Basin succession unconformably overlies, in various places, the Halls Creek Province, the Granites/Tanami Block, the Pine Creek Geosyncline, and the Birrindudu Basin. The late Adelaidean glacial successions of the East Kimberley are not assigned to any named basin.

The Arafura Basin (Plumb, 1965) contains the undeformed late Adelaidean Wessel Group and unconformably overlies the McArthur Basin. The succession passes up into a thick sequence offshore, about which little is known, including its upper age limit. The flat-lying Bukalara Sandstone overlying the southern McArthur Basin is probably an equivalent of the Wessel Group.

All the units just described are finally unconformably overlain by various Phanerozoic covers of the Georgina, Ord, Daly River, Wiso, Canning, Bonaparte Gulf, Money Shoals, and Carpentaria Basins, which are not discussed in detail in this paper.

The tectonic evolution of northern Australia from the early Precambrian to the Recent has been controlled by a regionally uniform pattern of lineaments, trending roughly northwest and north-northwest to north-northeast; westerly trends are locally important. The lineaments have controlled both sedimentation and subsequent deformation. The relative importance of the trends is difficult to determine. The northerly-trending structures include the largest faults in the region, with both strike-slip and vertical displacements, and associated folding. The northwest-trending structures include considerable reverse faulting and over-folding, with minor strike-slip faulting, and may have been a fundamental trend in the pre-cratonic tectonics of the basement.

INTER-REGIONAL CORRELATIONS AND GEOCHRONOLOGY

Field relationships and correlation of rock sequences, supported by isotopic age studies, have provided a chronostratigraphic framework for the Kimberley to Mount Isa region (Fig. 3).

Pine Creek Geosyncline area

Rum Jungle Complex. The younger granitic members give U-Pb zircon ages of 2500 or 2550 m.y. (Richards et al., 1966) and a Rb-Sr total-rock age of about 2400 m.y. (Richards & Rhodes, 1967). The high initial $^{87}Sr/^{86}Sr$ ratio obtained on the granites suggests that they were derived from reworked older crustal material. The adjacent Waterhouse Granite is about 2450 m.y. old (P.J. Leggo, BMR, unpubl.).

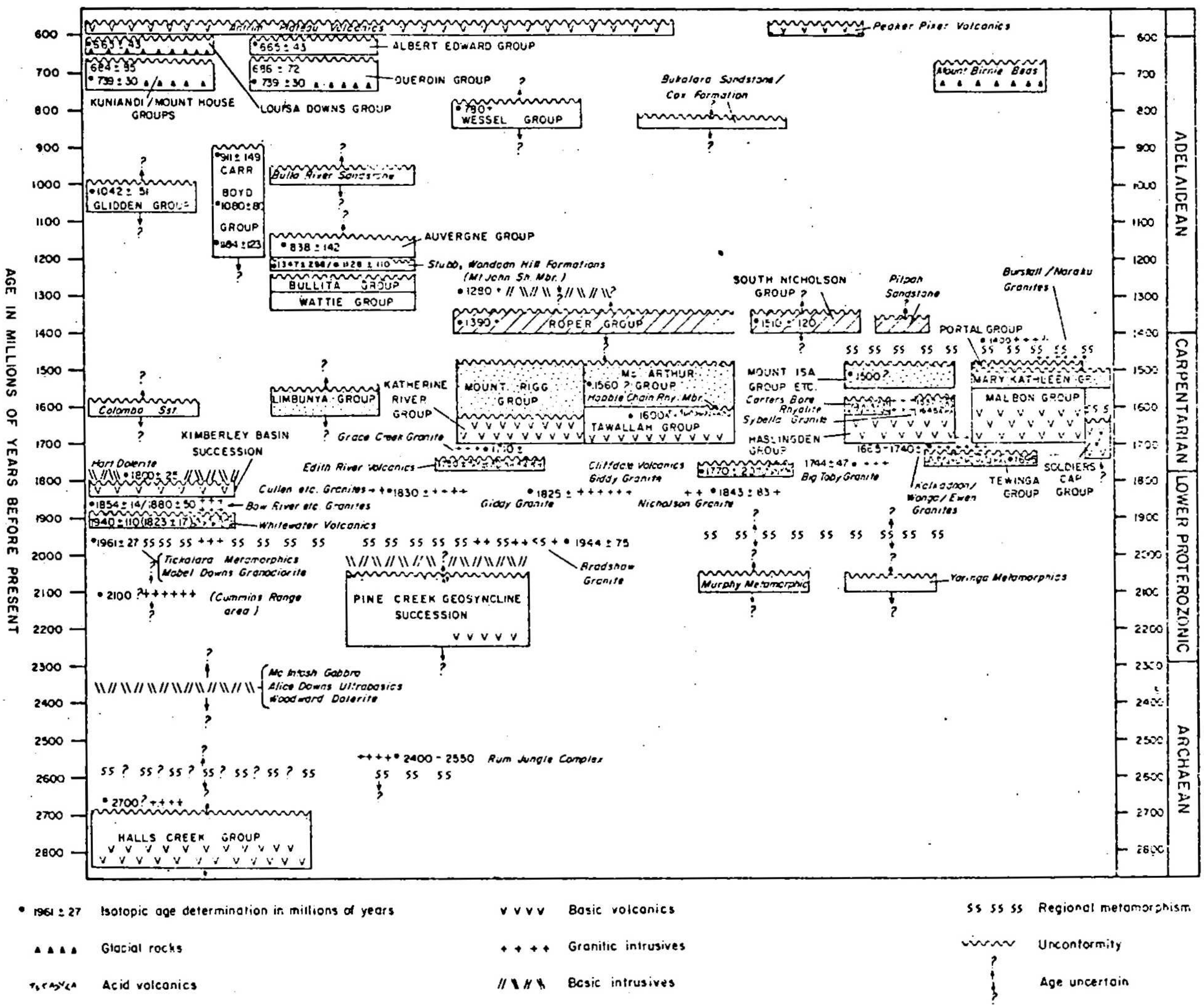

Figure 3. Time Relationships of Principal Precambrian rock units

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Pine Creek Geosyncline. The Rum Jungle Complex provides a maximum age for the unconformably overlying Pine Creek Geosyncline succession. The metamorphism producing the anatectic Bradshaw Granite of eastern Arnhem Land is now correlated with the deformation of the geosyncline, and is dated at 1944 ± 75 m.y. by a Rb-Sr total-rock isochron (A.W. Webb, AMDL Rep. An 1814/73, unpubl.).

Post-tectonic granites and acid volcanics. Widespread emplacement of discordant granites and acid volcanics, between the folding of the Pine Creek Geosyncline and initiation of the McArthur Basin and Mount Isa Geosyncline, is an important tectonic event in northern Australia. The Cliffdale Volcanics define the base of the Carpentarian (Dunn et al., 1966).

Eight total-rock samples of Cliffdale Volcanics give a precise Model I Rb-Sr isochron of 1770 ± 20 m.y. (Webb, op. cit.). The Norris Granite, which intrudes the volcanics, is of the same age (1773 ± 24 m.y.). The Nicholson Granite has given a less precise Model I total-rock isochron of 1843 ± 83 m.y. from five widely spaced samples, but there is considerable uncertainty as to its field relationship to the Cliffdale Volcanics.

McDougall et al. (1965) obtained similar K-Ar and Rb-Sr ages from individual samples of these granites. They also obtained an age of 1825 ± 25 m.y. by total-rock and biotite Rb-Sr analyses of a single sample of Giddy Granite in Arnhem Land; single biotite K-Ar ages are about 1760 m.y. (Giddy Granite) and 1750 m.y. (Caledon Granite).

Compston & Arriens (1968) report preliminary Rb-Sr data by P.J. Leggo and G.H. Riley from the Katherine-Darwin region: the Cullen Granite and related bodies are 1820 to 1830 m.y. old. Three samples of Edith River Volcanics gave a total-rock Rb-Sr isochron of about 1750 m.y. The Malone Creek Granite (about 1750 m.y. by single sample Rb-Sr method), Mount Bundey Syenite (1725 m.y., single sample concordant total-rock and mineral Rb-Sr isochron), and Grace Creek Granite (1710 m.y., three total-rock samples, Rb-Sr isochron) may be significantly younger. K-Ar biotite ages (Hurley et al., 1961) are all considerably younger (1720-1520 m.y.).

Halls Creek Province, Kimberley Basin

The Halls Creek Group resembles the Pine Creek Geosyncline succession. Its younger age limit is provided by high-grade metamorphic equivalents, the Tickalara Metamorphics and Mabel Downs Granodiorite, which give a precise Model I total-rock and mineral Rb-Sr isochron of 1961 ± 27 m.y. (Bofinger, 1967). This age is the same as that obtained for the Bradshaw Granite. Rb-Sr analyses of single samples of granite from the Cummins Range give a less reliable minimum age of about 2100-2250 m.y., while a single pegmatite sample, intruding the Halls Creek Group, gives an age about 2700 m.y. This latter result is the only reason for assigning a possible Archaean age to the Halls Creek Group.

Late Lamboo Complex. The acid Whitewater Volcanics and associated high-level intrusives rest unconformably on the Halls Creek Group and are intruded throughout the Kimberleys by coarse-grained granites. The volcanics had been considered to be early Carpentarian (e.g. Dunn et al., 1966; Plumb, 1968; Dow & Gemuts, 1969) but can now be shown to be significantly older than the Cliffdale Volcanics.

The coarse-grained granites give Rb-Sr isochrons of 1874 ± 32 m.y. or 1854 ± 14 m.y. in the East Kimberley (Bofinger, 1967), and a comparable 1880 ± 50 m.y. in the West Kimberley (Bennett & Gellatly, 1970). Bofinger obtained a Model IV Rb-Sr isochron of 1823 ± 17 m.y. for the Whitewater Volcanics and associated intrusives, whereas Bennett & Gellatly report a preliminary age of 1940 ± 110 m.y. for different sampling sites. These ages are all statistically indistinguishable. Bofinger's Whitewater isochron conflicts with the intrusive relationships of the coarse-grained granites, and shows variations due to initial $^{87}Sr/^{86}Sr$ ratios and open system chemistry; his sample sites lie near zones of deformation in the Halls Creek Mobile Zone. Bennett & Gellatly recommend further work.

The Kimberley Basin was correlated with the Carpentarian McArthur Basin (e.g. Dunn et al., 1966; Plumb, 1968), but is now shown to be significantly older than the Cliffdale Volcanics.

The maximum age limit to the succession is given by the underlying coarse-grained granites. The younger limit is given by the Hart Dolerite, which intrudes all units up to the Pentecost Sandstone (Fig. 6). The dolerite gives a precise Model I total-rock and mineral isochron, controlled by granophyres, of 1800 ± 25 m.y. (Bofinger, 1967). Concordant results are about 1807 m.y. for Carson Volcanics

(Rb-Sr isochron based on 2 total-rock analyses) and a Model III shale total-rock Rb-Sr isochron of 1789 ± 58 m.y. for the Wyndham Shale.

McArthur Basin

Three main suites are recognized in the basin: the oldest is a quartz arenite/basic volcanic suite (typified by the Tawallah Group), which is overlain by a carbonate suite (McArthur Group), which in turn is overlain with regional unconformity by an arenite-lutite suite (Roper Group). Different nomenclatures are applied to other parts of the basin (Fig. 7). The South Nicholson Group in the South Nicholson Basin is correlated with the Roper Group.

The absolute older limit to the succession is given by the Cliffdale Volcanics (1770 m.y.) or, less reliably, the Grace Creek Granite (1710 m.y.). The top of the Tawallah Group is fixed by the age of emplacement of the comagmatic Packsaddle Microgranite and Hobblechain Rhyolite Member, with a total-rock Rb-Sr isochron about 1600 m.y. (Webb, op. cit.). Glauconites from the underlying Aquarium Formation gave a young Model I Rb-Sr isochron of 1473 ± 56 m.y. (Webb, op. cit.); McDougall et al. (1965) recorded individual glauconite samples ranging in age from 1470 to 1580 m.y.

The only control on the McArthur Group is a model lead age of 1560 m.y. from the McArthur River lead-zinc deposit (Richards, 1963).

Glauconite ages from the Crawford Formation of the Roper Group range from 1100 to 1280 m.y. by the K-Ar method and 1270 to 1390 m.y. by the Rb-Sr method

(McDougall et al., 1965); 1390 m.y. is regarded as a minimum age for the formation. The upper age limit to the group is provided by dolerite sills intruding all units. K-Ar mineral ages range from 876 to 1280 m.y. (McDougall et al., 1965; Webb, op. cit.); 1280 m.y. is regarded as a minimum estimate only.

The Mullera Formation of the South Nicholson Group gave a shale total-rock Rb-Sr isochron of 1510 ± 120 m.y. (R.R. Harding, BMR, unpubl.). This indicated age is older than the granites and metamorphism in the Mount Isa domain which are thought to be older than the South Nicholson Group; an inherited isochron from detrital mica is possible. For the present the Roper and South Nicholson Groups are considered to be Adelaidean or Carpentarian.

Northwest Queensland Province

Three major rock suites within the Mount Isa region can be correlated with those of the McArthur Basin (Dunn et al., 1966). Isotopic age determinations so far support these correlations, although the pattern is complicated by metamorphic overprints and, sometimes, by isochrons based on different rock types from multiple intrusions.

The predominantly acid volcanic Tewinga Group is broadly correlated with the Cliffdale Volcanics. It is unconformably overlain by quartz arenite/basic volcanic suites of the Haslingden and Malbon Groups, which correlate with the Tawallah Group, and these in turn are overlain by carbonate suites of the Mount Isa, Mary Kathleen, and Portal Groups and equivalent units (Fig. 10), which broadly correlate with the McArthur Group. These sequences are then unconformably overlain by the South Nicholson Group, which is thought to post-date all the metamorphism and granite intrusion of the Mount Isa Orogenic Domain, but it is not impossible that the latest metamorphic and igneous activity was continuing in the 'Eastern Geosyncline' while deposition began in the South Nicholson Basin, 250 km to the northwest.

Kalkadoon-Leichhardt Block. The Kalkadoon Granite is a multiple intrusion intruding the Tewinga Group. It is unconformably overlain by the Haslingden, Mary Kathleen, and Mount Isa Group equivalents; the younger phases of the Kalkadoon Granite noted by Smith (1967) have not been found in areas so far mapped in detail. The Wonga and Ewen Granites also intrude the Tewinga Group; the Ewen Granite is unconformably overlain by the Haslingden Group while the Wonga Granite has no demonstratable relationship to younger units. The isotopic age data is still not clear.

A single sample of Ewen Granite gave a total-rock and mineral Rb-Sr isochron of 1780 ± 20 m.y. (McDougall et al., 1965). Four widely spaced total-rock samples from the Kalkadoon Granite gave a Rb-Sr isochron of about 1760 m.y. (Richards, 1966). Farquharson & Wilson (1971) derived a variety of isochrons between 1788 and 1930 m.y. from different groupings of widely spaced samples of different rock types in the Kalkadoon and Ewen Granites.

More recent Rb-Sr work (Page & Derrick, 1973), which is still continuing, gave a preliminary isochron of 1699 ± 172 m.y. for the Kalkadoon Granite. A granite-diorite mass in the Blockade Block, 20 km east of the

Kalkadoon-Leichhardt Block, which was mapped as Kalkadoon Granite by Carter et al. (1961), gave a firm isochron of 1681 ± 68 m.y.; this granite can probably be grouped with the Wonga Granite, in which separate Rb-Sr isochrons (R.W. Page, pers. comm.) demonstrate at least two distinct phases, one 1665 ± 16 m.y. old, and another 1738 ± 20 m.y. old. Rhyodacite from the Leichhardt Metamorphics, near the base of the Tewinga Group, has given a Rb-Sr total-rock isochron of 1694 ± 45 m.y., but the field relationships with the Kalkadoon Granite are still unclear. The Big Toby Granite, intrusive into the Big Toby/Yaringa Block west of Mount Isa, has given a firm 1744 ± 47 m.y. isochron.

Mount Isa Orogenic Domain. The maximum age of the Haslingden Group is possibly that of the unconformably underlying Leichhardt Metamorphics. The top of the Haslingden Group is fixed by the Sybella Granite, intrusive into the Judenan Beds (equivalent to Myally Beds) and unconformably overlain by the Mingera Beds (Fig. 10). Individual phases of the Sybella Granite give separate total-rock Rb-Sr isochrons of 1646 ± 15 m.y., 1577 ± 12 m.y., and 1537 ± 40 m.y., in agreement with field intrusive relationships (Hill et al., in prep.; Page & Derrick, 1973). These ages agree with the Packsaddle Microgranite at the top of the Tawallah Group.

Upper limits to the sequence are given by the post-Portal Group metamorphism and granites. Younger phases of the Burstall and Naraku Granites give total-rock Rb-Sr isochrons around 1400 m.y. (R.W. Page, pers. comm.) while the metamorphism is reflected in anomalously young Rb-Sr isochrons around 1400 to 1560 m.y. for some suites from the Tewinga Group (Page & Derrick, 1973). A variety of old and young granites, and metamorphic rocks, yield widespread K-Ar mica ages of about 1350 to 1450 m.y. (Richards et al., 1963).

Victoria River Basin/East Kimberley region

Correlations (Fig. 6) are obscured by major faults and facies changes between sequences. Field relationships indicate independent correlations of the Angalarri Siltstone with the Helicopter Siltstone, Golden Gate Siltstone, and Goobaieri Formation (I.P. Sweet, pers. comm.). Dow et al. (1964) showed an unconformity above the 'Mount John Shale', but subsequently defined the shale as a conformable member of the Wade Creek Sandstone (Dow & Gemuts, 1969). The Legune Formation and Lalngang Sandstone correlate well with the Pincombe Formation and Stonewall Sandstone (Pontifex & Sweet, 1972). The Tolmer Group is almost identical to the Wattie and Bullita Groups (Sweet et al., 1973a).

Detailed correlation between the late Adelaidean glacial successions is well established (Dow & Gemuts, 1969; Roberts et al., 1972).

Structural and stratigraphic considerations make it unlikely, though not impossible, that the Wattie and Bullita Groups are as old as the Roper Group.

Bofinger (1967) obtained the following shale total-rock Rb-Sr isochrons from the Carr Boyd Group: the Golden Gate Siltstone 1184 ± 123 m.y. (Model 1); the Glenhill Formation 1080 ± 80 m.y. (Model II); and the Pincombe Formation 911 ± 149 m.y. (Model 1). The Mount John Shale Member at 1128 ± 110 m.y. (Model I) is in agreement with field correlations. A combined Model III shale isochron for the Maddox and Matheson Formations gave 1042 ± 51 m.y.; correlation of the Glidden Group with the Glenhill Formation is consistent with their successions, although not decisive.

A.W. Webb (AMDL Rep. An 4067/74, unpubl.) obtained a shale total-rock Rb-Sr isochron of 1431 ± 440 m.y. from five samples of the Wondoan Hill Formation with a very wide scatter of data, whereas K-Ar and Rb-Sr dates on glauconites gave 1100 to 1200 m.y. (R.W. Page, pers. comm.). For the Stubb Formation and Angalarri Siltstone Webb obtained Model I shale isochrons of 1347 ± 298 m.y. and 838 ± 142 m.y., respectively, with four samples defining each isochron. The apparent anomalies between these data and field relationships have not been properly assessed yet; statistically the calculated ages do overlap.

Bofinger (1967) obtained the following shale total-rock shale isochrons from the late Adelaidean glacial successions: Landrigan and Moonlight Valley Tillites 739 ± 30 m.y. (composite Model III); Johnny Cake Shale Member 686 ± 72 m.y. (Model 1); Throssell Shale 684 ± 85 m.y. (Model 1); Elvire Formation 653 ± 48 m.y. (Model 1); and Timperley and McAlly Shales 665 ± 43 m.y. (composite Model I).

Birrindudu Basin

The Limbunya Group and Bungle Bungle Dolomite/Mount Parker Sandstone correlate well (Sweet et al., 1974), and both sequences are overlain with marked unconformity by the Victoria River Basin succession. Blake & Hodgson (1974) correlate their Birrindudu Group with the Bungle

Bungle Dolomite and Mount Parker Sandstone.

The Limbunya Group must be significantly older than the dated Stubb and Wondoan Hills Formations and Mount John Shale Member, and glauconite from the top of the basal unit of the Birrindudu Group has been dated at 1550 to 1620 m.y. (AMDL Rep., 3473/73, unpubl.). These data are consistent with correlation of the Bungle Bungle Dolomite and Mount Parker Sandstone or the Limbunya Group with the McArthur and Tawallah Groups of the McArthur Basin.

Arafura Basin

The Wessel Group (Fig. 6) is undeformed and overlies the McArthur Basin with marked unconformity. Farther south the Bukalara Sandstone and Cox Formation show a similar structural setting and are virtually identical lithologically to the Buckingham Bay Sandstone and Raiwalla Shale; they can probably be correlated. Both sandstones contain Scolithus. Glauconite from the Elcho Island Formation has been dated by K-Ar at 770 m.y. and by Rb-Sr at 790 m.y. (McDougall et al., 1965). These ages provide a minimum age for deposition of the Wessel Group.

REGIONAL GEOLOGY

HALLS CREEK PROVINCE

(Principal references: Dow & Gemuts, 1969; Gellatly et al., 1968; Gemuts, 1971).

Daniels & Horwitz (1969) applied the term Halls Creek Province to the exposures of metasediments and metavolcanics of the Halls Creek Group and the younger crystalline Lamboo Complex in the northern part of Western Australia. The stratigraphy is summarized in Table 1.

TABLE 1: SUMMARY OF ARCHAEAN(?) AND LOWER PROTEROZOIC STRATIGRAPHY, HALLS CREEK PROVINCE

Unit	Thickness (m)	Main Rock Types	Remarks
LAMBOO COMPLEX			
Late Lamboo Complex			
Bow River, Lerida, Lennard etc. Granites		Massive coarse-grained granite, adamellite, granodiorite.	Intrude Whitewater Volc. Minor Cu, Sn.
Whitewater Volcanics	Up to 12 000	Rhyodacite ash-flow tuff & lava; tuffaceous siltstone, sandstone & agglomerate.	Unconformable on Halls Cr Gp. Minor Cu, Pb, F.
Castlereagh Hill, Bickleys etc. Porphyries		Porphyritic microgranite, quartz-feldspar-porphyry.	Comagmatic with Whitewater Volc.
Early Lamboo Complex			
Kongorow Granite		Granite locally gneissic.	West Kimberley. Partly anatectic, partly post-Whitewater Volc.
Mabel Downs Granodiorite		Foliated granodiorite, tonalite	East Kimberley. Anatectic granite during Tickalara metamorphism.
Tickalara Metamorphics		Schist, amphibolite, paragneiss, granulite.	East Kimberley high-grade metamorphic equivalent of Halls Cr Gp.
Wombarella Quartz Gabbro		Orthopyroxene quartz gabbro, norite, tonalite.	West Kimberley. Mostly antedates metamorphism.
McIntosh Gabbro		Gabbro, troctolite, dolerite.	East Kimberley. Genetically related. Antedate Tickalara Met. Ni, Pt, Cr, Cu.
Alice Downs Ultrabasics		Pyroxenite, peridotite, anorthosite, schist.	
Woodward Dolerite		Dykes and sills of uralitized dolerite.	Intrude Halls Cr Gp throughout province.
HALLS CREEK GROUP			
Undifferentiated	Up to 6000	Subgreywacke, phyllite, slate, schist. Some rhyolite tuff & conglomerate.	
Olympio Formation	3000+	Subgreywacke, siltstone (turbidites); minor limestone & conglomerate.	Au (Halls Creek)
Biscay Formation	150 - 1500	Basic lavas, tuffaceous greywacke & siltstone.	Cu, Au. Prominent dolomite beds.
Saunders Creek Formation	0 - 190	Quartz sandstone, quartz greywacke.	U.
Ding Dong Downs Formation	300+	Basalt, tuff, tuffaceous greywacke.	Cu. Oldest unit in province.

Halls Creek Group

The Halls Creek Group consists of a tightly folded geosynclinal succession of basic volcanics passing up into thick monotonous turbidites. No basement to the succession is exposed. In the West Kimberley only the upper unit, the Olympio Formation, containing some rhyolite, rhyolite tuff, limestone, and conglomerate is recognized. There is no evidence, from the limited exposures in small inliers, of the original configuration of the geosyncline in which the group was deposited.

The sediments have been multiply folded along trends which alternate between parallel to the Halls Creek and parallel to the King Leopold Mobile Zones: at least two phases in the East Kimberley, and at least three in the West Kimberley.

In most areas the rocks belong to the greenschist facies of metamorphism, but in the East Kimberley progressive zones have been recognized up to the granulite facies of the low-pressure intermediate facies series. Polyphase metamorphism, up to amphibolite facies, is recognized in the West Kimberley, with moderately high-temperature/low-pressure conditions followed by high-temperature/high-pressure and, finally, low temperature/high-pressure conditions. In the East Kimberley, rocks above greenschist facies are mapped as Tickalara Metamorphics, but in the West Kimberley are left as Halls Creek Group.

Lamboo Complex

Matheson & Guppy (1949) applied the term Lamboo Complex to the intrusive and high-grade metamorphic rocks of the basement complex, and Gellatly et al. (1968) added the Whitewater Volcanics.

Early Lamboo Complex. Extensive sills, laccoliths, and dykes of mafic to ultramafic rocks were intruded before the main (Tickalara) metamorphism. In the West Kimberley at least one probable fold period, antedating intrusion of the mafic rocks, is recognized. Differentiation layering and segregation are present in some intrusions.

Regional (Tickalara) metamorphism was accompanied by anatexis and granite intrusion (Mabel Downs Granodiorite, Kongorow Granite). Isotopic dating suggests that some of the massive granites (such as at the Cummins Range) and pegmatites were emplaced prior to the Tickalara metamorphism.

Late Lamboo Complex. The extensive acid post-tectonic Whitewater Volcanics were accompanied by comagmatic high-level intrusives. They post-date the Tickalara metamorphism. In the East Kimberley there is a strong unconformity between the Whitewater Volcanics and Halls Creek Group, but the angular discordance is less well developed in the West Kimberley. All these rocks are intruded by large post-tectonic batholiths of coarse-grained porphyritic granite to granodiorite such as the Bow River and Lennard Granites.

In the King Leopold Mobile Zone the late Lamboo Complex was intensely sheared and folded about southeast axes before deposition began in the Kimberley Basin, but deformation in the Halls Creek Mobile Zone at this time was relatively mild. Since then the rocks of the Halls Creek Province have been repeatedly faulted and uplifted along the Halls Creek and King Leopold Mobile Zones.

PINE CREEK GEOSYNCLINE

(Principal reference: Walpole et al., 1968).

The Lower Proterozoic Pine Creek Geosyncline overlies Archaean basement in the west, and is unconformably overlain by the Carpentarian McArthur Basin in the east (Fig. 2). In the southwest it is unconformably overlain by the Adelaidean Victoria River Basin and Palaeozoic Daly River Basin. The western margin of the geosyncline appears to have been controlled by the northern extension of the Halls Creek Mobile Zone. The major tectonic elements of the geosyncline are illustrated in Figure 4 and the stratigraphy is summarized in Table 2.

The exposed geosyncline is only an inlier of a larger structure whose limits are unknown.

Smart et al. (1974) have shown that the metamorphic and migmatite complexes in western Arnhem Land are the result of Lower Proterozoic metamorphism of the geosynclinal succession, rather than Archaean basement on the eastern margin of an intracratonic basin (Walpole et al. (1968). The recent isotopic age determination (1944 m.y.) of the Bradshaw Granite, which is correlated with the Nanambu Complex (Dunnet, 1965), supports this revision. Smart et al. now describe the geosyncline as a eu-miogeosynclinal couple, with intense orogenesis and metamorphism in the eugeosyncline (Eastern Trough) and miogeosynclinal conditions in the Western Trough (Central Trough of Walpole et al.). The troughs may have been separated by a Median Ridge through the South Alligator River valley (Fig. 4).

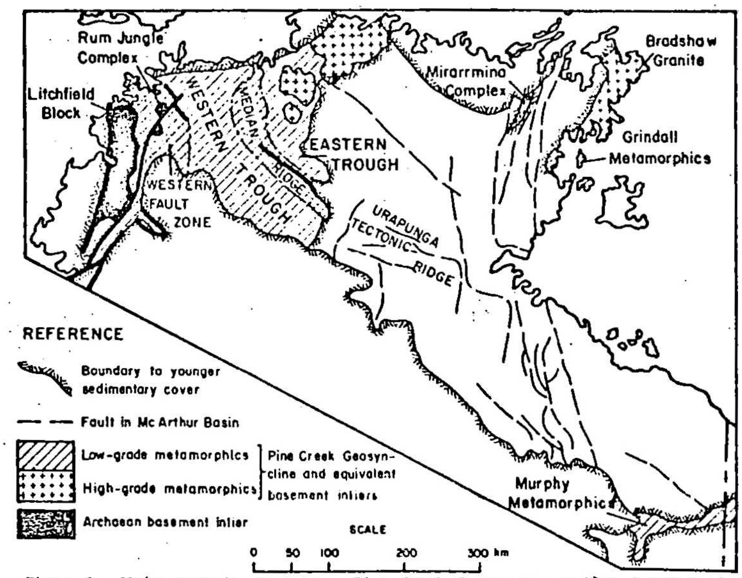

Figure.4. Major tectonic elements, Pine Creek Geosyncline and McArthur Basin basement inliers.

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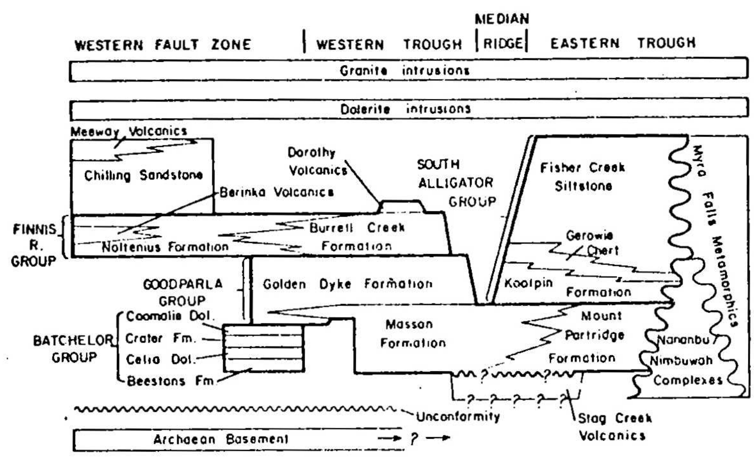

Figure 5. Diagrammatic relationship of Lower Proterozoic rock units, Pine Creek Geosyncline (After Walpole et al., 1968; Sweet et al., 1973; and Smart et al., 1974)

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TABLE 2: SUMMARY OF LOWER PROTEROZOIC STRATIGRAPHY, PINE CREEK GEOSYNCLINE AND McARTHUR RIVER BASEMENT INLIERS AND LOWER PROTEROZOIC TO CARPENTARIAN TRANSITIONAL GRANITES AND ACID VOLCANICS

Unit	Thickness (m)	Main Rock Types	Remarks
POST-TECTONIC GRANITES AND ACID VOLCANICS			
Sheridan Formation	150	Lithic greywacke, conglomerate, shale, feldspathic sandstone.	Locally derived valley-fill deposits overlying Fagan Volc.
YOUNGER(?) GRANITES			
Norris Granite		Biotite granite, adamellite, granophyric leucocratic granite.	Intrudes Cliffdale Volc. Sr, Wo.
Jimbu Granite		Granophyric porphyritic microgranite.	Inlier beneath Katherine R Gp.
Grace Creek Granite		Granophyric microgranite, adamellite.	Katherine-Darwin region Isotopic ages similar to or younger than Edith R Volc.
Mount Bundey Granite, Mount Goyder Syenite.		Porphyritic granite, adamellite, syenite.	
Malone Creek Granite		Aplitic granite.	
VOLCANICS			
Cliffdale, Scrutton, Fagan, Bickerton, Spencer Creek, Edith River Volcanics	150-1000	Porphyritic acid volcanics, ash-flow tuff; interbedded tuff, siltstone, feldspathic sandstone & greywacke; some dolerite intrusives.	U (Pandanus Creek) & minor Cu in Cliffdale Volc. U (Coronation Hill, Scinto, El Sherana) in Edith R Volc.
ARNHEM LAND BASEMENT			
Giddy, Caledon Granites		Porphyritic or granophyric granite & adamellite, fayalite granite.	May include both younger and older granites.
OLDER(?) GRANITES			
Cullen, Burnside, Wolfram Hill, Yeuralba, Allia, Jim Jim etc. Granites		Coarsely porphyritic & even-grained massive biotite-(muscovite)-(hornblende) granite, adamellite, granodiorite, & tonalite.	Katherine-Darwin region. Source of complex Sn, Au, Wo, Mo, Cu, Ag-Pb deposits (e.g. Pine Creek, Union Reefs, Maranboy, Wolfram Hill fields etc.)
Nicholson Granite		Massive, porphyritic & even-grained biotite granite & adamellite.	Murphy Tectonic Ridge. Uncertain relationship with Cliffdale Volc.
Litchfield Complex		Biotite granite to tonalite intrusives. Garnetiferous gneiss, migmatite, metabasics.	'Western Fault Zone', Pine Cr Geosyn. Two phases: late Lower Proterozoic discordant granites and Archaean basement.
Ritarango Beds	3000+	Lithic or feldspathic quartz greywacke, quartz sandstone, greywacke.	Probably Lower Proterozoic. Overlain unconformably by Fagan Volc, but probably unconformable on Mirarrmina Complex.
Basic Intrusives		Dolerite, epidiorite, amphibolite, gabbro.	Sills & dykes in Pine Cr Geosyn. & Mirarrmina Complex.
PINE CREEK GEOSYNCLINE (Katherine-Darwin Region).			
Nanambu, Nimbuwah Complexes, Myra Falls Metamorphics		Massive to foliated granite grading through migmatite & gneiss into pelitic, arenitic, & amphibolite schist & quartzite.	Metamorphosed South Alligator & Goodparla Gps. Mantled migmatic domes. U (Ranger, Koongarra, Jabiluka, Nabarlek).
Chilling Sandstone	450	Quartz sandstone.	'Western Fault Zone', Pine Cr Geosyn.
FINNISS RIVER GROUP	1500	Greywacke, siltstone, conglomerate (Burrell Cr, Noltenius Fms); Acid lavas, intrusives (Berinka, Meeway Volcs); basic lavas (Dorothy Volc).	Host rocks of Au, Sn, Cu, Ag-Pb-Zn in Burrell Cr Fm.

Table 2 (Cont.)

Unit	Thickness (m)	Main Rock Types	Remarks
SOUTH ALLIGATOR GROUP	6000+	Carbonaceous pyritic dolomitic shale, stromatolitic dolomite (Koolpin Fm); chert, siliceous siltstone (Gerowie Chert); siltstone, greywacke siltstone (Fisher Cr Sltst).	U (Ranger, Koongarra, Jabiluka, Nabarlek, South Alligator field) in Koolpin Fm.
GOODPARLA GROUP	5500+	Arkose, conglomerate, siltstone (Mt Partridge Fm); quartz greywacke, siltstone (locally pyritic, carbonaceous) (Masson Fm); carbonaceous dolomitic (pyritic) shale, carbonaceous (pyritic) siltstone, chert, dolomite (Golden Dyke Fm).	Fe (Frances Creek) in Masson Fm. U-Cu (Rum Jungle) & Pb-Zn (Woodcutters, Browns) in Golden Dyke Fm.
BATCHELOR GROUP	1500	Arkose, greywacke, quartz greywacke, siltstone, conglomerate (Beestons, Crater Fms); stromatolitic dolomite, siltstone (Celia, Coomalie Dols).	Phosphate in Coomalie Dol. Unconformably overlies Rum Jungle Complex.
Stag Creek Volcanics		Altered basalt, agglomerate ('greenstone').	Unconformably overlain by Mt Partridge Fm.
McARTHUR BASIN BASEMENT INLIERS			
Bradshaw, Myaoola Granites, Mirarrmina Complex		Massive and gneissic garnetiferous granite & adamellite; cordierite-garnet granulite, paragneiss.	Correlated with Nanambu & Nimbuwah Complexes.
Grindall, Murphy Metamorphics		Chlorite-muscovite slate, phyllite, & greenschist; sheared greywacke, volcanics.	Correlated with Pine Cr Geosyn.
ARCHAEAN BASEMENT INLIERS			
Rum Jungle Complex		Schist, paragneiss, granite, coarse granite.	Unconformably overlain by Batchelor Gp.
Hermit Creek Metamorphics		Schist, granulite, amphibolite, serpentinite.	Unconformably overlain by Noltenius Fm.

Archaean Basement inliers

The Rum Jungle Complex is unconformably overlain by the Lower Proterozoic Batchelor Group, but has domed up the younger rocks during late Lower Proterozoic folding, as in mantled gneiss domes (Rhodes, 1965). Rhodes recognizes six units (in order of decreasing age): schists and gneisses, granite gneiss, metadiorite, coarse granite, large-feldspar granite, and leucocratic granite, all of which are older than the Batchelor Group.

The Hermit Creek Metamorphics at the southern end of the Litchfield Block are unconformably overlain by the Noltenius Formation (Sweet et al., 1973a). Similar rocks within the Litchfield Complex are also unconformably overlain by the Noltenius Formation, but most of the poorly exposed complex consists of late Lower Proterozoic granite.

Pine Creek Geosyncline (Katherine-Darwin region)

The stratigraphic units of the Pine Creek Geosyncline show complex facies changes (Fig. 5). The maximum preserved thickness in the Western Trough probably does not exceed 6000 m (Walpole & Crohn, 1965), but may be greater in the poorly exposed Eastern Trough.

The basic Stag Creek Volcanics unconformably underlie the Goodparla Group in inliers along the Median Ridge. Walpole et al. considered them to be Archaean basement, but they could be part of the Lower Proterozoic geosynclinal succession,* and represent a classic eugeosynclinal initial stage of basic magmatism.

The uplift which followed the volcanism may have established the Median Ridge, about which the thick (3000 m) immature arkosic Mount Partridge Formation was

* Now confirmed (Smart et al., 1974)

deposited, grading laterally and vertically into the siltier Masson Formation of the Western Trough. Walpole et al. postulate an easterly source area but Needham & Smart (1972) suggest an easterly lateral change into lutites in the Eastern Trough. Arkosic rocks alternating with stromatolitic dolomite (Batchelor Group) were deposited on the Western Fault Zone at this time. These sequences all grade vertically, and to some extent laterally, into the carbonaceous, dolomitic, and sometimes pyritic lutites of the Golden Dyke and Koolpin Formations. Stromatolitic bioherms developed within the Koolpin Formation along the Median Ridge, and the formation grades vertically and laterally into the Fisher Creek Siltstone.

Tectonic movements along the Western Fault Zone produced the westerly derived turbidites and local volcanic lenses of the Finniss River Group, the Burrell Creek Formation being generally finer-grained than the Noltenius Formation. This event has not been detected in the Eastern Trough, although deposition of the South Alligator Group was probably continuing. The youngest rocks in the geosyncline are the quartz-rich arenites of the Chilling Sandstone, which were laid down over a much more restricted part of the Western Fault Zone than indicated by Walpole et al. (Sweet et al., 1973a).

The rocks of the central and western areas have been moderately to tightly folded about regional axes, trending from 300° in the southeast, through 360°, to 020° in the northwest, and the regional metamorphism only reached the low greenschist facies. In the Eastern Trough deformation is intense and the fold trends are variable (Smart et al., 1974). Regional metamorphism reached the almandine amphibolite facies in the Nanambu Complex, and there is a gradation from schist, through migmatite, into massive anatectic granite cores in the Nanambu and Nimbuwah Complexes. Faulting occurred over a long period: it apparently affected development of the geosyncline in areas such as the Western Fault Zone and Median Ridge; reverse and normal faults accompanied the folding; and post-Carpentarian and post-Adelaidean faulting also deformed the geosyncline.

Sills of tholeiitic dolerite, commonly metamorphosed, were emplaced both before and after the main folding.

McArthur Basin basement inliers

Inliers within the Murphy Tectonic Ridge (Murphy Metamorphics), eastern Arnhem Land (Grindall Metamorphics, Bradshaw Granite, and Mirarrimina Complex), and possibly the Big Toby/Yaringa Block (Yaringa Metamorphics) contain similar rocks to the Pine Creek Geosyncline and might be continuous with it in the subsurface (Figs 2, 4).

The Median Ridge is aligned with the younger Urapunga Tectonic Ridge. All the high-grade metamorphic rocks form a west-trending belt to the north of this line, with metamorphic grade decreasing southwards into the Grindall Metamorphics. Metamorphic grade reaches the biotite-cordierite-almandine subfacies of the granulite facies in the Bradshaw Granite (a complex of metamorphic rocks and anatectic granite). Volcanigenic rocks in the Grindall Metamorphics and Mirarrmina Complex are consistent with a eugeosyncline. Structural trends are dominantly easterly.

Ashstone is recorded from the Murphy Metamorphics. The connection of the Murphy and Yaringa Metamorphics to the Pine Creek Geosyncline is less certain.

It can be postulated that the Pine Creek Geosyncline was a large westerly trending structure, deflected to the north at its western end against the Halls Creek Mobile Zone, and divided into a eugeosyncline in the northeast and a miogeosyncline in the southwest.

Ritarango Beds

Beneath the Batten Trough in central Arnhem Land locally derived lithic and feldspathic arenites appear to rest unconformably on the Mirarrmina Complex. They were intensely sheared by closely spaced strike-slip faults before the unconformably overlying Fagan Volcanics were deposited. No related sequence is known anywhere else in northern Australia. The beds may reflect local initiation of the Batten Trough and are assigned to transitional tectonism.

Post-tectonic granites and acid volcanics

Late Lower Proterozoic to early Carpentarian post-tectonic granites and acid volcanics intrude or overlie the Lower Proterozoic metasediments in the Pine Creek Geosyncline and all basement inliers; they are unconformably overlain by the McArthur Basin succession (Fig. 7), and represent an important tectonic and geochronological event in northern Australia (together with the slightly older late Lamboo Complex of the Halls Creek Province and slightly younger rocks of the Kalkadoon-Leichhardt Block). They were assigned entirely to the Carpentarian by Walpole et al. (1965, 1968), but it is now thought that some of the granites may be significantly older than the Cliffdale Volcanics.

The volcanic rocks are widespread beneath the McArthur Basin, but granites are only exposed in the inliers which were basement ridges or basin margins during deposition in the McArthur Basin (Fig. 8). This may be fortuitous because of the limited extent of the inliers, but the initiation of sedimentation in the McArthur Basin has been attributed to uplift of the marginal areas during granite emplacement (Walpole et al., 1965, 1968). The granites and volcanics may also be related to waning activity in the geosyncline; they represent typical transitional tectonism (GSA, 1971).

The acid volcanics all appear to be of about the same age. They are mostly massive porphyritic ash-flow tuffs. Subordinate interbedded sediments occur in some formations. The rocks were only very mildly to moderately deformed before deposition in the McArthur Basin began. Small locally derived valley-fill deposits (Sheridan Formation) were laid down on the Fagan Volcanics before the Parsons Range Group was deposited.

There appear to be two groups of granites, although the age relationships of the older (e.g. Nicholson and Cullen Granites) are still unresolved. The apparently older granites are contact aureole or mesothermal granites. They intrude metasediments discordantly, have narrow to moderate contact thermal metamorphic aureoles, and may antedate the volcanics. The younger granites (e.g. Norris and Grace Creek Granites) either intrude or have isotopic ages younger than the volcanics and are spatially associated with the volcanics; their fabrics and minerals are typical of subvolcanic granites.

The Giddy and Caledon Granites of eastern Arnhem Land also appear to be subvolcanic granites: they have granophyric textures, monoclinic K-feldspar, spatial and petrological (both contain fayalite) affinity with volcanics, and depth zoning, but they are complex bodies which may include older granites. The dated sample (1825 ± 25 m.y.) possesses both subvolcanic (including fayalite) and contact aureole features.

KIMBERLEY BASIN

The Kimberley Basin is a relatively undisturbed structural basin over 160 000 km^2 in area, which was developed on the Kimberley Block in the far north of Western Australia (Fig. 2). It is flanked by the Halls Creek and King Leopold Mobile Zones to the southeast and southwest respectively, from which most of the basin succession has been eroded; the succession in the basin rests unconformably on the igneous and metamorphic rocks of the Halls Creek Province. The succession comprises the Speewah, Kimberley, Bastion, and Crowhurst Groups, of late Lower Proterozoic age, and is unconformably overlain by various Adelaidean sequences around the margins of the basin. To the north and west the basin is flanked by the Timor Sea, beneath which the basin is unconformably overlain by the Phanerozoic basins of the Northwest Shelf. The stratigraphy of the basin is summarized in Table 3 and Figure 6.

The Speewah Group only crops out along the southwestern and southeastern margins of the basin, where steep dips prevail adjacent to the mobile zones. It contains mainly feldspathic and quartzose arenites,

TABLE 3: SUMMARY OF LATE LOWER PROTEROZOIC STRATIGRAPHY, KIMBERLEY BASIN

Group	Unit	Main Rock Types	Thickness (m)	Remarks
	Wotjulum Porphyry	Quartz-feldspar porphyry.	60-600	Minor Cu
	Hart Dolerite	Tholeiitic dolerite, granophyre.	Up to 3000	Fluorite (Speewah); Pb (Costeos); minor Cu.
	Fish Hole Dolerite	Epidotized vesicular dolerite.	" 900	Minor Cu common.
CROWHURST GROUP	Hibberson Dolomite	Dolomite, dolomitic breccia, sandstone.	25+	Stromatolites
	Collett Siltstone	Siltstone, rarely pyritic; dolomite.	60	
	Liga Shale	Green shale, minor siltstone.	45	
	Hilfordy Formation	Quartz sandstone, siltstone, shale.	30	Possibly equivalent to Mendena Fm.
BASTION GROUP	Cockburn Sandstone	Quartz sandstone; micaceous sandstone, shale.	500+	
	Wyndham Shale	Green shale, fine sandstone.	690	
	Mendena Formation	Quartz sandstone, siltstone, dolomite.	110	Cu traces
KIMBERLEY GROUP	Pentecost Sandstone	Quartz & feldspathic sandstone, siltstone, glauconitic sandstone	420-1300	Fe (Yampi); some stratabound Cu.
	Elgee Siltstone	Red siltstone, sandstone, limestone, dolomite.	40-480	Teronis Mbr contains stromatolites, some stratabound Cu.
	Warton Sandstone	Quartz & feldspathic sandstone, siltstone.	240-900	Heavy mineral bands (rutile, zircon) locally.
	Carson Volcanics	Tholeiitic basalt, spilite; sandstone, siltstone, chert.	360-1100	Cu in flow tops and fractures; bedrock to bauxite (Mitchell Plateau).
	King Leopold Sandstone	Quartz sandstone, conglomerate.	900-1200	Radiometric anomalies common.
SPEEWAH GROUP	Luman Siltstone	Siltstone, shale.	100	
	Lansdowne Arkose	Feldspathic sandstone, arkose, siltstone, shale.	350-480	
	Valentine Siltstone	Chloritic siltstone, sandstone, rhyolite tuff.	30-75	
	Tunganary Formation	Sandstone, arkose, shale, siltstone.	200-300	
	O'Donnell Formation	Subgreywacke, shale, siltstone, granule sandstone.	Up to 300	Some radiometric anomalies & heavy mineral banding
	Revolver Creek Formation	Amygdaloidal basalt, quartz sandstone, siltstone, arkose.	Up to 1200	Equivalent to Kimberley Gp.
	Red Rock Beds	Quartz sandstone, conglomerate, siltstone.	2100	Equivalent to Speewah & Kimberley Gps.
	Moola Bulla Formation	Feldspathic sandstone, conglomerate, greywacke, siltstone.	3000+	

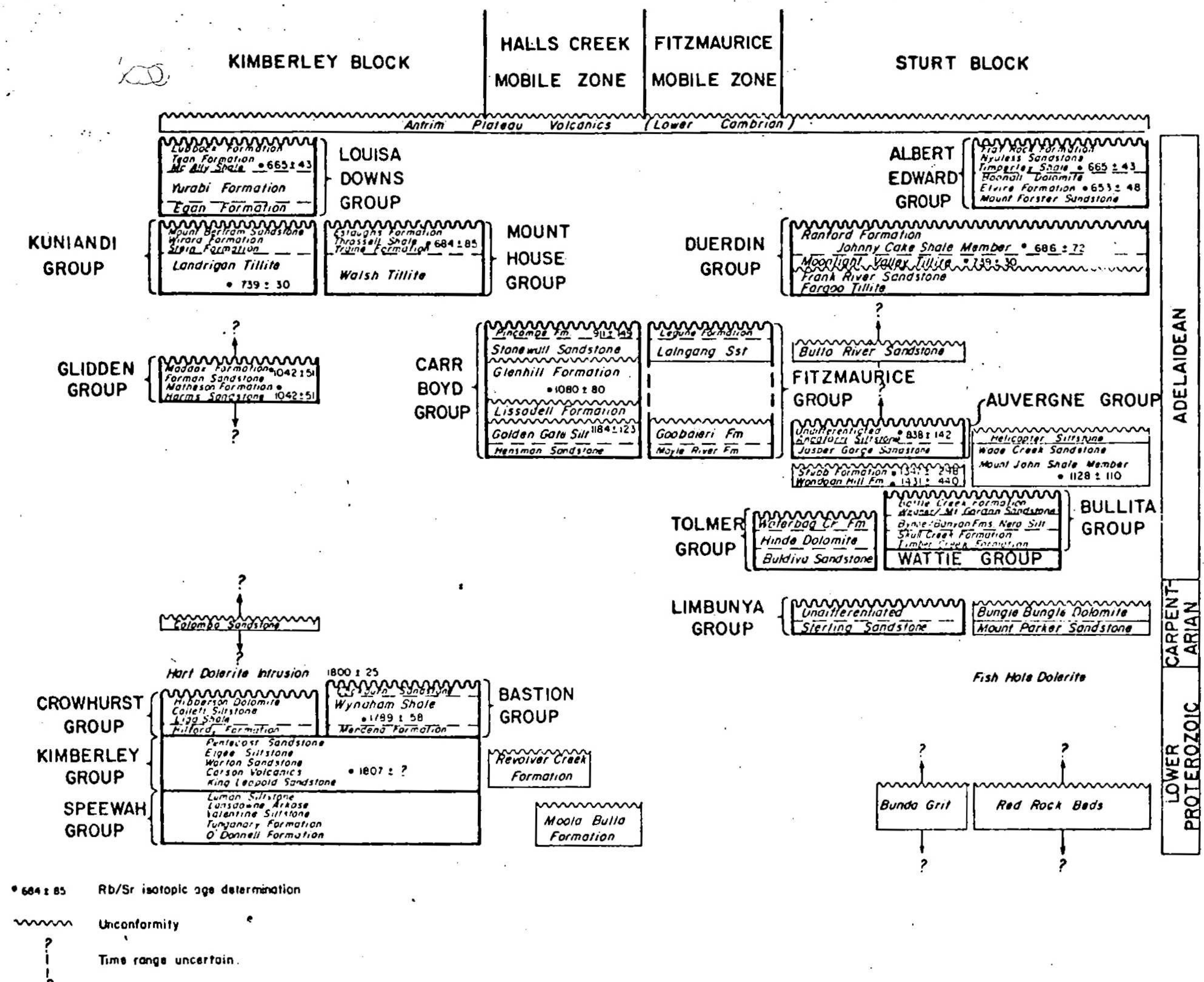

Figure 6. Stratigraphic correlation chart of Proterozoic sedimentary basins, Kimberley and Victoria River regions.

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subordinate lutites, and minor acid volcanics. Glauconite indicates marine conditions. A basal greywacke grit, derived from the underlying Whitewater Volcanics, is widespread in the east. Facies and thickness changes are complex; in general the arenites thin and become less feldspathic to the west (Gellatly, et al., 1970).

The Kimberley Group crops out throughout the basin and contains mainly mature quartz-rich arenites, deposited uniformly over wide areas. The Bastion and Crowhurst Groups are only preserved in the east. The tholeiitic Carson Volcanics vary widely in thickness and contain pillow lavas. The Elgee Siltstone redbeds show the most marked facies changes: the thickness increases, the sand/shale ratio decreases, and the stromatolitic dolomites (Teronis Member) thicken to the south. The feldspar content in the Pentecost Sandstone decreases southwards and the presence of glauconite indicates marine conditions for this unit at least. In the northwest a shoreline is indicated by the presence of basal conglomerate and beach breccia, abundant sand, and halite pseudomorphs in the Elgee Siltstone, and by fossil beach sands in the Yampi Sound iron ores at the base of the Pentecost Sandstone. These variations all agree with a consistent pattern of palaeocurrents from the north, which were interpreted by Gellatly et al. (1970) as steady longshore ocean currents.

The Revolver Creek Formation, Moola Bulla Formation, and Red Rock Beds are outliers of the Kimberley Basin succession equivalents preserved in the Halls Creek Mobile Zone. Facies changes and types of sediment show that the mobile zone was tectonically active at this time (Dow &

Gemuts, 1969), although the mobile zone contributed little detritus to the basin proper; local derivation from the mobile zone is only apparent in the Speewah Group. At this time, the direction of the palaeocurrents was from the northeast (Gellatly et al., 1970), but later there was a change to north in the King Leopold Sandstone; Speewah Group equivalents were not deposited in the northeast beneath the Revolver Creek Formation.

The tholeiitic Hart Dolerite sills intrude units up to at least the Pentecost Sandstone. It is one of the major dolerite bodies of the world, and underlies the whole basin (160 000 km^2), with a composite thickness of up to 3000 m. Individual sills are up to 2000 m thick, with granophyre differentiates up to 250 m thick at the top of the thicker sills. The sills are most extensive in the Speewah Group, and contain large blocks of sedimentary rocks, several kilometres square and several hundred metres thick, which have been rafted along fracture planes and are completely enclosed in dolerite. Only small inliers are exposed in the central part of the basin, where the total thickness of dolerite is unknown.

Post-depositional deformation of the Kimberley Basin was in response to movements in the marginal mobile zones. Deformation of the Halls Creek Mobile Zone is dominated by left-lateral strike-slip faulting on numerous major faults; individual horizontal displacements up to 30 km and vertical displacements up to 5 km have been demonstrated (Dow & Gemuts, 1969; Plumb, 1968). Deformation along the King Leopold Mobile Zone was by steep reverse faulting and overturned folding, with only minor strike-slip faulting

(Gellatly et al., 1968; Sofoulis et al., 1971). Movements along both mobile zones have occurred throughout the Proterozoic and, to a lesser extent, the Palaeozoic. The Kimberley Basin rocks were locally metamorphosed up to amphibolite grade in the Yampi area (Sofoulis et al., 1971) about 1550 and 600 m.y. ago (Bennett & Gellatly, 1970). Deformation of the basin falls off rapidly away from the mobile zones and reflects movements on a basement fracture pattern parallel to the mobile zones.

McARTHUR BASIN

The McArthur Basin is a relatively undeformed structure containing mainly shallow-water sediments, which are exposed over about 170 000 km^2 in the Northern Territory around the western side of the Gulf of Carpentaria. It is bounded by, and unconformably overlies, the Lower Proterozoic inliers of the Pine Creek Geosyncline, Murphy Tectonic Ridge, and northeast Arnhem Land; the succession also unconformably overlies late Lower Proterozoic to early Carpentarian post-tectonic acid volcanics and granites. In the north, south, and east the basin extends beneath the unconformably overlying covers of the Adelaidean Arafura Basin, the early Palaeozoic Georgina and Daly River Basins, and the Mesozoic Carpentaria Basin respectively, so that the full extent of the basin is unknown.

The succession is up to 12 km thick, and comprises three major subdivisions. Different stratigraphic nomenclatures have been applied in widely separated areas where the original formations can no longer be recognized

(Fig. 7). The three main units are as follows: the Tawallah Group and equivalents, which consist of quartz-rich arenites and subordinate basic volcanics, carbonates, and lutites up to 6 km thick; overlain by a dominantly carbonate sequence, the McArthur Group and equivalents, up to 5.5 km thick; on which rest with regional unconformity the Roper and Malay Road Groups, which consist of alternating quartz arenites and micaceous lutites up to 5 km thick. The stratigraphy of the McArthur Group has recently been revised (Plumb & Brown, 1973); a previously postulated barrier reef (e.g., Smith, 1964; Plumb & Paine, 1964) is not present. The Tawallah and McArthur Groups, together with the underlying Cliffdale Volcanics, comprise the type section for the Carpentarian (Dunn et al., 1966). The Roper Group might be Adelaidean or Carpentarian depending on final determination of the age of the type Adelaidean. The stratigraphy of the basin is summarized in Table 4.

A number of distinct tectonic elements are recognized within the McArthur Basin (Fig. 8). A very much thicker Carpentarian succession was deposited in the 50-60 km wide northerly trending fault-bounded Batten Trough than on the adjoining Arnhem, Caledon, Bauhinia, and Wearyan Shelves. The east-bounding Emu and Koolatong Faults were active during deposition, and the Parsons Range Fault, on the northwestern side was, by analogy, also probably active. In the south, however, the western margin to the trough is gradational. South of the Mallapunyah Fault the similarity of the stratigraphy within the trough to that on the Wearyan and Bauhinia Shelves may indicate proximity to the southern limit of the Batten Trough. An exceptionally thin

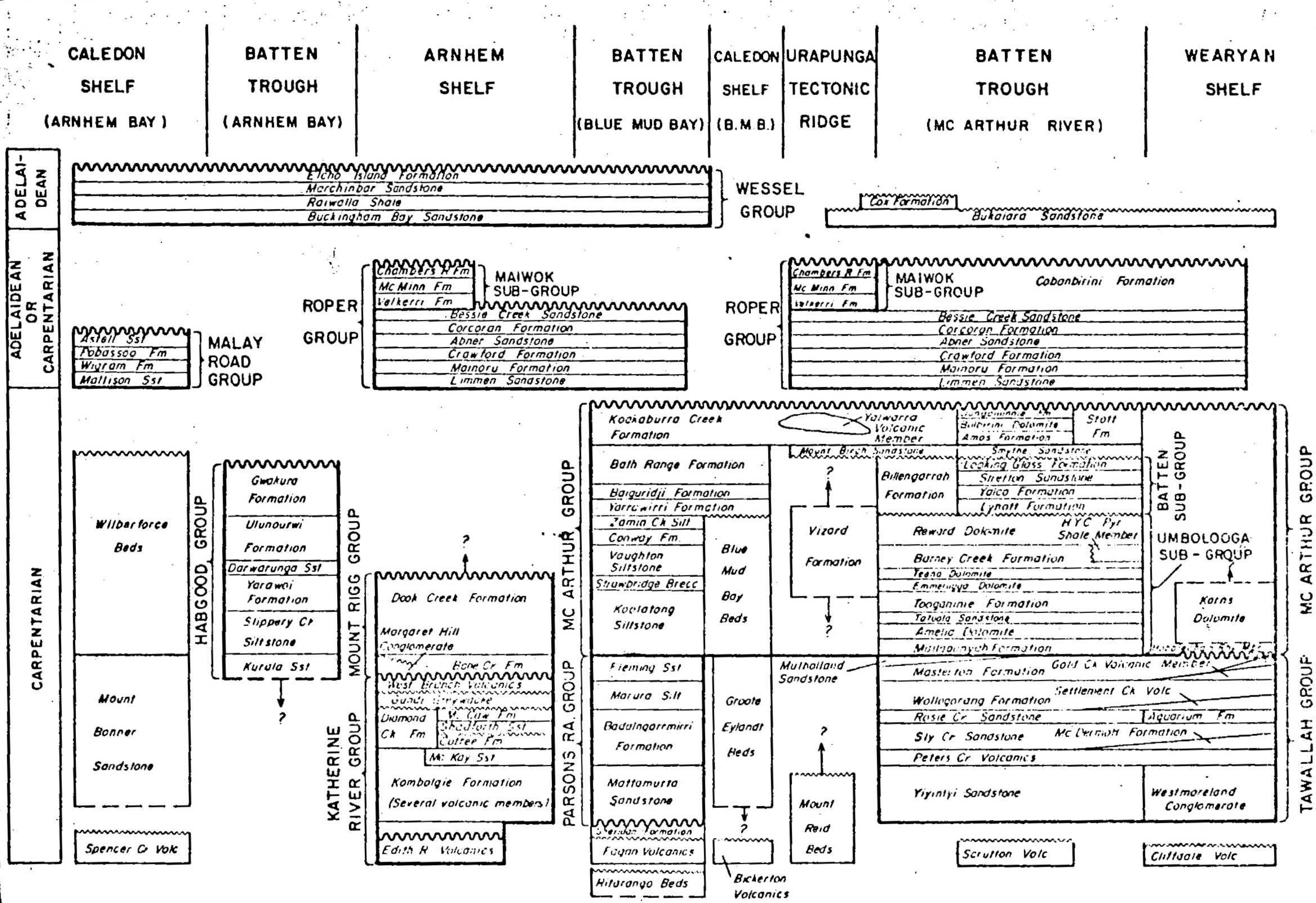

Figure 7. Stratigraphic correlation chart, Mc Arthur Basin, with underlying acid volcanic complexes and overlying Adelaidean basins.

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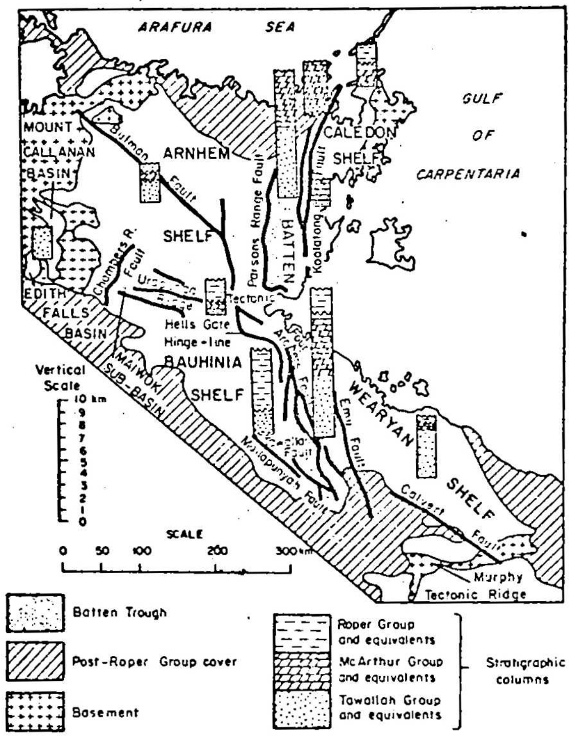

Figure 8. Major tectonic elements, Mc Arthur Basin.

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TABLE 4: SUMMARY OF CARPENTARIAN AND ADELAIDEAN(?) STRATIGRAPHY, McARTHUR BASIN

Unit and Locality	Thickness (m)	Main Rock Types	Remarks
Dolerite sills			Intrude Roper, Mt Rigg, Katherine R, & Malay Road Gps.
ROPER GROUP (Throughout basin)	500 - 5000	Quartz sandstone, minor ferruginous sandstone, shale (Limmen, Abner, Bessie Cr Ssts); micaceous siltstone (Mainoru Fm); micaceous glauconitic sandstone (Crawford Fm); interbedded micaceous fine sandstone, siltstone, & shale (Corcoran, Cobanbirini Fms, Maiwok Sub-Gp).	Fe (Roper R) in Sherwin Ironstone Mbr of McMinn Fm. Overlies McArthur & Mt Rigg Gps with regional unconformity.
MALAY ROAD GROUP (Caledon Shelf)	1550+	Quartz sandstone (Mallison, Astell Ssts); micaceous siltstone, quartz greywacke (Wi r n, Pobassoo Fms); black shale (Wigram Fm); glauconitic sandstone (Pobassoo Fm).	Unconformably overlies Wilberforce Beds. Correlated with Roper Gp.
McARTHUR GROUP	0 - 5500	Dominantly carbonate rocks	
Batten Trough - McArthur River area	1250	Chert-quartz sandstone, conglomerate (Smythe Sst); dolomite, siltstone, shale, chert, oolitic chert (Amos, Dungaminnie, Stott Fms); dolomite, dololutite, some stromatolites (Balbirini Dol).	Locally unconformable on Batten Sub-Gp.
Batten Sub-Group	1000	Dolomitic siltstone, sandstone, shale (Lynott Fm); interlaminated siltstone-chert (Yalco Fm); quartz sandstone (Stretton Sst); chert, cherty siltstone (Looking Glass Fm)	Locally unconformable on Umbolooga Sub-Gp.
Billengarrah Formation	1000	Chert, sandstone, dolomite, shale.	Correlated with Batten Sub-Gp.
Umbolooga Sub-Group	Up to 3250	Ferruginous & dolomitic sandstone & siltstone, dolomite (Mallapunyah Fm); dolomite, dololutite, abundant stromatolites (Amelia, Emmerugga, Teena, Reward Dols); flaggy sandstone (Tatoola Sst); alternating dolomite (stromatolites), dolomitic siltstone & sandstone (Tooganinie Fm); dolomitic, tuffaceous, bituminous, & pyritic shale (Barney Creek Fm), basic to intermediate volcanics (?Amelia Dol).	Pb-Zn (H.Y.C.) in H.Y.C. Pyritic Sh Mbr of Barney Cr Fm. Minor Pb in Emmerugga Dol & Cu in Amelia Dol & Tooganinie Fm.
Batten Trough - Blue Mud Bay area	4500	Siltstone, shale, dolomite (Koolatong Sltst); chert breccia (Strawbridge Breccia); black shale, dolomitic siltstone & shale (Stuff) (Vaughton Sltst); siliceous siltstone, chert (Conwry Fm, Zamia Cr Sltst); dolomitic siltstone, chert-quartz sandstone, conglomerate (Yarrawirrie Fm); interlaminated siltstone-claystone, feldspathic fine-grained sandstone (Baiguridji Fm); feldspathic tuffaceous siltstone, pelletal & oolitic chert, interlaminated siltstone-claystone, dolomitic siltstone (Bath Ra Fm).	Succession broadly similar to that at McArthur River although detailed correlations not possible - Vaughton Sltst probably equivalent to Barney Cr Fm.
Urapunga Tectonic Ridge	750+	Dolomitic & cherty siltstone; dolomite, stromatolitic dolomite; dolomitic, feldspathic, & quartz sandstones (Vizard, Kookaburra Cr Fms); feldspathic chert-quartz sandstone, conglomerate (Mt Birch Sst); oolitic chert (Kookaburra Cr Fm); basic to intermediate volcanics (Yalwarra Volc Mbr of Kookaburra Cr Fm).	Minor Pb, Cu in Kookaburra Cr Fm.
Wearyan Shelf	150	Dolomite, stromatolites common; dolomitic siltstone, sandstone, chert (Karns Dol).	Minor Pb. Time equivalent of McArthur Gp. Unconformable on Tawallah Gp.
Caledon Shelf - Blue Mud Bay area	1600	Dolomitic siltstone, chert, sandstone, dolomite, stromatolites (Blue Mud Bay Beds), plus Yarrawirrie, Baiguridgi & Bath Ra Fms.	Thickness includes Yarrawirrie, Baiguridgi, & Bath Ra Fms.
HABGOOD GROUP (Batten Trough - Arnhem Bay area)	4000	Dolomitic & cherty siltstone & sandstone, dolomite, stromatolites, conglomerate (Iaravoi, Ulunourwi, Gwakura Fms); micaceous siltstone, pyritic sandstone (Slippery Cr Sltst); quartz sandstone (Kurala, Darwarunga Ssts).	Base & top not exposed. Correlates with McArthur Gp & uppermost Parsons Ra Gp.
Wilberforce Beds (Caledon Shelf)	1500	Micaceous dolomitic siltstone, shale, & fine sandstone	Section incompletely exposed. Lateral equivalent of McArthur Gp.
MOUNT RIGG GROUP (Arnhem Shelf)	700	Quartz sandstone, conglomerate (Bone Cr Fm, Margaret Hill Cgl); dolomite, stromatolites, dolomitic siltstone & sandstone, chert, oolites (Dook Cr Fm).	Pb-Zn (Bulman). Correlated with McArthur Gp & uppermost Tawallah Gp.
TAWALLAH GROUP (Wearyan Shelf, Batten Trough - McArthur River area)	4000-5000	Quartz and feldspathic sandstones, conglomerate (Yiyintyi, Sly Creek, Mulholland Ssts, Westmoreland Cgl, Masterton Fm). Subordinate basic to intermediate volcanics, (Peters Cr, Settlement Cr Volcs, Gold Cr Volc Mbr of Masterton Fm); acid volcanics (Cobblechain Rhyolite & Tanumbirini Volc Mbrs of Masterton Fm); dolomite, dolomitic siltstone & sandstone (Wollogorang, McDermott Fms); glauconitic sandstone & siltstone (Aquarium Fm, Hosie Cr Sst).	U (Westmoreland) in dolorite dykes in Westmoreland Cgl. Minor U in Peters Cr Volc. Cu (Redbank) in breccia pipes in Gold Cr Volc Mbr.
KATHERINE RIVER GROUP (Arnhem Shelf)	1800-2700	Quartz sandstone, minor feldspathic or ferruginous sandstone, conglomerate (Kombolgie Fm, McKay, Shadforth Ssts); basic volcanics (various mbrs of Kombolgie Fm & West Branch Volc, McCaw Fm); (tuffaceous) quartz greywacke (Gundi Greywacke, West Branch Volc, Kombolgie Fm (locally)); dolomite, dolomitic siltstone & sandstone, siltstone, shale, glauconite (Cottee, McCaw, Diamond Cr Fms).	U (ABC) in McAddens Cr Volc Mbr of Kombolgie Fm. Correlated with Tawallah Gp. Several unconformities in succession. Group includes Edith R Volc (see Table 2).

Table 4 (Cont.)

Unit and Locality	Thickness (m)	Main Rock Types	Remarks
PARSONS RANGE GROUP (Batten Trough - Blue Mud Bay area)	6000	Quartz sandstone (Mattamurta, Fleming Ssts); quartz sandstone, ferruginous and feldspathic sandstones, siltstone, dolomite (Dudalyarralirri Fm); siltstone, shale, dolomite (Harura Sltst).	Correlated with Tawallah Gp.
Groote Eylandt Beds (Caledon Shelf)	9-600	Quartz sandstone, argillaceous sandstone, quartz greywacke, shale, conglomerate	Lateral equivalent of all or part of Tawallah Gp in Blue Mud Bay.
Mount Bonner Sandstone (Caledon Shelf)	150	Quartz sandstone, conglomerate	Lateral equivalent of all or part of Tawallah Gp near Arnhem Bay.
Mount Reid Beds (Urapunga Tectonic Ridge)	60	Porphyritic rhyolite overlain by sandstone & conglomerate	Possibly equivalent to Tawallah Gp & Cliffdale Volc; correlation uncertain.

Carpentarian succession at Urapunga indicates a westerly trending ridge (Urapunga Tectonic Ridge) between the Arnhem and Bauhinia Shelves. Eastward extrapolation of this ridge into the area of little outcrop near the coast appears to offset the Batten Trough, and it may be that the trough developed as two separate structures, separated by the ridge. The Mount Callanan and Edith Falls Basins, in the extreme west, are marginal downwarps in which abruptly thickened sequences of Kombolgie Formation were deposited while, in the southeast, the Tawallah Group thins abruptly onto the Murphy Tectonic Ridge.

The Batten Trough first developed in the north, where it controlled accumulation of both the Parsons Range and McArthur Groups; the older Ritarango Beds may have been laid down in an even earlier forerunner of the trough. In the McArthur River area to the south, the trough only achieved full significance during McArthur Group times; possible earlier effects are only seen as facies changes in the Tawallah Group, without marked differences in total thickness. During Roper Group times the zone of maximum sedimentation shifted westward onto the Bauhinia Shelf. The thickness decreases gradually to the north and east, and it is unclear what influence, if any, the Batten Trough faults had on Roper Group sedimentation. The Chambers River Fault controlled the westerly limit of the Roper Group. The name Maiwok Sub-Basin is applied to the area where the Maiwok Sub-Group was deposited. The Malay Road Group in northeast Arnhem Land probably accumulated in a distinct basin, which was separated from the Roper Group by a ridge along the site of the preceding Batten Trough.

Subsequent deformation of the basin has been most intense within the Batten Trough; complex large-scale block faulting uplifted the trough into the present-day anticlinorium or horst. Another zone of faulting concentrated along the Urapunga Tectonic Ridge.

Tawallah Group (and equivalent) sedimentation in the McArthur Basin began with the deposition of up to 3000 m of uniform cross-bedded quartz-rich sandstone (Yiyintyi Sandstone and equivalents). These sandstones are thickest, best sorted, and most uniform within the Batten Trough and, in the McArthur River region, appear to have been derived from the northeast. Source directions on the Wearyan and Arnhem Shelves were from the east and west respectively. The Westmoreland Conglomerate includes near-shore conglomerates and arkoses, derived from the adjacent fault-bounded(?) Murphy Tectonic Ridge, which was only transgressed intermittently. In the west, the Kombolgie Formation locally contains quartz greywackes in the marginal possibly fault-controlled(?) Mount Callanan and Edith Falls Basins.

The deposition of the basal arenites was followed by widespread flood basalt volcanism (Peters Creek Volcanics etc.). The volcanics are thickest and repeated throughout the Tawallah and Katherine River Groups on the Wearyan, Bauhinia, and Arnhem Shelves, but they die out rapidly to the north in the Batten Trough and are absent in the Parsons Range Group. This seems to contradict the commonly accepted hypothesis of an association of flood basalts with major fractures, and indicates a crustal structure beneath the trough different to that beneath the shalves and marginal ridges.

The initial volcanics (Peters Creek Volcanics etc.) are followed by sandstone alternating with siltstone, carbonates, and the later volcanics already referred to. The presence of glauconite in some units indicates shallow-marine conditions. The carbonates contain stromatolites locally, and considerable terriginous material. Sandstones predominate in the Batten Trough, while carbonates are best developed on the Arnhem and Wearyan Shelves. Several periods of erosion interrupted sedimentation on the Arnhem Shelf, particularly around domes overlying basement ridges. Regional facies variations indicate a general southwesterly provenance for the detritus laid down on the Arnhem, Bauhinia, and Wearyan Shelves, and in the southern part of the Batten Trough.

The Tawallah Group equivalent on the Urapunga Tectonic Ridge (Mount Reid Beds) is only 30 m thick. On the Caledon Shelf the Mount Bonner Sandstone and Groote Eylandt Beds (up to 600 m thick) represent the whole of Tawallah Group, and progressively transgress onto a stable basement ridge centred around Gove Peninsula and Blue Mud Bay.

On the Arnhem and Wearyan Shelves deposition of the Tawallah Group was followed by a period of erosion, but in the Batten Trough sedimentation continued without a break into the McArthur Group.

The McArthur Group is best known from the McArthur River area. The Batten Trough successions of the Blue Mud Bay and Arnhem Bay (Habgood Group) areas are similar (Fig. 7). The equivalents on the Arnhem and Wearyan Shelves (Dook Creek Formation and Karns Dolomite) are mainly shelf carbonates like the Umbolooga Sub-Group, although precise correlations are not possible. On the Bauhinia Shelf the Umbolooga Sub-Group is directly overlain by the Roper Group or Mount Birch Sandstone. The Vizard Formation on the Urapunga Tectonic Ridge is equivalent to all or part of the Umbolooga or Batten Sub-Groups, or both; facies changes preclude precise correlations. The shelves may have been largely areas of non-deposition during the period when the Batten Sub-Group was laid down, except on the Caledon Shelf where the younger units transgress, without significant changes in thickness, the thin Blue Mud Bay Beds.

The Umbolooga Sub-Group and equivalents were deposited in an arid hypersaline environment alternating, commonly cyclically, between supratidal, intertidal, and shallow subtidal conditions. Dolomite alternates with siltstone and sandstone. The presence of stromatolites, halite pseudomorphs, oolites, mud cracks, ripple marks, cross-beds, and red oxidized terriginous sediments attest to the environment. Similar conditions existed over most of the McArthur Basin. Thin potassium-rich tuffs are scattered through the sub-group and basic lavas were extruded locally near the base of the sequence northwest of Borroloola. During a later major transgression shale containing considerable tuffaceous material (Barney Creek Formation) was laid down in deeper water. At McArthur River the Bulburra Depression developed locally adjacent to the active Emu Fault; Brown (1969) has estimated that the depth of water may have been as much as 300 to 800 m. Up to 530 m of shale was deposited in the depression, including the H.Y.C. Pyritic Shale Member which contains the bedded sphalerite and galena of the H.Y.C. orebody (Croxford & Jephcott, 1972). The Vaughton Siltstone of the Blue Mud Bay area may correlate with the Barney Creek Formation. A regression resulted in a return to shallow shelf conditions (Reward Dolomite) at the top of the sub-group.

Subsequent tectonic adjustments are indicated by local unconformities at the base of the Batten Sub-Group, and by conglomerates at the base of the Yarrawirrie and Gwakura Formations in Arnhem Land. Sedimentation appears to have been largely restricted to the Batten Trough area, where the carbonate basinal facies of the Batten Sub-Group and equivalents was laid down in shallow to moderately deep water. The carbonate detritus probably derived from erosion of the shelves, and much of the abundant fine terriginous material may have been transported by wind. Potassium-rich tuffs are locally abundant in the Bath Range Formation in Arnhem Land.

Further tectonic adjustments are indicated by the presence of conglomerates, and by transgression of the Mount Birch and Smythe Sandstones across older units.

The presence of stromatolitic dolomites and oolites in the overlying units indicate a return to a shallow shelf environment. Local basic volcanics are interbedded with feldspathic sandstone in the Yalwarra Volcanic Member on the Urapunga Tectonic Ridge.

The erosional unconformity below the Roper and Malay Road Groups is believed to be of the same age as the folding and metamorphism in the Mount Isa Orogenic Domain. The groups are characterized by mica-rich siltstone and quartz greywacke alternating with clean quartz sandstone, typical of the unstable shelf association. Shallow-marine conditions are indicated by glauconite. The regional facies changes in the Roper Group suggest a general southwesterly provenance but the source of the Malay Road Group is unknown. Oolitic sideritic and hematitic iron ores (Sherwin Ironstone Member) were deposited in the Roper River area.

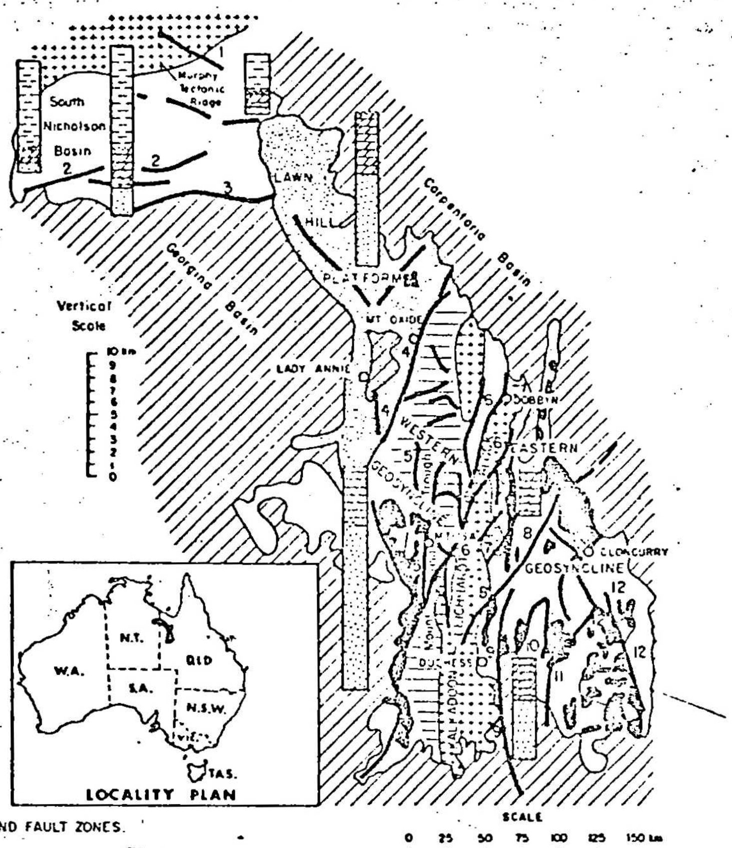
Tholeiitic dolerite sills intrude the Roper, Mount Rigg, and Katherine River Groups on the Arnhem Shelf and Urapunga Tectonic Ridge, and the Malay Road Group on the Caledon Shelf. They antedate the main deformation.

Deformation has been mainly in response to complex block faulting on pre-existing basement faults. It is most intense on northerly trending faults along the Batten Trough. Movements in the McArthur Basin are dominated by vertical displacements of up to 7.5 km. Horizontal displacements cannot be detected, but the forerunners of the McArthur Basin structures, seen as pre-McArthur Basin faults in the Lower Proterozoic Ritarango Beds, developed as a right-lateral strike-slip fault system. The Roper Group in the northeastern part of the Bauhinia Shelf has been deformed by north-trending right-lateral strike-slip faults, and on the Arnhem Shelf a similar stress field has resulted in the formation of a well-developed pattern of joints. A zone of west-trending high-angle reverse faults extends along the Urapunga Tectonic Ridge. The northwest-trending Bulman and Calvert Faults are striking features on the Arnhem and Wearyan Shelves, but show little displacement; minor left-lateral strike-slip can be seen in places. The similar trending Mallapunyah Fault is more obscure and has considerable vertical movement, north block down. Deformation of the McArthur Basin ceased before the Arafura Basin developed.

NORTHWEST QUEENSLAND PROVINCE

(Principal references: Carter et al., 1961; Glikson & Derrick, 1970; Derrick et al., 1971, in prep.; Glikson et al., in prep.).

The Northwest Queensland Province (Figs 2, 9) contains Lower Proterozoic to Adelaidean(?) rocks equivalent to the McArthur Basin and Pine Creek Geosyncline, but was the site of more intense tectonic activity than in the McArthur Basin during the Carpentarian. Precambrian rocks are exposed over about 80 000 km^2, including the South Nicholson area of the Northern Territory. In the northwest the Murphy Tectonic Ridge separates the province from the McArthur Basin, but elsewhere the province is bounded by cover rocks of the Palaeozoic Georgina Basin or Mesozoic Eromanga and Carpentaria Basins. Tectonic activity increases in



FAULTS AND FAULT ZONES.

1 Calvert
2 Mitchiebo
3 Littles Range
4 Mt. Gordon
5 Mt Isa
6 Gorge Cr – Mt Remarkable
7 Wonga
8 Fountain Range - Corella
9 Pilgrim
10 Rooring - Camel
11 Fence
12 Cloncurry 'Thrust'

Post-basement granites

Mount Isa trough

Post- South Nicholson Group cover

Basement

Stratigraphic Columns

South Nicholson groups

McArthur, Mount Isa, Portal and Mary Kathleen Groups

Tawallah, Haslingden, and Malbon Groups

Figure 9. Major tectonic elements, Northwest Queensland Province.

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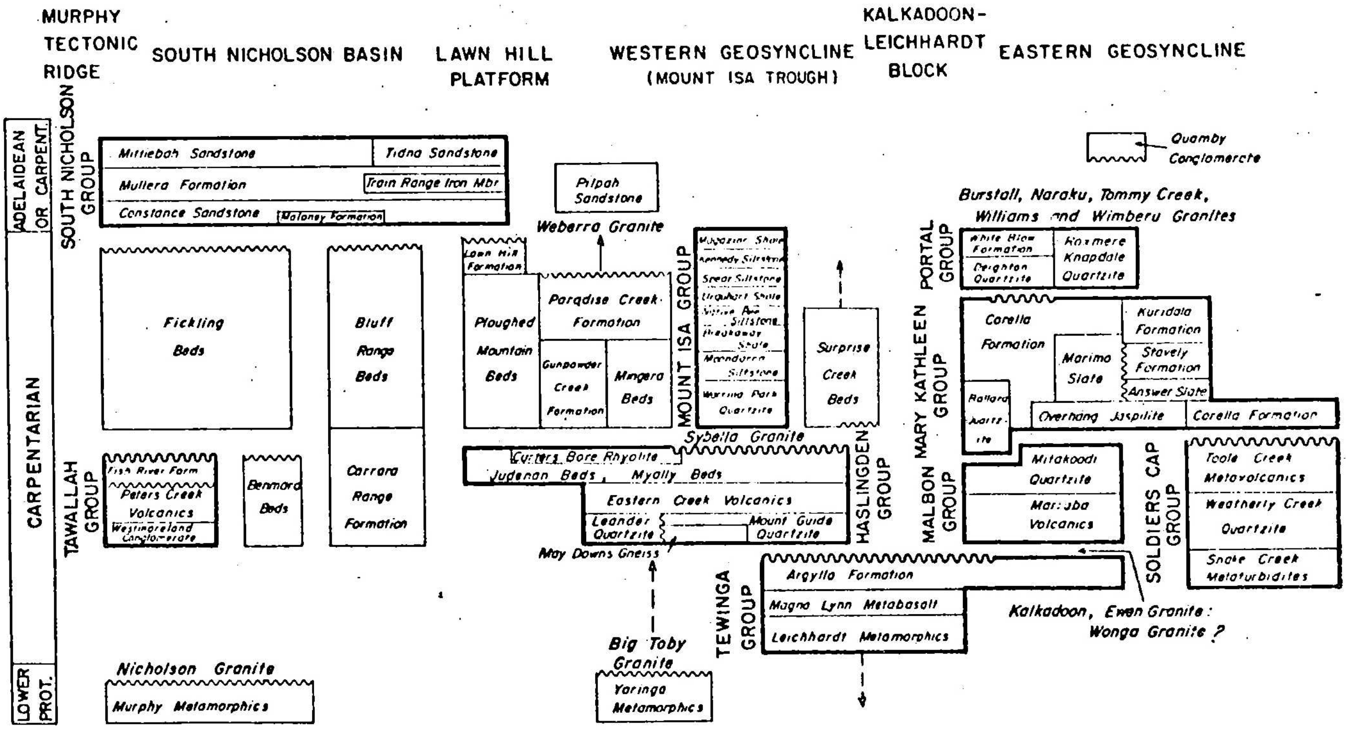

Figure 10. Stratigraphic correlation chart of Northwest Queensland Province.

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TABLE 5 : SUMMARY OF LOWER PROTEROZOIC(?) TO ADELAIDEAN(?) STRATIGRAPHY, NORTHWEST QUEENSLAND PROVINCE

Unit	Thickness (m)	Main Rock Types	Remarks
Mount Birnie Beds	180	Sandstone, shale, sandy siltstone, dolomite.	Found in Duchess area: Glacials probably equivalent to Moonlight Valley Tillite in East Kimberley. Boulders mainly Precambrian granite, metasediment, & metavolcanics: underlies M Cambrian.
Little Burke Tillite	20	Boulder tillite.	
SOUTH NICHOLSON BASIN			
SOUTH NICHOLSON GROUP			
Tidna Sandstone	300-350	Quartz sandstone.	Correlated with Mittiebah Sst.
Mittiebah Sandstone	500-2700+	Quartz sandstone, arkose, glauconitic sandstone.	
Mullera Formation	375-24 0	Siltstone, shale, quartz sandstone, glauconitic & ferruginous sandstones.	Various members recognized. Commonly micaceous.
Train Range Iron-bearing Member	150-600	Quartz sandstone, siltstone, ferruginous sandstone, oolitic ironstone.	Member of Mullera Fm. Fe (Constance Range)
Constance Sandstone	300-1650	Quartz sandstone; micaceous & glauconitic siltstone.	Unconformably overlies units of 'Lawn Hill Platform'. Various members mapped.
Maloney Formation	0-1500	Conglomerate, quartz sandstone, feldspathic sandstone.	Facies variant of lower Constance Sst.
Pilpah Sandstone	300	Feldspathic sandstone, conglomerate, siltstone.	Correlated with Sth Nicholson Gp.
'LAWN HILL PLATFORM'			
Weberra Granite		Red medium-grained granite.	Intrudes Ploughed Mountain Beds; narrow contact zone; some associated greisen and pegmatite.
Lawn Hill Formation	600-1500?	Sandstone, graphitic shale, acid volcanics.	Minor cross-cutting Pb.
Ploughed Mountain Beds	3000+	Sandstone, dolomite, siltstone.	
Paradise Creek Formation	3000+	Dolomite, siltstone, sandstone.	Stromatolites common. Stratiform Pb-Zn (Lady Loretta). Cu (Lady Annie).
Gunpowder Creek Formation	up to 600	Siltstone, shale, sandstone.	Stratabound Cu (Mount Oxide, Mammoth). Outcrops transitional into Mt Isa Orogenic Domain.
Fickling Beds	1200	Dolomite, siltstone, sandstone, chert.	Part of McArthur Gp.
Bluff Range Beds	2700	Sandstone, limestone, dolomite, siltstone.	Correlated with McArthur Gp.
Myally Beds	500+	Feldspathic sandstone.	Small domes beneath Ploughed Mountain Beds; main outcrop in Mt Isa Orogenic Domain to south.
TAWALLAH GROUP			
Fish River Formation	75-200	Feldspathic sandstone, quartz sandstone.	
Peters Creek Volcanics	500+	Basic to acid volcanics, sandstone, dolomite.	
Westmoreland Conglomerate	100	Sandstone, conglomerate.	Unconformably overlies Nicholson Gr.
Benmara Beds	500	Acid & basic volcanics, sandstone, conglomerate.	Unconformably overlies Murphy Metamorphics.
Carrara Range Formation	2300	Acid to basic volcanics, conglomerate, sandstone.	Correlated with Haslingden & Tawallah Gps.
MOUNT ISA OROGENIC DOMAIN			
WESTERN 'GEOSYNCLINE'			
Basic intrusives		Dolerite, metadolerite.	Rare dykes in Mt Isa Gp. Dyke swarms in lower Haslingden Cp in north-trending fractures.
MOUNT ISA GROUP			
Magazine Shale	210	Calcareous shale, some pyrite.	Some pyrite and carbonaceous material.
Kennedy Siltstone	306	Siltstone, dolomitic quartzite.	Some slump(?) breccia
Spear Siltstone	170	Dolomitic siltstone, shale.	Contains albite-rich marker bed.
Urquhart Shale	900	Ferruginous pyritic shale, tuff.	Cu-Pb-Zn (Mount Isa, Hilton, Mount Novit). Soda & potash-rich marker beds common.
Native Bee Siltstone	780*	Dolomitic siltstone, minor tuff.	Tuff forms thin marker beds.
Breakaway Shale	1000	Grey shale, minor siltstone.	
Moondarra Siltstone	1200+	Dolomitic siltstone, shale.	Some pyritic iron-rich bands.
Warrina Park Quartzite	100+	Quartzite, ferruginous siltstone.	Formerly part of Myally Beds; good marker bed, locally unconformable on Myally Beds.
Mingera Beds	up to 1400	Conglomerate, quartzite, shale, siltstone.	Unconformable over Sybella Gr; possible equivalent of Mt Isa Gp.
Surprise Creek Beds	up to 6000	Sandstone, dolomite, siltstone, shale, conglomerate.	Anomalous Pb-Zn zones in rocks similar to Mt Isa CP at Crystal Cr. Cu in quartzites in lower part of sequence. Stromatolites also present. Possibly equivalent to lower Mary Kathleen Gp.
Sybella Granite		Biotite granite, gneissose granite, micro-granite, quartz diorite, pegmatite.	Four separate phases in complex. Intrudes Haslingden Gp west of Mt Isa Fault; overlain unconformably by Mingera Beds. Inferred to be older than Mt Isa Gp. Pegmatites contain beryl, rare earths, & muscovite. Diorites related to contamination of granite by basic rock.
HASLINGDEN GROUP			
Carters Bore Rhyolite	150	Rhyolite, granite porphyry.	Also present at top of Myally Beds; possibly comagmatic with Sybella Gr.
Judenan Beds	1500+	Quartzite, schist, amphibolite.	
Myally Beds	400 to 10 000	Quartzite, siltstone, shale, conglomerate.	Essentially unmineralized; unconformable under Mt Isa Gp; very feldspathic.
Eastern Creek Volcanics	3600 to 7200	Metabasalt, quartzite.	Cu & U mineralization related to basic dykes.
Leander Quartzite	1500	Quartzite, metabasalt.	Essentially unmineralized.
Mount Guide Quartzite	6000+	Quartzite, greywacke, conglomerate.	Unconformable on Kalkadoon Gr & Argylla Fm; May Downs Gneiss Mbr is metamorphosed equivalent adjacent to Sybella Gr. Extensively intruded by dolerite.

Table 5 (Cont.)

	Unit	Thickness (m)	Main Rock Types	Remarks
EASTERN 'GEOSYNCLINE'				
	Quamby Conglomerate	300	Conglomerate, arkose, quartzite, sandstone locally ferruginous.	Overlies Corella Fm unconformably; probably post-metamorphic, but fault-bounded in graben structure. Some vein and related alluvial Au.
	Basic dykes		Dolerite.	Post-metamorphism and granite intrusion. Possibly final tectonic event, at 13[illegible]0 m.y.
	Burstall Granite		Granite, aplite, pegmatite, porphyry dykes.	Minor fluorite; possible source of U (Mary Kathleen).
	Naraku Granite		Granite, aplite.	Intrudes Corella Fm; some skarn in contact zones; possibly two ages of intrusion present.
	Tommy Creek Microgranite		Microgranite, porphyritic rhyolite.	Sills in Corella Fm; some U-bearing pegmatites.
	Wimberu Granite		Granite, aplite.	Intrudes Tewinga & Malbon Gps & Answer Slate. Some amethyst.
	Williams Granite		Granite, microgranite, soda aplite.	Intrudes Soldiers Cap & Mary Kathleen Gps.
	Basic intrusives		Dolerite and metadolerite.	Dykes and sills of pre- to post-metamorphic age.
	Lunch Creek Gabbro	1500+	Gabbro, diorite.	Forms layered sill in Corella Fm, but intruded by Burstall Gr.
PORTAL GROUP	White Blow Formation	915–1000	Siltstone, phyllite, shale, limestone.	Conformable and unconformable over Mary Kathleen Gp. Essentially unmineralized, but possibly equivalent to upper Mt Isa Gp.
	Deighton Quartzite	190–2700	Quartzite, siltstone.	
	Roxmere Quartzite	1000–2[illegible]00+	Quartzite, calcareous siltstone.	
MARY KATHLEEN GROUP	Mount Philip Agglomerate	200+	Tuff, agglomerate, calcareous granofels.	Possibly highly altered & fractured Corella Fm.
	Corella Formation	1500+	Calcareous granofels, limestone, schist, quartzite, metabasalt.	Cu in limestone, pelite, & phyllite; some sulphide-bearing shale. Numerous radiometric anomalies or U deposits (e.g. Mary Kathleen). Pb-Zn (Dugald River). Scapolite-rich.
	Marimo Slate	2600+	Slate, siltstone, marl, sandstone.	Facies equivalents of Corella Fm. Stratabound Cu. Some Pb-Zn anomalies and prospects. Siltstone member contains some shallow water structures.
	Kuridala Formation	2400+	Quartzite, schist, slate.	
	Stavely Formation	600– 2400+	Calcareous granofels, siltstone, shale.	
	Answer Slate	600?	Slate, siltstone, chert, schist.	
	Overhang Jaspilite	500+	Jaspilite, limestone, shale, marl, siliceous breccia.	Contains barite & Mn; transitional into Mitakoodi Qzt.
	Ballara Quartzite	500–2000	Quartzite, conglomerate, limestone.	Unconformable on basement complex; partly equivalent to Mitakoodi Qzt.
MALBON GROUP	Mitakoodi Quartzite	2500+	Quartzite, siltstone, minor basalt.	Minor Cu; conformable under Mary Kathleen Gp.
	Marraba Volcanics	1000–3000	Metabasalt, siltstone, limestone.	Cu associated with dolerite.
SOLDIERS CAP GROUP	Toole Creek Metavolcanics	5500+	Metabasalt, phyllite, chert, sandstone.	Widespread Cu, some scheelite. Some deposits stratabound, others related to dolerite and granite. Overlain unconformably by Mary Kathleen Gp.
	Weatherly Creek Quartzite		Quartzite, siltstone, micaceous sandstone, metabasalt.	
	Snake Creek Metaturbidites		Schist, metagreywacke, metabasalt.	
	Wonga Granite(?)		Gneissic granite.	Surrounded by regional metamorphic aureoles in Corella Fm, but only seen to intrude Argylla Fm. May form basement ridge north of Mary Kathleen, but may possibly be younger.
BASEMENT INLIERS				
KALKADOON-LEICHHARDT BLOCK				
	Basic intrusives		Dolerite, metadolerite.	Some dykes possibly antedate Eastern and Western 'Geosynclines'.
	Kalkadoon Granite		Granite, granodiorite.	Intrudes base of Tewinga Gp, & overlain by Haslingden Gp and Surprise Cr Beds.
	Ewen Granite		Granite.	
TEWINGA GROUP	Argylla Formation	1000+	Rhyolite, dacite, quartzite, tuff.	Unconformity with Ballara Qzt. Favoured zone for Cu mineralization. Partly equivalent to base of Soldiers Cap Gp.
	Magna Lynn Metabasalt	up to 700	Metabasalt, quartzite.	Cu traces in flow tops.
	Leichhardt Metamorphics	4000+	Rhyolite, rhyodacite, schist, gneiss.	Cu related to basic dykes and flows.
BIG TOBY-YARINGA BLOCK				
	Big Toby Granite		Granite, biotite granite, granodiorite.	Formerly part of Sybella Gr, but isotopic age older. Intrudes Yaringa Metamorphics.
	Yaringa Metamorphics	1500+	Schist, gneiss, migmatite, porphyritic rhyolite.	Possibly equivalent to Murphy Metamorphics, or to parts of younger May Downs Gneiss.

intensity to the southeast, and reaches a maximum in the Mount Isa/Cloncurry area.

The stratigraphy is summarized in Table 5 and Figure 10. The oldest rocks are the Lower Proterozoic(?) basement inliers of the Yaringa and Murphy Metamorphics, which are intruded by post-tectonic granites. The main basement inlier, the Kalkadoon-Leichhardt Block is younger and contains the 5 km thick, early Carpentarian, mainly acid metavolcanic, Tewinga Group and granite intrusives (e.g. Kalkadoon Granite), which can be broadly correlated with the Cliffdale Volcanics and granites of the Murphy Tectonic Ridge. The unconformably overlying Carpentarian Mount Isa Orogenic Domain and 'Lawn Hill Platform' correlate with the McArthur Basin. Quartz arenite/basic volcanic suites up to 15 km thick, the Haslingden and Malbon Groups and equivalents can be correlated with the Tawallah Group (5 km thick), while the conformably and unconformably overlying predominantly carbonate successions, up to 5 km thick, of the Mount Isa, Mary Kathleen, and Portal Groups and equivalents correlate with the McArthur Group (5.5 km thick). The Mount Isa domain, and to a lesser extent the 'Lawn Hill Platform', was intensely deformed before the 6.5-km thick quartz arenite/lutite sequence of the Adelaidean(?) or Carpentarian(?) South Nicholson Group, and equivalent Pilpah Sandstone, was deposited. These are correlated with the 5-km thick Roper Group.

Basement inliers

The metasediments of the Big Toby/Yaringa Block and Murphy Tectonic Ridge probably correlate with those of the Pine Creek Geosyncline. The Big Toby Granite was formerly mapped as part of the Sybella Granite, but is now shown to be a separate older body (Hill et al., in prep.).

The main mass of basement rocks is contained in the Kalkadoon-Leichhardt Block, a north-trending inlier 300 km long and up to 30 km wide flanked by the younger 'Eastern' and 'Western Geosynclines'; the Blockade Block, 10 km north-northwest of Mary Kathleen, is a small inlier of similar rocks. Structurally the Kalkadoon-Leichhardt Block has essentially a faulted western margin, a western core composed mainly of Kalkadoon Granite and elongate inliers of recrystallized acid volcanics, and an eastern flank of Tewinga Group, progressively younging eastwards. The Kalkadoon Granite is a complex of multiple granitic and granodioritic intrusions which probably post-date the Tewinga Group, although it is only seen intruding the Leichhardt Metamorphics. The Ewen and Wonga Granites both intrude the Argylla Formation. Possible younger phases of Kalkadoon Granite intruding the younger Haslingden Group (Smith, 1967) have not been confirmed by the current detailed mapping.

The oldest rocks of the Tewinga Group are rhyolite and rhyodacite porphyries and ash flows of the Leichhardt Metamorphics which become progressively more recrystallized towards the Kalkadoon Granite. Roof pendants of highly recrystallized volcanics within the core zone, although mapped as part of the same formation, have not been proved to be the same age. Subaerial to submarine flows of the Magna Lynn Metabasalt thin to the north and east and have been extruded over a predominantly east-dipping palaeoslope. Some flows occupy northeast-trending palaeovalleys. Rhyodacitic ash flows and sills of the Argylla Formation were deposited over large areas of the Kalkadoon-Leichhardt block and beneath the Eastern 'Geosyncline'; quartzite interbeds appear to increase in abundance from west to east.

Mount Isa Orogenic Domain

The rocks of the Mount Isa Orogenic Domain were deposited in Eastern and Western 'Geosynclines', to the east and west of the Kalkadoon-Leichhardt Block; their preserved sections are up to about 16 000 m and 27 000 m thick respectively. They contain numerous troughs, shelves, and hinge-lines which have not yet been completely delineated. Only one, the Mount Isa Trough, corresponding almost exactly with the Western 'Geosyncline', has been named (Glikson et al., in prep.).

The rocks in most of the Mount Isa domain are similar to those in the McArthur Basin, but some of the units, particularly the volcanics, are thicker, and deformation, metamorphism, and igneous activity was more intense. An suboceanic environment may have existed to the east of Cloncurry. Metamorphism, deformation, and granite intrusion are most intense in the Eastern 'Geosyncline'. The basic volcanics of the Soldiers Cap Group, to the southeast, are geochemically less continental, and were extruded in deeper water than the epicontinental volcanics of the Malbon and Haslingden Groups farther west (Glikson et al., in prep.). The units of the Soldiers Cap Group are comparable with the Alpine flysch facies (Snake Creek Metaturbidites), stable shelf orthoquartzite facies (Weatherly Creek Quartzite), and eugeosynclinal volcanic facies (Toole Creek Metavolcanics). The Snake Creek Metaturbidites may correlate with quartzite in the upper part of the Argylla Formation, and thus antedate the main Mount Isa Orogenic Domain.

The Weatherly Creek Quartzite and Toole Creek Metavolcanics may correlate with the Marraba Volcanics and Mitakoodi Quartzite of the Malbon Group. The Marraba Volcanics and Mitakoodi Quartzite represent a period of subaerial tholeiitic basalt extrusion followed by extensive near-shore deposition of coarse to medium sands. The sands were derived from relatively mature areas of the Tewinga Group and Kalkadoon-Leichhardt Block to the south and west.

By contrast, in the Western 'Geosyncline', the conglomerates in the Mount Guide Quartzite at the base of the Haslingden Group were derived from relatively rugged areas of the Kalkadoon-Leichhardt Block to the east. The conglomerates and associated arkosic grits grade up into massive cross-bedded arenites representative of a more stable trough or shelf margin. Near Mount Isa the Eastern Creek Volcanics rest conformably on the Mount Guide Quartzite but in the northwest they directly overlie the Ewen Granite basement, with a coarse arkosic conglomerate at the base. Continuity of basalt flows over large distances indicates extrusion from long fissures (Robinson, 1968), which were possibly localized along the western margin of the Kalkadoon-Leichhardt Block.

The succeeding arenites of the Myally and Judenan Beds thicken from 400 m south of Mount Isa to 10 000 m in the north. They are highly feldspathic, ripple-marked and cross-bedded, and southwesterly to northwesterly palaeocurrent directions north of Mount Isa indicate a possible source area near the Big Toby/Yaringa Block. The thin but persistent acid lava and tuff beds (e.g. Carters Bore Rhyolite) at the top of the Myally and Judenan Beds may have been associated with the intrusion of the Sybella Granite into the Haslingden Group.

Uplift, tilting, and erosion accompanied emplacement of the Sybella Granite, and the basal beds of the Mount Isa Group, the Warrina Park Quartzite, disconformably overlie the Myally Beds or, locally, the Eastern Creek Volcanics. The Surprise Creek Beds to the north-northeast of Mount Isa are apparently conformable on the Myally Beds but onlap and rest unconformably, on the Kalkadoon-Leichhardt Block, through conglomeratic arkosic grit, quartzite, and shale. To the west of Mount Isa shale and conglomerate of the Mingera Beds unconformably overlie the Judenan Beds and Sybella Granite.

In the Eastern 'Geosyncline' the Ballara Quartzite at the base of the Mary Kathleen Group resembles the lower Surprise Creek Beds; it onlaps the eastern side of the Leichhardt-Kalkadoon Block, from which it was derived as a sheet sand deposit typical of a 'linear clastic shoreline' (Selley, 1970). Farther east, detrito-chemical processes produced the Overhang Jaspilite in a shallow quiescent shelf environment marginal to mature exposures of Malbon and Tewinga Groups.

Hinge-lines related to basement ridges and penecontemporaneous faults (Smith, 1969) controlled facies changes during sedimentation, especially in the Western 'Geosyncline'. The Mount Isa Group was deposited in the Mount Isa Trough of the Western 'Geosyncline'; the sequence consists mainly of dolomitic siltstone and shale, with some ferruginous dolomite, potash-rich and soda-rich beds, and minor occurrences of halite and gypsum. Subsidence culminated with the deposition of the Urquhart Shale, when sulphide-bearing carbonaceous shale was deposited in a euxinic environment to produce the Mount Isa and Hilton lead-zinc orebodies.

The Surprise Creek Beds included two laterally equivalent facies: a shelf facies, containing stromatolitic dolomite, separates a deeper water silt-shale facies in the east from the similar facies of the Mount Isa Group, to the west. Only equivalents of the lower part of the Mount Isa Group are represented, and equivalents of the ore-bearing beds are absent. Similar relationships obtain in the Batten Trough and adjoining shelves in the McArthur Basin.

In the Eastern 'Geosyncline' north-trending basement ridges extended through Mary Kathleen and east of Cloncurry. The Mary Kathleen Group beds laid down on these ridges include thin beds of Ballara Quartzite, and the Corella Formation. The presence of scapolite and stromatolite-bearing carbonates, siltstone, and sandstone in the Corella Formation suggests a shallow hypersaline shelf environment similar to that of the Umbolooga Sub-Group in the McArthur Basin. The black shales etc. of the Marimo Slate and equivalent formations were deposited contemporaneously in a broad trough between blocks composed of the Malbon and Tewinga Groups, and the Soldiers Cap Group. Pillow and amygdaloidal basalts are common east of Mary Kathleen but rare to the west. Equivalents of the Urquhart Shale appear to be absent from the Mary Kathleen Group except possibly in the topmost part of the Corella Formation at the Dugald River lead-zinc deposit. The Portal Group is locally unconformable on the Mary Kathleen Group, and probably correlates with the upper part of the Mount Isa Group. A fluvial channel sand (Deighton Quartzite), overlain by shallow shelf carbonates, shale, and siltstone (White Blow Formation), similar to the Corella Formation, is reminiscent of the uppermost part of the McArthur Group at McArthur River (Smythe Sandstone and overlying units).

Low-amphibolite and greenschist facies metamorphism has affected the Eastern 'Geosyncline', but the Western 'Geosyncline' is only slightly metamorphosed, except adjacent to the Sybella Granite. Intense folding is predominant in the east, and faulting in the west. An early post-depositional period of mainly vertical fault movements in both the Western and Eastern 'Geosynclines' was followed by conjugate strike-slip faulting, with displacements of up to 25 km. Both periods of faulting are a result of east-west compression, and were accompanied by, or post-dated, a period of high-level granite intrusion in the east.

'Lawn Hill Platform'

The 'Lawn Hill Platform' contains less deformed stratigraphic equivalents of both the Haslingden and Mount Isa Groups (Fig. 10). In the northwest, adjacent to the Murphy Tectonic Ridge, the sequences are correlated with those of the McArthur Basin to the north. More detailed mapping will almost certainly result in further subdivision and correlation of the units so far mapped.

Exposures of the Haslingden Group (Myally Beds) and its equivalents, the Carrara Range Formation, Benmara Beds, and Tawallah Group, are restricted, but show the rock types typical of this part of the sequence: interbedded arenites and volcanic rocks.

Most exposures consist of the overlying carbonate sequences which are probably part-equivalents of the Mount Isa Group; precise correlations have yet to be established. Unconformities have recently been noted within the Fickling Beds (I.P. Sweet, pers. comm.). Facies changes are apparent between successions and a pattern of troughs and shelves, similar to those in the Mount Isa domain, may emerge from further mapping.

The Mingera Beds and Gunpowder Creek Formation are transition beds similar to the lower parts of the Mount Isa or McArthur Groups. The Mount Oxide and Mammoth copper deposits occur near the top of the Gunpowder Creek Formation. In the type area the overlying Paradise Creek Formation consists of a shallow-water carbonate sequence with abundant stromatolites; to the west they pass into a more terriginous sequence of dolomitic and carbonaceous siltstone and sandstone, mostly mapped as Ploughed Mountain Beds. The Lady Loretta lead-zinc deposit and Lady Annie copper deposit occur in shales of the Paradise Creek Formation within the zone of facies changes. Terriginous sediments increase in the upper part of the Ploughed Mountain Beds and overlying Lawn Hill Formation; the latter is also characterized by acid volcanics, and contains vein lead deposits associated with graphitic slate. The general succession of facies in the Fickling Beds is similar to that in the McArthur Group - shelf dolomite (Umbolooga Sub-Group) overlain by dolomitic siltstone (Batten Sub-Group), followed by feldspathic sandstone, siltstone, dolomite etc.

South Nicholson Basin

The South Nicholson Group and its probable stratigraphic equivalent (Pilpah Sandstone) has the same unstable shelf facies characteristics as the Roper Group - mica-rich siltstone and quartz greywacke alternating with quartz sandstone. The sequence of Constance Sandstone/Mullera Formation/Mittiebah Sandstone resembles the Limmen Sandstone/Mainoru Formation/Abner Formation of the Roper Group. Scattered glauconite throughout the succession indicates shallow-marine conditions. The sequence is thickest in the west, beyond a basement ridge of Murphy Metamorphics. Regional facies changes indicate an easterly provenance from the uplifted Mount Isa domain. The Constance Range iron deposit has a similar facies of oolitic siderite and hematite to the deposit in the Roper Group. The South Nicholson Basin is only very mildly deformed, mainly in response to easterly trending faults.

BIRRINDUDU BASIN

(Principal references: Dow & Gemuts, 1969; Sweet et al., 1974)

The Birrindudu Basin is a mildly deformed basin, about 120 000 km^2 in area, overlying the Sturt Block across the Western Australia/Northern Territory border. The basin succession comprises the laterally continuous Birrindudu Group (Blake & Hodgson, 1974), Limbunya Group, and Mount Parker Sandstone/Bungle Bungle Dolomite, and is overlain with a major regional unconformity by the Victoria River Basin succession. It is for this reason that we consider that the Redcliff Pound Group (Blake & Hodgson, 1974), a correlative of the Victoria Basin succession, should not be included in the Birrindudu Basin.

The stratigraphy is summarized in Table 6 and Figure 6. Most of the Limbunya Group formations can be identified in the Mount Parker Sandstone/Bungle Bungle Dolomite sequence (I.P. Sweet, pers. comm.).

The basal arenites, the Stirling and Mount Parker Sandstones, are thickest in the east and west, with a basement ridge between. The succeeding sediments reflect alternating transgressions and regressions with stromatolitic dolomite and associated dolarenite, deposited on intertidal, supratidal, and shallow subtidal shelves, alternating with shale deposited in a deeper water reducing environment. The easterly thinning of the sand beds in the Bungle Bungle Dolomite indicate at least local westerly provenance from the adjacent Halls Creek Mobile Zone.

The Birrindudu Basin was mildly folded, faulted, and eroded prior to development of the Victoria River

TABLE 6: SUMMARY OF ADELAIDEAN AND CARPENTARIAN STRATIGRAPHY, VICTORIA RIVER AND BIRRINDUDU BASINS AND EAST KIMBERLEY REGION

Unit	Thickness (m)	Main Rock Types	Remarks
GLACIAL SUCCESSIONS			
ALBERT EDWARD GROUP	1200-1800	Shale, siltstone, sandstone (Flat Rock, Elvire Fms, Timperley Sh); quartz sandstone (Mt Forster, Houless Ssts): dolomite (Boonall Dol).	Unconformable on Duerdin Gp; unconformably overlain by L Cambrian Antrim Plateau Volc.
LOUISA DOWNS GROUP	4000	Tillite, dolomite, sandstone (Egan Fm); feldspathic sandstone, subgreywacke, minor shale & dolomite (Yurabi, Tean Fms); shale, siltstone, fine sandstone (McAlly Sh, Lubbock Fm).	Unconformable on Kuniandi Gp; unconformably overlain by L Cambrian. Correlates with Albert Edward Gp.
DUERDIN GROUP	630	Tillite, dolomite, conglomerate (Fargoo, Moonlight Valley Tillites); dolomitic sandstone, subgreywacke (Frank R Sst); siltstone, shale (micaceous), sandstone, subgreywacke (Ranford Fm).	Unconformable on Victoria R & Birrindudu Basin successions & older units east of Halls Cr Fault.
KUNIANDI GROUP	1000	Tillite, dolomite, feldspathic sandstone (Landrigan Tillite); shale, siltstone, sandstone (Wirara Fm); ferruginous sandstone, greywacke, minor shale (Mt Bertram Sst, Stein Fm).	Unconformable on Glidden Gp & older units in Halls Cr/King Leopold Mobile Zones, Kimberley Block. Correlates with Duerdin Gp.
MOUNT HOUSE GROUP	450+	Tillite, dolomite, sandstone (Walsh Tillite); shale, fine sandstone (Throssell Sh); ferruginous or dolomitic sandstone, siltstone (Traine, Estaughs Fms).	Unconformable on Kimberley Basin succession. Correlates with Duerdin Gp.
VICTORIA RIVER BASIN SUCCESSION			
Bullo River Sandstone	320	Ferruginous and feldspathic sandstone; conglomerate.	Unconformable on Auvergne Gp.
AUVERGNE GROUP	1035	Quartz sandstone, minor siltstone & dolomite (Jasper Gorge, Pinkerton, Spencer Ssts, Saddle Creek Fm); siltstone, shale (Angalarri Sltst); dolomite, dolomitic siltstone & sandstone (Lloyd Cr, Shoal Reach Fms).	Unconformable on Stubb & Wondoan Hill Fms.
Stubb & Wondoan Hill Formations	260	Sandstone, shale, siltstone.	Unconformable between Auvergne & Bullita Gps. Stubb Fm relationship revised.
Helicopter Siltstone Wade Creek Sandstone Mount John Shale Member	155 360	Laminated siltstone, shale. Quartz sandstone. Shale, siltstone, minor sandstone.	Osmond Ra, East Kimberley. Unconformable on Bungle Bungle Dol. Helicopter Sltst correlates with Angalarri Sltst; Wade Cr Sst (upper) with Jasper Gorge Sst; Mt John Sh Mbr & Wade Cr Sst (lower) with Stubb & Wondoan Hill Fms.
BULLITA GROUP	850	Dolomite, dolomitic siltstone (Timber Cr, Skull Cr, Banyan Fms); siltstone, shale, dolomitic sandstone (Bynoe, Nero, Battle Cr Fms); sandstone(Weaver, Mt Gordon Ssts).	Conformable on Wattie Gp; unconformably overlain by Wondoan Hill Fm. Minor Pb in Skull Cr, Banyan Fms; Cu in Bynoe Fm.
WATTIE GROUP	930	Quartz sandstone (Wickham Fm, Hughie, Reave, Seale Ssts) alternating with siltstone & sandstone (Burtawurta, Mt Sanford, Gibbie Fms).	Unconformable on Limbunya Gp.
TOLMER GROUP	600	Siltstone, sandstone (Buldiva Sst, Waterbag Cr Fm); dolomite, siltstone (Hinde Dol).	Unconformable on Pine Cr Geosyn; unconformably overlain by L Cambrian Antrim Plateau Volc. Correlated with Wattie plus Bullita Gps.
HALLS CREEK/FITZMAURICE MOBILE ZONES			
CARR BOYD GROUP	9000	Quartz sandstone (Hensman Sst); black (pyritic) shale, siltstone, fine sandstone, minor quartz sandstone or quartz greywacke (Golden Gate Sltst); quartz sandstone alternating with siltstone, shale, fine sandstone (Lissadell, Glenhill, Pincombe Fms); quartz sandstone, ferruginous or feldspathic sandstone, minor shale & conglomerate (Stonewall Sst, Bandicoot Ra Beds).	Northern part of Halls Cr Mobile Zone. Unconformable on Revolver Cr Fm, Lamboo Complex, or Halls Cr Gp. Most formations separated by unconformities. Hensman Sst & Golden Gate Sltst correlate with Auvergne Gp. Fe in Golden Gate Sltst (Pompeys Pillar) & Bandicoot Ra Beds.
FITZMAURICE GROUP	3665+	Quartz sandstone, minor siltstone & conglomerate (Moyle R Fm, Lalngang Sst); shale, siltstone, fine sandstone (Goobaieri Fm); alternating quartz sandstone & siltstone (Legune Fm).	Fitzmaurice Mobile Zone. Unconformable on Pine Cr Geosyn or Lamboo Complex. Unconformity above Goobaieri Fm. Goobaieri Fm correlates with Angalarri Sltst, & Legune Fm/ Lalngang Sst with Pincombe Fm & Stonewall Sst.
HALLS CREEK/KING LEOPOLD MOBILE ZONES; KIMBERLEY BLOCK			
GLIDDEN GROUP	550	Quartz sandstone (Harms, Forman Ssts); micaceous or black shale & siltstone, minor sandstone (Matheson, Maddox Fms).	Unconformable on Kimberley Basin succession; unconformably overlain by Kuniandi Gp. Correlation uncertain; could correlate with Glenhill Fm.
BIRRINDUDU BASIN SUCCESSION			
LIMBUNYA GROUP	1540	Dolomite (Pear Tree, Mallabah, Campbell Springs Dols); dolomite, siltstone, chert, sandstone (Nongery, Amos Knob, Blue Hole, Fraynes, Killaloc Fms; Kunja Sltst); quartz sandstone (Stirling, Farquharson Ssts).	Correlated with Birrindudu Gp.
Bungle Bungle Dolomite Mount Parker Sandstone	1450 150-300	Dolomite, dolomitic shale, quartz sandstone. Quartz sandstone.	Osmond Ra, East Kimberley. Unconformable on Red Rock Beds. Correlated with Limbunya Cp.
Colombo Sandstone	100+	Quartz sandstone, chert-pebble breccia.	Unconformable on Kimberley Basin succession in Louisa Downs area. Possibly correlates with Mt Parker Sst.

Basin. Intensity of deformation increases westwards towards the Halls Creek Fault.

VICTORIA RIVER BASIN AND EAST KIMBERLEY EQUIVALENTS

(Principal references: Sweet et al., 1973a,b, 1974; Dow & Gemuts, 1969; Roberts et al., 1972; Dow et al., 1964)

The Adelaidean stratigraphy of this area is summarized in Table 6 and Figure 6. I.P. Sweet (pers. comm.) has recently recognized an unconformity beneath the Jasper Gorge Sandstone and removed the Stubb Formation from the Auvergne Group.

The Victoria River Basin covers an area of about 160 000 km^2 on the Sturt Block; it lies across the Northern Territory/Western Australia border and is virtually undisturbed, except near its western boundary with the Fitzmaurice/Halls Creek Mobile Zone. The basin succession is relatively thin (up to 3400 m) and comprises a typical stable shelf association - quartz sandstone, carbonate, and shale - deposited in a paralic or shallow-marine environment. Important environmental indicators are glauconite (shallow marine), stromatolites (intertidal or shallow subtidal), halite pseudomorphs (hypersaline), and mud cracks (subaerial). Unconformities in the sequence reflect periods of erosion, accompanied by only mild warping.

Much thicker successions (up to 9000 m) were deposited along narrow belts in the adjoining Fitzmaurice, Halls Creek, and King Leopold Mobile Zones (Fitzmaurice, Carr Boyd, and Glidden Groups). Correlations with the Victoria River Basin succession (Fig. 6) depend largely on the similarity of lithological successions and the apparent continuity of outcrop between units mapped in various places as Angalarri Siltstone, Golden Gate Siltstone, and Goobaieri Formation (I.P. Sweet, pers. comm.). The total successions are only partly equivalent, and some of the facies changes support the correlations; the Golden Gate Siltstone, for example, has a near-shore facies in the west and a deep pyritic black shale facies in the east, while the Glenhill Formation shows a local easterly provenance, consistent with erosion on the Sturt Block at that time.

The Adelaidean rocks of the mobile zones consist entirely of terrigenous detritus laid down on unstable shelves, mostly in relatively shallow waters. The presence of glauconite in some units indicates that they, at least, are marine; complex facies changes are common. Unconformities are common and separate thick (5000 m) rhythms composed of basal sandstone grading up into predominantly siltstone. Syndepositional faulting is apparent. The mobile zone sediments have been subsequently deformed by large left-lateral strike-slip and thrust faults. They are locally tightly folded, cleaved, and metamorphosed adjacent to, or within, major shear zones.

GLACIAL SUCCESSIONS

(Principal references: Dow & Gemuts, 1969; Roberts et al., 1972)

Well exposed late Adelaidean glacial successions rest unconformably on a variety of rocks in the Kimberley and Victoria River regions, and are unconformably overlain by the Lower Cambrian Antrim Plateau Volcanics (Table 6, Fig. 6). Precise correlations are possible between the different areas, and the sequences are divided into a lower unit (Duerdin, Kuniandi, and Mount House Groups), and an unconformably overlying upper unit (Albert Edward and Louisa Downs Groups). The glacial periods represented by the lower parts of the sequences are referred to as the Moonlight Valley (lower) and Egan (upper) Glaciations respectively. The Little Burke Tillite in northwest Queensland (de Keyser, 1972), which underlies Cambrian rocks of the Georgina Basin, shows remarkable similarities to the lower glacial successions.

Glacial pavements are common and the tillites are of undisputed glacial origin. Dolomite is commonly closely associated with the tillites, and the overlying sequences consist mainly of siltstone or shale.

ARAFURA BASIN

The Arafura Basin (Fig. 1) is an undeformed inter-cratonic basin, on the north coast of the Northern Territory, which transects most of the structures in the unconformably underlying McArthur Basin and Pine Creek Geosyncline. Palaeotopographic features in the basement are preserved, and much of the sediment was derived from the immediately adjacent McArthur Basin area.

The exposed succession (Table 7) comprises the 1450-m thick late Adelaidean Wessel Group. Most of the basin underlies the Arafura Sea, where a largely unknown sequence may continue up into the Palaeozoic; estimated depths to aeromagnetic basement indicate over 10 000 m of section and Money Shoals No 1 well intersected a thin Silurian section (Balke et al., 1973). The thick Mesozoic and Cainozoic sections unconformably overlying the western Arafura Basin have been assigned to the Money Shoals Basin (Williams, Forman, & Hawkins, 1973).

TABLE 7

SUMMARY OF ADELAIDEAN STRATIGRAPHY, ARAFURA BASIN AND EQUIVALENTS

	Unit	Thickness (m)	Main Rock Types
WESSEL GROUP	Elcho Island Formation	150+	Feldspathic, micaceous, glauconitic sandstone & siltstone; quartz sandstone; dolomitic siltstone.
	Marchinbar Sandstone	240	Quartz sandstone
	Raiwalla Shale	ca. 600	Argillaceous dololutite, shale, fine-grained (micaceous) sandstone.
	Buckingham Bay Sandstone	150-450	Quartz greywacke, quartz sandstone, conglomerate.
	Cox Formation	45+	Micaceous siltstone, shale, quartz sandstone.
	Bukalara Sandstone	30-300	Feldspathic sandstone, quartz sandstone, conglomerate.

The Bukalara Sandstone and Cox Formation shows a similar structural relationship to the southern part of the McArthur Basin as the Wessel Group to the north, and are lithologically very similar to the lower part of the Wessel Group. The glauconite isotopic age of about 790 m.y. from the Elcho Island Formation is considered firm evidence of a late Precambrian age for the sequence, despite the presence of *Scolithus*-like structures, previously considered to be confined to the Phanerozoic, in both the Buckingham Bay and Bukalara Sandstones.

The presence of scattered glauconite throughout the Wessel Group indicates deposition on a shallow marine shelf. The alternation between arenites and carbonate-rich lutites can be explained by variations in the rate of erosion and supply of terrigenous material, perhaps due to climate, rather than variations in the depth of water. The carbonate-rich lutites may reflect arid periods, the fine terrigenous material being introduced by wind; the arenites were laid down during periods of increased erosion in the source areas due to minor uplift or a wetter climate.

PHANEROZOIC HISTORY

The Kimberley to Mount Isa region has been exceptionally stable throughout the Phanerozoic. Close parallelism of Tertiary, Mesozoic and early Palaeozoic land surfaces are apparent in many areas. The geological history was dominated by emergence and steady erosion.

The Lower Cambrian flood basalts (Antrim Plateau Volcanics and equivalents) extend from the East Kimberley to Nicholson River area. Early Palaeozoic sediments were deposited in the Georgina, Daly River, Ord, Wiso, Canning, and Bonaparte Gulf Basins around the periphery of the exposed Precambrian rocks, but thick accumulations, including late Palaeozoic rocks, were confined to the northwest, in the Canning and Bonaparte Gulf Basins. The Palaeozoic basins were largely controlled by old Precambrian structural features. Thick deposits of phosphate accumulated in the eastern Georgina Basin.

Thick accumulations of Mesozoic sediments were confined to present-day offshore areas of the Northwest Shelf and Money Shoals and Carpentaria Basins. A late Mesozoic transgression is represented by thin scattered outliers of Lower Cretaceous rocks scattered throughout the region. The Groote Eylandt manganese was deposited during this period.

The Cainozoic was a period of weathering, erosion, and broad uplift, with widespread development of Tertiary laterite. The deep weathering severely modified outcropping mineral deposits, and formed major deposits of bauxite, such as the Gove deposit developed on Lower Cretaceous claystones, and the Mitchell Plateau deposit overlying basalts of the Lower Proterozoic Carson Volcanics.

REGIONAL PATTERNS OF MINERALIZATION

The Kimberley to Mount Isa Region shows many regional patterns of mineralization which provide valuable clues to exploration.

COPPER

Copper is widespread throughout the region, but most of the occurrences are small. Most of them are found in the northwest Queensland Province and the Kimberley Region.

Two main associations are significant - basic igneous rocks and sedimentary associations.

Basic igneous rocks. Sparse disseminated copper is common, and sometimes ubiquitous, in most of the tholeiitic basalts of the region. Primary sulphides, secondary oxides or carbonates, and in places native copper, are all present. Although concentrations in amygdales at the tops of flows are known, economic deposits only occur in structurally suitable situations:

(1) Structurally prepared host rocks of favourable lithology (e.g. black shale, dolomite, acid volcanics) in juxtaposition with basic igneous rocks, such as dykes or faulted lavas. Examples include deposits in the Mary Kathleen Group (e.g. Great Australia and Mount Elliot), and in the Tewinga Group (e.g. Blockade, Brooks et al., 1974). Mount Isa is also suggested as an example of this type (Smith & Walker, 1971), although others (e.g. Bennett, 1965) favour a syngenetic origin.

(2) Faults and shears within basic igneous rocks. Most deposits are small. Examples are the Success and Lone Hand in the Marraba Volcanics (Brooks et al., 1974), and uneconomic deposits within the Eastern Creek, Peters Creek, and Carson Volcanics, and the Magna Lynn Metabasalt.

(3) Breccia pipes in the Gold Creek Volcanic Member at Redbank.

Sedimentary associations. Copper mineralization can be associated with specific beds (excluding igneous rocks) but economic concentrations again depend on proximity to suitable structures. The majority of deposits are associated with near-shore facies, particularly in carbonate associations.

In the Northwest Queensland Province most of the deposits occur in equivalents of the Mount Isa Group: Mount Oxide and Mammoth at the top of the Gunpowder Creek Formation, Lady Annie in the Paradise Creek Formation, and deposits of the Mary Kathleen Group, particularly in the middle part of the Corella Formation and in the Marimo and Answer Slates. Around McArthur River small deposits occur along shears within dolomite and siltstone of the Umbolooga Sub-Group: Kilgour and Coppermine Creek in the Amelia Dolomite, Yah-Yah at the top of the Tooganimie Formation, and Turnbull and Squib in the Emmerugga Dolomite. Copper has been recorded at many levels in the Kimberley region. The Ilmars, Angelo, and Saunders Creek Prospects are associated with dolomitic shale of the Biscay Formation (Halls Creek Group). In the Kimberley Basin succession sedimentary copper has been investigated in the carbonate-redbed facies of the Teronis Member of the Elgee Siltstone, and in interbedded siltstone and sandstone of the Penetcost Sandstone and Mendena Formation.

At Rum Jungle, in the Pine Creek Geosyncline, copper is associated with the uranium deposits. Copper is commonly associated with acid volcanics and granites throughout the Kimberley to Mount Isa region, but the deposits have generally proved to be small. Exceptions are the Mount Colin and Mount Lindsay deposits adjacent to the Burstall Granite near Mary Kathleen.

GOLD

Most of the gold deposits are small and were mined during the late 19th and early 20th centuries. Much of the gold was won from alluvial deposits. The primary deposits are generally quartz reefs in favourable structural situations; associated sulphides are common. The deposits are all found in orogenic domains and, although the original source of the gold is obscure, most show a stratigraphic control.

In the East Kimberley the deposits around Halls Creek are confined to a narrow zone along the boundary of the Biscay and Olympio Formations (Dow & Gemuts, 1969). Shale is a favourable host rock but some deposits occur in volcanic rocks and dolerite dykes.

The deposits in the Pine Creek Geosyncline (Walpole et al., 1968) fall into two groups. Those in the Brocks Creek and Golden Dyke areas are restricted to pyritic shales, containing nodules and lenses of quartz, in the Golden Dyke Formation. The deposits of the Pine Creek region are clustered about the Cullen Granite and related bodies; they are associated with faults and shear zones in greywacke and slate of the Burrel Creek and Masson Formations, and have complex mineral associations such as gold-copper-lead-zinc.

Small deposits in the Northwest Queensland Province are reported from the stratigraphically equivalent Overhang Jaspilite (Top Camp diggings), the lower part of the Surprise Creek Beds (Bower Bird/Sunday Gully fields), and the Mingera Beds. All occur as auriferous fissure quartz veins in shales.

IRON

Iron deposits occur at several stratigraphic levels in the region. The only evidence of a regional stratigraphic control are the Roper River (Canavan, 1965) and Constance

Range (Harms, 1965) deposits, which occur in the broadly equivalent Roper (McMinn Formation) and South Nicholson (Mullera Formation) Groups respectively. Both deposits consist of several beds of hematitic, sideritic, and chamositic oolites and ferruginous sandstone deposited in a very shallow basin, perhaps nearshore.

The Yampi deposits in the West Kimberley occur in the Pentecost Sandstone, (Kimberley Group) and are interpreted as fossil iron beach sands (Gellatly, 1972). The hematite beds at Pompeys Pillar and Bandicoot Range in the Adelaidean Carr Boyd Group of the East Kimberley were also deposited in a near-shore environment.

The Frances Creek hematite deposit in the Lower Proterozoic Pine Creek Geosyncline was formed by supergene enrichment of iron-rich sediments in the Masson Formation, while the Pritchards Lode at Mount Bundey (magnetite and minor sulphides) is a product of magmatic segregation, or contact metasomatic replacement, resulting from the intrusion of the Mount Goyder Syenite (Walpole et al., 1968).

Numerous small uneconomic ironstone bodies throughout northern Australia were formed by supergene enrichment during Tertiary weathering.

LEAD-ZINC

The outstanding example of stratigraphic distribution of mineralization in northern Australia is lead-zinc mineralization in the Carpentarian McArthur Group, and its equivalents, throughout the McArthur Basin and Northwest Queensland Province. Prime examples are the H.Y.C. deposit in the Barney Creek Formation at McArthur River, and the Mount Isa, Hilton, and Mount Novit deposits in the

Urquhart Shale of the Mount Isa Group. Lesser examples are the Bulman deposit in the Mount Rigg Group of Arnhem Land, the Lady Loretta (Paradise Creek Formation) and Lawn Hill (Lawn Hill Formation) deposits on the 'Lawn Hill Platform', and the Dugald River deposit in the Corella Formation of the Eastern 'Geosyncline', together with numerous minor occurrences in the Fickling Beds, the Karns Dolomite at Calvert Hills, the Vizard Formation at Roper River, and the smaller deposits in the McArthur River area, such as Cooley, Cooks, Cox, Bald Hills, W-Fold, and Reward.

The H.Y.C., Mount Isa, Hilton and Mount Novit deposits show remarkable analogies. They occur about the middle of the McArthur or Mount Isa Group sequences. They were deposited in troughs flanked by shallow shelves. Sections on the shelves are incomplete and equivalents of the ore-beds are missing. The ores are finely laminated. The host rocks are laminated carbonaceous, pyritic, dolomitic shales deposited in restricted depressions. Tuffaceous material is abundant. Evaporites lower in the sequence could have provided brines. The orebodies are adjacent to major faults; the Emu Fault at McArthur River was active during deposition of the ore-beds, and the Mount Isa Fault may have been active. The structural and climatic conditions appear ideal for a restricted reducing environment, and analogies can be drawn with modern Red Sea brines.

All these conditions - stratigraphic position, rock types, and structural setting - are met by the Vaughton Siltstone in Arnhem Land. It must be considered a prime exploration target, particularly adjacent to the Koolatong Fault, although exploration is hampered by lack of outcrop, and no mineralization has been reported so far.

The Lady Loretta, Lawn Hill, and Dugald River deposits may also fit the same pattern, but full details of their settings are not known to us.

Most of the other deposits listed occur in shelf dolomite. Disseminated galena is common in certain formations and secondary concentrations have been formed by mobilization along suitable structures. The Bulman deposit is a special case of scattered pods of massive galena in massive dolomite, immediately above a dolerite sill. The lead may have been derived from the dolerite or by mobilization of sedimentary galena in the dolomite during heating by the dolerite; we prefer the latter. The Cooley deposits at McArthur River occur in brecciated dolomite of the Cooley Dolomite Member, a facies equivalent of, and immediately adjacent to, the H.Y.C. Pyritic Shale Member. Bodies of coarse galena are developed within dolomite in the Emu Fault Zone adjacent to the main H.Y.C. orebody.

Small occurrences of lead are known in other carbonate units, such as in the Victoria River and Birrindudu Basins. The Woodcutters (Roberts, 1973) and the nearby Browns prospects at Rum Jungle occur in graphitic dolomitic shale of the Lower Proterozoic Golden Dyke Formation.

Small occurrences of galena are associated with various igneous rocks of the region. Some production took place from the Costeos deposit (Sofoulis, 1968) in the East

Kimberley where galena occurs in quartz-filled shears within the Hart Dolerite.

TIN-WOLFRAM

All tin and wolfram deposits are associated with post-tectonic (transitional tectonism) granites. Most of the production has come from fault and fissure deposits in country rocks around the Cullen Granite and related bodies in the Katherine-Darwin region. Minor production has come from deposits within granites of the West Kimberley and the Murphy Tectonic Ridge.

URANIUM

Northern Australia has been the principal source of uranium in Australia. Future production is likely to follow this pattern, although significant uranium deposits have been discovered recently in southern Australia. Production from the Mary Kathleen deposit exceeded that from the Lower Proterozoic rocks of the Pine Creek Geosyncline, even though this latter area contained the largest number of deposits. However, the Pine Creek Geosyncline is now the main exploration target because of the recent discoveries of large deposits at Ranger, Nabarlek, Koongarra, and Jabiluka in the Alligator Rivers area. Dodson & Prichard (1974) have described the main features of the region.

The principal feature which the deposits in Lower Proterozoic rocks have in common is their stratigraphic control; they all occur in carbonaceous shale or chlorite schist of the stratigraphically equivalent Golden Dyke Formation (Rum Jungle) and Koolpin Formation (El Sherana, Rockhole, Palette, Ranger, Nabarlek, Koongarra, and Jabiluka). They are situated adjacent to basement highs of the Rum Jungle Complex and Median Ridge. They are localized in suitable structures such as folds or fractures (Rum Jungle, South Alligator Valley), or in shears and collapse structures near or at the margins of granitic and metamorphic complexes (Ranger, Koongarra, etc.).

Although found in the Carpentarian Mary Kathleen Group, the Mary Kathleen deposit shows some analogy to the Alligator Rivers deposits, in that it is situated above a basement ridge of the Eastern 'Geosyncline' and is adjacent to the Burstall Granite.

The many other deposits associated with the Lower Proterozoic and Carpentarian rocks of northern Australia are relatively small. The early Carpentarian acid Edith River Volcanics (Coronation Hill) and Cliffdale Volcanics (Pandanus Creek) have yielded small amounts of ore and contain numerous radiometric anomalies. The radioactivity of conglomerates in the King Leopold Sandstone, Lansdowne Arkose, and O'Donnell Formation of the lower Kimberley Basin succession is due to thorium. Small prospects are located within the Carpentarian basic rocks of the McAddens Creek Volcanic Member of the Kombolgie Formation near Katherine (ABC), the Peters Creek Volcanics near Westmoreland, and the Eastern Creek Volcanics north of Mount Isa. The Westmoreland deposit occurs in joints and fractures adjacent to a trachyandesite dyke (a possible feeder to the Peters Creek Volcanics) which intrudes the Westmoreland Conglomerate.

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