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REGIONAL GEOLOGY OF THE PHOSPHOGENIC PROVINCE OF THE GEORGINA BASIN

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INTRODUCTION

The rapid depletion of the high-grade Oceania phosphate deposits in the early 1960s accelerated need for Australia to find new sources of this important commodity. A number of mining companies undertook vigorous exploration programes in many Australian sedimentary basins, including the Georgina Basin. New impetus was given to the search in the Georgina Basin late in 1965 by Dr R.P. Sheldon of the U.S. Geological Survey, who was acting as a consultant to the Bureau of Mineral Resources at that time (Sheldon, 1966). He pointed out that the Cambrian rocks of the eastern portion of the Georgina Basin were particularly prospective because of the occurrence there of black mudstones and cherts. As a result, BMR directed the attention of mining companies to this region. The subsequent discovery of phosphatic Middle Cambrian sediments in the Black Mountain No. 1 and The Brothers No. 1 oil wells strengthened the prospects of the area. In August 1966, Broken Hill South Limited located extensive Middle Cambrian phosphorites in the area to the south of Duchess, and later in nine other areas to the north and west. Shortly after the initial discovery, Continental Oil Corporation located the Sherrin Creek deposit, and IMC Development Corporation the D Tree deposit (Fig. 1). In 1967 and 1968, deposits were also discovered in Middle Cambrian sediments of the Northern Territory. The sequence of events leading to these various discoveries has been discussed in detail by Russell (1967), Thomson & Russell (1971), Russell & Trueman (1971) and Howard (1971, 1972).

Intensive geological investigations by the exploration companies and by the Bureau of Mineral Resources (de Keyser, 1968, 1969a, b, 1971; de Keyser & Cook, 1972; Cook, 1972) have greatly increased our knowledge of the stratigraphy of the Georgina Basin, particularly of the Middle

Cambrian sediments, in which all of the known major phosphate deposits are located, and has led to revisions of the stratigraphic schemes proposed by earlier workers. This paper discusses the regional stratigraphy of the phosphate-bearing and associated Middle Cambrian sediments in the northeast portion of the Georgina Basin in the light of recent investigations.

GENERAL STRATIGRAPHY

The general geology of the Georgina Basin is summarized in this Volume by Smith. The Cambrian stratigraphic nomenclature was first proposed by Öpik in a series of publications (Öpik, 1954; 1956a, b; 1960; 1961; 1967a, b; 1968; 1970). As pointed out by de Keyser (1973) these earlier schemes included many lithostratigraphic and biostratigraphic units not readily mappable by the field geologist. As an alternative he advocated that many of the names first suggested by Öpik should be retained, but that they be fitted into a framework composed of magnafacies and parvafacies (see Krumbein & Sloss, 1963, p. 316-326). Although this is not a radical departure from the existing nomenclature, it clarifies considerably the inter-relationships of the various rock units and highlights their diachronous nature. Six basic lithosomes* may be recognized, and discussion of the phosphorites and their stratigraphic setting will be on this basis. The relationships of the lithosomes, the time zones, magnafacies, and parvafacies are shown schematically in Figure 2. In general, the detrital sediments of the basinal margin are replaced by limestones, and ultimately by massive dolomites in the more central part of the embayment. In most of the Georgina Basin outcrop is poor, and stratigraphic information can only be obtained by drilling. Around the eastern perimeter, however, outcrop is good and consequently the information given on the various units comes primarily from this region.

* Krumbein & Sloss (1963, p. 301) use the term lithosome for 'masses of essentially uniform lithologic character which have intertonguing relationships with adjacent masses of different lithology'.

The sedimentary sequence is everywhere underlain by Precambrian basement rocks of the Cloncurry Complex and its equivalents. In places, Precambrian basement is overlain by a thin Lower Cambrian basaltic sequence, known as the Colless Volcanics in the eastern, the Peaker Piker Volcanics in the central and the Helen Springs Volcanics in the western portions of the basin. Elsewhere, Middle Cambrian sediments rest directly on Precambrian basement, or overlie a basal sandstone-conglomerate lithosome. This lithosome ranges in age from late Precambrian to early Cambrian and perhaps early Middle Cambrian in places. It includes such units as the Mount Birnie Beds (in the Burke River Outlier), the Riversdale Formation (in the Ardmore Outlier), and the 'Mount Hendry Formation' (in the Lady Annie Outlier). The sedimentary sequence in the phosphogenic portion of the basin ranges in age from early Middle Cambrian to Ordovician. The remainder of the discussion will be concerned primarily with undoubted Middle Cambrian sediments because of all known phosphate deposits are restricted to this portion of the sequence.

MIDDLE CAMBRIAN SEDIMENTS

The stratigraphic scheme used by de Keyser & Cook (1972) and de Keyser (1973) is followed here. Some of the previously used litho-stratigraphic-biostratigraphic units and their lithosomal equivalents are summarized in Table 1. In addition, the age relationships of the various units are shown schematically in Figure 2. Each of the Middle Cambrian ltihosomes is now discussed briefly. They are considered not in a chronological framework but in their inferred spatial framework with the most seaward facies considered first and the most shoreward last.

Dolomite Lithosome

This is the most extensive unit of the northeastern portion of the Georgina Basin. It is comparatively thin on the margins of the basin

(100 m or less) but thickens considerably towards the centre, reaching a maximum thickness of about 700 m in the Barkly Tableland area. It is composed of thin to massively bedded dolomite, much of it strongly recrystallized, though dololutites and dolarenites are present in places. There are also rare oolitic dolomites, dolopelmicrites, and penecontemporaneous (?) breccias. Chert nodules, stringers, and beds are abundant; a few thin beds of limestone are present. Fossils are fairly common in the siliceous units but rare to absent in the calcareous units.

The dolomite lithosome was probably laid down in very shallow (at times hypersaline) water. This picture may at first appear to be inconsistent with the maximum development of this unit in the more central portion of the embayment, but this central area was probably a region of extensive shoals, perhaps analogous to the present-day Bahaman Banks, surrounded by somewhat deeper more normal marine conditions (see Fig. 3).

Limestone Lithosome

The limestone lithosome is best developed in the Burke River Outlier, where it has a maximum thickness of about 600 m. It consists of grey laminate to thin-bedded limestones (calcilutites and calcarenites), oolitic limestones, and brecciated limestones, with sedimentary structures such as current troughs, ripple marks, and cross laminae comparatively common. Chert laminae and nodules are present in a few areas. Fossils (particularly bivalved crustacea and trilobites) are fairly abundant but frequently comminuted.

The depositional environment was probably shorewards of the environment in which the dolomite lithosome was deposited; it was also slightly deeper, more open water than the dolomite environment, with normal marine salinities prevailing.

Chert-siltstone-limestone-phosphorite lithosome

This lithosome is up to 100 m thick and is best developed around the margins of the basin. It consists of white or grey siliceous claystone, chert, siltstone, limestone, and pelletal and non-pelletal phosphorites. Bedding ranges from thin to medium; cross-laminations, penecontemporaneous breccias, and cut-and-fill structures are present in places. There is a rich fauna including trilobites, brachiopods, bradoriids, echinoderms, sponge spicules, and hyolithids. This lithosome contains all the major phosphate deposits of the Beetle Creek Formation and its lateral equivalents. Consequently it is also the most intensively studied unit; drilling has revealed that the phosphatic intervals range from uniformly bedded units such as at Duchess and Ardmore, to lenticular bodies such as those encountered in parts of the Lady Annie deposits. The detailed stratigraphy of some of the major phosphate deposits is discussed later in this volume by Rogers & Keevers & Howard, Cooney, & Perrino.

The abundance of fossils indicates that the lithosome was deposited mainly under marine or paralic conditions. The complex facies variations suggest a highly variable environment such as would be encountered near-shore. Features such as cross-bedding and trough-and-fill structures imply moderately high energy at times. The phosphorites and cherts indicate that nutrients were abundant. However, the abundance of non-phosphatic mudstones also shows that there was periodically an abundant supply of fine detritus into a low-energy environment. The black carbonaceous-rich nature of some of the sediments also implies that reducing conditions prevailed below the sediment-water interface. The clay mineralogy (Cook & Armstrong, 1972) also suggest a near-shore deposit. The formation was probably laid down, not in a single basin, but in several separate sub-basins which may have ultimately coalesced. The possible range of environments includes lagoonal, estuarine, littoral, and sub-littoral.

Silt-shale-chert lithosome

This unit is composed of grey shaly siltstone and claystone (black in places below the weathering profile) and thin-bedded chert, silty sandstone, and limestone (calcilutite). Thin impersistent phosphatic intervals are present at a few localities. The lithosome has a maximum thickness of 220 m, in the Burke River Outlier. There is evidence of penecontemporaneous brecciation and slumping in places; cross-bedding and current lineations are also present in places. Agnostid trilobites and phosphatic brachiopods are fairly common; sponge spicules are particularly common in the chert bands.

The depositional environment was evidently very shallow marine or transitional. De Keyser (1973) suggests that, at times, conditions may have become toxic in areas of localized upwelling in the near-shore and possibly estuarine zone.

Sandstone-siltstone lithosome

This unit is developed only on the eastern margin of the basin, where it has a maximum thickness of about 100 m. It consists of shaly siltstone and mudstone and fine sandstone with rare chert bands in the Burke River Outlier, but becomes coarser to the west. There is comprises brown fine to coarse-grained sandstone and silty sandstone with abundant cross-beds and ripple marks. Fossils, particularly trilobites, are abundant; these indicate a marine environment for this lithosome. The coarseness of the unit and the sedimentary structures suggest a very shallow marine environment close to the strand line at or just below low water mark.

SUMMARY OF MIDDLE CAMBRIAN SEDIMENTATION

The presence of extensive basalts (the Antrim Plateau Volcanics and its equivalents) suggests that late in the Precambrian or early in the Cambrian, some tectonic activity took place in, or to the north of, Northern Australia. In the vicinity of the Georgina Basin this episode was less cataclysmic, though it was responsible for minor volcanics, and subsequently, by early Middle Cambrian times, gentle downwarping and the development of shallow but extensive epicontinental seas. At first a widespread dolomite lithosome prograded over most of the northeast portion of the basin; hypersaline conditions prevailed at times, which resulted in extensive dolomitization of biostromal, and in places biohermal, limestones. The water then became less saline as a result of gradual deepening and the less restricted access of oceanic seawater into most of the northeast embayment of the Georgina Basin, or alternatively as a consequence of marginal 'freshening', resulting from increased river runoff into the embayment. This established the depositional pattern illustrated schematically in Figure 3, consisting of dolomites deposited under hypersaline conditions in the centre of the embayment, presumably as bank and shoal deposits. This was surrounded by a deeper zone of more normal marine conditions in which limestones were deposited. Approaching the shoreline the sea was shallower and a wide variety of sediments was deposited, including sandstones, mudstones, cherts, and at times phosphorites. The abundance of fossils and the presence of cherts, carbonaceous matter, and phosphorites indicate that this near-shore zone was exceptionally rich in nutrients, perhaps as a result of localized upwelling or the prevalence of estuarine conditions. The presence of a low or arid hinterland flanking the basin was also important for the development of phosphorites; at times there was little terrigenous sedimentation to dilute chemical or biochemical (phosphatic) sedimentation to any significant extent. It appears that the preferred site of phosphate deposition was close to the shore either next to or on topographic highs such as the Mount Murray high (Russell & Trueman, 1971), in the paralic zone such as the D Tree area, or in a small embayment such as the Ardmore Outlier. It was not a single factor but a combination of conditions, governing the supply of nutrients, the lack of terrigenous material, and the prevailing depositional environment that was responsible for phosphate deposition in the Georgina Basin. These conditions were apparently only attained in Middle Cambrian time, during deposition of the chert-siltstone-limestone-phosphorite lithosome in units such as the Beetle Creek Formation.

References

COOK, P.J., 1972 - Petrology and geochemistry of the phosphate deposits of northwest Queensland, Australia. <u>Econ. Geol.</u>, 67, 1193-1213.

COOK, P.J., & ARMSTRONG, K.A., 1972 - Clay mineralogy of the Middle Cambrian Beetle Creek Formation, Georgina Basin, Northwestern Queensland. <u>Bur. Miner. Resour. Aust. Bull.</u> 125, 7-16.

DE KEYSER, F., 1968 - The Cambrian of the Burke River Outlier. <u>Bur. Miner. Resour. Aust. Rec.</u> 1968/67 (unpubl.).

DE KEYSER, F., 1969a - On the genesis of the Georgina Basin phosphorites, northwest Queensland. <u>Bur. Miner. Resour. Aust. Rec.</u> 1969/79 (unpubl.).

DE KEYSER, F., 1969b - The phosphate-bearing Cambrian formations of the Lawn Hill and Lady Annie districts, northwestern Queensland. <u>Bur. Miner. Resour. Aust. Rec.</u> 1969/147 (unpubl.).

DE KEYSER, F., 1971 - A late Proterozoic tillite at Duchess, northwestern Queensland. <u>Bur. Miner. Resour. Aust. Bull.</u> 125, 1-6.

DE KEYSER, F., 1973 - A review of the Middle Cambrian stratigraphy in the Queensland portion of the Georgina Basin, Northwestern Queensland. <u>Bur. Miner. Resour. Aust. Bull.</u> 139.

DE KEYSER, F., & COOK, P.J., 1972 - The geology of the Middle Cambrian phosphorites and associated sediments of northwest Queensland. <u>Bur. Miner. Resour. Aust. Bull.</u> 138 79 p.

HOWARD, P.F., 1971 - The discovery of phosphorites in northern Australia. <u>Soc. Mining Engrs</u>, 250, 269-273.

HOWARD, P.F., 1972 - Exploration for phosphorite in Australia - a case history. <u>Econ. Geol.</u>, 67, 1180-1292.

KRUMBEIN, W.C., & SLOSS, L.L., 1963 - STRATIGRAPHY AND SEDIMENTATION. Freeman, San Francisco, 660 p.

ÖPIK, A.A., 1954 - Cambrian stratigraphy of the Camooweal region (progress report). Bur. Miner. Resour. Aust. Rec. 1954/31 (unpubl.).

ÖPIK, A.A., 1956a - The Cambrian geology of Queensland. In El sistema Cambrico, su Paleogeografie y el problema de su base. 20th int. geol. Cong., Mexico, 2, 1-24.

ÖPIK, A.A., 1956b - Cambrian geology of the Northern Territory. Ibid., 2, 25-84.

ÖPIK, A.A., 1960 - Cambrian in The geology of Queensland. J. geol. Soc. Aust., 7, 89-114.

ÖPIK, A.A., 1961 - The geology and palaeontology of the headwaters of the Burke River Outlier, Queensland. Bur. Miner. Resour. Aust. Bull. 53.

ÖPIK, A.A., 1967a - The Mindyallan fauna of northwestern Queensland. Ibid., 74, 2 vols.

ÖPIK, A.A., 1967b - The Ordian Stage of the Cambrian and its Australian Metadoxididae. Ibid., 92, 133-70.

ÖPIK, A.A., 1968 - Ordian (Cambrian) Crustacea Bradoriida of Australia. Ibid., 103.

ÖPIK, A.A., 1970 - Redlichia of the Ordian (Cambrian) of northern Australia and New South Wales. Ibid., 114.

RUSSELL, R.T., 1967 - Discovery of major phosphate deposits in northwest Queensland. Qld Govt Min. J., 68 (786), 153-7.

RUSSELL, R.T., & TRUEMAN, N.A., 1972 - The geology of the Duchess phosphate deposit, Northwest Queensland, Australia. Econ. Geol., 66, 1186-1214.

SHELDON, R.P., 1966 - Preliminary appraisal of the Australian continent for sedimentary phosphate deposits. Bur. Miner. Resour. Aust. Rec. 1966/16 (unpubl.).

THOMSON, L.D., & RUSSELL, R.T., 1971 - Discovery, exploration and investigations of phosphate deposits in Queensland. Aust. Inst. Min. Metall. Ann. Conf. Proc. 1, 1-19.

Table 1 : Middle Cambrian lithosomes and some of their lithostratigraphic-biostratigraphic equivalents, in the northeastern part of the Georgina Basin.

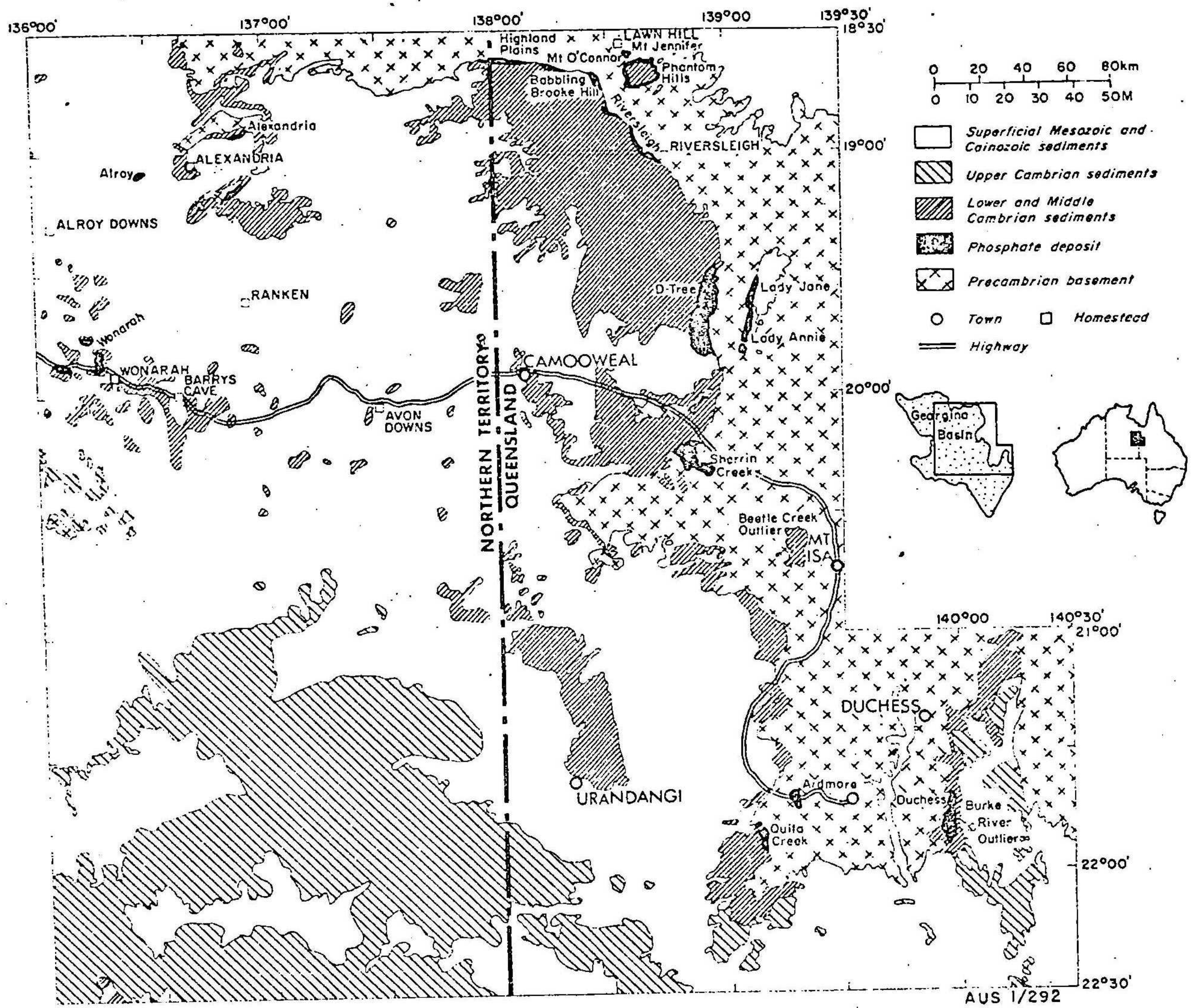
LITHOSOME (magnafacies)	PREVIOUSLY USED NAMES (parvafacies)
1. Dolomite	Camooweal Dolomite, Thorntonia Limestone, Age Creek Formation.
2. Limestone	Devoncourt Limestone, Selwyn Range Limestone, Currant Bush Limestone, V-Creek Limestone, Mail Change Limestone, Quita Formation, Mungerebar Limestone.
3. Chert-siltstone-limestone-phosphorite	Beetle Creek Formation, Border Waterhole Formation, Burton Beds, Wonarah Beds, Anthony Lagoon Beds.
4. Silt-shale-chert	Inca Formation, Blazan Shale, Lancewood Shale, Roaring Siltstone.
5. Sandstone-siltstone	O'Hara Shale, Steamboat Sandstone, Split Rock Sandstone.

CAPTIONS

<u>Figure 1</u> Locality map

<u>Figure 2</u> Time and spatial relationships of rock (lithosomal) units in the phosphogenic part of the Georgina Basin (time zones modified from Öpik, 1956a, 1960, 1970)

<u>Figure 3</u> Facies distribution in the eastern Georgina Basin in earth middle Cambrian (Xystridura - Gibbus 1a) time.



136°00'
137°00'
138°00'
139°00
139°30'
18°30'
Highland Plains
LAWN HILL
Mt Jennifer
Mt O'Connor
Phantom Hills
Babbling Brooke Hill
Riversleigh
RIVERSLEIGH
19°00'
Alexandria
ALEXANDRIA
Alroy
ALROY DOWNS
RANKEN
D-Tree
Lady Jane
Lady Annie
Wonarah
WONARAH
BARRYS CAVE
AVON DOWNS
NORTHERN TERRITORY
QUEENSLAND
CAMOOWEAL
20°00'
Sherrin Creek
Beetle Creek Outlier
MT ISA
140°00
140°30'
21°00'
DUCHESS
URANDANGI
Ardmore
Duchess
Burke River Outlier
Quita Creek
22°00'
22°30'
AUS 1/292
0 20 40 60 80km
0 10 20 30 40 50M
Superficial Mesozoic and Cainozoic sediments
Upper Cambrian sediments
Lower and Middle Cambrian sediments
Phosphate deposit
Precambrian basement
Town
Homestead
Highway
Georgina Basin

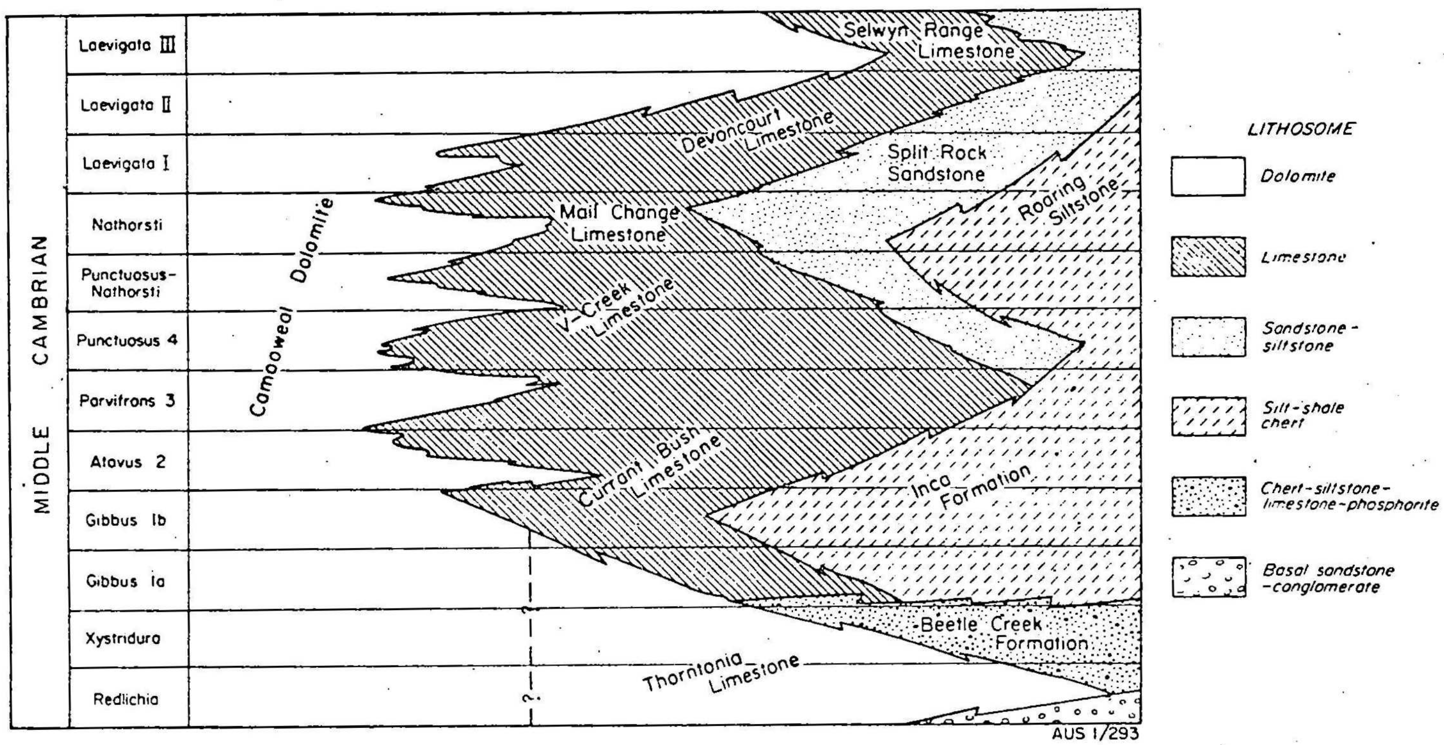
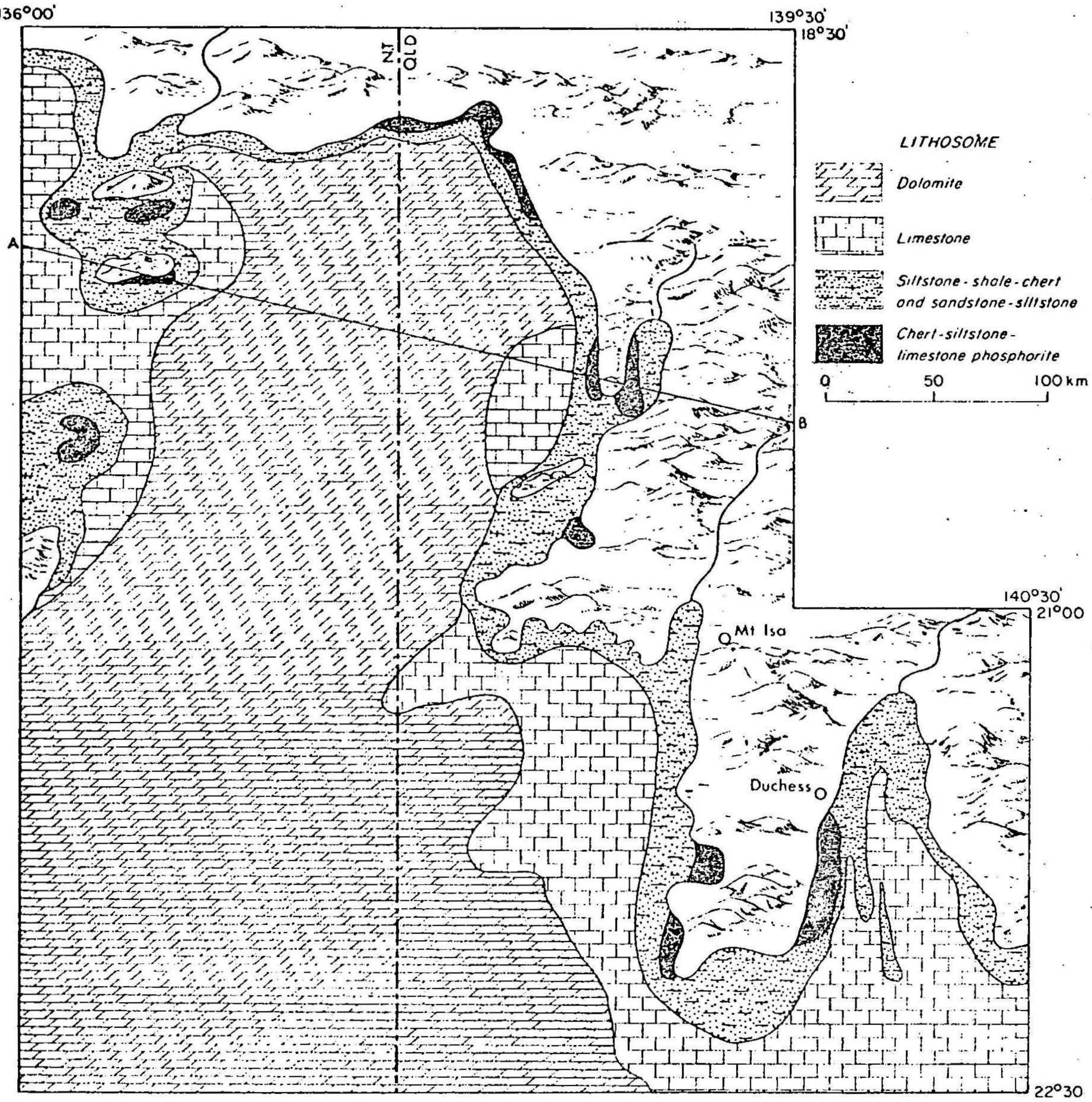
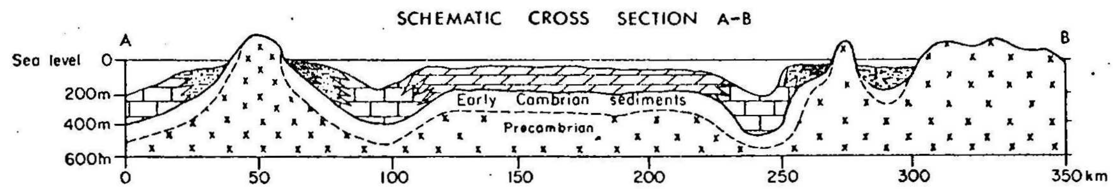


Fig 2 Rock and time relationships of Middle Cambrian sediments on the eastern margin of the Georgina Basin


136°00'
139°30'
18°30'
NT
QLD
LITHOSOME
Dolomite
Limestone
Siltstone - shale - chert and sandstone - siltstone
Chert - siltstone - limestone phosphorite
0 50 100 km
A
B
140°30'
21°00
Mt Isa
Duchess
22°30


SCHEMATIC CROSS SECTION A-B
A
B
Sea level 0
200m
400m
600m
Early Cambrian sediments
Precambrian
0 50 100 150 200 250 300 350 km

AUS 1/294