Cainozoic stratigraphy in the Roe Palaeodrainage of the Kalgoorlie region, Western Australia

by

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Abstract

Drilling for assessment of groundwater resources in palaeochannels near Kalgoorlie intersected sediments of Middle to Late Eocene age. These sediments consist of a basal sandstone and overlying shale, and could not be correlated directly with the previously erected Rollos Bore Formation, which is poorly known from bores and a shaft near Coolgardie.

New stratigraphic units, the Wollubar Sandstone and the Perkolilli Shale, are defined and described for these early Tertiary sediments occurring in the Roe Palaeodrainage. The sedimentary sequence is distinct from that to the south in the Lefroy Palaeodrainage which contains marine carbonate sediments.

KEYWORDS: Cainozoic, stratigraphy, Kalgoorlie, palaeodrainage, drilling

Introduction

In the course of drilling to assess groundwater resources in the Kalgoorlie region of Western Australia (Commander et al., 1991), a large amount of core material was collected from Tertiary sediments in palaeodrainages. As the Tertiary sediments of the region were not previously well known, new stratigraphic units are defined for the Eocene sedimentary rocks, and brief descriptions are given of Tertiary weathering products and Quaternary units.

The core material, which has been described in detail by Kern et al. (1989), is stored by the Geological Survey of Western Australia, and is available for further study.

Geological setting

The Kalgoorlie area lies within the Eastern Goldfields Province of the Yilgarn Craton and has been summarized geologically by Griffin (1990). Essentially, it consists of a granite–greenstone terrane of Archaean age with linear, northerly trending belts of supracrustal volcanic and metasedimentary rocks, intruded by granite (Fig. 1).

The present topography is basically a dissected peneplain incised by a Cretaceous to early Tertiary drainage system which discharged eastwards into the Eucla Basin. The remnants of this drainage system have been termed palaeodrainages (Beard, 1972; Bunting et al., 1974; van de Graaff et al., 1977). The Roe Palaeodrainage system (Fig. 1) drained into the Roe Palaeoriver which formerly flowed through the existing Lake Roe area (Smyth and Button, 1989). The Roe Palaeodrainage is bounded to the north and to the south by the Rebecca and Lefroy Palaeodrainages respectively.

A variety of early Tertiary sedimentary rocks was deposited in the valleys cut by the Roe Palaeoriver and its tributaries. These sediments are now concealed by a surficial cover of Quaternary age, and the broad present-day valleys are occupied by discontinuous salt lakes (playas). Figure 2 shows the probable configuration of the palaeochannel system, and the locations of twenty-two lines drilled during the 1988 groundwater assessment program.

Previous work

Tertiary sediments from the upper part of the Roe Palaeodrainage, first described by Blatchford (1899) and Maitland (1901), came from an isolated occurrence in Rollos Bore and Shaft, and neighbouring bores, near Coolgardie (Fig. 2). These were later identified as Eocene by Balme and Churchill (1959), and stratigraphic names were formalized by Playford et al. (1975) and by Cockbain and Hocking (1989). Blatchford (1898) also described 'deep leads' at Kanowna, and ascribed a probable late Tertiary age to them.

Clarke (*in* Urquhart, 1956) postulated that the drainage system in the Kalgoorlie region was early Cainozoic, and Urquhart (1956) carried out a refraction seismic survey southeast of Kalgoorlie to locate possible auriferous deep leads. Following extensive drilling for placer gold north and east of Kalgoorlie, Smyth and Button (1989) described the Tertiary sediments in the lower part of the Roe Palaeodrainage east of Kalgoorlie, but did not formalize the stratigraphic nomenclature.

Early Tertiary sediments have also been described from farther south in the Lefroy Palaeodrainage (Griffin, 1989; Jones, 1990) and the Cowan Palaeodrainage (Clarke et al., 1948; Cockbain, 1968a).

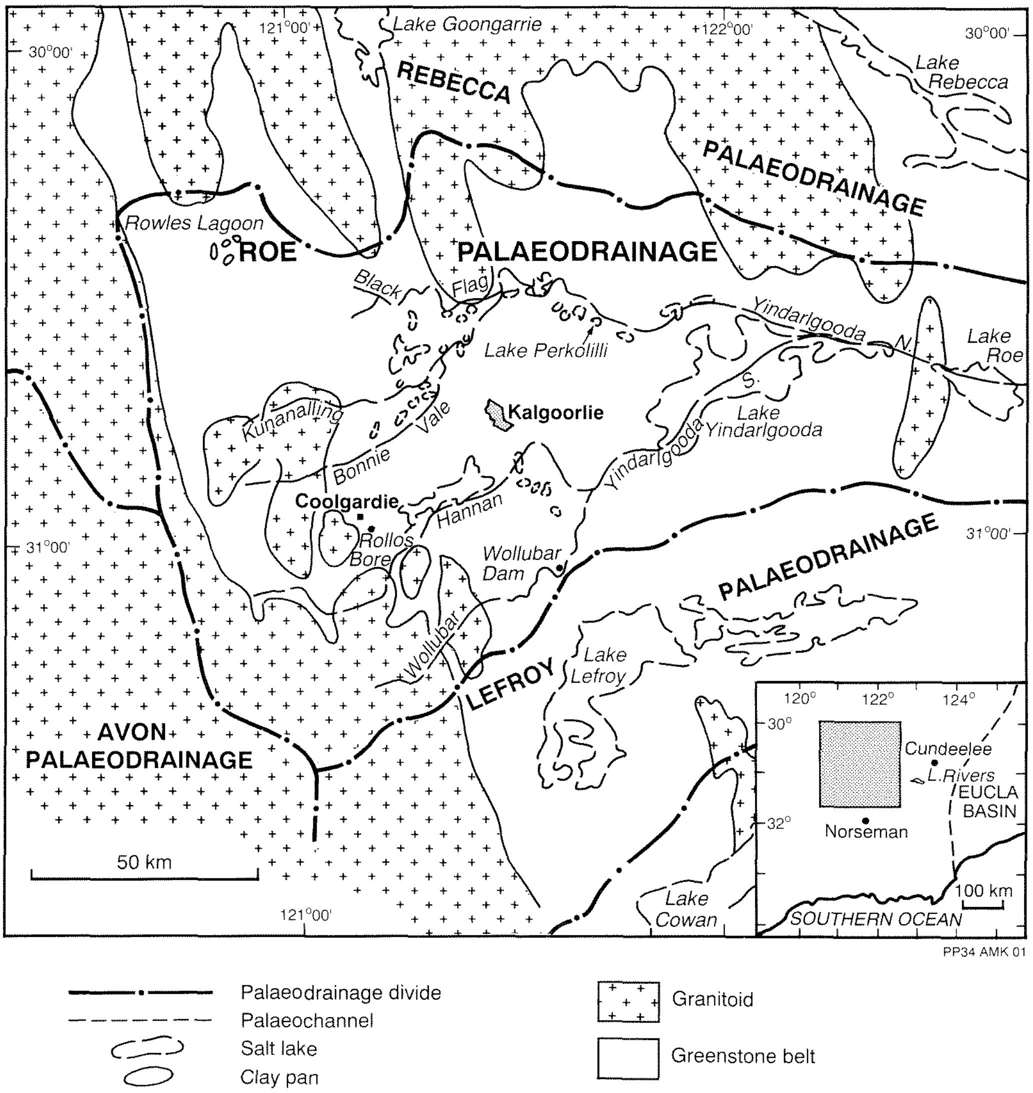


Figure 1. Location map

Tertiary drainage system

The Early Tertiary rivers within the palaeodrainages cut deep, narrow valleys into the Archaean bedrock. Only the main palaeochannels of the drainage system, now infilled with Middle to Late Eocene sediments, are preserved. In cross section the palaeochannels in the upper parts of the catchments range in width from about 400 to 700 m, and in depth from 25 to 40 m. East of Kalgoorlie, the corresponding widths and depths are about 1000–1500 m and 55–75 m respectively.

The palaeochannels are generally V-shaped and, except in Lines L and M, the flanks are often asymmetric (Fig. 3). In Lines K, N and Q the cross sections are noticeably wide and flat bottomed. It is likely that these lines were drilled oblique to the palaeochannel. Cross sections may also cut across meanders as indicated by the apparent double valley-bottom intersections in Lines K and N.

Some cross sections show a deeply incised valley floor on the steeper side of a much wider valley, such as in Lines D, P and R (Fig. 3). This may be due in part to variable resistance to erosion where there is a complex assemblage of bedrock as in the vicinity of Lines P and R.

The thalwegs of the palaeochannels have low gradients. They are steepest (greater than 1 m per km) in the upper parts of the catchments, especially where the drainage lines traverse relatively resistant greenstone belts. The gradient is more gentle east of Kalgoorlie and is only 0.14 m per km between Lines M and N.

Stratigraphy

The name Rollos Bore Beds was proposed by Playford et al. (1975) — and amended Rollos Bore Formation by Cockbain and Hocking (1989) — for the dark claystone and shale with thin beds of lignite and minor conglomerate found in Rollos Bore and Shaft and nearby bores. The type section extends from 2 m to a depth of 122 m (about 280 m AHD), based on the geological sections of Maitland (1901), and on a sample from ?119 m dated by Balme and Churchill (1959).

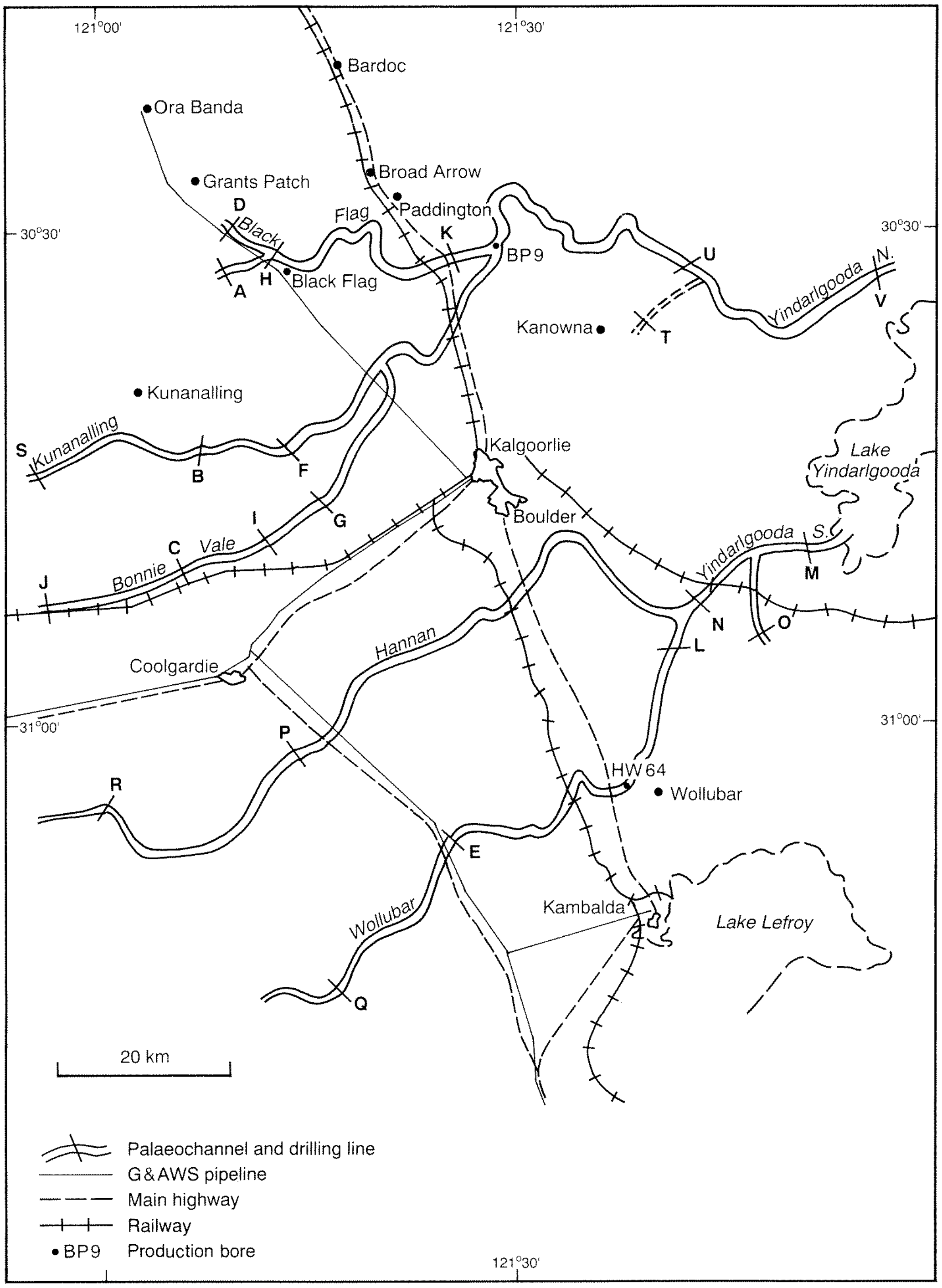


Figure 2. Location of drilling lines

This depth is well below the base of the Tertiary sediments elsewhere in the area (Figs 3 and 4) and the discrepancy may be explained by the original misidentification of weathered Archaean bedrock as Tertiary sediments, and a wrongly marked sample depth. The Tertiary sediments probably extend to a maximum depth of 90 m (310 m AHD), and may be even less than 60 m thick in Rollos Bore.

The present study has confirmed that a consistent division of the Tertiary sediments, into a lower sandstone and an upper shale, extends over a distance of 150 km (Smyth and Button, 1989). However, because of the uncertain affinity and correlation of the strata in Rollos Bore, the name Rollos Bore Formation is not used in this paper, and new formation names are erected.

The Tertiary sediments in the Roe Palaeodrainage are quite distinct from those in the Lefroy Palaeodrainage (Fig. 5). Those east of Lake Rivers consist of Middle Eocene marine sandstone overlain by spongolite of Late Eocene age (Jones, 1990). However, in the Lake Lefroy

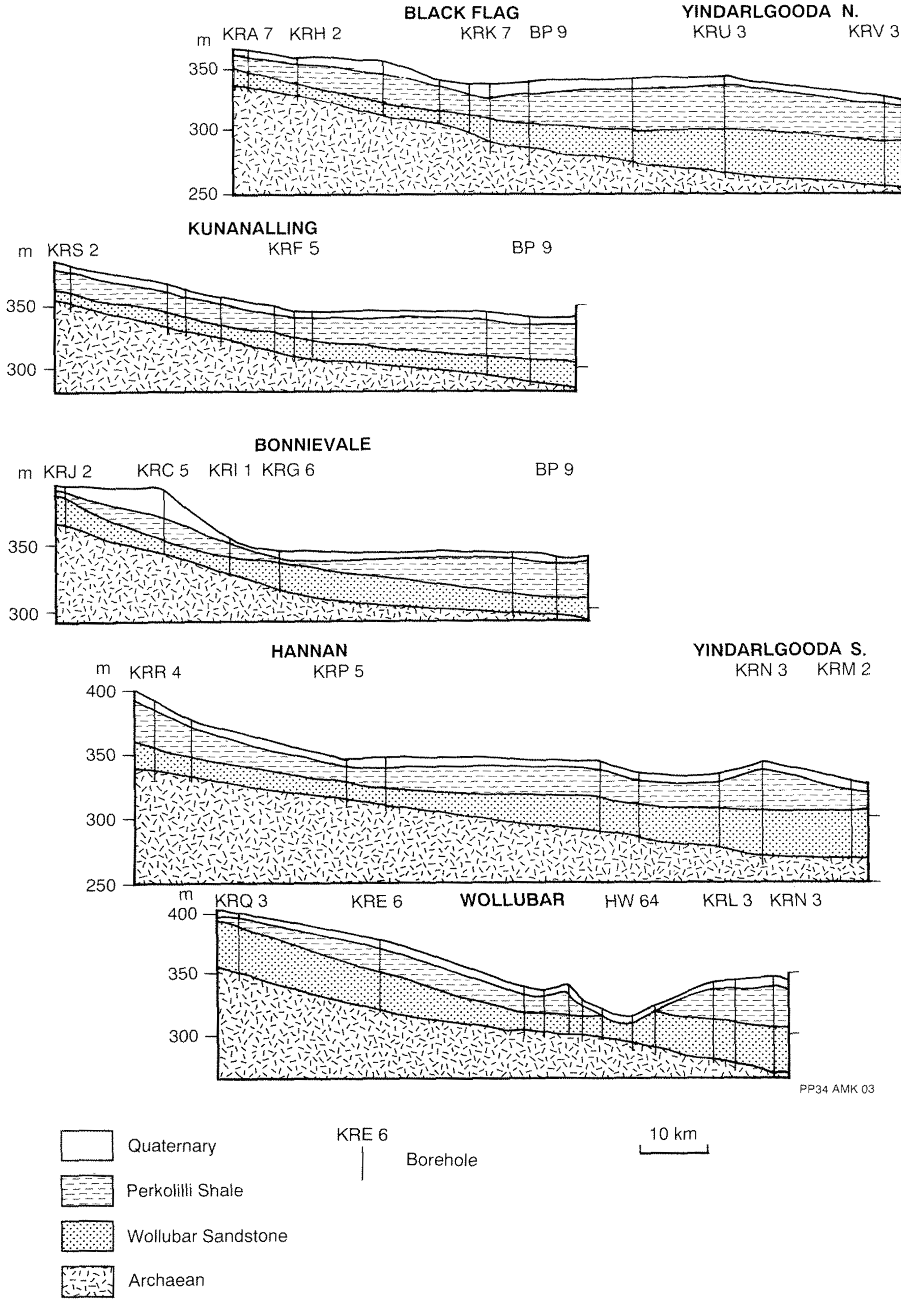


Figure 3. Geological cross sections

area they comprise sandstone, shale, and lignite (Griffin, 1989) overlain by marine carbonate of the Late Eocene Eundynie Group (Cockbain, 1968a).

Wollubar Sandstone

Name

The name Wollubar Sandstone is proposed for a unit of grey to buff sandstone, with minor clay and lignite, occurring in the Roe Palaeodrainage. The formation is named after Wollubar Dam, about 13 km north of Kambalda (Fig. 2).

Type section

The type section lies between 37.7 and 73.5 m in bore KRN-3 (universal grid reference UF 772824, KANOWNA 1:100 000 topographic sheet) situated approximately 30 km southeast of Kalgoorlie (Kern et al., 1989).

Lithology

The Wollubar Sandstone consists of mottled-grey, buff, yellow and brown quartz sandstone with minor conglomerate, clay, silt, carbonaceous siltstone and lignite. The quartz grains are frosted, very coarse to fine, subangular to subrounded and moderately to poorly sorted. Well-sorted quartz is uncommon. The quartz grains are generally more angular in the upper parts of the catchment. Traces of ferromagnesian minerals may be present as accessory minerals, and pyrite occurs at the base of the sand in bore KRN-3. The sand is rarely lithified, although the quartz grains are occasionally bound with siliceous and ferruginous cement. Cross-bedding is developed at some localities. Granitoid rocks are believed to be the primary source of the Wollubar Sandstone.

The base of the Wollubar Sandstone is frequently conglomeratic with subangular pebbles of quartz, and more rarely of Archaean igneous rocks, up to 100 mm in diameter. Beds of clay and sandy clay are commonly found on the sides of the palaeochannels where they interfinger with the sand. Intermittent sandy clay occurs at the top of the sand sequence and grades into the overlying Perkolilli Shale. Thin beds of carbonaceous silt and lignite appear sporadically in bores in the east of the area and, like the clay beds, are present mainly on the sides of the channels.

Stratigraphic relationships

The Wollubar Sandstone rests unconformably on Archaean rocks throughout the Kalgoorlie region, and is typically conformably overlain by the Perkolilli Shale. Occasionally, where this shale is absent, the Wollubar Sandstone is unconformably overlain by late Cainozoic alluvial and colluvial sediments that are difficult to distinguish from the early Tertiary formations. The contact with the Perkolilli Shale is generally sharp, but may be gradational in places.

Distribution and thickness

The Wollubar Sandstone is found only in the palaeochannels and is not seen in outcrop (Fig. 4). It also occurs in lateral tributaries in Lines O and T, where it extends to a higher elevation than in the main palaeochannels.

The formation is 35.8 m thick at the type section and reaches a maximum known thickness of 37.9 m in bore KRM-2 (Kern et al., 1989).

Age and correlation

The lignite and carbonaceous silt in the Wollubar Sandstone contain palynomorphs of the Middle *Nothofagidites asperus* Zone of late Middle to early Late Eocene age (Backhouse, 1989). Similar assemblages have been described from the Werillup Formation in the Bremer Basin (Hos, 1975; Stover and Partridge, 1982). The Wollubar Sandstone probably correlates with the unnamed basal unit of the Eundynie Group (Griffin, 1989) and the Hampton Sandstone in the western part of the Eucla Basin (Lowry, 1970) and eastern part of the Lefroy Palaeodrainage (Jones, 1990).

Environment of deposition

The Wollubar Sandstone is believed to be essentially a continental fluvial deposit with minor lacustrine and paludal components.

Perkolilli Shale

Name

The name Perkolilli Shale is proposed for the grey clay (mottled reddish brown and yellow where weathered) with minor beds of sandy clay occurring in the Roe Palaeodrainage. The formation is named after Lake Perkolilli situated approximately 30 km northeast of Kalgoorlie (Fig. 2).

Type section

The type section lies between 5.4 and 39.0 m in bore KRU-3 (universal grid reference UG 757203, KANOWNA 1:100 000 topographic sheet), situated 3 km north of Lake Perkolilli along Carmelia Road (Kern et al., 1989). The formation rests conformably on the Wollubar Sandstone and is overlain unconformably by younger, Quaternary deposits.

Lithology

The Perkolilli Shale consists of grey and mottled, dark-red, brown and yellow clay with minor sandy clay. Although the clay is generally plastic, it becomes friable near the surface where it is weathered. It consists mostly of kaolinite (up to 70%) with minor illite and smectite. In places the Perkolilli Shale has been silicified and has a porcelanized texture.

In the upper parts of the Roe Palaeodrainage, on Lines E, J, Q and S (Fig. 4), sandy clay is common at the top of the unit and is difficult to distinguish from Quaternary alluvium (Kern et al., 1989).

Pisolites, consisting of well-rounded ferruginous concretions up to 5 mm diameter, are scattered within the clay. They are more abundant near the base of the formation and are believed to have formed in situ.

Stratigraphic relationships

The Perkolilli Shale rests conformably on the Wollubar Sandstone. The contact is usually sharp, indicating a rapid change of facies, although in some bores this interface is transitional with alternating beds of sand and clay.

The Perkolilli Shale is in turn unconformably overlain by Quaternary deposits and the top of the formation is frequently weathered. The contact between the Perkolilli Shale and the Quaternary deposits is generally subhorizontal and occurs some 4–6 m below the modern land surface. It is often difficult to distinguish the

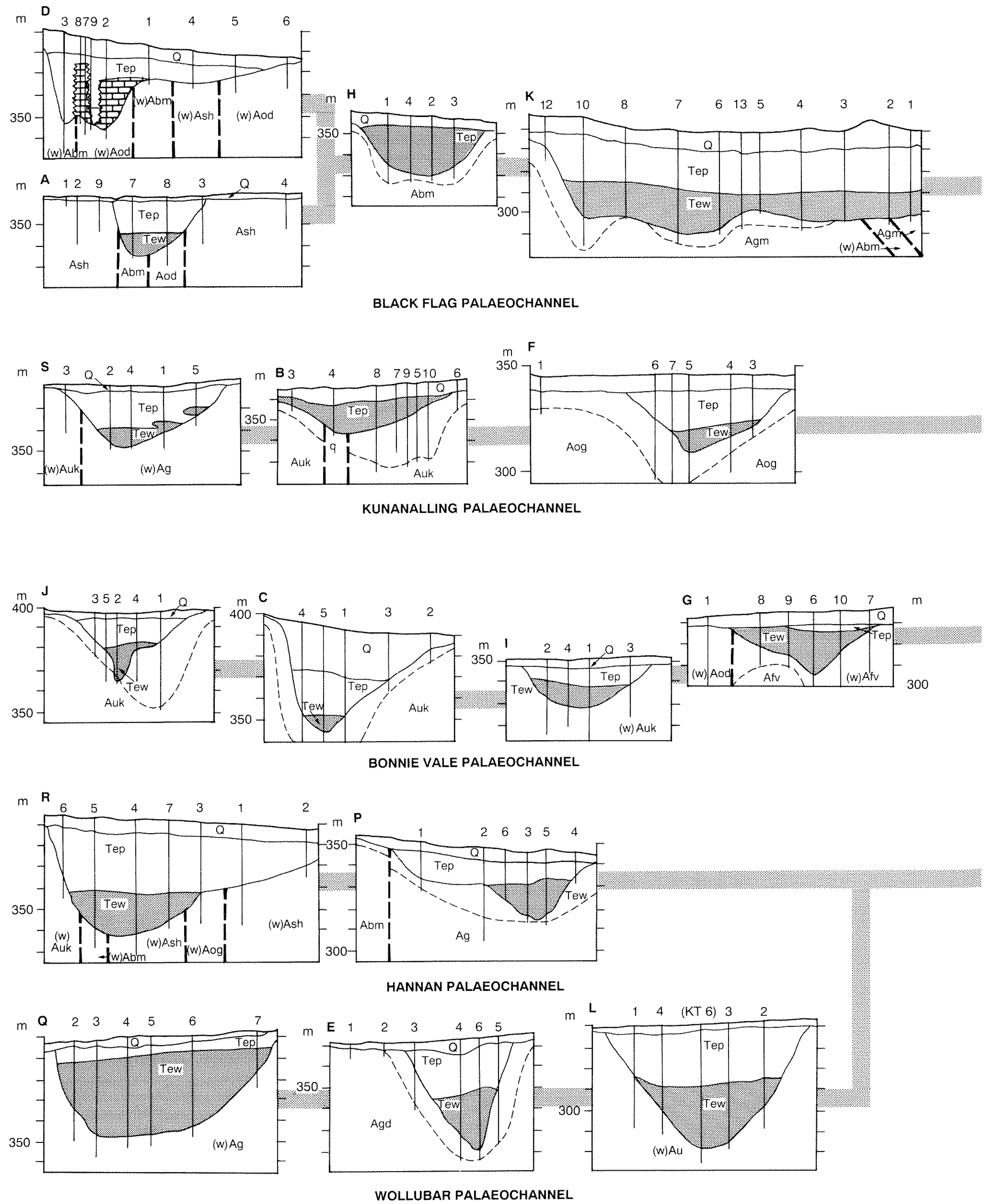
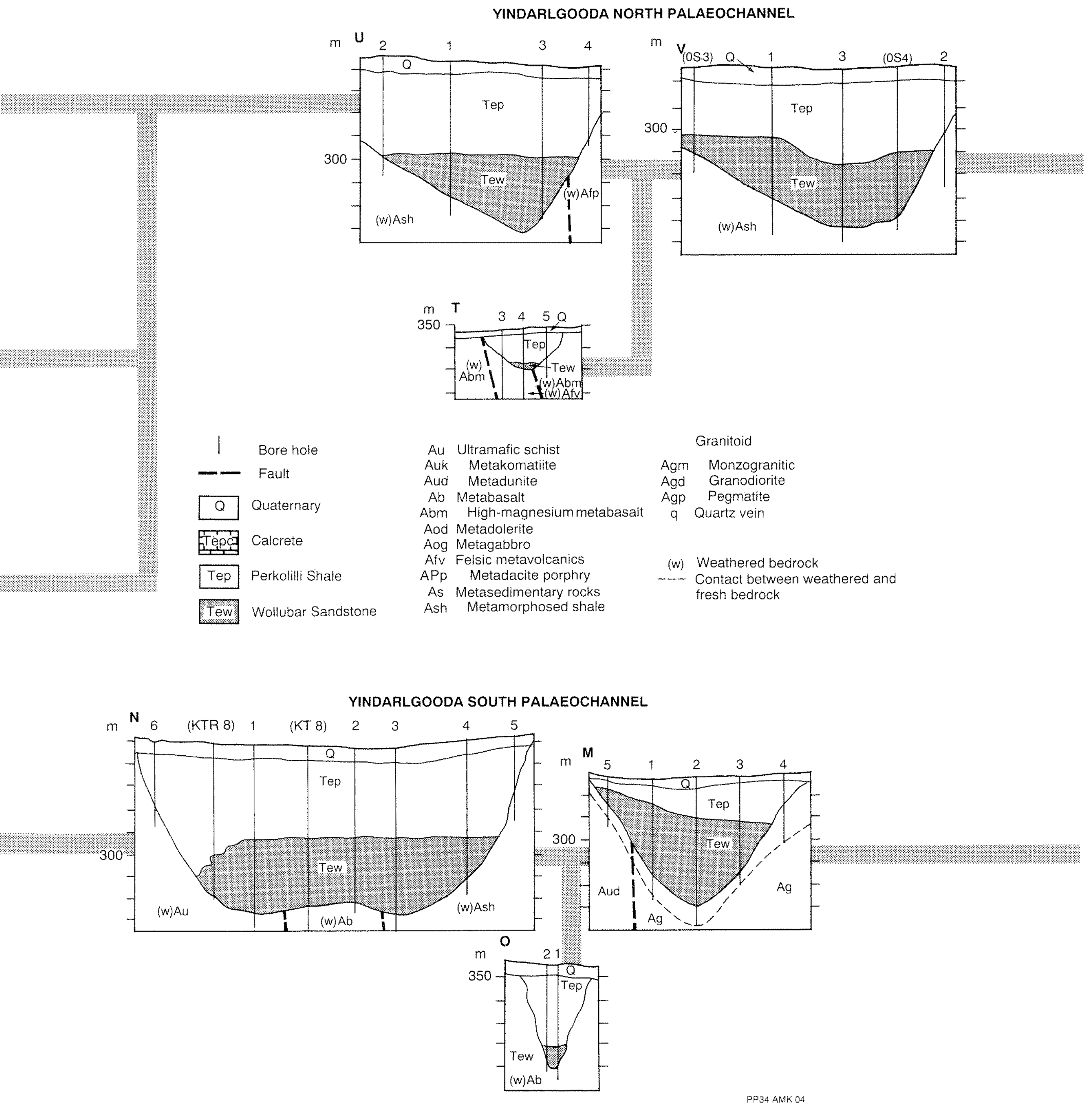


Figure 4. Longitudinal profiles of palaeochannels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Bore hole
Fault
Q Quaternary
Tepc Calcrete
Tep Perkolilli Shale
Tew Wollubar Sandstone
Au Ultramafic schist
Auk Metakomatiite
Aud Metadunite
Ab Metabasalt
Abm High-magnesium metabasalt
Aod Metadolerite
Aog Metagabbro
Afv Felsic metavolcanics
APp Metadacite porphry
As Metasedimentary rocks
Ash Metamorphosed shale
Granitoid
Agm Monzogranitic
Agd Granodiorite
Agp Pegmatite
q Quartz vein
(w) Weathered bedrock
Contact between weathered and fresh bedrock
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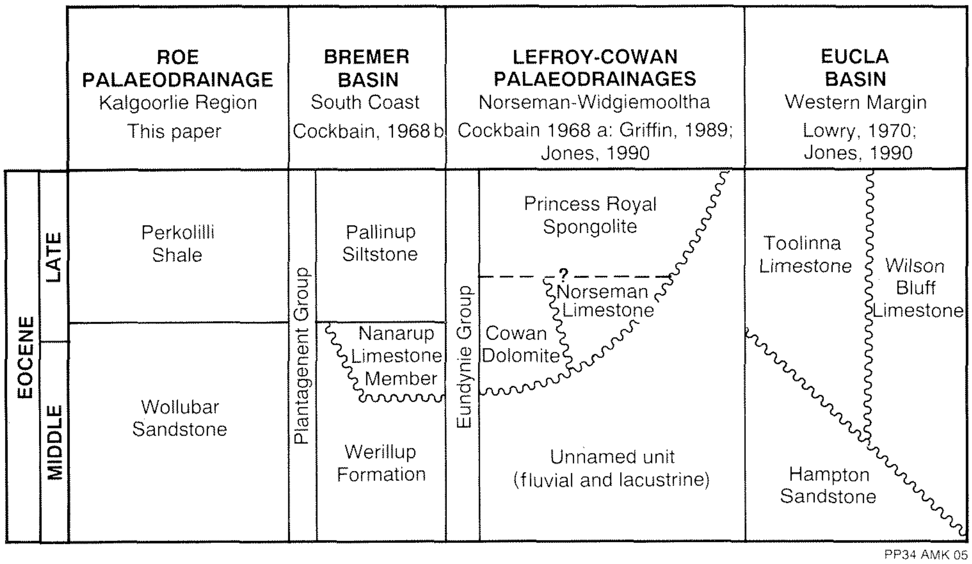

Figure 5. Stratigraphic correlation

contact between the Perkolilli Shale and the clayey Quaternary sediments which may comprise reworked underlying material. The relationship is also obscured by ferruginization, although the Quaternary sediments typically contain more quartz.

Distribution and thickness

As with the Wollubar Sandstone, the Perkolilli Shale occurs only in palaeochannels and is not observed as outcrop (Fig. 4). The formation is 33.6 m thick at the type section and reaches a maximum thickness of 39.0 m in bore KRV-3 (Kern et al., 1989).

Age and correlation

No palynomorphs were recovered from the formation as the clay is largely oxidized. However, the Perkolilli Shale is assumed to be early Late Eocene in age as it conformably overlies the Wollubar Sandstone.

Lithologically, the Perkolilli Shale correlates with the Pallinup Siltstone of the Plantagenet Group and the lacustrine facies of the lower unnamed unit of the Eundynie Group (Griffin, 1989). The Perkolilli Shale probably correlates with the Princess Royal Spongolite in the Lefroy Palaeodrainage (Jones, 1990), and the Toolinna Limestone and upper part of the Wilson Bluff Limestone of the Eucla Group (Lowry, 1970).

Environment of deposition

The Perkolilli Shale is considered to be a freshwater lacustrine deposit, laid down in a drainage system which was drowned as a result of a relatively distant rise in sea level. Unlike the Lefroy Palaeodrainage to the south (Jones, 1990), the closest evidence of Eocene marine deposition in the Roe Palaeodrainage is near Cundeelee, 180 km east of Kalgoorlie (Bunting and van de Graaff, 1977).

Tertiary weathering

The early Tertiary sediments have been modified by weathering in situ, particularly by processes involving silicification, ferruginization and calcification.

Silicification

The localized silicification of the Perkolilli Shale generally occurs just above the contact with the underlying Wollubar Sandstone. Replacement of clay by cryptocrystalline quartz and opal, giving a porcelanized texture, is particularly well developed in Line C; in Line B, silicification occurs above a quartz vein (Kern et al., 1989).

Van de Graaff (1983) observed that silicification generally precedes laterite formation as indicated by common, partial lateritization of silcrete. The age of the silicification in the Tertiary sediments is uncertain.

Laterite

A widespread lateritic profile occurs throughout the Eastern Goldfields, and is developed on the Eocene sediments outcropping in the Lefroy Palaeodrainage. In the Roe Palaeodrainage only localized lateritization of the Perkolilli Shale was observed. The upper part of the Perkolilli Shale is typically ferruginized, ranging from a slight ferruginous mottling to a massive and hard limonite-cemented clay. Scattered pisolites also occur in otherwise unferruginized clay. The ferruginized zone is mostly above the modern watertable, but in places extends well below it. Nodular ferruginization occurs throughout the formation in bore KRD-3 (Kern et al., 1989).

Calcrete

Massive carbonate development up to 25 m thick, interpreted as a groundwater calcrete, was intersected in bores along Line D (Kern et al., 1989). The calcrete ranges from friable and powdery to indurated vuggy calcrete, with crystal-lined vugs. In the cores there are very sharp subvertical contacts between calcrete and unaltered Perkolilli Shale, indicating an origin consistent with replacement of clay minerals. It is notable that bores only 150 m apart on Line D show a lateral transition from a completely ferruginized section (KRD-3) to calcrete (KRD-7/8) and, further, to unaltered sediment (KRD-9) within a few hundred metres.

Chemical analyses by the Chemistry Centre (W.A.) show that the composition of the calcrete is calcium–magnesium carbonate (dolomite) with about 29% calcium oxide and 20% magnesium oxide (Table 1). In the three samples analysed the silica content decreased from 6% at 32 m in bore KRD-8 to less than 0.1% at 20 m indicating a progressive removal of silica towards the surface.

The calcrete in Line D appears to be overlain by unaltered colluvial material. Mann and Horwitz (1979) suggest that calcrete formation could have occurred by chemical deposition and replacement over a lengthy period of time, and may still be taking place. Groundwater calcrete was not intersected elsewhere in the drilling program, and is not known to outcrop in the Roe Palaeodrainage. Mann and Horwitz (1979) give the southern boundary of groundwater calcrete as 30°S; the occurrence at Line D is therefore the southernmost documented. Glassford (1987) assigns similar calcrete to the Yeelirrie Member of the Menzies Formation.

Table 1. Chemical analysis of calcrete from bore KRD-8

Depth (m)	GSWA no.	CCWA no.	CaO%	MgO%	SiO_2%
20.0	85978	399	31.0	21.0	<0.1
26.4	85979	400	28.5	20.3	3.78
32.8	85980	401	28.2	19.4	6.45

Quaternary

A veneer of unconsolidated sediments of presumed Quaternary age occurs throughout the region. The sediments comprise colluvium, alluvium and playa lake deposits and are described in detail in Kriewaldt (1969). Glassford (1987) describes a similar suite of Tertiary and Quaternary sediments from Yeelirrie 400 km to the north, and has assigned formation names to them.

Most of the detrital deposits consist of colluvium in fans and on broad flood-washed plains. They consist of conglomerate, gravel, sand, and clay derived from the laterite profile and the underlying Archaean bedrock. The thickness of colluvial material is 24 m on Line C at the foot of Mount Burges (Kern et al., 1989), but elsewhere it is less than 10 m.

Alluvial deposits occur along the gently sloping and poorly defined drainage lines and are generally 3–6 m thick. The alluvium consists of sand, silt, and clay in the valley flats, with gravel near bedrock outcrops. The sand is generally poorly sorted and the quartz grains are more angular than in the Tertiary sediments, suggesting a nearby source. The sand is often extremely fine and silty.

Extensive playa lake systems, the largest of which is Lake Yindarlgooda, occur in the palaeodrainage. They contain saline and gypsiferous clay and silt, possibly up to 10 m thick. The margins of the playa lakes, particularly the southern and eastern sides, contain stabilized dune deposits of unconsolidated sand and gypsum. Gypsiferous sand, equivalent to the Miranda Member of the Darlot Formation (Glassford, 1987), was intersected in bores in Line K (Kern et al., 1989).

Where the base of the Quaternary deposits consists of reworked Eocene sediments it is often difficult to establish the contact between the Tertiary and Quaternary units, especially if they are clayey and ferruginized.

Limonite pebbles are common in the Quaternary deposits in the eastern part of the drainage and appear to be derived from older deposits. However, limonite nodules may also have formed in situ in the phreatic zone. Epigenic limestone nodules (kankar) are also common in the area (Kriewaldt, 1969).

Geological history

The Roe Palaeodrainage and other similar systems were probably in existence in the Early Cretaceous, supplying terrigenous material to the Eucla Basin (Lowry, 1970; Jones, 1990). There was then a hiatus in deposition between the end of the Late Cretaceous and the Middle Eocene, when downwarping of the Eucla Basin recommenced and the complete separation of Australia and Antarctica occurred (McGowran, 1989; Middleton, 1990). The ensuing marine transgressions, and rise in the base level of drainages, resulted in the aggradation of the clastics of the Wollubar Sandstone in the late Middle Eocene and early Late Eocene. This was followed by the development of lacustrine conditions, and the deposition of the Perkolilli Shale in the early Late Eocene. This was coeval with the deposition of the Toolinna and Wilson Bluff Limestones in the Eucla Basin.

The maximum penetration of marine influences occurred during the early Late Eocene marine transgression when sea level approached the present elevation of 320 m AHD in the Kambalda area, south of Kalgoorlie. The sea also presumably drowned the lower part of the Roe Palaeodrainage, but the only evidence of marine sedimentation is 180 km east of Kalgoorlie where spongolite correlating with the Eundynie Group outcrops at an elevation of 300 m AHD on the northern side of Ponton Creek, 3 km south of Cundeelee Mission (Bunting and van de Graaff, 1977).

A period of low erosion rates characterized by soil formation, deep weathering, and lateritization followed the Late Eocene sedimentation. The main period of lateritization in the Kalgoorlie region is likely to have been completed by the Middle Miocene, as the Middle Miocene Colville Sandstone in the northern part of the Eucla Basin shows no sign of lateritization (Lowry, 1970). The significant concentration of kaolinite in the Perkolilli Shale, possibly resulting from chemical weathering of aluminosilicate minerals, suggests that deep-weathering processes may have already started by the Late Eocene.

Post-Miocene uplift and tilting to the southeast in the Kalgoorlie region is demonstrated by the steady southeastward drop in elevation of the playa lakes which now occupy the palaeodrainages (Bunting et al., 1974). Van de Graaff et al. (1977) estimated a regional tilt to the south of about 1.5 minutes by correlating lake levels in the Eastern Goldfields. Because of the southward tilt, headward erosion from the south has cut back through the catchment divide between the Lefroy and Roe Palaeorivers in the Wollubar area, and diverted both surface drainage and groundwater flow (Commander et al., 1990) from the Wollubar and Hannan Palaeochannels into Lake Lefroy.

Deep weathering of the bedrock adjacent to the palaeochannels occurred after they were filled with Eocene sediments. The presence of saline groundwater could have accelerated the weathering process as the thickness of the weathered zone increases downstream where the salinity is highest.

Since the Miocene, the climate appears to have been largely arid to semi-arid with the river systems becoming inactive, although Early Pliocene sediments have been identified from the upper part of the Cowan Palaeodrainage (Bint, 1981). The salt-lake sediments and associated gypsiferous dunes are believed to have been deposited over cyclic arid and pluvial phases during the Pleistocene.

Conclusion

The Late Eocene sedimentary rocks in the Roe Palaeodrainage represent a widespread and uniform sequence consisting of a basal fluvial sandstone overlain by a lacustrine shale. They are correlatives of the Plantagenet Group of the Bremer Basin and represent continental facies of formations in the Eucla Basin. The Tertiary sediments originally described from Rollos Bore are atypical, and this nomenclature is now superseded. The definition of the stratigraphy gives a framework for the further study of the auriferous Tertiary sedimentary rocks, and for the assessment and management of the region's groundwater resources.

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