Revised stratigraphy of the Ordovician (Late Tremadoc–Arenig) Prices Creek Group and Devonian Poulton Formation, Lennard Shelf, Canning Basin, Western Australia

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The Early Ordovician (late Tremadoc to Arenig) Prices Creek Group outcrops only on the northern margin of the Canning Basin in a small area centred on Prices Creek, 60 km southeast of Fitzroy Crossing. Recent hydrocarbon and mineral exploration has shown that the Prices Creek Group, previously defined as consisting of a lower Emanuel Formation and an upper Gap Creek Formation can now be subdivided into four formations. The new formations comprise a basal transgressive sandstone unit, here named the Kunian Sandstone, which is overlain by a dolomitic carbonate-dominated unit, here named the Kudata Dolomite. The Kunian Sandstone does not outcrop, but the Kudata Dolomite, which was formerly included in the Emanuel Formation, is exposed at the base of the type section of that unit along Emanuel Creek. The Kudata Dolomite is conformably overlain by the revised Emanuel Formation.

Introduction

Ordovician sediments are widely distributed in the Canning Basin (Forman & Wales, 1981), but outcrop is limited to a small area in the vicinity of Prices Creek, 60 km southeast of Fitzroy Crossing and to a number of small sandstone exposures, known as the Carranya Beds, located south of Halls Creek (Fig. 1).

Re-examination of outcrop sections, mineral exploration core holes and petroleum exploration wells on the shelf and shelf margin has provided the essential data for a revision of the lithostratigraphy of these Ordovician sediments on the eastern end of the Lennard Shelf. In general, these revisions of the stratigraphy formalise the observations of Henderson (1963), and they form the basis of a lithological correlation of the Lennard Shelf sediments to the classic Ordovician Nambeet–Willara–Goldwyer–Nita Formations succession in the subsurface Canning Basin.

Previous work

The Ordovician age of rocks in the Prices Creek area on the northern margin of the Canning Basin was first recognised from fossils found in 1949 by D.J. Guppy and A.W. Lindner (Guppy & Opik, 1950) during the mapping of rocks previously considered to be of Devonian age. These rocks were the first Ordovician sediments to be recognised in the basin and still represent the largest exposure of Ordovician age sediments. The discovery was made by Guppy & Opik (1950) when they established the Prices Creek Group, which was subdivided into a lower Emanuel Limestone and an upper Gap Creek Dolomite. The type section of the Emanuel Limestone was measured along Emanuel Creek (Guppy & Opik, 1950, p. 205), just south of the Emanuel Range (Fig. 2), and was reported to be 509 m (1670 feet) thick.

The name of the Emanuel Limestone was changed to the Emanuel Formation by Guppy & others (1958, p. 17). The type section was re-measured at 595 m (1950 feet) in outcrop and extended by an additional 56 m (182 feet) from sediments intersected in a shallow drill hole associated with a seismic survey (Smith, 1955; Guppy & others, 1958, p. 18). The exact location of the 1955 BMR Test Drill Hole (Guppy & other, 1958, p. 87) is not known, but the thickness of the ‘crystalline brown limestone’ at the base of the outcrop section combined with an additional 22 m (72 feet) from the top of the test hole gives a thickness of 95 m (312 feet) for this dolomitic interval. The basal part of the section in the test hole consisted of 34 m (110 feet) of sandstone. It is not clear from their text if Guppy & others (1958, p. 18) considered this sandstone as part of the Emanuel Formation or as part of a separate, but undefined, stratigraphic unit.

Veevers & Wells (1961) briefly discussed the Prices Creek Group. They placed the sandy dolomite and arkosic sediments found in the BMR 3 Prices Creek (now renamed Noonkanbah No. 3) drillhole in the base of the Emanuel Formation.

Henderson (1963) further described the sequence in this stratigraphic drillhole, located adjacent to Emanuel Creek and near the base of the Emanuel Formation type section (Fig. 2). He interpreted the sequence as consisting of an upper 10.6 m (35 feet) of sandy limestone belonging to the Emanuel Formation overlying an 88 m (290 feet) interval of sandy doleranite and dolomitic shale with basal quartz sandstone which, in turn, overlies 82 m (268 feet) of arkose forming the base of the sedimentary sequence. The hole bottomed in Precambrian tuffs and metamorphics. Henderson (1963, p. 49) considered both the doleranite and arkose units as separate formations, distinct from the Emanuel Formation, but because they were known only from the single drillhole they were not formally named.

Exposed in the vicinity of Gap Creek and north of the Emanuel type section (Fig. 2) were named the Gap Creek Formation by Guppy & Opik (1950). The type section

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was detailed by Guppy & others (1958) and a lower Trenton (Late Ordovician) age was indicated for the unit. McTavish (1973) included the lower part of the Gap Creek Formation (sensu herein) in the top of the Emanuel Formation. The lithologic analysis of the formation in this study indicated that the boundary between the Emanuel and Gap Creek Formations lies well below the base of section RM 10.

A thick Ordovician section on the eastern part of the Lennard Shelf has been intersected in three petroleum exploration wells (Fig. 1) near the shelf margin and in numerous shallow mineral exploration coreholes in the Prices Creek area (Fig. 2). These data considerably increase knowledge of the extent and nature of Ordovician sedimentation in this part of the basin beyond that of the restricted exposures. The penetration of both the dolomitic and sandstone units in a number of recent petroleum and mineral exploration holes (Fig. 4) demonstrates that both of these units have regional distribution and should be recognised as formal stratigraphic units.

Revised Lennard Shelf Stratigraphy

Kunian Sandstone (new name)

The Kunian Sandstone (Roche, 1990) is the basal transgressive Ordovician sandstone on the eastern portion of the Lennard Shelf (Fig. 3). The type section, 82 m thick, is in BMR Noonkanbah No. 3 drillhole (Henderson, 1963) from where cores 4–6 were supposedly taken in this unit. These were described as consisting of "medium hard pale grey and pale brown very fine to coarse-grained arkose" with glauconite and pyrite (Henderson, 1963, pl. 3). We have examined cores 4–6, and because they are vastly different from the original descriptions of the drillsite geologist, we can only assume that they have become confused with cores from other drillholes (see Appendix). We therefore assume the original descriptions to be essentially accurate because they conform with observations made in nearby core holes. Examination of several BHP coreholes indicates that the unit is not so much an arkose but a quartz-lithic arenite with occasional glauconite-rich units throughout.

The Kunian Sandstone has been intersected in the petroleum exploration wells Grevillea No. 1 (90.5 m thick), Gap Creek No. 1 (77 m), Justago No. 1 (in excess of 100 m), and in several BHP stratigraphic coreholes (Fig. 4), the most complete section of which is to be found in BHP’s diamond drillhole PHD 1 where it is 112 m thick (Handley, 1991). This latter hole was drilled in 1990 by BHP Minerals Ltd as part of their Lennard Shelf base metal exploration program.

The name of the unit is taken from Kunian Gap which passes through the Emanuel Range north of the type locality.
**Kudata Dolomite (new name)**

The Kudata Dolomite (Roche, 1990; Fig. 3 herein) is named for Kudata Gap, a water gap through the Emanuel Range (west of Kunian Gap) located about 6 km north of the type section. The type section is located along Emanuel Creek and in the adjacent BMR 3 Prices Creek (= Noonkanbah No. 3) drillhole where the unit is 88 m thick and represented by cores 1-3. In outcrop, the formation consists of brown to brownish-grey recrystallised dolomite and dolomitic limestone which is medium to thick bedded in the lower part, becoming silty to shaly with thin dolomite beds in the upper part.

Unlike those purported to be from the underlying unit, the cores (1–3, see Appendix) identified as coming from BMR Noonkanbah No. 3, agree more closely with the description of those cores and cuttings in the drilling report (Henderson & others, 1963, pl. 3). We therefore assume that they are probably correctly identified.

The Kudata Dolomite has also been intersected in the petroleum exploration wells Grevillea No.1 (69 m thick), Gap Creek No.1 (84 m), Justago No.1 (160.5 m), and in several BHP stratigraphic coreholes, the most complete section of which is to be found in BHP’s drillhole PHD 1 where it is 85 m thick.

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**Figure 2.** Geological map of the Prices Creek outcrop area showing the location of wells and outcrop section (see locality information).
The upper member of the Emanuel Formation is in excess of 150 m thick and extends upward to the base of the Gap Creek Formation. This member is not well exposed and is characterised by shale, siltstone and small diameter limestone nodules. In the upper part of this member, the abundance of nodular limestone decreases and exposure becomes poorer. The upper part of the formation consists of shale and siltstone with only occasional beds of nodular limestone. On the measured section the uppermost exposure of the Emanuel Formation consists of 1.5 m of shale below a thick caliche deposit with exposures of Devonian limestone a short distance upstream.

The transition to the dolomitic carbonates of the overlying Gap Creek Formation is not exposed, but can be seen in BHP’s diamond drillholes PHD 2 and PHD 3. Here, it is an apparently transitional contact, with the degree of dolomitisation determining the position of the actual contact. McTavish (1973) placed the upper boundary of the Emanuel Formation at the base of a thick dolomite bed near the crest of a hogback ridge. However, our interpretation of the exposure is that the entire McTavish RM 10 section should be placed in the Gap Creek Formation.

The Emanuel Formation has been intersected in the petroleum exploration wells Grevillea No.1 (234 m thick), Gap Creek No. 1 (204 m), Justago No. 1 (315 m), and in several BHP stratigraphic coreholes, the best section of which is to be found in BHP PHD 1 where an incomplete section is 405 m thick.

**Emanuel Formation (revised)**

The Emanuel Formation (Fig. 3) is redefined to exclude the basal Kunian Sandstone and the Kudata Dolomite that were included, in whole or in part, in the formation by both Guppy & others (1958) and Veevers & Wells (1961). The type section of the Emanuel Formation is located in and alongside Emanuel Creek, as originally measured by Guppy & Opik (1950). In this study, the base of the Emanuel Formation is placed at the top of the highest dolomitic limestone of the Kudata Dolomite. In the type section, the Emanuel Formation can be subdivided into three informal members:

- The basal member is 142 m thick and very poorly exposed with only a few intervals of shale and siltstone and a few thin limestone beds outcropping in the section. The first significant fossiliferous exposure is 23 m above the base of the formation.

- The middle member of the Emanuel Formation is 143 m thick and is distinguished from the underlying unit by the relatively continuous exposure, the abundance of bedded limestone or beds of large (>100 mm) diameter carbonate nodules, interbedded with siltstone and shale. This middle member of the formation is abundantly fossiliferous.

- The upper member of the Emanuel Formation is in excess of 150 m thick and extends upward to the base of the Gap Creek Formation. This member is not well exposed and is characterised by shale, siltstone and small diameter limestone nodules. In the upper part of this member, the abundance of nodular limestone decreases and exposure becomes poorer. The upper part of the formation consists of shale and siltstone with only occasional beds of nodular limestone. On the measured section the uppermost exposure of the Emanuel Formation consists of 1.5 m of shale below a thick caliche deposit with exposures of Devonian limestone a short distance upstream.

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**Gap Creek Formation**

The Gap Creek Formation (Fig. 3) conformably overlies the Emanuel Formation and the two units are apparently in a transitional relationship. The Gap Creek Formation is a silty to sandy calcarenite and siltstone that has been secondarily dolomitised. The base of the Gap Creek Formation is taken at the incoming of a significant amount of dolomitic siltstone replacing the predominant shale of the upper part of the Emanuel Formation.

The type section of the Gap Creek Formation (Fig. 2) is east of Gap Creek and about 1.5 km southeast of Gap Spring (Guppy & Opik, 1950). The type section corresponds to a series of traverse section conodont samples (WCB 701) collected for this study. An additional section, WCB 708, was measured by BMR 2.5 km west of Gap Spring. This section starts low in the Gap Creek Formation, but above the Emanuel Formation which is not exposed at the locality. The top of section WCB 708 is in the Poulton Formation. A third section, WCB 707, was measured 0.5 km west of the type section and is from near the stratigraphic base of the formation.

The Gap Creek Formation can be divided into two informal members in the exposures adjacent to Gap Creek. The lower 120 m of the formation consist of dolomitic siltstones and sandstones, and dolomites. A rich macrofossil fauna can be found in this lower part of the formation, but the faunal diversity is low when compared with the underlying Emanuel Formation. Principal components of this fauna include trilobites (Lycophron sp.), brachiopods (Spondylo poda holoskingiae), gastropods (Teichischira sp.), and conodonts (Opikodas communis, Bergstroemognathus habeiensis).

The upper member of the formation is about 80 m thick and consists of similar rock types but has a greater percentage of siltstone. Fossils are rare in the upper member and
nODULES IN THE UPPER HALF OF THE UNIT ARE PSEUDOMORPHS AFTER EVAPORITIC MINERALS, INDICATING PROBABLE ELEVATED SALINITY AT THE TIME OF DEPOSITION. LARGE MACLURITACEAN GASTROPODS ARE FOUND IN THE UPPER 20 M OF FORMATION IN SECTION WCB 708.

THE GAP CREEK FORMATION HAS BEEN INTERSECTED IN THE PETROLEUM EXPLORATION WELLS GREVILLEA NO.1 (212 M THICK), GAP CREEK NO. 1 (114.5 M), JUSTAGO NO. 1 (297.5 M), AND IN SEVERAL BHP STRATIGRAPHIC COREHOLES, THE MOST COMPLETE SECTION OF WHICH IS TO BE FOUND IN BHP PHD 2 WHERE AN INCOMPLETE SECTION IS 93 M THICK.

**POULTON FORMATION**

THE GAP CREEK FORMATION IS PARACONFORMABLY OVERTWN BY A PREVIOUSLY UNNAMED STRATIGRAPHIC UNIT THAT IS HERE CORRELATED WITH THE POULTON FORMATION (PLAYFORD & OTHERS, 1975) FOUND IN THE SUBSURFACE OF THE WESTERN PART OF THE LENNARD SHELF (FIG. 3). THE TYPE SECTION OF THE POULTON

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**Figure 4.** Stratigraphic correlation of the Kunian Ss, Kudata Dol. and Emanuel Fm. in petroleum exploration wells (Grevillea No. 1, Gap Creek No. 1 and Justago No. 1), stratigraphic drill holes (BHP PHD 1, Noonkanbah No. 3) and the outcrop in the Prices Creek area. See Figure 1 for the location of the line of section.
Formation is located in Blackstone No. 1 (1941–2220 m) and the unit has also been reported in nearby wells, such as Meda No. 1 and Napier No. 1 (Towner & Gibson, 1983). The Poulton Formation has not previously been reported from outcrop. Based on both lithologic similarity and stratigraphic relationships, we extend the Poulton Formation to include the outcrop exposures in the Prices Creek area.

In outcrop sections, the Poulton Formation consists of dolomite, siltstone, dolomite, and dolomitic sandstone with some shale intervals. The base of the unit is marked by pebble conglomerates in some localities and quartz pebbles are found in the lower part of the unit at several locations. Some of the dolomites appear to be algal laminates, and halite pseudomorphs were found in dolomite in measured section WCB 708 (sample 144 A). Apart from two beds containing unidentified gastropods located near the base of the unit in traverse section WCB 709, no macrofossils or phosphatic microfossils have been recovered from the unit. Based on microfloras, a Middle Devonian age has been ascribed to the Poulton Formation (Playford & others, 1975).

In the type section (Blackstone No.1), and in outcrop, the Poulton Formation is overlain by the Lower Dolomite of the Pillara Formation with angular unconformity. This same angular relationship is indicated in the subsurface of the western part of the Lennard Shelf (Playford & others, 1975). However, near Cadgebaut Mine, the basal arkose of the Devonian sequence (possibly the Poulton Formation) is apparently conformably overlain by the lower dolomite of the Pillara Formation. Hence, the angular unconformity in the type and other sections may be due to a local tectonic event.

The Poulton Formation has been intersected in the petroleum exploration wells Grevillea No. 1 (136 m thick), Gap Creek No. 1 (53.5 m), and Justago No. 1 (102.5 m).

Age relationships

An Ordovician age for the Prices Creek Group was not recognised until 1949 (Guppy & Opik, 1950). At that time, Guppy & Opik (1950) correlated the Ordovician of the Canning Basin with stages of the North American succession. They correlated the base of the Emanuel Formation with the Upper Ozarkian, the top of the Emanuel Formation with the Lower Trenton, Teichert & Glenister (1954), using cephalopods, concluded that the upper part of the Emanuel Formation was of Canadian age, or slightly older than the age indicated by Guppy & Opik (1950), but they had no cephalopod control on the age of the base of the Emanuel Formation.

More recent palaeontological studies by McTavish (1973), McTavish & Legg. (1976) and Legg (1976, 1978) suggested that the top of the Prices Creek Group is older than the Lower Trenton age proposed by Guppy & Opik (1950). McTavish (1973) examined conodont faunas from the Emanuel Formation and the base of the Gap Creek Formation (his top Emanuel Formation, see above) and compared them with the conodont biozonation of the Baltic. On this basis, McTavish (1973) concluded that the Emanuel Formation represented the entire interval of the Latorp Stage, that is the lower part of the Arenig-Arenig, Legg (1976, 1978) also concluded that the Emanuel–Gap Creek interval was essentially Latorpian in age, but suggested that the base of the Emanuel might extend down into the upper part of the Tremadoc.

Analysis of biostratigraphic collections made in 1990 in the Prices Creek area are now in progress, and preliminary analysis of conodont and trilobite faunas indicate some revision of the age determinations given by previous authors is needed.

There is no faunal evidence for the age of the Kunian Sandstone. No macrofossils were observed in any of the core examined, and glauconitic and friable sands examined for phosphatic microfossils were barren. New K-Ar dates of 515±4 and 504±4 Ma obtained from the Spielers Shear in the Oscar Range Inlier (Shaw & others, 1992) suggest that tectonism in the northern margin was active as late as about the Cambrian-Ordovician boundary. Shaw & others (1992) apply the term Spielers Event to this period of apparent crustal shortening and uplift. As the Kunian Sandstone and Kudata Dolomite yield no clear evidence of metamorphism, and conodonts from the Kudata Dolomite have a low conodont color alteration index (CAI = 1), it is probable that sedimentation in the basin was initiated in the Early Ordovician. The Kunian Sandstone is thus most likely to be of Warendian (=Tremadoc) age, and to represent the major transgressive phase following the Kelly Creek Eustatic Event (Nicoll & others, 1992) in the Amadeus and Canning Basins.

The Kudata Dolomite contains no datable macrofossils, but conodonts recovered from both surface and subsurface samples indicate a Tremadoc age for the unit. Taxa recorded include Scolopodistes bolites and Drepanois-todus sp. This fauna is similar to the conodont fauna described by Repetski (1982) from the lower part of the El Paso Formation in Texas and correlated with conodont fauna D. delifer Zone of the North American conodont zonation.

In the Emanuel Formation, as defined in this study, both the conodont and trilobite faunas indicate that the unit is of early Arenig age. The conodont fauna includes Prioniodus oepiki, Paracordylodus gracilis, Bergstroemognathus ex-tensus, and Serratognathus bilobatus.

The top of the Emanuel Formation and the base of the Gap Creek Formation have not been adequately sampled to determine their age because this contact does not outcrop. However, conodonts from the base of sections WCB 707 and WCB 708, which are presumed to begin low in the Gap Creek Formation, indicate an Arenig age based on the recovery of species such as Oepikodus communis and Bergstroemognathus habeinensis. This same fauna appears to extend through the lower member of the Gap Creek Formation. The upper member of the Gap Creek Formation has only a very sparse macro fauna and an apparently non-diagnostic conodont fauna.

The Poulton Formation, as noted above, lacks age diagnostic fossils in the outcrop sections, but palynomorphs from subsurface samples (Playford & others, 1975) indicate that the unit is most probably of Middle Devenian age.

Canning Basin outcrop to subsurface correlation

Precise correlation of the Prices Creek Group with the subsurface Ordovician of the rest of the Canning Basin (Fig. 5) is difficult because adequate faunal studies are
REVISED STRATIGRAPHY OF ORDOVICIAN 71

available only from the Emanuel Formation (Legg, 1973; McTavish, 1973). Subsurface biostratigraphy has been based primarily on petroleum exploration wells, and is limited to work by Legg (1976, 1978) and McTavish & Legg (1972, 1976). Re-evaluation of the conodont biostratigraphy of the subsurface (Nicoll, 1992b) now provides a general framework against which to correlate the new outcrop collections.

The Kunian Sandstone is lithologically correlated with the basal transgressive sands of the Nambeet Formation (McTavish & Legg, 1976). There is no direct palaeontological evidence on which to establish an age for either sandstone unit, but biostratigraphic control provided by the overlying Kudata Dolomite and the non-sandstone facies of the lower part of the Nambeet Formation suggest equivalence.

The Kudata Dolomite correlates with the lower part of the Nambeet Formation. Conodont faunas from the lower part of the Nambeet Formation in Samphire Marsh No. 1 are the same age as the conodont fauna from BHP PCD 158 and are assigned to the Drepanoistodus–Paltodus Zone (Nicoll, 1992b).

The revised Emanuel Formation is correlated with the upper part of the Nambeet Formation on the presence of elements of the *Prioniodus elegans–Bergstroemognathus extensus* Zone in both units (Nicoll, 1992b). The Gap Creek Formation is correlated with part of the Wilia Formation, but there is no faunal evidence presently available for the age of the upper part of the Gap Creek Formation. In the outcrop area, near Prices Creek, the top of the Gap Creek Formation is marked by an eroded, unconformable surface over lain by the Poulton Formation which has elsewhere been dated as Middle Devonian (Playford & others, 1975). This indicates that on at least the eastern part of the Lennard Shelf, there is no equivalent of the Goldwyer or Nita Formations preserved. It is possible that sediments equivalent to these units were deposited in the area, but were removed subsequently by erosion.

The Ordovician section in the western part of the Lennard Shelf is intersected in the WAPET Blackstone No. 1 petroleum exploration well and has been interpreted by McTavish & Legg (1976) as consisting of 444+ m of the Goldwyer Formation (2606.7–3050.3 m = TD) overlain by 386 m of the Nita Formation (2221–2606.7 m). The Poulton Formation was named by Playford & others (1975) for the interval 1941–2220 m in the Blackstone No. 1 well. Lehmann (1984) interpreted the Blackstone No. 1 section to include 134 m of the Worral Formation (2102–2236 m) and 168 m of the Poulton Formation equivalent units (1934–2102 m). However, conodonts from core 16 (2220–2229 m) are of Ordovician age (e.g. *Drepanoistodus*) and belong with the underlying unit. This review places the Poulton Formation in Blackstone No. 1 between 1934–2221 m, a thickness of 287 m, much as indicated by Playford & others (1975) and correlates this interval with the lithologies of the exposures in the Prices Creek area.

Examination of the conodont faunas from Blackstone No. 1

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<th>AMADEUS BASIN</th>
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Figure 5. Correlation of the Canning Basin subsurface and Lennard Shelf areas with the Amadeus and Georgina Basin Ordovician succession. The sea-level curve is modified from Nielsen (1992). The vertical scale is time linear.
cores 16 to 19 (2221–2460) indicates that the conodont fauna from this interval of the Nita Formation belongs to the *Phragmodus–Plectodina* Zone. This zone is found in the upper part of the Goldwyer Formation and in the Nita Formation in the subsurface throughout the basin and confirms the stratigraphic interpretation of McTavish & Legg (1976).

**Interbasin correlation and palaeogeography**

Correlation of the Ordovician sedimentary sequences of the Canning, Amadeus and Georgina Basins (Fig. 5) is here revised from the scheme proposed by Nicoll & others (1988) following the results of ongoing biostratigraphic studies in the three basins. The relationship of the sedimentation pattern between the Canning and Amadeus Basins (Fig. 6) is very close, because the two basins were thought to be physically linked as a single depositional system throughout much of Ordovician time (Webby, 1978; Nicoll & others, 1988, 1989; Cook & Totterdell, 1991). The Georgina Basin is more remote and is only indirectly linked to the Canning Basin, but all three basins were subjected to essentially the same tectonic and eustatic controls on depositional patterns.

The Canning Basin in Ordovician time was located in Eastern Gondwanaland (Fig. 7) in an equatorial position (Webby, 1978) on what became the Australian Plate (Nicoll & Totterdell, 1990). West of the present continental margin were what were to become the Tsaidam, Sibumasu, South China, Indochina, Tarim and North China Blocks (Fig. 6).

The Larapintine Seaway, one of several subparallel depressions that extended across the northern part of Eastern Gondwanaland (Nicoll & Totterdell, 1990), was apparently not the site of Cambrian sedimentation in the area of the present Canning Basin as no record of Cambrian rocks has been found in the major part of the basin. The Middle Cambrian rocks of the Ord Basin (Mory & Beere, 1985), extending south to the vicinity of Hall's Creek, are not known to extend into the Canning Basin proper. Cambrian sediments are also known in the western Amadeus Basin (Wells & others, 1965) and on the Shan-Thai Block to the west (Burrett et al., 1990).

Ordovician sedimentation was initiated in the Canning Basin in the latest Tremadoc by the Kelly Creek transgression, following the Kelly Creek Eustatic Event (Nicoll & others, 1992). The inundation was probably from the west and the oldest dated sediments are in the Samphire Marsh No 1 and Prices Creek areas. Initial Ordovician sedimentation (basal Nambeet Formation = Kunian Sandstone = Carranya Beds) spread across the Canning Basin and the Larapintine Seaway was established when the connection through the Amadeus and Warburton Basins to the eastern Australian marginal shelf was completed. For most of the
remainder of the Ordovician, a series of regressive and transgressive couplets, bounding major eustatic events, can be identified in the Canning, Amadeus and Georgina Basins (Nicoll & others, 1992; Nielsen, 1992). The depositional environment was shallowest in the Amadeus Basin and usually deeper during the corresponding time in the Canning and Warburton Basins. Thus, time correlative units, such as the Willara Formation = Horn Valley Siltstone, or the Emanuel Formation = Pacoota Sandstone (unit 4) record deeper-water sediments in the Canning Basin than in the adjacent Amadeus Basin.

Eustatic event 9 of Nicoll & others (1992) is interpreted to occur in the Canning Basin between the Kudata Dolomite and the overlying Emanuel Formation. In the Amadeus Basin, this is equivalent to the break recognised between Pacoota Sandstone units 3C and 4. The following transgression led to the deposition of the Emanuel Formation and Pacoota Sandstone unit 4 and is represented by the Prioniodus elegans-Bergstroemognathus extensus transgression conodont fauna.

Based on conodont correlations, the Ellery Creek Eustatic Event (new name = event 10 of Nicoll & others, 1992) is considered to lie between the Emanuel Formation and the Gap Creek Formation in the Canning Basin and between the Pacoota Sandstone unit 4 and the Horn Valley Siltstone in the Amadeus Basin. In the Canning Basin, this eustatic event interval is not well exposed; but the interval is well exposed in the Amadeus Basin, at sections on Ellery Creek and Maloney Creek (Laurie & others, 1991). There may be little or no recognisable depositional break in the Canning Basin sequence, but a major hiatus can be demonstrated in parts of the Amadeus Basin, as at Maloney Creek section (Laurie & others, 1991). This Ellery Creek regression marks the end of the Prioniodus elegans-Bergstroemognathus extensus Zone fauna and the introduction of the Oepikodus communis Zone fauna on the following transgression.

The basal dolomitic beds of the Horn Valley Siltstone (units 1-3, Fig. 5) are correlated with the base of the Gap Creek Formation (section RM 10 of McTavish, 1973) on the basis of the presence of Oepikodus communis and Bergstroemognathus hubeiensis in both units. The lower part of the Gap Creek Formation also contains specimens of the asaphid trilobite Lycophron similar to Lycophron howchini (Etheridge, 1894) found in the lower trilobite assemblage of the Horn Valley Siltstone. Also found at this level in the Gap Creek Formation is the peculiar macluritacean gastropod Teichispira sp., which also occurs in the Coolibah Formation in the Georgina Basin (Gilbert-Tomlinson, 1973, p. 70) and in the Kärrbäck Limesone of southern Tanzania (Laurie, 1991, p. 21).

The Horn Valley Eustatic Event (HVEE) of Gorter (1992) was first recognised in the Amadeus Basin where it is marked by the abrupt lithological change in the lower part of the Horn Valley from the dolomite limestone unit at the base of the formation, units 1-3 of Elphinsone & Gorter (1991) or unit 15 of Gorter (1991), to the shale and siltstone dominated unit that overlies it. Palaeoontological evidence suggests that this event is located in the Gap Creek Formation at the abrupt faunal shift between the lower and upper members, at about 110 m (section WCB 708) above the base of the formation. In the subsurface, this event is identified by the boundary of the Oepikodus communis and Jurundontus gananda Zones.

Events 12 through 14 are not recognised in the outcropping Canning Basin sequence. They are established from the Horn Valley Siltstone curve of Nielsen (1992), but have not yet been detailed in the Canning Basin subsurface and may not have been preserved in the Gap Creek Formation.

The Maloney Creek Eustatic Event (Nicoll & others, 1991) is marked in the Amadeus Basin by the abrupt incursion of clastic sedimentation seen in the Stairway Sandstone. In the Canning Basin, this event is not as clearly defined but appears to occur with the shift from predominantly carbonate deposition in the upper part of the Willara Formation to the mixed shale-carbonate depositional pattern of the lower part of the Goldwyer Formation (McTavish & Legg, 1976).

With the possible exception of the section in the Blackstone No. 1 well area (discussed earlier), no record exists of sediments equivalent to the Goldwyer or Nita Formations on the Lennard Shelf. There is no reason to believe equivalent sediments were not deposited in the area, but they may have been removed prior to Middle Devonian deposition of the Poulton Formation.

Economic implications

The interest in the economic potential of Ordovician sediments in the Canning Basin dates to 1919 when a well drilled at Prices Creek recovered traces of oil (Guppy & others, 1958). In 1921, the Western Australian Government drilled a hole to 90 feet in the same area and recovered traces of hydrocarbons. On the basis of these reports, the Feney Oil Company Limited drilled a series of four holes in the years 1922-23 in the Prices Creek area (Guppy & others, 1958). Three of these holes, all in Ordovician rocks, recovered traces of oil. The deepest of these holes, drilled to a depth of 1008 feet (307.3 m), was drilled entirely in the Emanuel Formation and produced shows of oil. This was the last initiative in the early phase of interest in the Ordovician on the Lennard Shelf.

In the second round of exploration drilling in the 1980s, the
The economic importance of the pre-Gap Creek Formation sediments on the Lennard Shelf is related to its source and reservoir potential for hydrocarbon accumulation. The 500 to 700 m thick Emanuel Formation acts as a regionally extensive seal and source for hydrocarbons that can be reservoired in the underlying sandstone and dolomite units. This situation is analogous to the Amadeus Basin where the slightly younger Horn Valley Siltstone acts as both source and seal for the Pacoota Sandstone (Gorter, 1984).

There are also some minor lead-zinc traces in some of the mineral exploration cores that intersect the Kudata Dolomite, but for the most part the depth of the unit below the surface precludes most economic mineral interest.

Conclusions

The Early Ordovician (late Tremadoc to Arenig) Prices Creek Group outcrops only in the Prices Creek area of the Lennard Shelf. Recent exploration has shown that the Prices Creek Group, previously defined as consisting of a lower Emanuel Formation and an upper Gap Creek Formation, can now be subdivided into four formations. The new formations comprise a basal transgressive sandstone unit, here named the Kunian Sandstone. This unit is most abundant in the upper part of the Nambeet Formation and in the Goldwyer Formation (Foster & others, 1986; Taylor, 1992). The upper Nambeet Formation occurrence would correlate with the lower part of the Emanuel Formation. In the Amadeus Basin, *G. prisca* is most abundant in the Horn Valley Siltstone (Foster & others, 1986; Taylor, 1992).

The sandstone-dolomite-shale sequence of the lower Prices Creek Group has some economic potential, both for hydrocarbons and minerals. The oil is probably sourced from the Emanuel Formation, which also serves as an effective regional seal. Traces of lead and zinc have also been found in the Kudata Dolomite.

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Locality information

Eight BMR measured or traverse sections were collected as part of the faunal studies associated with this investigation. The locality information and stratigraphic information for each locality is given below. In addition a number of BHP-Utah mineral exploration core-holes were examined and biostratigraphic samples were selectively collected.

WCB 700  Gap Creek Formation, lower member. Traverse section. Base: 125°55’00”E, 18°38’25”S

WCB 701  Gap Creek Formation, lower & upper members. Traverse section. Base: 125°55’00”E, 18°38’10”S; Top: 125°55’15”E, 18°37’53”S

WCB 702  Gap Creek Formation, mostly upper member. Traverse section. Base: 125°54’45”E, 18°37’30”S; Top: 125°54’50”E, 18°37’23”S

WCB 703  Emanuel Formation, Traverse section. follo...coordinates.

WCB 705  Emanuel Formation, Measured section. Follows the line of the type section of Guppy & Opik (1950). Base: 125°54’00”E, 18°39’00”S; Top: 125°55’05”E, 18°39’12”S

WCB 707  Gap Creek Formation, lower part lower member. Measured section, correspond approximately to McTavish section RM 10. Base: 125°54’38”E, 18°38’10”S; Top: 125°54’42”E, 18°38’07”S

WCB 708  Gap Creek (lower & upper members) and Poulton Formations. Measured section. Base: 125°53’40”E, 18°36’20”S; Top: 125°53’47”E, 18°36’05”S

WCB 709  Poulton Formation. Traverse section. 125°52’55”E, 18°35’10”S

BHP PHD 1 Emanuel Formation. 125°53’00”E, 18°36’30”S

BHP PCD 153 Kunian Sandstone. 125°53’00”E, 18°40’12”S

BHP PCD 158 Kunian Sandstone and Kudata Dolomite. 125°53’10”E, 18°40’25”S

Appendix 1

Description of cores from BMR 3 Prices Creek (=Noonkanbah No. 3)


Core 1:
50°–51’9” — light grey micaceous siltstone with wispy fragments and laminae of dark-grey fine siltstone/mudstone.
51’9”–58’3” — buff to pale-brown medium to fine-grained sandy dolomite with occasional laminae and very thin beds of medium to dark-grey micaceous siltstone becoming more common toward bottom.
58’3”–58’4” — breccia (flat pebble conglomerate?) with rounded pebble sized clasts incorporated into a crystalline carbonate groundmass.
58’4”–60’ — light grey fine to medium-grained dolomite with wispy interlaminae of medium grey to greenish grey micaceous siltstone/mudstone. Lower 15 cm bioturbated by well-developed burrows.

Core 2:
148°–154’9” — light grey fine to medium-grained dolomite with wispy interlaminae of dark to medium grey micaceous mudstone/siltstone with occasional bioturbation.
154’9”–156’4” — light grey, fine to medium-grained dolomite of saccharoidal appearance
156’4”–156’7” — light grey, coarse-grained dolomite.

Core 3:
250°–259’2” — light brownish grey to pinkish grey, fine to coarse grained, cross-bedded carbonate cemented quartz sandstone with occasional greenish grey, micaceous, shaly partings.

The remaining cores 4–6 are so vastly different from the original descriptions of the drillsite geologist, we can only assume that they have become confused with cores from other drillholes.

Core 4 is a fine to medium-grained light greygreen or light chocolate brown clay cemented quartz-lithic sandstone. Core 5 mostly consists of a heavily slickensided and silicified, and in some places brecciated, siltstone or mudstone in the top portion of the core with a well-developed mylonite near the base.

The pieces of core tentatively identified as Core 6? consist of a light grey clayey friable siltstone to fine sandstone containing many fragments of vascular plants. We believe this last core is possibly Permian.