1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

NOONKANBAH
WESTERN AUSTRALIA

SHEET SE/51-12 INTERNATIONAL INDEX

DEPARTMENT OF NATIONAL DEVELOPMENT & ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

DEPARTMENT OF MINES, WESTERN AUSTRALIA
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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COMPILED BY R. W. A. CROWE & R. R. TOWNER

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA 1981

DEPARTMENT OF NATIONAL DEVELOPMENT & ENERGY
MINISTER: SENATOR THE HON. J. L. CARRICK
SECRETARY: A. J. WOODS

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DIRECTOR: A. F. TRENDALL

Published for the Bureau of Mineral Resources, Geology and Geophysics by the Australian Government Publishing Service

ISBN 0 642 06743 0

Printed by Graphic Services Pty Ltd, 516-518 Grand Junction Road, Northfield, S.A. 5085

Explanatory Notes on the Noonkanbah Geological Sheet (Second Edition)

Compiled by R. W. A. Crowe & R. R. Towner*

The Noonkanbah Sheet area, WA is bounded by latitudes 18° and 19°S and longitudes 124°30′ and 126°E. It lies within the large Phanerozoic Canning Basin, near the basin's northeastern edge.

Access to the area is gained from the Great Northern Highway which connects Derby, 230 km to the northwest, with Halls Creek 210 km to the east. An alternative route through the adjoining Mount Anderson Sheet area connects Kalyeeda Station, south of the Fitzroy River, with the Great Northern Highway and thence with Derby or Broome. Access within the area is provided by station tracks. Although the Fitzroy River forms a barrier to north–south travel, there is an all-weather bridge at Fitzroy Crossing and a natural ford near Noonkanbah homestead. Cross-country travel by four-wheel-drive vehicle is practicable except in the St George Ranges and the eastern limestone ranges, where vehicle access is limited to the major valleys. All the tracks that were passable in 1974 are shown on the geological map.

The only township in the area is Fitzroy Crossing, and there are fourteen station homesteads of which two (Warrimbah and Millajiddee) had been abandoned at the time of the latest systematic BMR/GSWA field work in 1974. The area experiences a hot, rainy, monsoonal summer and a cool, dry winter. The average annual rainfall is about 500 mm, and the average annual evaporation about 2500 mm (Commonwealth Statistician, 1973). The area is characterised by extensive grassy black-soil and gravel plains, and intervening spinifex-covered sand plains and dissected hills. Near the major drainages the vegetation is denser and consists of mixed eucalypts and *Acacia,* and minor *Casuarina* and boab trees.

Base maps and aerial photographs

Mapping bases available include contoured topographic maps at scales of 1:250 000 and 1:100 000, aerial photographs at nominal scales of 1:50 000 (1947) and 1:80 000 (1967), and photomosaics at scales of 1:253 440 and 1:63 360. These are available from the Commonwealth Division of National Mapping or the Lands & Surveys Department of Western Australia.

History of investigations

The first recorded geological observations were made by Hardman (1884, 1885) during his regional survey of the Fitzroy valley. Fossils collected by him were described by Nicholson (1890), Hinde (1890) and Foord (1890).

In 1906, Jack traversed the area, visiting Minnie Pool and Oscar Range, and in the same year Woodward collected fossils from Barker Gorge in the Napier

* Geological Survey of Western Australia.

Range which were described by Glauert (1910). Etheridge (1918) made brief descriptions of the fossils collected by Jack (1906), and by Basedow (1918) on a later expedition.

Following the discovery of traces of oil at Prices Creek in 1918 (Waterford, 1941) Blatchford and Talbot, from 1921 to 1929 (Blatchford, 1922, 1927), made geological investigations of the Poole Range and Prices Creek areas. The first systematic stratigraphic studies of the Permian sediments and a rapid reconnaissance of the Devonian sediments were made by Wade (1924, 1936) during his examination of the West Kimberley District. Fossils collected by Wade were examined by Chapman (1924a), who recorded fifteen Devonian species. Blatchford and Talbot, following Wade's recommendation, located a drilling site in the Poole Range (Blatchford, 1929, 1930).

During reconnaissance in 1925 through various parts of Western Australia, Clapp (1925, 1926a, b) examined parts of the Canning Basin and reported unfavourably on its oil prospects. In 1929, Forman summarised the geology of the Canning Basin and discussed the oil potential.

During the 1930s, Devonian corals and brachiopods were studied intensively by Prendergast (1935), Hill (1936, 1937), and Ripper (1937); and Hosking (1933) prepared a classification of Devonian rocks based on palaeontological evidence.

Aerial reconnaissance of the area was pioneered by Woolnough in 1933. In 1940 and 1941, Caltex geologists made extensive investigations in the northern Canning Basin, and their reports (Bremner, 1940; Maddox, 1941; Findlay, 1942; Kraus, 1942) laid the foundations for the systematic stratigraphy of the basin.

In the decade 1939–49, Teichert (1939, 1940, 1941a, c, d, 1943, 1947, 1949) contributed six papers on the Devonian sequence of the Fitzroy Basin. Some of the newly discovered fossils were described by other specialists: Fenton (1943) described algae, Fletcher (1943) worked on pelecypods, and Howell (1944) reported on sponges.

Reeves (1949, 1951) summarised the then known geology of the Devonian sequences and attempted the first compilation of the geology of the Canning Basin.

Following aerial photography of the Canning Basin in 1947, the BMR began systematic mapping of the northern part of the Basin from 1947 to 1952. The results of this survey were published in reports by Guppy & others (1952, 1958) and by Brunnschweiler (1951a, b; 1954; 1957), who published information concerned mainly with the Mesozoic rocks. As a result of this initial survey Thomas (1958a) compiled the First Edition of the Noonkanbah map and Explanatory Notes. Guppy & Öpik (1950) first recognised and described the Ordovician rocks, and Ordovician cephalopods were described by Teichert & Glenister (1952, 1954). Undoubted Carboniferous rocks were also recognised for the first time in the Canning Basin, and Thomas (1957, 1958c, 1959) gave an account of their lithology, stratigraphy, and palaeontology.

Following this initial systematic field mapping, a comprehensive examination of the rich and diverse Devonian and Permian faunas was undertaken, including work on the Teichert collection of Devonian atrypid brachiopods (Coleman, 1951) and work on Devonian corals (Hill, 1954), sponges (Howell, 1952; 1956; 1957), brachiopods (Coleman, 1957), ammonoids (Glenister, 1958), Permian Orthotetacea (Thomas, 1958b), Permian bryozoans (Crockford, 1957), Devonian brachiopods (Veevers, 1959), and Permian pelecypods and gastropods (Dickins, 1963).

The initial geological reconnaissance of the Canning Basin was completed in 1957 and the results reported in BMR Bulletin 60 (Veevers & Wells, 1961); the geology of the Noonkanbah Sheet area was also incorporated in a synthesis of the Phanerozoic geology of Western Australia by McWhae & others (1958).

In 1962, the Geological Survey of Western Australia began a detailed investigation of the Devonian reef complexes in the northern part of the Canning Basin (Playford & Lowry, 1966). The most recent summary of this work is by Playford (1980). Glenister & Klapper (1966) systematically described conodonts from reef complexes and briefly worked on faunas recovered from the Fairfield Group.

The alkaline igneous plugs originally described by Wade & Prider (1940) and dated by Compston *in* Prider (1960) were dated again by Kaplan & others (1967) and by Wellman (1973).

Exploration for coal in the area has been carried out by Premier Mining Co. Pty Ltd from 1965 to 1966 (Baarda, 1967); Australian Inland Exploration from 1970 to 1972; Esso Exploration & Production Australia Inc. in conjunction with Dampier Mining Co. Pty Ltd from 1973 to 1974 (Galloway & Howell, 1975); and by Dampier Mining Co. Pty Ltd from 1973 to 1975. Geological information from bores drilled by Australian Inland Exploration is reported in Galloway & Howell (1975) and the positions of all the bores drilled by the time of map compilation are shown on the map and are tabulated in Figures 4, 5 and 6.

Most mineral exploration in the area has been for lead and zinc. Apart from the reports listed by Playford & Lowry (1966), only one company report has been released (CRA, 1965–66). There was some exploration for diamonds between 1967 and 1971 (reviewed by Carter, 1974), and Mines Exploration Pty Ltd has explored for phosphate (Russell, 1966). Recent work on the adjacent Lennard River Sheet area to the north has resulted in a number of new kimberlite plugs being located, some of which are diamondiferous.

From May to August 1972, a joint BMR and GSWA party carried out detailed field-work in the vicinity of Fitzroy Crossing in order to resolve the differing interpretations of the Fairfield Group of previous workers. Detailed reports include those prepared on the conodonts (Nicoll & Druce, 1979), lithofacies (Radke, 1976), geochemistry (Druce & Radke, 1977a), and geology (Druce & Radke, 1977b). Continuously cored, shallow stratigraphic holes were drilled to provide subcrop information (Druce & Radke, 1973). All stratigraphic holes drilled in the area by BMR are listed in Table 2.

The Lennard River Sheet area to the north was remapped (Derrick & Playford, 1973) as part of the regional mapping of the Precambrian Kimberley Block by the Bureau of Mineral Resources, Geology & Geophysics (BMR) and the Geological Survey of Western Australia (GSWA) in the late 1960s and of the detailed mapping of the Devonian by GSWA officers in 1962–64 (Playford & Lowry, 1966). The Mount Ramsay Sheet area to the east was re-mapped in 1967 (Roberts & others, 1968).

From 1972 to 1976 the Sedimentary Basins Study Section of the Petroleum Exploration Branch of BMR made a comprehensive study of the petroleum geology of the Canning Basin, incorporating all available data from previous geological and geophysical surveys and drilling (Gorter & others, 1979).

As part of a project, begun in 1972, to re-map the geology of the Canning Basin, a combined geological field party of BMR and the Geological Survey of Western Australia (GSWA) re-mapped the Permian and Mesozoic rock units in 1974 and revised the topographic information in the Noonkanbah Sheet area; these notes result principally from this work, and also from work done by P. E. Playford (GSWA) on the Devonian reefs and from information on the Fairfield Group provided by E. C. Druce (BMR).

Geophysical surveys

The geophysical surveys, all for petroleum, are listed in Table 1.

TABLE 1. GEOPHYSICAL SURVEYS FOR PETROLEUM EXPLORATION

Survey name	*Type*	*Organisation*	*Reference*
Canning Basin	Reconnaissance aeromagnetic	BMR	Quilty, J. H., 1960
Fitzroy & Canning Basins	Reconnaissance gravity	BMR	Flavelle, A. J., & Goodspeed, M. J. (1962)
Canning Basin	Aeromagnetic	WAPET	WAPET (1966c)
Laurel Downs–Virgin Hills	Gravity	WAPET	WAPET (1962b)
Laurel Downs	Seismic	WAPET	WAPET (1962a)
Gogo	Seismic	WAPET	WAPET (1963)
St George Ranges	Seismic	CONOCO	CONOCO (1965a)
Poole Range	Seismic	CONOCO	CONOCO (1965b)
Broome Swell	Seismic	CONOCO	CONOCO (1965c)
Barbwire Range	Seismic	CONOCO	CONOCO (1965d)
Noonkanbah	Gravity	CONOCO	CONOCO (1968)
Gogo Trig	Seismic	WAPET	WAPET (1970a)
Laurel	Seismic	WAPET	WAPET (1970b)
Crossland Platform	Seismic	WAPET	WAPET (1971a)
Poulton	Seismic	WAPET	WAPET (1971b)
Lennard Shelf	Seismic	WAPET	WAPET (1972a)
East Canning	Seismic	WAPET	WAPET (1972b)
Dampier Downs	Seismic	WAPET	WAPET (1972c)

A BMR reconnaissance aeromagnetic survey of the Canning Basin has been described by Quilty (1960). A more extensive reconnaissance aeromagnetic survey was flown for West Australian Petroleum Pty Ltd (WAPET) in 1955 (WAPET, 1966c). In 1972 WAPET carried out the Lennard Shelf Aeromagnetic Survey (WAPET, 1972d). The Pinnacle and Fenton Fault systems were located by these surveys.

Gravity surveys that have included the Noonkanbah Sheet area include a BMR gravity reconnaissance survey which delineated the regional structural framework (Flavelle & Goodspeed, 1962) and the Laurel Downs–Virgin Hills Gravity Survey (WAPET, 1962b) which determined the gravity expression of the Pinnacle Fault in the area of Prices Creek, near the eastern edge of the Sheet area. The Noonkanbah Gravity Survey (CONOCO, 1968) helped delineate the structure on the edge of the Lennard Shelf.

WAPET and Continental Oil Company of Australia (CONOCO) have carried out seismic surveys. The Laurel Downs Seismic Reconnaissance Project (WAPET, 1962a) delineated three subsurface structures; it was followed by the Gogo Seismic Survey (WAPET, 1963) which detailed the Gogo Anticline.

The St George Ranges Reconnaissance Seismic Survey (CONOCO, 1965a) demonstrated that the St George Ranges structure is a large anticline plunging east and west with a total estimated sedimentary section of 5500 m. The Poole Range Detailed Seismic Survey (CONOCO, 1965b) showed that the Poole Range Structure is more complex at depth than at the surface and that the Permian section may be as much as 3600 m thick.

The Broome Swell Seismic Survey (CONOCO, 1965c) and the Barbwire Range Seismic Survey (CONOCO, 1965d) were conducted in the south of the Sheet area to investigate the Crossland Platform and its boundary with the Fitzroy Trough.

In 1970 WAPET (1970a, 1970b) reinvestigated the Gogo Anticline and the Laurel Downs area and, in 1971, carried out the Crossland Platform Seismic Project (WAPET, 1971a) which was mainly concerned with areas farther south. This survey, and others to the south, indicated that the Fitzroy Trough is separated from the Crossland Platform by a terrace. In 1971 WAPET also carried out the Poulton Seismic Project (WAPET, 1971b) which yielded structural detail in the Oscar Range area.

In 1972, WAPET carried out three seismic surveys in the Sheet area: the Lennard Shelf Seismic Survey (WAPET, 1972a), the East Canning Basin Seismic Survey (WAPET, 1972b) and the Dampier Downs–Collins Seismic Survey (WAPET, 1972c). These surveys provided additional regional and detailed information on the structure of the sedimentary strata.

Petroleum exploration drilling

By the end of 1979, eight petroleum exploration wells had been drilled (Table 2). The two more recent wells were subsidised: CONOCO St George Ranges No. 1 and WAPET Mount Hardman No. 1. The completion reports are available at BMR and GSWA (CONOCO 1966; WAPET 1973). Data packages (including geophysical information) for all relinquished tenements are available from GSWA.

PHYSIOGRAPHY

Physical regions

The Noonkanbah Sheet area lies within the Fitzroyland Physical Division of Jutson (1934). The subdivisions described below were erected by Wright (1964).

Most of the Sheet area lies within the *Fitzroy plains province* (Fig. 1). Altitudes range from 58 m in the west to 337 m in the east. The Fitzroy plains province includes the following four regions.

(1) The *Fitzroy ranges,* formed of Devonian limestone, trend northwest and include rocky hills and plateaus. Relief above the surrounding plains averages 60 m and reaches 80 m at Prices Hill. Extensive gilgai and stony plains form pediments in front of the main ranges and in valleys. Drainage is mainly controlled by the underlying geology, although the Fitzroy River follows a transverse course through Geikie Gorge, a water gap, in the Geikie Range. Both Geikie Gorge and nearby Brooking Gorge are superimposed features according to Playford & Lowry (1966);

TABLE 2. PETROLEUM EXPLORATION WELLS AND BMR STRATIGRAPHIC HOLES

	Year drilled	*Latitude*	*Longitude*	*Total depth (m)*	*Hydrocarbon shows*	*References*
Petroleum exploration wells						
Prices Creek No. 1	1922	18°40′30″	125°55′00″	310	Minor oil shows	Waterford, L. M. (1941)
Prices Creek No. 2	1923	18°40′40″	125°55′55″	103.6	Minor oil shows	Waterford, L. M. (1941)
Prices Creek No. 3	1923	18°41′02″	125°55′55″	247	Minor oil shows	Waterford, L. M. (1941)
Prices Creek No. 4	1923	18°40′55″	125°54′05″	135	Nil	Waterford, L. M. (1941)
Poole Range No. 3	1930	18°53′06″	125°47′20″	995	Minor oil shows	Waterford, L. M. (1941)
Poole Range No. 5	1933	18°52′27″	125°49′02″	471	Nil	Waterford, L. M. (1941)
St George Ranges No. 1	1966	18°41′30″	125°08′11″	4437	Minor gas shows	CONOCO (1966)
Mount Hardman No. 1	1973	18°00′38″	124°54′48″	3360	Minor gas shows	WAPET (1973)
Stratigraphic holes						
BMR Noonkanbah 1	1972	18°34′13″	125°58′16″	155.4	Nil	Druce & Radke (1973)
BMR Noonkanbah 2	1956	18°07′06″	125°20′05″	1219	Nil	Henderson (1956b)
BMR Noonkanbah 3	1956	18°38′00″	125°54′00″	212	Nil	Henderson (1956b)
BMR Noonkanbah 4	1972	18°04′30″	125°25′00″	68.9	Nil	Druce & Radke (1973)
BMR Noonkanbah 5	1972	18°40′00″	125°59′40″	68.6	Nil	Druce & Radke (1973)

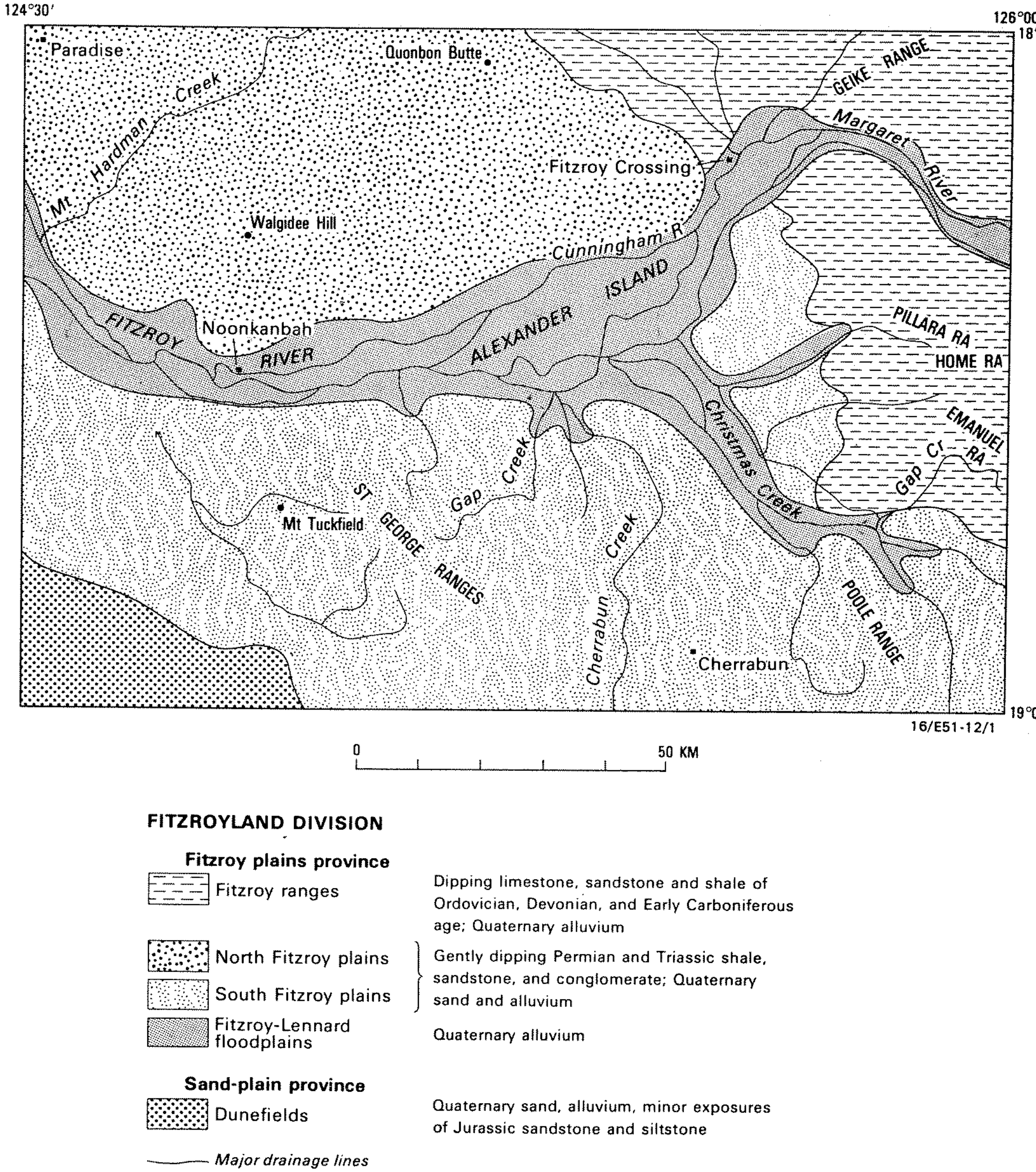

Fig. 1. Physical regions (after Wright, 1964).

Menyous Gap in the Pillara Range is a wind gap which resulted from the beheading of Horse Creek. Playford & Lowry also believe that surface drainage predominates over subsurface drainage in the limestone ranges, even though karst features are well developed.

(2) The *North Fitzroy plains* consist principally of aeolian sand and gravel, mainly underlain by lateritised sandstone and mudstone of Permian and Triassic age. Isolated peaks of Fitzroy Lamproite and Permian rocks occur, particularly in the west.

Mount Hardman Creek is the most prominent watercourse, and claypans in the central part occur in small, internal drainage depressions.

(3) The mainly rubble-covered *South Fitzroy plains* include the dissected anticlinal highlands of the St George Ranges and Poole Range (up to 190 m above plain level) and the strike-controlled Shore Range; the buttes of Mount Amy and Mount Hutton represent the dissected remnants of another anticlinal range.

Drainage on the plains is sparse and mainly transverse to the main structural trend; several of the creeks appear to follow obscured north–south fault lines (e.g. Cherrabun Creek). Drainage in the St George Ranges is more complex, and includes the anticlinal valleys of Carolyn Creek and Gap Creek, and the valley that contains Tullock Peak. A dendritic pattern is developed over the easily weathered Poole Sandstone; in contrast, the drainage over the Grant Group follows strike-, fault-, and joint-controlled valleys, giving rise to a trellis pattern.

(4) The *Fitzroy–Lennard floodplains* occur along the courses of the Fitzroy River and its main tributaries, the Margaret River and Christmas Creek. The plains,

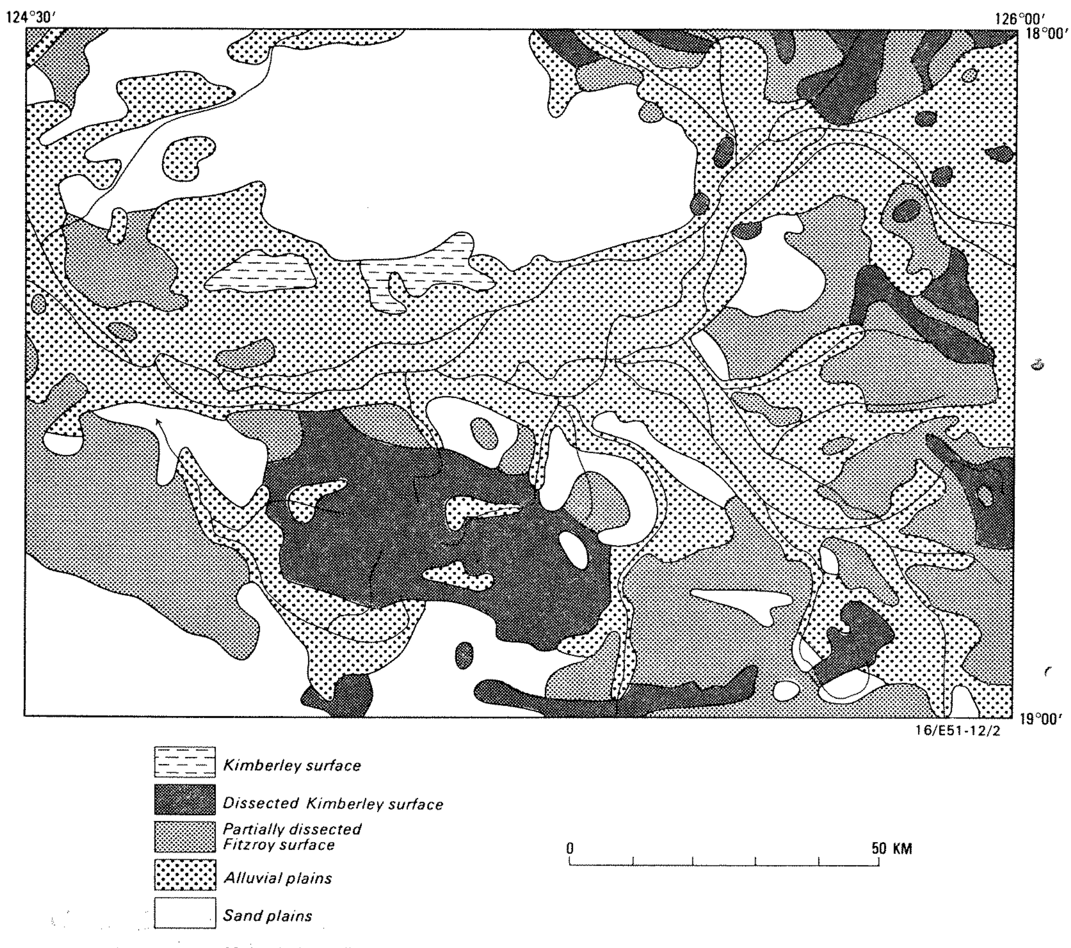

Fig. 2. Geomorphic land systems (simplified from Wright, 1964).

mainly underlain by extensive black soil, contain many anabranches, natural levées, and billabongs (oxbow lakes).

Wright (1964) has subdivided the sand–plain province into the 'dune fields' and 'western sand plains'; only the 'dune field' unit occurs in the Noonkanbah Sheet area.

The *dune fields* contain low isolated outcrops of Jurassic rocks in the valleys between the longitudinal dunes. The dunes are oriented east-southeast, indicating that they were formed by east-southeast prevailing winds. Drainage in the area is limited to a few floodways.

History of the present land surface

Present relief suggested to Wright (1964) the presence of three old land surfaces in various stages of dissection (Fig. 2):

(1) The *Kimberley surface* is thought to have developed after uplift in the Jurassic and to have been eroded by consequent drainage that reached maturity when the area was lateritised, probably in the early Tertiary. This surface also includes an exhumed Permian surface represented by the top of the limestone ranges (Playford & Lowry, 1966).

(2) The *Fitzroy surface* was formed by subsequent erosion (leaving the *dissected Kimberley surface*), probably initiated by Miocene tilting about a coastal hinge-line (David, 1950), and upwarping of the Fitzroy Trough margins (Wright, 1964). This theory implies relative downwarping of the Fitzroy River valley area and, if correct, would explain remnants of the old Kimberley Surface which are preserved close to the river. The present course of the Fitzroy River in the Sheet area is thought to have become established during this period.

(3) The *partially dissected Fitzroy surface* was formed by a further lowering of the base level and the Fitzroy River was incised by up to 30 m.

As the climate became drier, extensive flood plains developed—the *alluvial plains*. Deposition of alluvium has continued up to the present, although a Quaternary arid period led to aeolian sand movement and formation of the *sand plains*. Relatively recent amelioration of the climate has led to reactivation of the drainage and redistribution of older sediment as well as deposition of new detritus.

STRATIGRAPHY

The stratigraphy is summarised in Table 3.

PRECAMBRIAN

Rocks designated *undivided Precambrian* (p€) form a few isolated exposures around the Pillara Range that have not been assigned to particular units or to a particular era. In the cross-sections basement rocks are grouped together also as *'undivided Precambrian'*.

Proterozoic

The main exposures of Proterozoic rocks in the Sheet area occur in the Pillara Range inlier. Sofoulis & Gellatly (1968) have mapped the inlier and the description and mapping of these units here are based on their work.

The oldest rocks in the inlier are schists assigned to the *Halls Creek Group* (Ⓟh) (Dow & others, 1964), which is older than 1961 ± 27 m.y. (Dow & Gemuts,

TABLE 3. SUMMARY OF STRATIGRAPHY

Age		*Rock unit and symbol*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Fossils*	*Remarks*
CAINOZOIC	QUATERNARY	Alluvium (Qa)	10±	Mud, silt, sand, and gravel			Good aquifer at shallow depth
		Mixed alluvial and aeolian deposits (Qs)	10±	Mixed sand and silt; minor gravel		Crocodile and giant kangaroo bones of Pleistocene age	Characterised by mixed grass and spinifex growth. Occurs in depressions, on gravel plains and on lee side of hills
		Aeolian deposits (Qz)	0–20	Sand, red; minor silt			Characterised by spinifex growth without other grasses. Occurs as isolated dunes and as dune fields
		Gilgai soil (Qg)	10±	Clay and silt; patterned form of black soil	Overlies argillaceous rocks		Wavy and lattice patterns. Occurs on black soil plains
		Black soil (Qb)	10±	Clay and silt, dark brown to dark grey, minor gypsum	Overlies argillaceous and calcareous rocks		Occurs on plains mainly adjacent to main drainage lines
		Laterite (Czl)	5±	Pisolitic and massive laterite	Overlies Mesozoic and Permian rocks		
		Silcrete (Czs)	3±	Extensively silicified rock	Formed on Jurassic rocks		Caps exposures adjacent to Fenton Fault
		Calcrete (Czk)	0–5	Limestone, arenaceous; minor chalcedony	Common at base of limestone ranges		Includes, kunkar, calcite, and travertine; good aquifer
		Warrimbah Conglomerate (Czh)	10±	Unconsolidated cobble and minor pebble conglomerate	Unconformable on Permian and Triassic rocks		Probably ancient river deposit. Crops out in flood plain on Fitzroy River. Clasts mainly brown
		Lawford Beds (Czw)	5+	Unconsolidated pebble and minor cobble conglomerate	Equivalent to Warrimbah Conglomerate		Confined to flood plain of Christmas Creek. Clasts mainly white quartzite

TABLE 3. SUMMARY OF STRATIGRAPHY—(*continued*)

Age	*Rock unit and symbol*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Fossils*	*Remarks*
MESOZOIC, POSSIBLY TERTIARY	Fitzroy Lamproite (fv)		Leucite lamproite	Plugs, dykes		Rb-Sr date Jurassic; K-Ar date Miocene
MESOZOIC	Undivided (M)		Fine-grained micaceous sandstone, siltstone; laminated to thin-bedded	Unconformable on Permian rocks		
LATE JURASSIC	Alexander Formation (Ja)	60?	Fine to medum-grained sandstone; minor siltstone; medium-bedded, ripple marks	Conformable on Wallal Sandstone, probably overlies and interfingers with Barbwire Sandstone. Overlain by Cainozoic deposits	Pelecypods and wood fragments; bioturbated	Occurs to southwest of Fenton Fault
	Barbwire Sandstone (Jb)	35±	Fine, medium, and coarse sandstone; minor siltstone and conglomerate; cross-bedded, variable sorting	Probably overlain by Alexander Formation. Unconformably overlies Liveringa Group and Noonkanbah Formation	Plant fossils, abundant wood fragments	May have covered plains to west of St George Ranges. Includes exposures previously mapped as James Sandstone
	Wallal Sandstone (Jl)	50±	Sandstone; minor siltstone and conglomerate	Unconformable on Grant Group. Overlain conformably by Alexander Formation	Microflora and microplankton	Subsurface only. Occurs south of Fenton Fault
			UNCONFORMITY			
EARLY TRIASSIC	Blina Shale (Rb)	185±	Mudstone, sandy mudstone, minor sandstone; thinly bedded to laminated	Unconformable on Hardman Formation and on Millyit Sandstone outside Sheet area	*Lingula,* conchostracans, amphibian bones, fish plates, plant remains, palynomorphs, trace fossils	Poor aquifer
	Millyit Sandstone (Rm)	20?	Fine sandstone, minor siltstone; thin-bedded, ripple marks, well sorted	Unconformable on Hardman Formation	Trace fossils	Tentatively recognised in McLarty Syncline
			UNCONFORMITY			

TABLE 3. SUMMARY OF STRATIGRAPHY—(*continued*)

Age	Group / Formation	*Rock unit and symbol*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Fossils*	*Remarks*
PERMIAN		Undivided (P)	5	Siltstone, shale, sandstone	—	—	Outcrops highly weathered and ferruginised
LATE PERMIAN	LIVERINGA GROUP; Hardman Formation (Ph)	Undivided (Ph)		Fine sandstone, siltstone, thin-bedded	Disconformable on Lightjack Formation	—	Outcrops highly weathered
LATE PERMIAN	LIVERINGA GROUP; Hardman Formation (Ph)	Cherrabun Member (Phc)	60–85	Grades from mudstone, with minor sandstone and limestone near base to mainly sandstone with cross-bedding near top; minor coal	Possibly disconformable on Hicks Range Sandstone Member. Unconformably overlain by ?Millyit Sandstone and Blina Shale	Abundant brachiopods, pelecypods, bioturbation and plant fossils (*Glossopteris*); palynomorphs	Recognised mainly from subsurface information; poorly exposed
LATE PERMIAN	LIVERINGA GROUP; Hardman Formation (Ph)	Hicks Range Sandstone Member (Phh)	100–325	Lower part of mudstone (and minor sandstone and coal) with ripple marks and mud cracks. Upper part of sandstone and minor siltstone; cross-bedding	Conformable on Kirkby Range Member. Possibly disconformably overlain by Cherrabun Member	Trace fossils, bioturbation, palynomorphs	Recognised mainly from subsurface information; poorly exposed
LATE PERMIAN	LIVERINGA GROUP; Hardman Formation (Ph)	Kirkby Range Member (Phk)	75–300+	Lower part of mudstone and fine sandstone with minor limestone. Upper part of cross-bedded sandstone	Disconformable on Lightjack Member and Condren Sandstone. Conformably overlain by Hicks Range Sandstone Member	Abundant brachiopods and pelecypods; bioturbation; palynomorphs	Recognised mainly from subsurface information; poorly exposed
LATE PERMIAN	LIVERINGA GROUP	Condren Sandstone (Pr)	50±	Medium to coarse sandstone, cross-bedded, poorly sorted, conglomeratic; minor coal	Lies conformably on Lightjack Formation. Possibly disconformably overlain by Kirkby Range Member and Ph	Plant fossils abundant in adjoining Sheet areas	Only one outcrop recognised in Sheet area. Probably a good aquifer
EARLY TO LATE PERMIAN	LIVERINGA GROUP	Lightjack Formation (Pj)	80–135	Lower part of shale and siltstone, calcareous, some coarse-grained sandstone lenses. Middle part of fine-grained, cross-bedded sandstone, coal-bearing. Upper part of siltstone and fine-grained sandstone, thinly interbedded; ripple marks	Conformably overlain by Condren Sandstone but disconformably overlain by Kirkby Range Member	Lower part contains abundant pelecypods, gastropods, some brachiopods, and rare ammonoids. Middle part contains fossil root horizons and abundant plant fossils. Upper part contains trace fossils	Middle part is probably good aquifer and contains thickest coal seams in area

TABLE 3. SUMMARY OF STRATIGRAPHY—(*continued*)

Age	*Rock unit and symbol*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Fossils*	*Remarks*
EARLY PERMIAN	Noonkanbah Formation (Pn)	310–405	Interbedded mudstone, shale, and fine-grained sandstone; calcareous; minor beds of finely crystalline limestone. Sandstone more abundant near Fenton Fault	Conformably overlain by Lightjack Formation; conformably overlies Poole Sandstone	Abundant brachiopods; some pelecypods, gastropods, bryozoans, foraminifera, arthropods, corals; microfossils include palynomorphs and some conodonts	Poor aquifer; very little outcrop
LATE PERMIAN	Undivided (Pp)		Sandstone, mudstone	Unconformable on Grant Group and conformably overlain by Noonkanbah Fm		
	Poole Sandstone (Pp): Christmas Creek Member (Ppc)	0–25+	Poorly sorted sandstone and conglomerate, cross-bedded, ripple marks	Overlies Tuckfield Member with interfingering contact. Underlies Noonkanbah Formation (contact not seen)	Trace fossils	Present in Poole Range – St George Ranges area. Wedges out to west
	Poole Sandstone (Pp): Tuckfield Member (Ppt)	30–245+	Very fine and fine sandstone with minor siltstone, conglomerate lenses, abundant small-scale cross-bedding and wave-formed ripple marks; thin-bedded, traces of coal	Conformably and disconformably overlies Nura Nura Member and is conformably overlain by Christmas Creek Member or ?disconformably by Noonkanbah Formation	Plant fossils, trace fossils, palynomorphs	Moderate to good aquifer. Thickest along crest of St George Ranges – Poole Range Anticline
	Poole Sandstone (Pp): Nura Nura Member (Ppn)	0–30	In west, thin-bedded sandstone, siltstone; calcareous, ripple-marked. In east, poorly sorted, cross-bedded sandstone and conglomerate; root horizons	Conformably and disconformably overlain by Tuckfield Member. Unconformably overlies Millajiddee Member	Brachiopods, ammonites, bryozoa, foraminifera, pelecypods, conodonts, crinoids, ostracods, conulariids; leaf and root fossils	Characterised by varied lithology

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TABLE 3. SUMMARY OF STRATIGRAPHY—*(continued)*

Age	*Rock unit and symbol*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Fossils*	*Remarks*
	GRANT GROUP (Pg): Undivided (Pg)	720–1735	Sandstone, mudstone, minor conglomerate	Unconformable on Carboniferous and possibly on Devonian rocks; overlain by Nura Nura Member		Outcrops too small to divide into the various formations
	GRANT GROUP (Pg): Carolyn Formation (Pc): Millajiddee Member (Pcm)	40–110?	Lower part of thin-bedded, ripple-marked fine sandstone and siltstone. Middle part of medium-grained, cross-bedded sandstone. Upper part of slumped, very fine-grained sandstone and siltstone	Overlain unconformably by Nura Nura Member. In places cut out by unconformity. Conformably overlies Wye Worry Member	Lower part contains abundant trace fossils	Good aquifer. Hard to recognise in Poole Range because of extensive slumping
	GRANT GROUP (Pg): Carolyn Formation (Pc): Wye Worry Member (Pcw)	25–?100	Lowermost part consists of graded laminae of siltstone and claystone. Middle and upper parts are grey mudstone, poorly bedded, containing facetted and striated dropstones, and poorly sorted; calcareous, with concretions	Conformably overlain by Millajiddee Member. Possibly disconformably overlies rest of undivided Carolyn Formation	Pelecypods, gastropods, brachiopods, bryozoans, crinoids in middle part of member. Plant fossils and trace fossils in upper part	Poor aquifer. Becomes sandy and hard to recognise to west. Hard to recognise in Poole Range because of extensive slumping
	GRANT GROUP (Pg): Carolyn Formation (Pc): Undivided (Pc)	135–650	Massive to poorly bedded, medium to coarse sandstone, conglomeratic in part; minor feldspar	Conformably overlies Winifred Formation; probably also unconformable on older rocks as unit overlaps onto basin margin	Wood fragments, trace fossils, bioturbation, palynomorphs	Forms rounded cliffs. Excellent aquifer
	GRANT GROUP (Pg): Winifred Formation (Pw)	40–225	Siltstone and shale, calcareous, carbonaceous; minor fine sandstone, pyrite. Predominantly sandstone in north	Conformably overlies Betty Formation; probably also unconformable on older rocks	Palynomorphs; bryozoans and crinoids found outside Sheet area	Not differentiated in cross-section; identified in well logs
LATE CARBONIFEROUS TO EARLY PERMIAN	GRANT GROUP (Pg): Betty Formation (Pb)	380–650	Very fine to coarse sandstone, minor silt and clay. Conglomeratic and calcareous	Unconformable on Carboniferous and possibly also on Devonian rocks	Palynomorphs	Not differentiated in cross-section; identified in well logs. Contains glacial erratics

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TABLE 3. SUMMARY OF STRATIGRAPHY—(*continued*)

Age		*Rock unit and symbol*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Fossils*	*Remarks*
CARBONIFEROUS		Anderson Formation (Ca)	1360±	Alternating sandstone, siltstone, shale; minor limestone, dolomite, and anhydrite	Overlain unconformably by Grant Group. Unconformably(?) overlies Fairfield Group	Palynomorphs. Possible plant fossils found to east of Sheet area	Defined in subsurface. Probably crops out in Mount Ramsay Sheet area
LATE DEVONIAN TO EARLY CARBONIFEROUS		Undivided (DCf)		Limestone, shale, siltstone; minor dolomite, sandstone	Unconformably(?) overlain by Anderson Formation		Cross-section only
	FAIRFIELD GROUP	Laurel Formation (Cll)	357–1360	Interbedded limestone, shale, siltstone, sandstone. Upper part dominantly shale, lower part dominantly limestone	Unconformable beneath Grant Group, possibly unconformable beneath Anderson Formation. In outcrop area conformably overlies Yellow Drum Sandstone	Algae, brachiopods, conodonts, corals, fish, pelecypods, nautiloids, ammonoids, ostracods, bryozoans, palynomorphs	Remnants of sandstone conformably overlying unit in outcrop area may be Anderson Formation
	FAIRFIELD GROUP	Yellow Drum Sandstone (Duy)	70±	Medium to coarse, cross-bedded sandstone; porous, medium to thick-bedded dolomite, brecciated near base; minor shale and siltstone; rare thin limestone beds	Overlies Gumhole Formation and Pillara Formation, although lower contact not exposed	Brachiopods, gastropods, ostracods, algae; some conodonts	
LATE DEVONIAN (FAMENNIAN)	FAIRFIELD GROUP	Gumhole Formation (Dug)	20–71+	Limestone, colour-laminated, cross-bedded, thick-bedded, interbedded with siltstone and shale; minor sandstone and dolomite	Overlain by and interfingers with Yellow Drum Sandstone. Overlies and interfingers with Pillara Formation. Possibly equivalent to part of Napier Formation. Probably equivalent to Luluigui Formation	Brachiopods, bryozoans, pelecypods, corals, nautiloids, fish, conodonts, ostracods, algae, palynomorphs	
DEVONIAN OR PERMIAN?		(DPc)	150?	Boulder, cobble, and pebble conglomerate; sandstone	Older beds may be equivalent to Bobs Bore Conglomerate. Younger beds may be equivalent to parts of Grant Group, and Yellow Drum Sandstone		Generally exposed as scree. Matrix arkosic

TABLE 3. SUMMARY OF STRATIGRAPHY—(*continued*)

Age	*Rock unit and symbol*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Fossils*	*Remarks*
DEVONIAN	Undivided (D)	?1000±	Siltstone, shale sandstone; minor limestone and dolomite	Disconformably overlies Tandalgoo Red Beds. Partly equivalent to Devonian reef complexes	Palynomorphs, ammonoids, conodonts, ostracods	Subsurface only. May be parts of Poulton and Luluigui Formations, and Clanmeyer Siltstone (Playford & others, 1975)
LATE DEVONIAN FAMENNIAN	Piker Hills Formation (Di)	300?	Shale, siltstone calcilutite (basin facies); calcarenite, calcirudite, minor interbedded shale and siltstone (marginal-slope facies)	Conformably overlies Virgin Hills Formation	Ammonoids, conodonts; brachiopods; some foraminifera	Basin facies generally poorly exposed. Rolled blocks of reef limestone abundant in some beds
FRASNIAN TO FAMENNIAN	Bugle Gap Limestone (Du)	150?	White to pink medium to thick-bedded calcarenite grading to calcirudite	Marginal-slope facies. Conformably overlies and interfingers with upper part of Virgin Hills Formation. Upper part probably equivalent to lower part or Piker Hills Formation	Sparse fauna of brachiopods, etc. Dated on conodonts	Rolled blocks of reef limestone in some beds. One small exposure in south-east of Sheet area
	Napier Formation (Dn)	150?	Red, yellow, and light grey silty calcarenite, ?interbedded with siltstone, shale, sandstone	Marginal-slope and basin facies. Equivalent to part of Virgin Hills Formation, and possibly also to part of Piker Hills Formation. Interfingers with Pillara Limestone	Stromatolites, stromatoporoids, conodonts, goniatites, brachiopods, foraminifera	Very poorly exposed
	Virgin Hills Formation (Dr)	450?	Interbedded calcareous siltstone, shale, sandstone, calcarenite, calcilutite (basin facies); calcarenite; calcirudite, minor sandstone and siltstone (marginal-slope facies)	Conformably overlies Gogo Formation and Sadler Limestone	Rich conodont and ammonoid faunas. Others include brachiopods, corals, sponges, foraminifera, radiolaria, ostracods, gastropods, bivalves, trilobites	Red colour characteristic, especially in basin facies. Large rolled blocks of reef common, in some areas forming megabreccias
FRASNIAN TO ?FAMENNIAN	Bobs Bore Conglomerate (Do)	60?	Boulder, cobble, and pebble conglomerate; sandstone	Interfingers with Virgin Hills Formation and Sadler Limestone		Generally present as scree

TABLE 3. SUMMARY OF STRATIGRAPHY—(*continued*)

Age	*Rock unit and symbol*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Fossils*	*Remarks*
MIDDLE TO LATE DEVONIAN — GIVETIAN? TO FRASNIAN	Pillara Limestone (Dp)	600–900?	Yellow to light grey, medium-bedded, algal, stromatoporoid, and coral limestone, calcarenite, calcilutite; oolite in Oscar Range	Platform facies. Unconformably overlies Gap Creek Formation and Precambrian basement	Mainly algae and stromatoporoids; corals	Stromatoporoid, birdseye limestone, coral, and oncolite subfacies of Playford & Lowry (1966)
	(Dpr)	600–900?	Massive to very poorly bedded, yellow to white limestone (locally dolomitised). Commonly recrystallised and replaced	Reef-margin subfacies	Mainly algae and stromatoporoids: corals, brachiopods, and sponges locally important	Framework of colonial organisms essentially in growth position
	Sadler Limestone (Dd)	450?	Yellow to light grey calcarenite, calcirudite, thinner interbeds of soft sediments (probably calcareous siltstone) and shale	Marginal-slope facies. Equivalent of Gogo Formation. Unconformably overlies basement	Silicified brachiopods, ammonoids, conodonts, corals, stromatoporoids, algae, gastropods, bryozoans	Slump-folding common. Limestone commonly thin-bedded, especially near base of fore-reef slope. Rolled blocks of reef limestone in some parts
	Gogo Formation (Dg)	450?	Black to light grey shale and siltstone, thin lenses of limestone and layers containing abundant limestone concretions	Basin-facies equivalent of Sadler Limestone. Unconformably overlies basement	Ammonoids, conodonts, nautiloids, radiolarians, fish, crustaceans, sponges, ostracods, brachiopods, gastropods	Nodules 20–300 mm across
EARLY DEVONIAN	Tandalgoo Red Beds (Dt)		Sandstone, claystone, siltstone, minor dolomite	Conformably overlies Carribuddy Formation. Overlain by Devonian rocks	Fish scales	Subsurface only
LATE ORDOVICIAN? TO EARLY DEVONIAN	Carribuddy Formation (Sc)		Siltstone, claystone, sandstone, dolomite; minor limestone, anhydrite	Overlies Ordovician disconformably(?); overlain by Devonian rocks		Subsurface only

TABLE 3. SUMMARY OF STRATIGRAPHY—(*continued*)

Age		*Rock unit and symbol*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Fossils*	*Remarks*
ORDOVICIAN		Undivided (O)		Siltstone, sandstone, shale, minor dolomite, limestone	Overlies basement, overlain by Carribuddy Formation	Graptolites, trilobites, conodonts, palynomorphs, etc.	Subsurface only. Probably partly equivalent to Prices Creek Group and Nambeet, Willara, Goldwyer, and Nita Formations (Playford & others, 1975)
	PRICES CREEK GROUP	Gap Creek Formation (Og)	190+	Dolomite, silty dolomitic limestone; sandy beds common	Conformably overlies Emanuel Formation, unconformably overlain by Pillara Formation	Brachiopods, conodonts, trilobites, nautiloids	
	PRICES CREEK GROUP	Emanuel Formation (Oe)	775	Limestone and interbedded shale	Unconformably overlies Precambrian rocks; overlain conformably by Gap Creek Formation	Brachiopods, trilobites, graptolites, nautiloids, gastropods, conodonts	

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PRECAMBRIAN PROTEROZOIC LAMBOO COMPLEX	(ap)	Aplite with localised pegmatitic phases; felsite; muscovite granite and adamellite	Intrudes adamellite, tonalite, and Whitewater Volcanics	Probably residual phase of adamellite magma. Occurs mainly as dykes; one lensoid body 1.5 km south-west of Mountain Home Spring
	(Ᵽbp$_3$)	Biotite tonalite and microtonalite, locally porphyritic; minor biotite granodiorite	Intrudes adamellite	Differs only slightly in composition from granodiorite
	(Ᵽbp$_2$)	Coarse biotite and plagioclase-rich granodiorite	Intrudes Halls Creek Group; intruded by dykes of porphyritic microtonalite	Distinguishable in field from adamellite by higher biotite content. Forms discrete pluton at north-west end of inlier
	(Ᵽbp$_1$)	Coarse biotite adamellite; minor granodiorite	Intrudes Halls Creek Group and Whitewater Volcanics; intruded by tonalite and aplite dykes	Commonly xenolithic near contacts with older rock. Forms major part of inlier
	Whitewater Volcanics (Ᵽw)	Fine-grained, locally bedded, porphyritic rhyolitic ash-flow tuff	Unconformably overlies Halls Creek Group schists. Intruded by adamellite, aplite, and tonalite	Graded bedding indicates right way up. Dip consistently to southwest
UNCONFORMITY				
HALLS CREEK GROUP (Ᵽh)		Pelitic biotite–muscovite schist with andalusite pseudomorphs; minor semipelitic quartz–biotite schist	Overlain unconformably by Whitewater Volcanics; intruded by adamellite and granodiorite	Sericite and sericite–corundum pseudomorphs after andalusite, as in Lennard River Sheet area
	pЄ	Igneous, metamorphic, and sedimentary rocks	Basement of Canning Basin	Isolated exposures around Pillara Range

1969) but probably younger than 2200 m.y. (Page, 1976); it is therefore thought to be Early Proterozoic. The schists, which crop out in two small areas in the northwest of the inlier, show no appreciable contact metamorphism from the nearby, and more extensive, granite and consist mainly of pelitic biotite–muscovite–quartz schist with minor semi-pelitic quartz–biotite schist. Thin sections show that the schist contains aggregates 2–3 mm long of finely crystalline sericite containing rare small inclusions of corundum; Sofoulis & Gellatly (1968) consider the inclusions to have been derived from andalusite that has undergone retrograde metamorphism.

BMR terms the *Lamboo Complex* (Derrick & Playford, 1973) 'Early Proterozoic to Carpentarian', and GSWA 'Lower Proterozoic'. The group consists of acid intrusives and extrusives in the Noonkanbah Sheet area.

The acid *Whitewater Volcanics* (Ᵽw) (Dow & others, 1964) of the Lamboo Complex, which overlie the Halls Creek Group, are porphyritic rocks similar to those in the Lennard River Sheet area. They are strongly sheared ash-flow tuffs with a metamorphic foliation and consist of phenocrysts and fragments of quartz and feldspar set in a cryptocrystalline groundmass. Granitic rocks intrude the Whitewater Volcanics with sharp or gradational, steeply dipping contacts which generally appear concordant with bedding in the volcanics, although locally the granite bodies are transgressive. Quartz and aplite veins are common in the volcanics close to granite contacts.

The rest of the Lamboo Complex consists of four main suites of acid intrusive rocks: coarse *biotite adamellite* (Ᵽbp$_1$), coarse *biotite granodiorite* (Ᵽbp$_2$), *biotite tonalite and microtonalite* (Ᵽbp$_3$), and medium-grained *leucocratic aplite* (ap). The first suite (Ᵽbp$_1$) crops out over most of the inlier, and the four suites are apparently derivatives of a single magma. The coarse plutonic rocks are tentatively correlated with parts of the Bow River Granite of the East Kimberley (Roberts & others, 1965) and the microtonalite with the Violet Valley Tonalite (Gemuts, 1965).

The biotite adamellite contains minor granitic and granodioritic phases and is locally foliated to give a gneissic appearance. Xenoliths of biotite-rich metasediment and Whitewater Volcanics are also present. The biotite granodiorite, which occurs in the northwestern part of the inlier, is distinguishable from the adamellite in hand specimen by its higher biotite content, but otherwise resembles the adamellite.

Rocks of the tonalite suite are readily distinguishable by their dark-grey colour and smaller grainsize. The microtonalite occurs as thin dykes which cut the granodiorite.

The aplite suite includes dykes of leucocratic fine-grained granite and adamellite and larger masses of leucocratic fine-to-medium-grained muscovite-bearing granite and adamellite. The latter is similar to the Mount Amy Granite of the Lennard River Sheet area (Derrick & Playford, 1973).

PALAEOZOIC

Ordovician

The oldest known Phanerozoic sediments in the basin are Ordovician rocks, south of the Lennard Shelf, that are shown as *undivided Ordovician* (O) in the cross-sections. Although no wells drilled within the Sheet area have penetrated these rocks, information from outside the area, combined with seismic evidence, indicates that an aggregate thickness of up to 2000 m of Ordovician siltstone, sandstone, and shale with minor dolomite and limestone may be present in the Noonkanbah Sheet area. These sediments are probably partly equivalent to the exposed Prices Creek Group and include possible equivalents of the Nambeet, Willara, Goldwyer, and Nita Formations (Playford & others, 1975).

The *Prices Creek Group* (Guppy & Öpik, 1950) crops out in a small area around Prices Creek and Gap Creek on the southwestern side of the Emanuel Range. The group contains the Emanuel Formation conformably overlain by Gap Creek Formation (Guppy & Öpik, 1950; Guppy & others, 1958).

The *Emanuel Formation* (Oe) is poorly exposed as low rubbly rises and as a discontinuous section in the bed of Emanuel Creek, the type section (lat. 18°39′S, long. 125°55′E). The base is not exposed, although it was intersected in BMR Noonkanbah No. 3 (Prices Creek) bore where the formation rests on sheared volcanic rocks (Henderson & others, 1963), probably the Whitewater Volcanics. The formation contains a rich fauna including well-preserved brachiopods, nautiloids (Teichert & Glenister, 1954), conodonts (McTavish, 1961), trilobites, and graptolites which indicate an Early Ordovician age (Guppy & others, 1958).

The *Gap Creek Formation* (Og) is better exposed than the underlying Emanuel Formation because it contains a resistant light-brown dolomite. The type section is in Gap Creek (lat. 18°40′S, long. 125°55′E). The Gap Creek Formation is less fossiliferous than the Emanuel Formation and the fossils are commonly silicified. The age of the formation is regarded as Early Ordovician, possibly extending into the Middle Ordovician (Playford & others, 1975).

Late Ordovician? to Early Devonian

The *Carribuddy Formation* (Sc) (Koop, 1966) has been penetrated in several wells south of the Fitzroy Trough. It probably extends into the trough but not onto the Lennard Shelf. In nearby Matches Springs No. 1 (Total Exploration Australia Pty Ltd, 1970) it overlies the Nita Formation (apparently disconformably) and is overlain by the Tandalgoo Red Beds; in this well it is mainly composed of dolomite, shale, and sandstone, but elsewhere halite and anhydrite are dominant. To the west of the Sheet area the unit is thought to have been the source of evaporite that formed a diapiric structure on the Jurgurra Terrace. The age of the Carribuddy Formation is indefinite but it is tentatively placed in the Silurian on stratigraphic evidence (Playford & others, 1975).

Early Devonian

The *Tandalgoo Red Beds* (Dt) (Koop, 1966), a unit of brown sandstone with claystone, siltstone, and minor dolomite, has been dated as Early Devonian (Gross, 1971) but it may range into the Silurian. The Tandalgoo Red Beds may not be present northeast of the Barbwire Terrace (see geological cross-sections).

Rocks of the *Devonian reef complexes* (information from P. E. Playford) are exposed in the Oscar, Geikie, Pillara, Home, and Emanuel Ranges and in adjacent areas. Each range represents an exhumed limestone reef complex (Guppy & others, 1958; Playford & Lowry, 1966; Playford, 1976). Seven formations in the reef complexes are recognised in the Sheet area: the Pillara Limestone, Sadler Limestone, Gogo Formation, Virgin Hills Formation, Bugle Gap Limestone, Piker Hills Formation, and Napier Formation (Fig. 3). In addition a Devonian terrigenous conglomerate, the Bobs Bore Conglomerate, occurs in the Virgin Hills area.

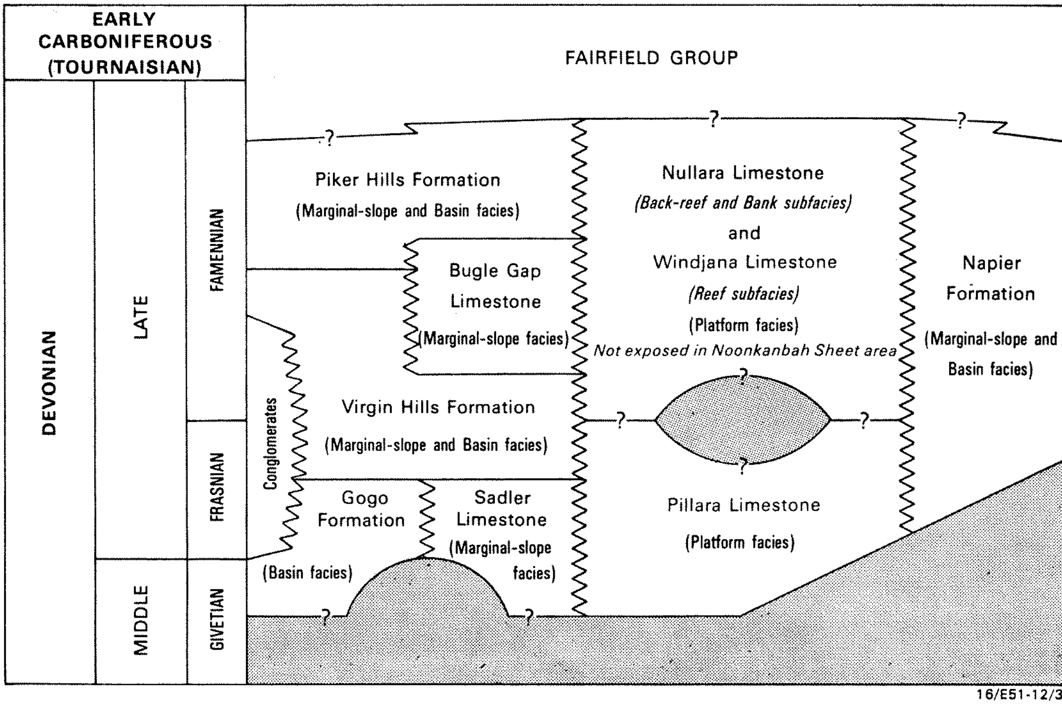

Fig. 3. Correlation chart of Devonian reef complexes.

Playford & Cockbain (1976) recognise three basic facies in the reef complexes, which they name the platform, marginal-slope, and basin facies. Reef-margin, reef-flat, patch-reef, back-reef, and bank sub-facies are distinguished in the platform facies, and fore-reef, fore-bank, reefal-slope, and stromatolite sub-facies in the marginal-slope facies. However, the only sub-facies differentiated on the map is the reef-margin.

The platform facies was deposited as reef-fringed limestone platforms which stood from a few metres to a maximum of perhaps 200 to 300 m above the surrounding inter-reef basins, and covered areas ranging from a few hectares to hundreds of square kilometres. The platforms were banked by marginal-slope deposits, laid down on depositional slopes ranging from a few degrees to about 35° where they consisted of loose sediment (largely talus), and to near-vertical where the sediment was bound by organisms. At the foot of the slopes the marginal-slope facies passed into the basin deposits, which are largely composed of terrigenous detritus, and were laid down nearly horizontally.

The platforms are of late Givetian and Frasnian age in the Pillara, Home, and Emanuel Ranges, whereas the Oscar Range and Geikie Range platforms are probably entirely Frasnian. The exposed marginal-slope and basin facies range in age from early Frasnian to late Famennian, but they are believed to extend into the late Givetian in the subsurface. Famennian platforms (referred to the Nullara and Windjana Limestones, see Fig. 3) do not occur in the area, having apparently been entirely removed by pre-Permian erosion. They are, however, exposed in neighbouring Sheet areas.

The total thickness of sediment of the Devonian reef complexes in the area (below the Fairfield Group) probably exceeds 2000 m.

The *Gogo Formation* (Dg) (Wade, 1936; Guppy & others, 1958) is a unit of shale and siltstone with calcarenite and calcilutite lenses and is characterised in part by calcareous nodules. It is of Frasnian age, and may extend into the late Givetian in the subsurface. The formation is interpreted as a basin deposit equivalent to the marginal-slope facies represented by the Sadler Limestone. The type section, about 430 m thick, is on the north side of the Pillara Range near Menyous Gap (lat. 18°24'S, long. 125°52'E).

The *Sadler Limestone* (Dd) (Guppy & others, 1958; Playford & Lowry, 1966) consisting of calcarenite and calcirudite with minor megabreccias, is interpreted as marginal-slope facies; it includes reefal-slope, fore-reef, and fore-bank sub-facies. The exposed part of the unit is of Frasnian age, although it probably extends into the late Givetian below the surface. The type section is at Sadler Ridge on the north side of Emanuel Range (lat. 18°36'S, long. 125°56'E) and is about 300 m thick.

The *Pillara Limestone* (Dp) (Guppy & others, 1958; Playford & Lowry, 1966) consists mainly of stromatoporoid limestone, fenestral limestone, and oolite. The formation belongs to the platform facies and the predominant rock type is stromatoporoid limestone in the Pillara, Home, Emanuel, and northeastern Geikie Ranges, fenestral limestone in the southern Geikie Range, and oolite in the southeastern Oscar Range. The formation is locally dolomitised and the type section, 410 m thick, is at Menyous Gap in the Pillara Range (lat. 18°24'S, long. 125°52'E).

The *reef-margin subfacies* (Dpr) of the Pillara Limestone consists of a framework of colonial organisms which is massive or very poorly bedded. It occurs as a narrow rim around the reef platforms.

The *Bobs Bore Conglomerate* (Do) (Playford & Lowry, 1966) interfingers with the Virgin Hills Formation in the Virgin Hills area and consists of conglomerate and sandstone. The clasts of the conglomerate consist of various Precambrian rocks, especially quartzite. The type section is located in the Virgin Hills near Bobs Bore (lat. 18°31'20"S, long. 125°50'40"E.), and is about 240 m thick.

The *Virgin Hills Formation* (Dr) (Guppy & others, 1958) consisting of interbedded siltstone, shale, sandstone, calcarenite, calcilutite, and calcirudite, is characterised by its red or reddish colour. The formation consists of marginal-slope and basin facies, and is of late Frasnian to Famennian age. The marginal-slope facies includes reefal-slope, fore-reef, and stromatolite sub-facies. Pillara Limestone equivalent to the lower part of the Virgin Hills Formation is known to occur in the area, but a platform facies equivalent to the Famennian part of the formation is not known in the Noonkanbah Sheet area. The type section of the Virgin Hills Formation is located east of Needle Eye Rock (lat. 18°16'30"S, long. 125°52'E) and is about 220 m thick.

The *Napier Formation* (Dn) (Guppy & others, 1958) consists of calcarenite interbedded with siltstone, shale, calcareous sandstone, and conglomerate and in its exposed parts belongs to the marginal-slope facies, but it also includes some basin deposits. The type section is at Barker Gorge on the adjoining Lennard River Sheet area. It is mapped in the Geikie and Oscar Range areas and is equivalent to the Virgin Hills and Piker Hills Formations.

Only one outcrop of the *Bugle Gap Limestone* (Du) (Guppy & others, 1958) occurs in the area. The formation consists mainly of calcarenite grading to calcirudite and is interpreted as marginal-slope facies. In the adjoining Mount Ramsay Sheet area, the Bugle Gap Limestone overlies and interfingers with the upper part of the Virgin Hills Formation and the upper part of the Bugle Gap Limestone is probably equivalent to the lower part of the Piker Hills Formation.

The *Piker Hills Formation* (Di) (Playford & Lowry, 1966) consists of calcarenite and calcirudite in the marginal-slope facies, with interbedded shale, siltstone, and calcilutite in the basinal facies. The type section is in the Piker Hills in the adjoining Mount Ramsay Sheet area.

Devonian

Undivided Devonian (D) is shown on the cross-sections and refers to subsurface units that are probably basin equivalents of the reef complexes (see below) and that may be parts of the Poulton Formation, Clanmeyer Siltstone, and Luluigui Formation. The aggregate maximum thickness of these sediments may reach 1000 m in the Fitzroy Trough (Playford & others, 1975).

Poorly exposed undivided *Devonian and Permian? conglomerate* (DPc) occurs in the northeast corner of the Sheet area. The lower part may correlate with the Bobs Bore Conglomerate and the upper part with part of the Grant Group and with the Yellow Drum Sandstone. The exposure is too poor to allow subdivision of the outcrops.

Late Devonian to Early Carboniferous (information from E. C. Druce)

The *Fairfield Group* (Druce & Radke, 1977a, b) was originally subdivided into two units by Guppy & others (1958). Playford & Lowry (1966) preferred to map the group as one unit, but more detailed investigation has allowed subdivision into three formations, and the unit has therefore been raised to group status.

The *Gumhole Formation* (Dug) (Druce & Radke, 1977b), the lowermost formation in the Fairfield Group, consists of limestone that is colour-laminated, thick-bedded, and cross-stratified and consists of bioclastic, intraclastic, and oolitic sandy grainstone. The limestone is interbedded with softer siltstone, shale, and claystone which is rarely exposed and contains a rich fauna. The conodont evidence indicates a late Famennian age. The type section is 71 m thick and is at lat. 18°07′30″S, long. 125°27′25″E, along the Great Northern Highway.

The middle formation of the Fairfield Group, the *Yellow Drum Sandstone* (Duy) (Druce & Radke, 1977b), consists mainly of sandstone and dolomite with minor shale and siltstone and rare thin limestone beds. The biota of the formation is greatly impoverished in comparison with the enclosing units, although there are a few thin beds of fossiliferous limestone. The formation is diachronous and was deposited during the latest Devonian and earliest Carboniferous. The type section is at lat. 18°05′35″S, long. 125°25′00″E.

The *Laurel Formation* (Cll) (Thomas, 1959; Druce & Radke, 1977b), the uppermost unit in the Fairfield Group, is dominated in its lower part by limestone, whereas it is mainly shale in its upper part. These two parts are recognised as two distinct, but unnamed, members. The limestone is mainly well-bedded skeletal grainstone which is laterally discontinuous. Macrofossil evidence indicates an Early Carboniferous age, although there has been some discussion about the validity of this date (see Thomas, 1971, and Hill *fide* Thomas, 1962). Conodonts indicate a Tournaisian age (Nicoll & Druce, 1979) and the palynomorphs have been assigned to the 'Lycosporoid' microflora of Balme (1964).

The *undivided Fairfield Group* (DGf) is shown on the cross-sections and refers to subsurface units that are probably basin equivalents of the outcropping formations. The aggregate maximum thickness of these sediments may reach 1300 m in the Fitzroy Trough.

Early Carboniferous

The *Anderson Formation* (Ca) (McWhae & others, 1958) of mainly Early Carboniferous age (Playford & others, 1975) is not definitely known to be exposed in the Noonkanbah Sheet area. However, in places remnants of sandstone conformably overlying the Laurel Formation beneath the pre-Grant Group unconformity may be Anderson Formation. The formation occurs in the subsurface in the Fitzroy Trough and was identified in St George Ranges No. 1 (CONOCO, 1966) where it is 1360 m thick.

In Mount Ramsay Sheet area at Bohemia Ridge a possible Early Carboniferous unit (Veevers & others, 1967) overlies the Fairfield Group. It consists of cyclic large-scale cross-bedded, coarse sandstone with conglomerate, fining upwards to planar-bedded mudstone. Although previously mapped as Grant Group (Playford & Lowry, 1966; Roberts & others, 1968), the immaturity of the sediment and the obvious cyclicity is not like any part of the exposed Grant Group. The unit is therefore identified as Anderson Formation (see also Playford & others, 1975, p. 339).

In St George Ranges No. 1 well, CONOCO (1966) identified a unit above the Anderson Formation between 1518 and 2487 m. They named this as a separate formation, but here it is included in the Anderson Formation. Generally, it is a finer-grained sequence than the lower part of the Anderson Formation and includes redbeds.

CONOCO (1966) interpreted the contact between the Anderson Formation and the underlying Fairfield Group as an unconformity in the subsurface.

Late Carboniferous to Early Permian

The *Grant Group* (formerly Grant Formation of Guppy & others (1952); redefined by Crowe & Towner (1976)) was previously recognised in the area but was not subdivided (Thomas, 1958a). Crowe & Towner (1976a) defined three formations within the group, but only the upper Carolyn Formation and its Millajiddee and Wye Worry Members are thought to crop out in the Noonkanbah Sheet area.

The *Betty Formation* (Pb) does not crop out in the Sheet area but has been identified in Mount Hardman No. 1 (WAPET, 1973), St George Ranges No. 1 (CONOCO, 1966), and Esso No. 27 (see Table 4). The unit is thickest in the middle of the Fitzroy Trough, and palynological evidence indicates it may be mainly Late Carboniferous (WAPET, 1973). The middle *Winifred Formation* (Pw) has been identified in the same bores as the Betty Formation and also appears to be thickest in the middle of the trough. The Winifred Formation contains marine

TABLE 4. LOCATIONS OF PERMIAN COAL EXPLORATION BORES

Bore No.	*Lat. (S)*	*Long. (E)*
ESSO–Dampier bores		
1	18°15′	124°34′
2	18°20′	124°35′
3	18°24′	124°41′
4	18°23′	124°47′
5	18°16′	124°44′
6	18°19′	124°49′
7	18°20′	124°54′
8R	18°10′	124°46′
9	18°09′	124°52′
10	18°06′	124°57′
11	18°06′	124°42′
12	18°01′	124°46′
13	18°02′	124°52′
15	18°06′	124°47′
18R	18°25′	124°53′
19	18°20′	124°59′
20R	18°21′	125°05′
21R	18°20′	125°10′
22	18°20′	125°16′
23R	18°27′	125°08′
24	18°17′	125°18′
25	18°20′	125°11′
26	18°13′	125°04′
27	18°05′	125°06′
28	18°25′	125°58′
29	18°43′	124°39′
30	18°42′	124°42′
31	18°45′	124°47′
32	18°47′	124°46′
33	18°51′	124°46′
34	18°53′	124°49′
35	18°58′	124°51′
36	18°40′	124°44′
37	18°54′	124°56′
38	18°53′	125°02′
40	18°59′	124°59′
41	18°51′	124°56′
42	18°52′	124°55′
43	18°47′	124°55′
44	18°48′	124°55′
45	18°47′	124°50′
46	18°52′	125°05′
47	18°58′	124°55′
48	18°53′	124°55′
49	18°52′	124°55′
50	18°52′	124°55′
51	18°49′	124°52′
52	18°47′	124°47′
Australian Inland Exploration bores		
P1	18°07′	124°36′
P2	18°08′	124°37′
P3	18°10′	124°39′
P4	18°11′	124°40′
P5	18°12′	124°41′
P6	18°13′	124°42′
Dampier bores		
1	18°40′	124°34′
2	18°39′	124°34′
3	18°36′	124°36′
4	18°36′	124°36′
5	18°37′	124°35′
6	18°38′	124°35′
7	18°38′	124°34′
8	18°39′	124°34′
9	18°35′	124°37′
10	18°32′	124°30′
11	18°31′	124°30′
12	18°30′	124°30′
13	18°31′	124°30′
14	18°33′	124°30′
16	18°36′	124°36′
17	18°45′	124°45′
18	18°41′	124°30′
21	18°33′	124°33′
Premier bores		
A-1	18°05′	124°36′
A-2	18°05′	124°36′
A-3	18°05′	124°36′
A-4	18°06′	124°36′
A-5	18°06′	124°36′
A-6	18°06′	124°35′
A-7	18°06′	124°36′
A-8	18°06′	124°35′
A-9	18°06′	124°35′
A-10	18°06′	124°35′
A-11	18°07′	124°35′
A-12	18°05′	124°36′
A-13	18°04′	124°37′
A-14	18°04′	124°37′
A-15	18°04′	124°37′
A-16	18°04′	124°37′
A-17	18°04′	124°37′
A-18	18°04′	124°37′
A-19	18°04′	124°38′
A-20	18°04′	124°38′
A-21	18°04′	124°38′
A-21A	18°04′	124°38′
A-21B	18°04′	124°38′
A-22	18°04′	124°38′
A-23	18°04′	124°39′
S-1	18°03′	124°36′
S-2	18°03′	124°36′
S-3	18°03′	124°36′
C-1	18°09′	124°35′
C-2	18°10′	124°34′
D-1	18°08′	124°30′
D-2	18°09′	124°30′
D-3	18°08′	124°30′
D-4	18°08′	124°30′
D-5	18°08′	124°30′
D-6	18°08′	124°30′
D-7	18°08′	124°30′

macrofossils in the southern part of the Canning Basin (WAPET, 1966a), so it is at least partly marine in origin.

The part of the Carolyn Formation exposed below the Wye Worry Member consists of sandstone with minor conglomerate and is mapped as undivided *Carolyn Formation* (Pc). It is best exposed in the core of the St George Ranges Structure. The *Wye Worry Member* (Pcw) overlies this sandstone, probably disconformably, and consists mainly of calcareous siltstone and sandy siltstone which contains locally abundant glacial dropstones. Crowe & Towner (1976b) recognise glacial varves in the lower part of the member, and in the middle part there are marine fossils that indicate a Late Sakmarian (*sensu lato*) age (Dickins & others, 1977). The member is thinnest in the middle of the St George Ranges and thickest in the east of the ranges where Crowe & Towner (1976a) have defined the type section at lat. 18°46′45″S, long. 125°18′50″E.

The *Millajiddee Member* (Pcm) conformably overlies the Wye Worry Member and consists mainly of sandstone. It contains a middle part that is characterised by abundant large-scale cross-bedding. The upper part is commonly slumped so that in parts of the Poole Range the member could not be differentiated from the the rest of the Carolyn Formation. In such places the outcrops are labelled as undivided Carolyn Formation.

The thickness of the Millajiddee Member varies, mainly as a result of erosion before deposition of the overlying Poole Sandstone. At Mount Thorlan and near Millajiddee homestead the member is completely cut out by this unconformity. The age of the Millajiddee Member is inferred to be Sakmarian and the type section is at lat. 18°45′00″S, long. 124°55′25″E (Crowe & Towner, 1976a). At the top of this section the member is unconformably overlain by a thin lenticular unit (averaging 1 m thick) containing breccia blocks derived from the underlying beds, and boulders of igneous and metamorphic rocks that are probably derived from the Wye Worry Member. This unit is unconformably overlain by the Nura Nura Member of the Poole Sandstone, and as its affinities are unknown it has not yet been named. It is too thin to be shown on the map.

Undivided Grant Group (Pg) forms small outliers unconformably overlying the Devonian reef complexes; the outliers possibly belong to the Carolyn Formation.

Permian

Subdivisions of the *Poole Sandstone* (Pp) (Guppy & others, 1952) were not shown on the previous edition of the geological map (Thomas, 1958a) although Guppy & others (1958) believed that the basal Nura Nura Member was present in the area. From the present mapping Crowe & Towner (1976a; 1977) have in addition defined an upper Christmas Creek Member and middle Tuckfield Member.

The *Nura Nura Member* (Ppn) (Guppy & others, 1952) is well exposed in the St George Ranges, in the Poole Range, and at Mount Hutton. North of the Fitzroy River it has been identified in WAPET Mount Hardman No. 1 well (WAPET, 1973) and tentatively in the Lauris Range area. The member is normally identifiable by its unconformable lower boundary and distinctive upper boundary as well as by its characteristic heterogeneous lithology. Crowe & Towner (1976c) have described the variations within the member. The Nura Nura Member thins to the east and is considered to be of Late Sakmarian (*sensu lato*) age (Glenister & Furnish, 1961).

The *Tuckfield Member* (Ppt) is characterised by its fine-grained, thin-bedded nature and by the smooth rounded hills that it forms. It is extensively exposed on the flanks of the St George Ranges and Poole Range. Crowe & Towner (1976b) have reported that the unit contains abundant ripple marks, probably wave-formed. It thickens westwards and additionally towards the middle of the St George Ranges–Poole Range Structure (on the geological map, the colour for undivided Poole Sandstone has been printed in error for areas of Tuckfield Member in the Poole Range). Plant fossils, particularly roots, are abundant in the eastern part of the area, but are not age-diagnostic. Palynomorphs from the Tuckfield Member elsewhere in the basin indicate an early to late Artinskian age (Yeates & others, 1975b).

The beds now defined as the *Christmas Creek Member* (Ppc) were originally included in the Noonkanbah Formation, but are now included in the Poole Sandstone (Crowe & Towner, 1976a) as they interfinger with the Tuckfield Member. The Christmas Creek Member appears to be restricted to the central part of the Sheet area. Crowe & Towner (1976a) have defined the type section of the Christmas Creek Member at Mount Piper in the Poole Range (lat. 18°54′00″S, long. 125° 47′30″E).

Extensive areas on the southern flanks of the St George Ranges, together with small areas west of the Poole Range and north of the Fitzroy River, consist of thin-bedded, very fine and fine-grained sandstone. They are mapped as *undivided Poole Sandstone*, although many of the exposures may be equated with the Tuckfield Member.

The *Noonkanbah Formation* (Pn) (Guppy & others, 1952) underlies large parts of the Sheet area but is easily weathered and crops out poorly. The best exposures occur as low, scree-covered hills on the northwestern side of the St George Ranges. Elsewhere the formation is exposed as scattered rubble on large deflation flats and is mapped as small scattered outcrops. The type section of the formation is at lat. 18°44′35″S, long. 125°37′30″E, near Bruten Hill. The unit thickens from the edge of the basin into the middle of the Fitzroy Trough, and is considered to be Artinskian in age (Guppy & others, 1958).

The *Liveringa Group* as redefined by Yeates & others (1975a) consists of the basal Lightjack Formation, the middle Condren Sandstone, and the upper Hardman Formation. The Hardman Formation is subdivided into three members. All these units were recognised in the Noonkanbah Sheet area and have been identified from the electric logs of coal-exploration bores (Table 4).

The *Lightjack Formation* (Pj) is well exposed in the area and has been intersected in WAPET Mount Hardman No. 1 and many coal-exploration bores (Table 4). Crowe & Towner (1976b) recognise upper, middle, and lower parts, which are well exposed at Lightjack Hill, the type section (lat. 18°59′08″S, long. 125° 50′38″E). Near the base of the Lightjack Formation in the Christmas Creek area, a thin oolitic sandstone bed contains approximately 50% Fe_2O_3; this bed probably correlates with similar deposits described by Edwards (1953) from the adjoining Mount Anderson Sheet area.

Drilling (Galloway & Howell, 1975) indicates that the upper part of the Lightjack Formation is absent in the northwest of the Sheet area (Crowe & Towner, 1976b). The lower part of the formation contains a rich marine fauna which indicates a late Artinskian to Kungurian age (J. M. Dickins, pers. comm.).

Only one exposure of the *Condren Sandstone* (Pr) was recognised in the Sheet area (lat. 18°49′00″S, long. 124°48′15″E). Many coal-exploration bores have intersected the unit, although it pinches out in the northwest (see Table 4). From subsurface data (Galloway & Howell, 1975) and information outside the area (Yeates & others, 1975b) it is evident that the formation thickens south and southeast of the Sheet area.

Several exposures of the *Hardman Formation* (Ph), particularly in the McLarty Syncline region, could not be divided into members as the formation is poorly exposed. North of the Fitzroy River on Noonkanbah and Liveringa Stations, the members were identified mainly in bore logs. The patchy surface exposures were then tied in with the subsurface data. Guppy & others (1958) defined the type section of the Hardman Formation at Mount Hardman (lat. 18°18′45″S, long. 124°38′52″E); this section is now known to represent the uppermost part of the formation, the Cherrabun Member.

The best-exposed section of the lowermost *Kirkby Range Member* (Phk) (Yeates & others, 1975a) occurs just north of the Fitzroy River to the south of Shedforth Bore on the old Fitzroy River road. Drilling (Galloway & Howell, 1975) indicates that the member thickens towards the St George Ranges. The *Hicks Range Sandstone Member* (Phh) (Yeates & others, 1975a) is relatively well exposed at Mount Abbot and Mount Noreen, and also appears to thicken towards the St George Ranges (Galloway & Howell, 1975). The uppermost *Cherrabun Member* (Phc) (Yeates & others, 1975a) is best exposed at Mount Hardman and shows an overall thickening southwards into the McLarty Syncline.

A small area of outcrop southwest of Outcamp Hill is mapped as *undivided Permian* (P). The outcrops consist of weathered sandstone and siltstone which cannot be confidently assigned to formally named units of any of the Early Permian formations.

Mesozoic

Early Triassic

Beds of sandstone exposed in the middle of the McLarty Syncline are tentatively correlated with the basal Triassic *Millyit Sandstone* (Rm). The Millyit Sandstone was described by Yeates & others (1975b) from the Crossland Sheet area where it unconformably overlies the Hardman Formation. The correlation is based on similar lithology and the same stratigraphic relationships. The unit does not occur elsewhere in the Noonkanbah Sheet area.

The *Blina Shale* (Rb) (Brunnschweiler, 1954) crops out very poorly in the area and is mainly covered by pisolitic laterite on Quanbun and Calwynyardah Stations. The best exposures occur in gravel pits along the road between Calwynyardah and Noonkanbah homesteads. McKenzie (1961) has described the diverse fauna from the Blina Shale, and Helby (*in* Galloway & Howell, 1975) has demonstrated that there is a time gap between it and the underlying Hardman Formation. Field evidence suggested to Crowe & Towner (1976b) that the contact between the Triassic and Permian rocks in the Fitzroy Trough is in places an angular unconformity, whereas elsewhere it is disconformable.

Late Jurassic

The term *Wallal Sandstone* (J1) was introduced by McWhae (*in* Johnstone, 1961) for the basal Jurassic sandstone intersected in petroleum exploration wells in the western part of the Canning Basin. The formation is 101 m thick in Total Matches Springs No. 1 well (Total Exploration Australia Pty Ltd, 1970) in the Mount Anderson Sheet area, and probably extends into the southwest corner of the Noonkanbah Sheet area.

Guppy & others (1958) defined the type locality for the *Barbwire Sandstone* (Jb) in the Barbwire Range (lat. 18°58′S, long. 125°01′E). The present mapping has shown that the lower part of the section in the Barbwire Range is part of the Permian Lightjack Formation, and a maximum of 34 m of Barbwire Sandstone is exposed above the angular unconformity which separates the two units. Exposures mapped by Thomas (1958) as James Sandstone (Guppy & others, 1958) are not significantly different from the Barbwire Sandstone and have been included in it.

On the plains around Taylors Bore in the McLarty Syncline there are numerous patches of pebbles and very coarse sand. Such coarse-grained sediment is not known from the underlying Liveringa Group, so these patches of colluvium are thought to be remnants of the Barbwire Sandstone, which is known to occur at places beneath the plains (e.g. at lat. 18°47′05″S, long. 124°40′30″E). If the identifications are correct, they would explain the complex pattern of photo-interpreted trend-lines in the area, and it would imply that the surrounding plains represent an exhumed Jurassic land surface.

Brunnschweiler (1954) defined the *Alexander Formation* (Ja) in the Mount Anderson Sheet area. The exposure at lat. 18°54′30″S, long. 124°37′55″E in the Noonkanbah Sheet area is correlated with the Alexander Formation, as it is similar in lithology and it contains the same species of pelecypods. Other outcrops to the south and west of the locality in the Noonkanbah Sheet area have been photo-interpreted. Brunnschweiler (1954) gives the faunal list for this formation, which indicates a Kimmeridgian to early Tithonian age.

Undivided Mesozoic (M)

Two small exposures south of the Great Northern Highway, near the eastern margin of the Sheet area, consist of sandstone and siltstone which appear to overlie Permian rocks. These outcrops could not be confidently assigned to any known formation.

Mesozoic, possibly Tertiary

The *Fitzroy Lamproite* (fv) (Thomas, 1958a) occurs mainly north of the Fitzroy River, as plugs and dykes which intrude the Permian and Triassic formations. In some places (e.g. White Rocks) contact-metamorphic quartzite rims the intrusions. One new occurrence of a possible Fitzroy Lamproite was recorded in the St George Ranges at lat. 18°43′35″S, long. 124°57′23″E, where the lamproite is intruded along a fault. This small occurrence constitutes the most southerly extent of the Fitzroy Lamproite known in the basin.

The rocks are described by Wade & Prider (1940), Prider (1960), Prider (1969), and Derrick & Gellatly (1972). Jurassic Rb-Sr age determinations were made by Compston (*in* Prider, 1960), and by Kaplan & others (1967). However, more recent K-Ar determinations by Wellman (1973) have given early Miocene ages from 16 to 21 m.y.

CAINOZOIC

The *Lawford Beds* (Czw) (Casey & Wells, 1964) are the deposits of the ancestral Christmas Creek and are confined to its flood plain. The beds crop out as low rises of pebbles and minor cobbles with little matrix. The clasts are well rounded and consist mainly of quartzite. The Lawford Beds are equivalent to the *Warrimbah Conglomerate* (Czh) (Guppy & others, 1958), the deposits of the ancestral Fitzroy River. The clasts in the Warrimbah Conglomerate are mainly of cobble size and are brown whereas those in the Lawford Beds are mainly pebbles and are white. The Warrimbah Conglomerate is mainly confined to within 15 km of the Fitzroy River and is less than 20 m above the present river bed. Pleistocene fossil kangaroo and crocodile bones found at Alligator Dam on Quanbun Station (Glauert, 1921) may come from the Warrimbah Conglomerate. No oldest age limit is known for the unit, so it is referred to as undivided Cainozoic.

Calcrete (Czk) includes both pedogenic and fluvio-lacustrine forms. Small exposures are scattered over the Sheet area but the unit is most common where it flanks the Devonian limestone ranges in the northeast. *Silcrete* (Czs) occurs mainly as a capping to exposures of the Barbwire Sandstone close to the Fenton Fault. A thin siliceous skin (not mapped) is commonly present on exposures of the Grant Group. Pisolitic and massive *laterite* (Czl) is not common in the Noonkanbah Sheet area and is mainly confined to areas underlain by the Blina Shale. Scattered remnants of a laterite cover are also present on the plains overlying the shaly Permian formations but no laterite was found capping the ranges in the area, although it is common on other ranges in the Canning Basin.

Gilgai soil (Qg) (Hallsworth & Beckman, 1969) is mapped where the *black soil* (Qb) has a pattern. Linear or wavy gilgai is the most common form, but lattice gilgai occurs on the plains north of Fitzroy Crossing. *Black soil without gilgai pattern* (Qb) is widespread in the area and forms flat or gently sloping plains which mainly overlie calcareous and argillaceous rocks: similar black soil plains also flank the major drainages of the Sheet area. Qb thus includes both alluvial and residual soils.

Aeolian deposits (Qz) form both plains and longitudinal or seif dunes which can be seen easily on aerial photographs and are shown on the map. More poorly defined sand dunes occur north of the Fitzroy River where they are associated with other Quaternary deposits. All the sand dunes in the Noonkanbah Sheet area can be classified as simple longitudinal dunes (terminology of Crowe, 1975).

Mixed alluvial and aeolian deposits (Qs) constitute the most widespread soil type in the Noonkanbah Sheet area and are characterised by a growth of mixed spinifex and other grasses. *Alluvium* (Qa) includes sediment deposited in claypans as well as fluvial deposits. Where thick alluvium occurs adjacent to the major drainages it is a valuable aquifer, for example at Fitzroy Crossing (Table 5).

STRUCTURE

Tectonic subdivisions

The *Fitzroy Trough* (Reeves, 1951, Playford & others, 1975), the most prominent feature in the area, is essentially a northwest-trending graben bounded on the northeast by the Pinnacle Fault System and on the southwest by the Fenton Fault System. The trough contains up to 7500 m of Palaeozoic and minor Mesozoic sediments, and several west-northwest-trending anticlinal and synclinal

TABLE 5. WATER BORES TESTED IN 1974

Property and bore name	*Salinity (mg/l)*	*Total depth (m)*	*Aquifer*
Brooking Springs			
Kundra	200	—	Czk
Homestead	300	—	D
Homestead well	250	—	D
Peters	200	—	Qa
Calwynyardah			
Meters	700	107	Ph
Little Laymans	675	—	Qa+Ph
Wapet*	340	—	Pn–Pp?
Surprise	925	—	Ph
Cherrabun			
Topyard*	1 300	14	Pn
Rexona	1 550	53	Pn
Blue Bush	8 500	159	Pp
Panorama	2 250	149	Pn–Pj
Paradise	4 500	18	Pj
Old Homestead	90	15	Qa
Gap Creek	2 000	35	Pn
Big Mona	675	27	Pn
Little Mona*	1 225	18	Pn
Cockatoo*	1 400	15	Pn
Surprise	1 275	161	Pn
Alberts	2 400	102	Pp
Gilberts	2 900	66	Pp
Huttons	1 575	—	Pp?
Tank*	1 550	15	Pn
Wye Worry	260	—	Pg
Supplejack	700	—	Pp
Manta Ray	825	—	Pp
Christmas Creek			
Prices Creek	500	33	Pg
Bloodwood	600	49	Pj
Middle*	1 900	—	Pp
Woods*	1 575	28	Pn
Barrys	2 000	49	Pp
Fig Tree	1 900	140	Pn
Poole Range	1 020	91	Pg
Homestead	700	157	Pp
Mt Synnot	900	80	Pg
Warrels	1 350	23	Pp
Foemans	500	122	Pj
Chestnut	800	183	Czw–Pn
Wilkinson	1 550	—	Pg
Brutens Flow*	2 750	—	Pn
Six Mile	320	—	Pj
Hot Springs	850	—	Pn
Flowing*	875	—	Pn
Daws	500	—	Pn
Fitzroy Crossing			
D.C.A.	260	—	Pg
Crossing Inn	300	—	Qa
Post Office	100	—	Qa
Hospital	150	—	Qa
Police Station	250	—	Qa
Fossil Downs			
Homestead	220	21	D
Colins (aerodrome)	140	27	D
Old Station	500	21	D
Nhillabublica	200	9	D
Champagne	200	21	D
Minnie Richie	250	63	D
Red Hill	180	51	D
Boabab	2 000	—	D
Gogo			
No. 1 Outcamp	675	49	Qa+Pn
Forrest	600	33	Qa+Pn
Bobs	430	61	D
Pinbilly	280	15	D
Pillara Spring	180	—	D
No. 2 Outcamp	300	111	D
No. 3 Outcamp	460	73	D
Emanuels	150	30	D
Donalds Mill	550	41	Pg?
Vicziany	200	61	Pg?
Double A	1 260	61	Pg?
Eight Mile	300	15	Pg?
San Maggil	775	50	Pn
River Paddock	200	—	Qa
Jillyardie	220	—	Qa
Laidlaws*	825	—	Pn
New Bore	180	—	D
No. 12	1 500	—	Pp
Mugford	1 600	—	Pp?
Jubilee Downs			
No. 1	1 000	55	Pn?
No. 2	400	37	Pp
No. 3	350	70	Pp
No. 4	450	102	Pg
No. 5	600	107	Pg
No. 7	800	—	Pp
Nine Mile	600	—	Qa
Homestead	200	—	Qa
Kalyeeda			
Rodneys	2 500	91	Ph
Andys	2 900	58	Ph
Daves	4 200	—	Ph
Fentons	1 350	—	Pj
Liveringa–Paradise			
Hardmans Tank	2 500	63	Ph
Roosevelt No. 1	500	98	Ph
Churchill	3 900	96	Ph
Boundary	>15 000	54	Rb
Pyramid	2 800	—	Ph
Robbins	2 000	—	Pn?
Mickeys No. 1	220	13	Ph
Troys	1 400	—	Ph?

TABLE 5. WATER BORES TESTED IN 1974—(*continued*)

Property and bore name	*Salinity (mg/l)*	*Total depth (m)*	*Aquifer*
Quanbun			
Youella	250	58	Pp
Winjimorra	200	73	Pg
Minnie	660	91	Pp?
Leichardt	325	66	Pp
Layman	800	165	Pn?
Furlong	200	62	Pp
Two Mile	3 000	215	Ph
Boab	7 000	46	Pn?
Bowden	660	55	Pj?
Brennon	1 100	63	Ph
Pelican	3 000	—	Ph
Leana	600	—	Ph
Johns	250	—	Ph
Homestead	400	—	Ph?
Salty	10 000	—	Rb
Verity's	3 500	—	Ph?
Roys	>15 000	—	Rb
Spinks	2 000	—	Ph
Desmonds	900	—	Pp
Argies	1 200	—	Ph
Pinjarra	240	—	Pp?
Browns	2 500	—	Ph
Noonkanbah–Millajiddee			
No. 14	2 000	205	Ph
No. 13	1 000	198	Ph?

Property and bore name	*Salinity (mg/l)*	*Total depth (m)*	*Aquifer*
No. 5	1 800	30	Pj
No. 20	1 000	238	Rb
Crosbys	1 075	—	Pj
No. 1	2 800	—	Pn
Mickeys	220	—	Ph
West Kimberley Research Station			
Two Wells	400	—	C–D
Laurel Downs	250	—	Pg
Cockatoo	340	—	Pg?
Jabiru	330	—	Pg?
Kits	300	—	Pg
Limestone	350	—	C–D
Homestead	450	—	Pg
No. 8	300	—	Pg
Margaret River			
bores (2)	120+130	—	Qa
Teal	450	—	C–D
Aboriginal reserve			
Unnamed bore near new bridge	220	—	Qa
Unnamed bore to NW	260	—	Pg

REFERENCE

Qa — Alluvium
Czk — Calcrete
Czw — Warrimbah Conglomerate
Rb — Blina Shale
Ph — Hardman Formation
Pj — Lightjack Formation
Pn — Noonkanbah Formation
Pp — Poole Sandstone
Pg — Grant Group
C–D — Fairfield Group
D — Devonian rocks

* Artesian bore

structures that are cut by numerous en-echelon meridional to north-northwest-trending faults. The trough probably first developed during the Devonian.

To the northeast, the *Lennard Shelf* (Playford & Johnstone, 1959) is an area of relatively shallow basement. The sediments on the shelf thicken basinward and consist mainly of Devonian reef and reef-associated deposits with lesser accumulations of Ordovician, Carboniferous, and Permian rocks. The Precambrian *Pillara Range Inlier* (Sofoulis & Gellatly, 1968) in the shelf area consists mainly of granitoid rocks.

The *Barbwire Terrace,* to the southwest of the Fitzroy Trough, is bounded by the subsurface Dummer Range Fault to the southwest, and the Fenton Fault to the northeast. Basement is 2500 to 3000 m below sea level and probably formed a terrace in the strict sense only from the late Middle Devonian to the late Early Carboniferous.

In the extreme southwest the Sheet area includes a small part of the *Broome Arch* (formerly part of the Broome Platform of Koop, 1966), southwest of the Dummer Range Fault. The arch is a broad area of relatively shallow basement, 2500 m below sea level, which contains gently southward-dipping Palaeozoic sediments.

Faults

Most prominent in the area is the northwest-trending *Fenton Fault System* which dips steeply to the northeast and has a maximum normal throw of 6000 m in pre-Permian rocks (Playford & others, 1975); the maximum throw at Mount Fenton in the Noonkanbah Sheet area (cross-section A-B) is just under 4000 m. During Late Triassic to Jurassic time there was apparently reverse movement along the fault, resulting in the present distribution of younger rocks on the southern side. Since then there has been only minor movement. The apparently reverse movement is believed to have been caused by regional right-lateral shear movements combined with compression of the Fitzroy Trough area between the Kimberley Block to the north and the Broome Arch to the south (Rattigan, 1967; Smith, 1968).

The *Pinnacle Fault System,* of down-to-the-southwest normal faults with about 4000 m of basement displacement, has a similar history to the Fenton Fault System.

The *Dummer Range Fault,* separating the Barbwire Terrace from the Broome Arch, has been identified from seismic surveys (WAPET, 1971a). It is sub-parallel to the Fenton Fault, has down-to-the-northeast normal movement and is believed to have been quiescent since the Permian.

The Fitzroy Trough contains many north-northwest-trending transverse faults arranged en echelon between the bounding Fenton and Pinnacle Faults. Normal faults predominate, although a few reverse faults occur and there are several low-angle thrust faults in the Poole Range that may mark the soles of gravity slide blocks in the upper part of the Grant Group. The normal faults have an average dip of 70°. Fault-plane measurements on slickensides indicate that movements were essentially vertical on about 40 percent of the faults and on the rest movements were at up to 40° from the vertical, averaging 18°. The maximum observed throw in the St George Ranges is 200 m, and the en echelon arrangement of these faults indicates that they were probably formed by the Late Triassic–Jurassic compressive movements on the major faults which bound the Fitzroy Trough (see also Rattigan, 1967).

Folds

The most prominent fold in the area is the *St George Ranges Anticline* and its extension, the *Pool Range–Mount Hutton Anticline* (terms of Guppy & others, 1958). Basically these structures comprise a single west-northwest-trending anticline whose areas of closure are marked by the ranges. Subsidiary folds are associated with each anticline. The whole structure is cut by numerous north–

northwest-trending transverse faults. To the west of the Sheet area the St George Ranges Anticline passes into the Nerrima Anticline.

To the south of this anticlinal belt is the *McLarty Syncline* and to the north is the *Quanbun Syncline* (a new name introduced in an unpublished exploration report by Galloway & Howell, 1975). Other named structures in the Sheet area include the eastern end of the *Mount Wynne Anticline* and the northwestern part of the *Talbot Syncline* (terms of Guppy & others, 1958).

Dips range up to 15°, and are locally steeper next to faults. Most of the folds appear slightly asymmetrical, and drilling (Galloway & Howell, 1975) and mapping suggest that the axial planes dip slightly to the south. There is some evidence (Crowe & Towner, 1976b; Galloway & Howell, 1975) that the major anticlines have acted alternately as positive and negative features during the past; for instance the Poole Sandstone is markedly thicker than in the axial region of the St George Ranges, Mount Hutton, and Poole Range Anticlines, than to the north and south, suggesting faster subsidence in that area while the Poole Sandstone was being deposited (see Crowe & Towner, 1976b), whereas the Wye Worry Member is thinnest in the axial region.

There are numerous small-scale folds associated with faults.

Joints

Joints are common in the more competent units. They are particularly prominent in the Grant Group and show up clearly on aerial photographs. In the St George Ranges Anticline the master joints occur roughly parallel to the axis and minor joints appear to be parallel to the faults.

GEOLOGICAL HISTORY

The earliest recorded event was the deposition of the Halls Creek Group, probably in the Early Proterozoic. This was followed, possibly extending into the Carpentarian, by extrusion of the Whitewater Volcanics and then by intrusion of the Lamboo Complex granitoid rocks. No younger Precambrian rocks are exposed in the Sheet area, but evidence of several periods of Proterozoic tectonism, volcanism, transgression, regression, and erosion, and also of two probable glaciations, is preserved in thick Proterozoic sequences exposed in the adjoining regions to the north and east (Roberts & others, 1968; Derrick & Playford, 1973); related sequences may be present at depth in the Noonkanbah Sheet area.

In the Canning Basin, sedimentation first occurred in the Early Ordovician when a marine transgression deposited sand, mud, and minor carbonate. Deposition of the Carribuddy Formation, probably in the Silurian, took place south of the Lennard Shelf, evidently in a regressive, partly marine and partly evaporitic environment. As regression continued, the continental Tandalgoo Red Beds were laid down, probably in Early Devonian times, in the southwestern part of the area.

Following a period of erosion, a further marine transgression deposited mud, sand, and carbonate (D) in the early Middle Devonian. Subsequently there was a period of block faulting on the Lennard Shelf before the late Middle Devonian and Late Devonian reef complexes started to form. As the reefs were growing, marine-basin deposits of mud, carbonate, and sand were being laid down south of the Lennard Shelf. There was also some contemporaneous faulting on the Lennard Shelf in the Late Devonian.

The reef platforms formed atolls, fringing reefs, and barrier reefs and eventually reached heights of tens to hundreds of metres above the surrounding inter-reef basins. The Pillara Range and Home Range reef complexes developed around an island of Precambrian rocks, while the Emanuel Range complex grew on older, Ordovician carbonates (Gap Creek Formation). The Oscar Range platform also fringed an island of Precambrian rocks (Lennard River Sheet area), and the Geikie Range platform is thought to rest on Precambrian rocks (not exposed). The limestone platforms were normally rimmed by narrow algal or stromatoporoid reefs; these formed barriers around shelf lagoons in which stromatoporoid, cryptalgal, coral, and oolitic limestones were deposited. The marginal-slope facies was deposited largely as talus from the platforms, and depositional dips were commonly as high as 35°. Between the reef masses terrigenous material was laid down in the inter-reef areas (basin facies) and, as the reefs were forming, large alluvial fans of terrigenous gravel were being deposited landward of the reef complexes and interfingering with them (Bobs Bore Conglomerate). It is thought that the gravel was shed from the Kimberley Block during a period of active faulting.

As the reefs became extinct towards the end of the Devonian, carbonate, mud, and minor sand (Gumhole Formation) were deposited in a shallow-marine environment on a broad subtidal platform relatively close to the shoreline (Radke, 1976), the lower part evidently during a transgression, the upper part during a regression. Intertidal and supratidal conditions followed in the latest Devonian to earliest Carboniferous, when sand and carbonate accumulated (Yellow Drum Sandstone). Shallow marine platform conditions then prevailed, firstly carbonate and then muds (Laurel Formation) being deposited. A major regression followed in the Carboniferous, depositing mainly sand in a continental environment (Anderson Formation).

Further uplift and erosion were followed late in the Carboniferous by deposition of the sand, gravel, and minor mud of the Betty Formation in an environment partly continental and partly marine. Tentatively identified glacial erratics (WAPET, 1973) suggest deposition in a glacial environment, or at least in a sea traversed by drifting icebergs. Broadly similar conditions continued into the Early Permian when the land became low-lying and a possible lacustrine environment prevailed, receiving finer-grained sediments (Winifred Formation), although parts of the Winifred are known to be marine in the southern half of the Canning Basin (WAPET, 1966a).

Coarse sand and gravel (undivided Carolyn Formation) may have in part been deposited by rivers. The presence of varves at the base of the Wye Worry Member in the central St George Ranges suggests the muds were deposited in a quiet-standing body of relatively fresh water which contained floating ice depositing glacial erratics. This water body soon became connected to the open sea as indicated by the lack of varves and the presence of a marine fauna. Towards the end of the Sakmarian, the eastern shoreline migrated westwards, depositing regressive shoreline and delta deposits of fine sand and silt (Millajiddee Member); permafrost conditions prevailed in the east and were followed by deposition of glacial outwash and then apparently non-glacial fluviatile deposits (Crowe & Towner, 1976b). The area was then uplifted and eroded, with development of local mudflows and slumps.

The western part of the Sheet area was then flooded by a shallow sea depositing sand, mud, and carbonate, and the eastern part was traversed by rivers bringing in sand and gravel (Nura Nura Member) (Crowe & Towner, 1976c). The diverse fauna indicates a warming of the climate. The whole Sheet area apparently then became part of the shallow-water (possibly lagoonal) environment where fine sand and silt were deposited (Tuckfield Formation). The eastern part of the Sheet area supported vegetation and was eventually covered by coarser material deposited by rivers (Christmas Creek Member). The sea then transgressed the Sheet area (except in the northeast), depositing mud, carbonate, and fine sand (Noonkanbah Formation).

There is no evidence that the rivers, lakes, and shallow seas in which the Poole Sandstone and Noonkanbah Formation were deposited ever occupied the areas where Devonian and Precambrian rocks now crop out, so the Permian seas may have been restricted to much the same area as that occupied by the Permian outcrops today.

After the Noonkanbah Formation was deposited, the area underwent three recognisable regressions and transgressions (Liveringa Group), as an imbricate delta system was laid down in a continually but unevenly subsiding basin (Crowe & Towner, 1976c).

In the earliest Triassic, there was local movement uplift and erosion before fluvial sand and silt were laid down—now preserved (e.g. McLarty Syncline area) as Millyit Sandstone on the southwestern edge of the Fitzroy Trough. In the north, erosion probably continued until the area was covered by very shallow water which deposited mainly mud (Blina Shale). The evidence indicates that the area was exposed subaerially from time to time, suggesting a mudflat environment.

Tectonism followed Triassic deposition and was characterised by reverse movement along the Fenton Fault and the formation of an en echelon series of north-northwest-trending normal faults, particularly in the St George Ranges area. The faulting was accompanied by folding, producing the main anticlines and synclines in the area. Emplacement of the lamproite may have taken place during the Jurassic and was possibly related to the tectonism.

In the Jurassic in the southwest corner of the Sheet area, sand, minor silt, and gravel were laid down in a paralic, largely shallow-marine environment (Wallal Sandstone). The sea then transgressed these deposits and laid down fine sand and mud in a tidal environment (Alexander Formation). At the same time, coarser sand and gravel (Barbwire Sandstone) were being laid down in channels north of the Fenton Fault which are inferred to have debouched into the sea, possibly forming deltas.

During the rest of the Mesozoic and in the Cainozoic, subaerial erosion continued, and the major drainage lines began to develop. Minor post-Mesozoic uplift (early Tertiary) is thought to have modified the drainage patterns (Brunnschweiler, 1957; Wright, 1964). The only record of possibly pre-Quaternary sedimentation is the gravel along Christmas Creek (Lawford Beds) and the Fitzroy River (Warrimbah Conglomerate). Deep chemical weathering affected part of the area during a humid climatic period, and laterite surfaces developed. It is possible that the lamproites were emplaced in the early Miocene. As the climate became drier, extensive alluvial plains formed. Deposition of alluvium has continued up to the present. With the onset of arid conditions, the laterite was eroded and ranges and hills formed; and the unconsolidated alluvial deposits were blown and sorted by dominant easterly winds to produce dune fields.

Petroleum

Six of the eight petroleum exploration wells in the area have recorded shows of oil and gas (Table 2), but no fields have been found.

Burne & Kantsler (1977) have discussed reasons for the limited quantities of hydrocarbons recovered so far from the wells in the Canning Basin. They consider that the most suitable source rocks are Ordovician, and Middle Devonian to Early Carboniferous. The Late Carboniferous to Permian sediments are immature except in some of the anticlines in the Fitzroy Trough. Indicators of the level of organic metamorphism, well temperature data, and information on potential reservoirs suggested to Burne & Kantsler that certain Devonian, Carboniferous, and Permian sediments of the Lennard Shelf and Fitzroy Trough have the greatest potential for the commercial discovery of liquid and gaseous hydrocarbons; however, despite extensive drilling in these areas, the limited recovery of hydrocarbons to date is attributed by these authors generally to breaching of structure by early Mesozoic erosion, lack of porosity or flushing of reservoirs, unsuitable traps, and lack of potential source rocks. In 1980, petroleum exploration was continuing in the Sheet area, the main targets being Devonian reefs.

Coal

Bores drilled for coal exploration in the area are shown on the map. Figures 4–6 tabulate these bores and give a stratigraphic interpretation of the rock units and coal intersected. The middle part of the Lightjack Formation contains the most widespread and thickest coal seams (maximum thickness 2 m). However, the coal is of low rank (sub-bituminous to bituminous), and contains thin sandstone interbeds, and the overburden ratio throughout much of the area is fairly high. Parts of the Hardman Formation also contain thin coal seams.

Coal is also recorded from the Poole Sandstone in Warrells Bore, a water bore, to the east of the Poole Range. The occurrence of many root horizons in outcrops of the Poole Sandstone suggests this unit may be prospective. Traces of coal have also been recorded in the Grant Group (Galloway & Howell, 1975).

Diamonds

Exploration for diamonds has taken place in the Sheet area following a suggestion by Prider (1960) that the Fitzroy Lamproite is genetically related to kimberlite. Exploration by three companies has included aeromagnetic, radiometric, drilling, and surface sampling surveys but no diamonds or indicator minerals have been found within the Sheet area. However, some diamonds have been recovered in the Lennard River Sheet area to the north, following the discovery of a number of kimberlite plugs.

Lead and zinc

Two lead–zinc orebodies were mined intermittently from 1906 to 1964 in the Devonian Napier Formation at Narlarla in the Lennard River Sheet area to the north (Halligan, 1965). Exploration has been aimed at Mississippi Valley-type lead–zinc deposits in the Devonian rocks in the Noonkanbah Sheet area, based on the general similarity of the Canning Basin Devonian reef limestones to those in Canada (see Playford, 1969). Geochemical and aerial surveys have been carried

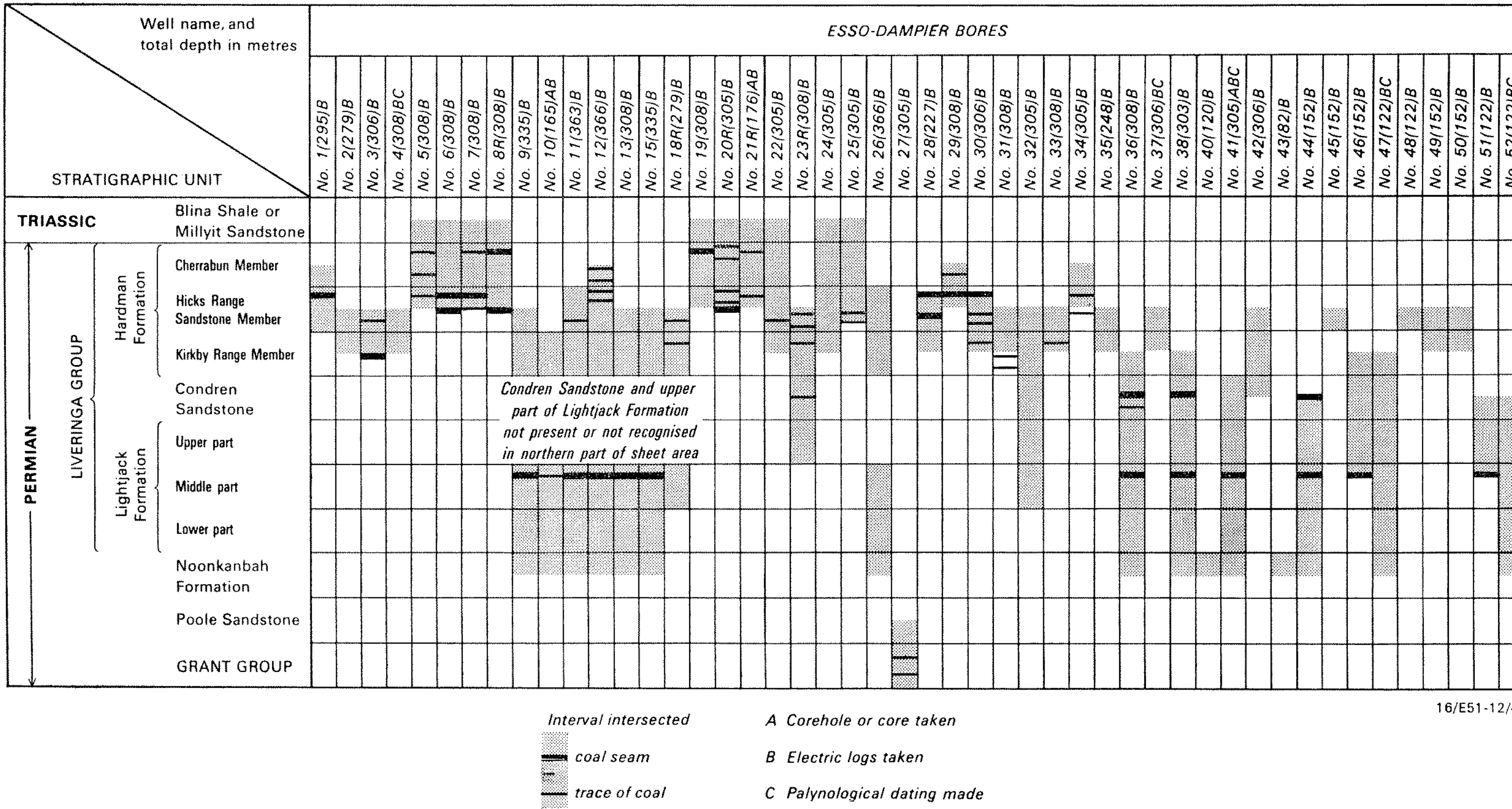

Fig. 4. Permian coal exploration bores: Esso Exploration & Production Australia Inc./Dampier Mining Co. Pty Ltd.

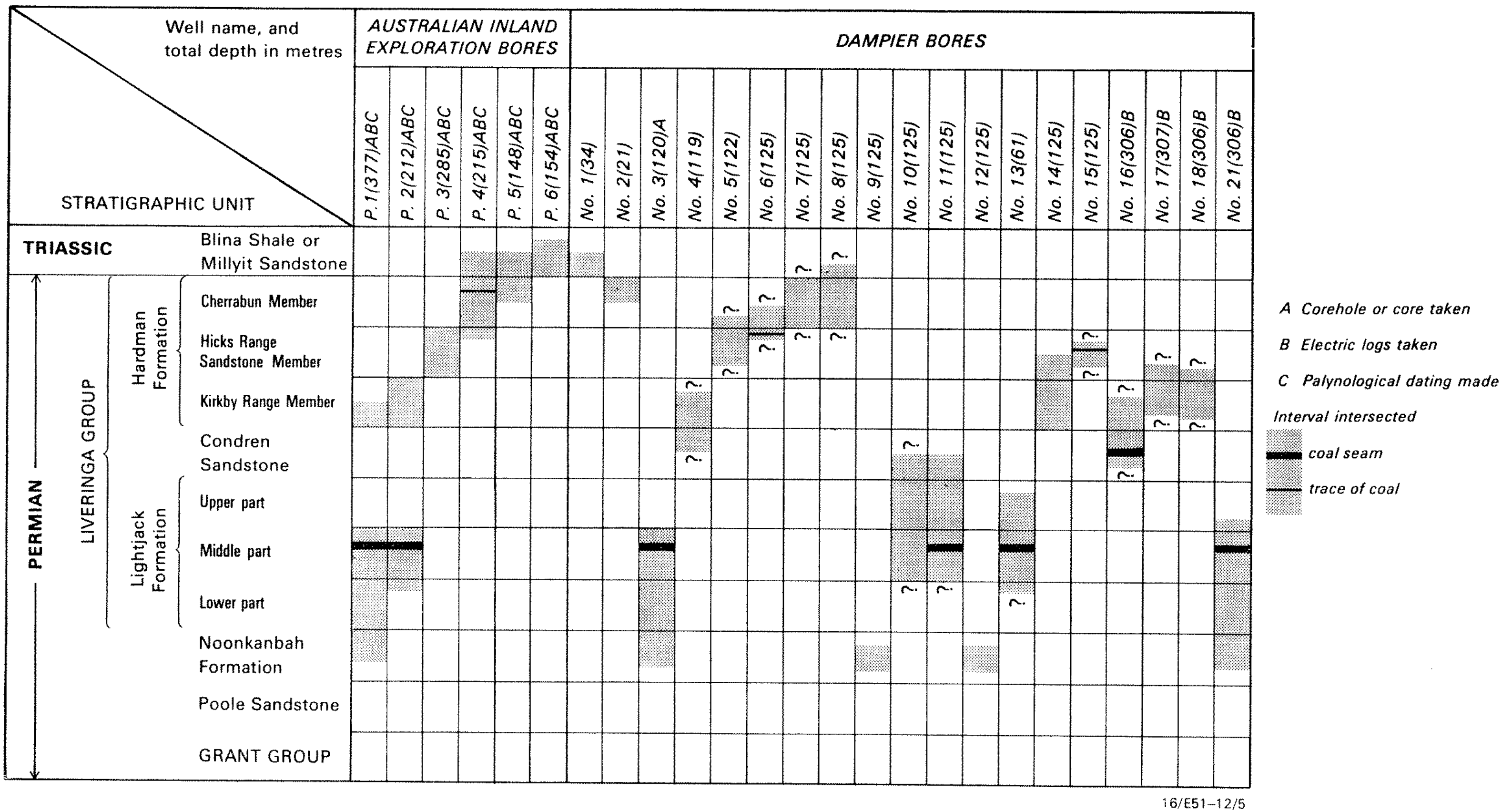

Fig. 5. Permian coal exploration bores: Australian Inland Exploration; Dampier Mining Co. Pty Ltd.

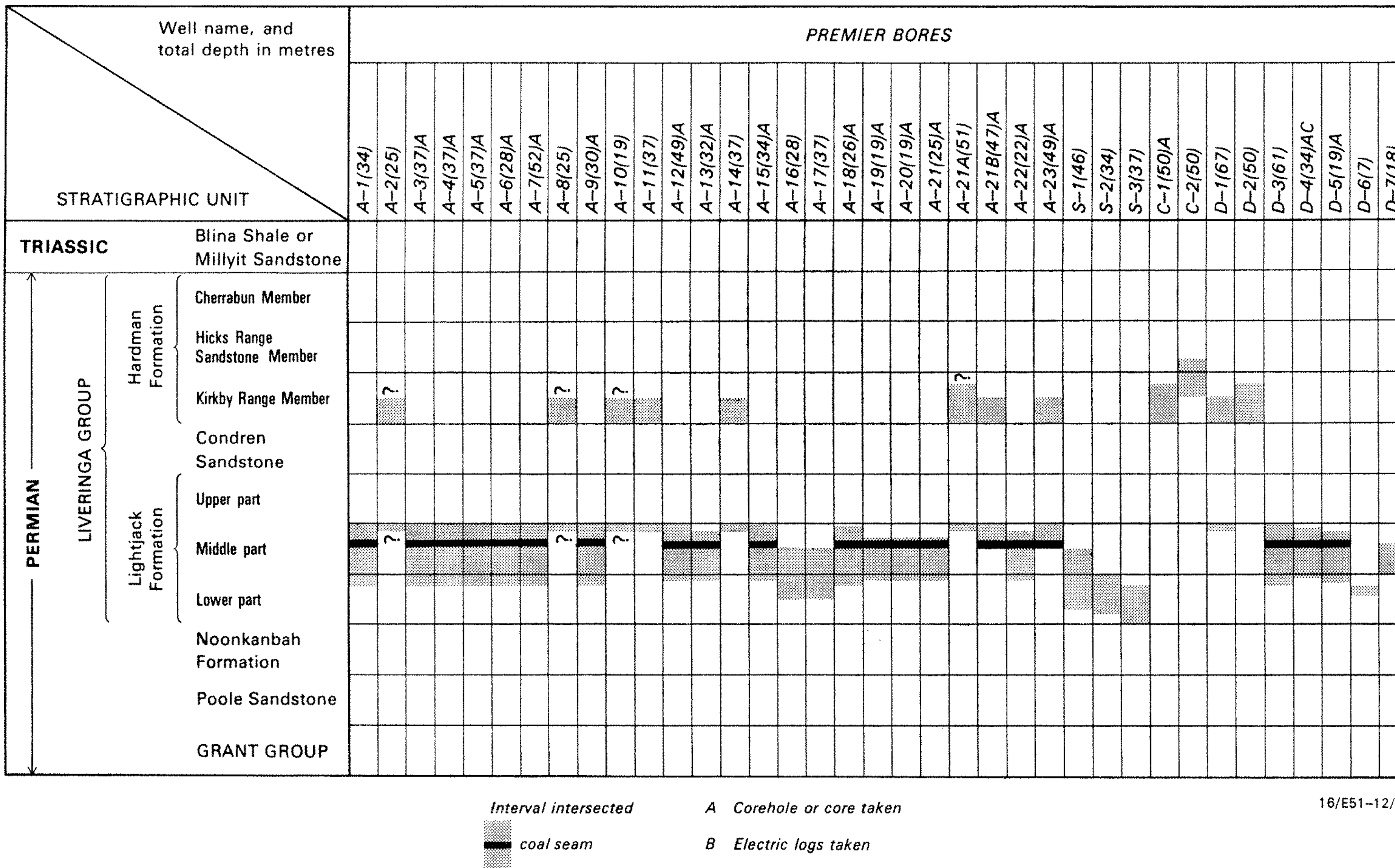

Fig. 6. Permian coal exploration bores: Premier Mining Co. Pty Ltd.

out to find gossans and prospective areas, and this work has in many cases been followed up with induced polarisation surveys (i.e. CRA, 1965–66). Drilling of these prospects has in some cases proved disappointing because the sulphide mineralisation has been mainly pyrite; in other areas galena and minor sphalerite have been discovered. Exploration in the area by several companies was continuing at the time of writing.

Phosphate

One company has explored for phosphate in the area (Russell, 1966), the main target being the Triassic Blina Shale. Although the Blina Shale does have a higher than normal phosphate content, no economic discoveries have been made.

GROUNDWATER RESOURCES

As indicated by Guppy & others (1958), the most prospective units for groundwater are the Grant Group and the Quaternary alluvial deposits along the major drainages; other good aquifers exist in Devonian rocks, the Poole Sandstone, the middle part of the Lightjack Formation, and in several parts of the Hardman Formation. The least permeable units are the Blina Shale, the Noonkanbah Formation, and parts of the Devonian sequence, although the Noonkanbah Formation does contain some artesian aquifers.

Table 5 lists the salinity of each water bore that was tested during the 1974 field mapping survey. The salinity figures given are for total dissolved salts (mg/L) and are approximate.

Also shown in Table 5 is an interpretation, for each bore, of the rock unit that contains the main producing aquifer.

Below are shown the average salinities of water from the rock units, as calculated from Table 5 (these figures do not take account of the many unsuccessful bores that have been drilled in the area).

Quaternary alluvium (Qa)	—	500 mg/L
Blina Shale (Rb)	—	13 300 mg/L
Hardman Formation (Ph)	—	1775 mg/L
Lightjack Formation (Pj)	—	1450 mg/L
Noonkanbah Formation (Pn)	—	1600 mg/L
Poole Sandstone (Pp)	—	1100 mg/L
Grant Group (Pg)	—	500 mg/L
Devonian limestone, shale & conglomerate (D)	—	350 mg/L

The area to the southwest of the Fenton Fault has not been tested; drilling in that area would probably encounter permeable Jurassic sandstone, which contains potable groundwater in adjoining Sheet areas.

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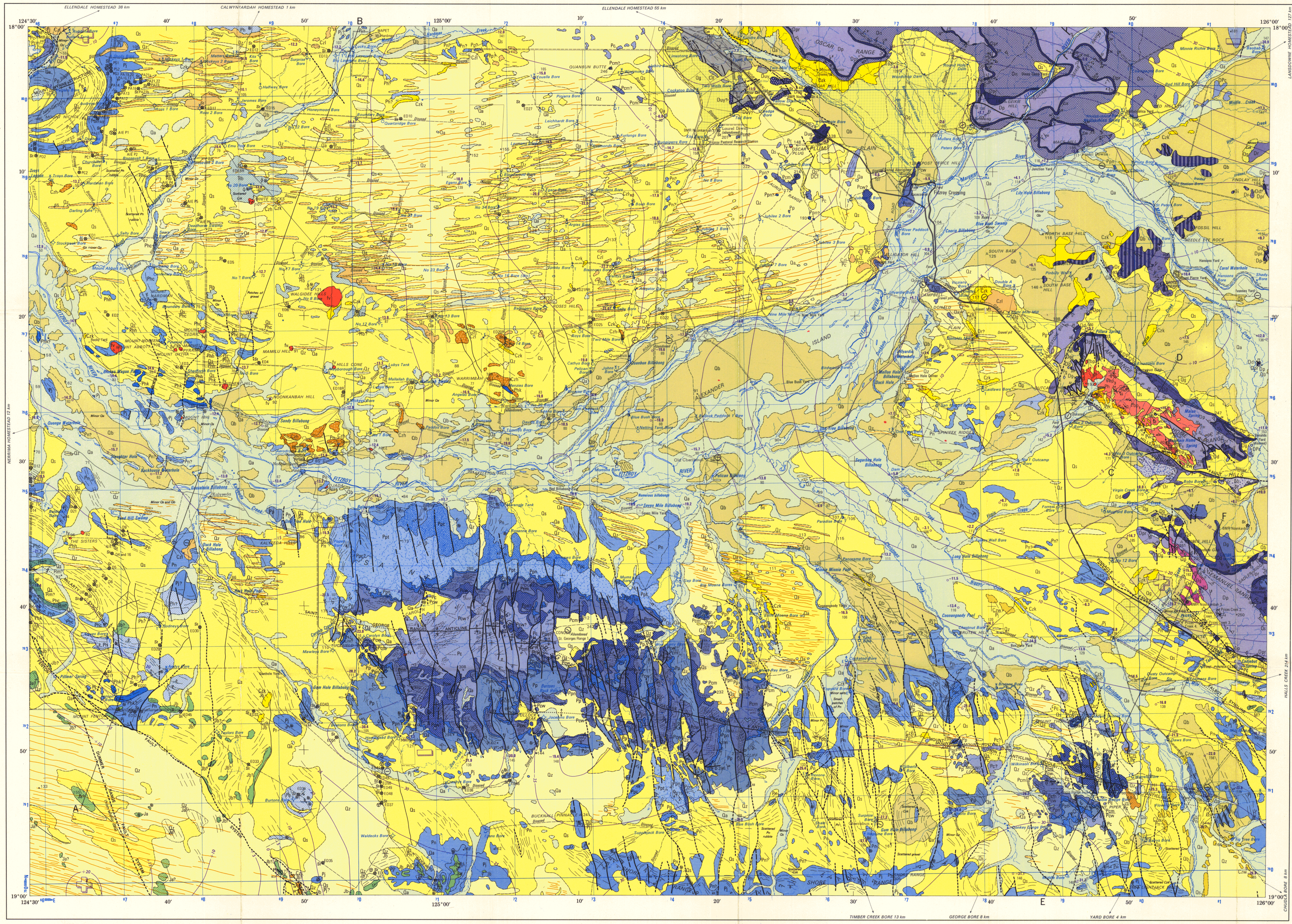
NOONKANBAH

WESTERN AUSTRALIA

AUSTRALIA 1:250 000 GEOLOGICAL SERIES

SHEET SE 51-12

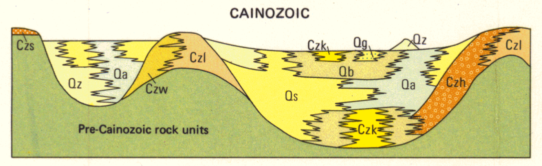


Reference

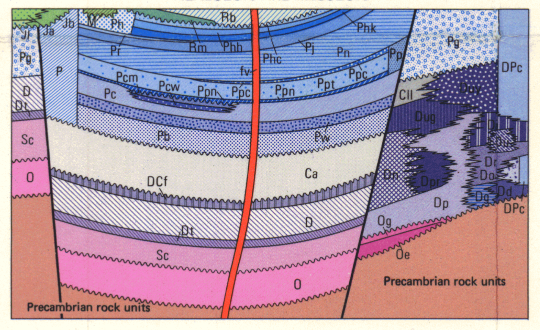
CAINOZOIC	QUATERNARY		Qa	Mud, silt, sand, gravel: alluvial
			Qs	Sand, silt; minor gravel; fossiliferous: mixed alluvial and aeolian
			Qz	Red sand; minor silt: aeolian
			Qg	Heave soil (gilgai): pedogenic
			Qb	Clay, silt; minor gypsum, black soil: pedogenic
			Czl	Pisolitic and massive laterite: pedogenic
			Czs	Silcrete: weathering product
			Czk	Calcrete; minor chalcedony: evaporitic, pedogenic
		Warrimbah Conglomerate	Czh	Conglomerate, cobble and pebble, unconsolidated: fluvial
		Lawford Beds	Czw	Conglomerate, cobble and pebble, unconsolidated: fluvial
	MESOZOIC POSSIBLY TERTIARY	Fitzroy Lamproite	fv	Leucite lamproite
MESOZOIC			M	Sandstone, fine; siltstone, micaceous, laminated to thin-bedded
	LATE JURASSIC	Alexander Formation	Ja	Sandstone, fine to medium; minor siltstone; fossiliferous: marine
		Barbwire Sandstone	Jb	Sandstone, fine, medium and coarse; conglomerate, siltstone; cross-beded; plant fossils: fluvial
		Wallal Sandstone	Jl	Sandstone; minor siltstone, conglomerate. Rock relationship diagram only
	EARLY TRIASSIC	Blina Shale	Rb	Mudstone, sandy mudstone; minor sandstone; thin-bedded, laminated; fossiliferous: brackish water
		Millyit Sandstone	Rm	Sandstone, fine; minor siltstone; thin-bedded, ripple marks: continental
PALAEOZOIC			P	Siltstone, shale, sandstone
	LATE PERMIAN	Liveringa Group: Hardman Formation	Ph	Sandstone, fine, siltstone, thin-bedded; ferruginised
		Cherrabun Member	Phc	Mudstone, calcareous, fossiliferous in lower part, sandstone, cross-bedded; minor limestone in upper part: regressive marine
		Hicks Range Sandstone Member	Phh	Sandstone, mudstone; minor siltstone, some cross-bedding; plant fossils: lagoonal to fluvial
		Kirkby Range Member	Phk	Mudstone, fine sandstone, calcareous, laminated to thin-bedded, cross-bedded in upper part; fossiliferous: regressive marine
		Condren Sandstone	Pr	Sandstone, medium to coarse, conglomeratic, poorly sorted, cross-bedded: fluvial
	EARLY TO LATE PERMIAN	Lightjack Formation	Pj	Shale, siltstone in lower part, fossiliferous; fine sandstone in middle part, plant fossils; siltstone, sandstone in upper part; trace fossils: regressive marine
	EARLY PERMIAN	Noonkanbah Formation	Pn	Mudstone, shale, fine sandstone, calcareous; minor limestone; fossiliferous: marine
		Poole Sandstone	Pp	Sandstone, mudstone
		Christmas Creek Member	Ppc	Sandstone, poorly sorted, conglomerate, cross-bedded: fluvial
		Tuckfield Member	Ppt	Sandstone, very fine to fine; abundant ripple marks, cross bedded, thin bedded, clay pellets, conglomerate lenses, minor siltstone; plant fossils: lagoonal
		Nura Nura Member	Ppn	In west sandstone, siltstone, thin-bedded, calcareous; marine fossils. In east sandstone, conglomerate; cross-bedded, root horizons: fluvial to marine
		Grant Group	Pg	Sandstone, mudstone; minor conglomerate
		Millajiddee Member	Pcm	Sandstone, fine to medium, siltstone; cross-bedded in middle part, slumped in upper part: regressive marine
		Wye Worry Member	Pcw	Siltstone, claystone, graded in lowermost part, calcareous mudstone, concretions, facetted and striated dropstones, poorly bedded; marine fossils: glacial lacustrine to marine
		Carolyn Formation	Pc	Sandstone, medium to coarse, massive to poorly bedded, cross-bedded; minor conglomerate
	LATE CARBONIFEROUS TO EARLY PERMIAN	Winifred Formation	Pw	Siltstone, shale, calcareous, carbonaceous; minor fine sandstone (rock relationship diagram only)
		Betty Formation	Pb	Sandstone, very fine to coarse; minor conglomerate (rock relationship diagram only)
	CARBONIFEROUS	Anderson Formation	Ca	Sandstone, siltstone, shale; minor limestone, dolomite, anhydrite. Section only
	LATE DEVONIAN TO EARLY CARBONIFEROUS	Fairfield Group	DCf	Limestone, shale, siltstone; minor dolomite, sandstone
		Laurel Formation	Cll	Limestone, shale, siltstone, sandstone; fossiliferous: shallow marine
	LATE DEVONIAN FAMENNIAN	Yellow Drum Sandstone	Duy	Sandstone, dolomite, minor shale, siltstone, limestone: fossiliferous: fluvial to intertidal
		Gumhole Formation	Dug	Limestone, siltstone, shale; minor sandstone, dolomite; fossiliferous: shallow marine
	DEVONIAN OR PERMIAN?		DPc	Conglomerate, boulder, cobble and pebble, sandstone
	DEVONIAN		D	Siltstone, shale, sandstone; minor limestone, dolomite; fossiliferous. Section only
	LATE DEVONIAN: FAMENNIAN	Piker Hills Formation	Di	Calcarenite, calcirudite, shale, siltstone, calcilutite; fossiliferous: basin and marginal slope facies
		Bugle Gap Limestone	Du	Calcarenite, white to pink, medium to thick-bedded, grading to calcirudite; fossiliferous: marginal slope facies
	FRASNIAN TO FAMENNIAN	Napier Formation	Dn	Calcarenite, red to light grey, siltstone, shale, sandstone; fossiliferous: marginal-slope and basin facies
		Virgin Hills Formation	Dr	Siltstone, calcareous, interbedded shale, very fine sandstone, calcilutite, calcarenite, calcirudite; fossiliferous: basin and marginal slope facies
	FRASNIAN TO FAMENNIAN?	Bobs Bore Conglomerate	Do	Conglomerate, boulder, cobble and pebble, sandstone
	MIDDLE TO LATE DEVONIAN: GIVETIAN? TO FRASNIAN	Pillara Limestone	Dp	Limestone, algal, stromatoporoid and coral, oolite, yellow to light grey, medium-bedded, calcarenite, calcilutite; fossiliferous: platform facies
			Dpr	Limestone, yellow to white, massive to very poorly bedded, dolomitised in part; fossiliferous: reef margin sub-facies
		Sadler Limestone	Dd	Calcarenite, yellow to light grey, grading into calcirudite, calcareous siltstone and shale; fossiliferous: marginal slope facies
		Gogo Formation	Dg	Shale and siltstone, black to light grey with characteristic limestone concretions; minor limestone beds; fossiliferious: basin facies
	EARLY DEVONIAN	Tandalgoo Red Beds	Dt	Sandstone, claystone, siltstone; minor dolomite (section and rock relationship diagram only)
	LATE ORDOVICIAN? TO EARLY DEVONIAN	Carribuddy Formation	Sc	Siltstone, claystone, sandstone, dolomite; minor limestone, anhydrite (section and rock relationship diagram only)
	ORDOVICIAN	Prices Creek Group	O	Siltstone, sandstone, shale; minor dolomite, limestone (section and rock relationship diagram only)
		Gap Creek Formation	Og	Dolomite, silty dolomitic limestone, sandstone; fossiliferous: marine
		Emanuel Formation	Oe	Limestone, shale; fossiliferous: marine
PRECAMBRIAN	PROTEROZOIC	Lamboo Complex	ap	Aplite, aplite dyke; minor acid intrusives
			q	Quartz vein
			Pbp₃	Tonalite, microtonalite; minor granodiorite
			Pbp₂	Biotite granodiorite
			Pbp₁	Biotite adamellite; minor granodiorite
		Whitewater Volcanics	Pw	Ash-flow tuff, porphyritic, rhyolitic
		Halls Creek Group	Ph	Pelitic schist; minor semipelitic quartz-biotite schist
			p€	Igneous, metamorphic and sedimentary rocks

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

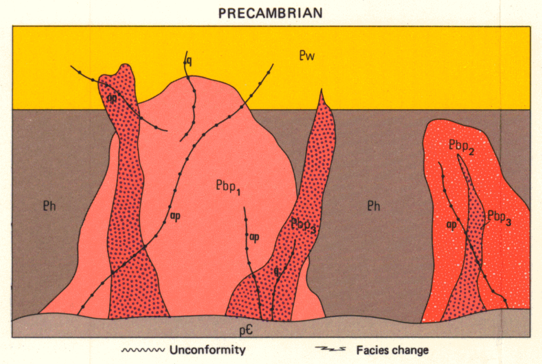
CAINOZOIC

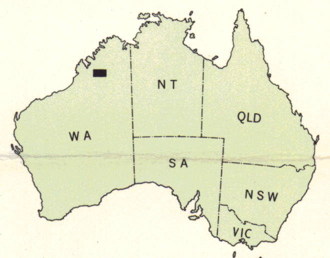


PALAEOZOIC AND MESOZOIC



PRECAMBRIAN





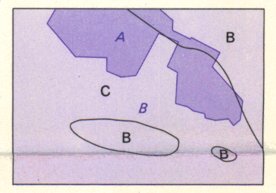
INDEX TO ADJOINING SHEETS

SCALE 1:250 000

BLUE NUMBERED LINES ARE 10 000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 51

TRANSVERSE MERCATOR PROJECTION

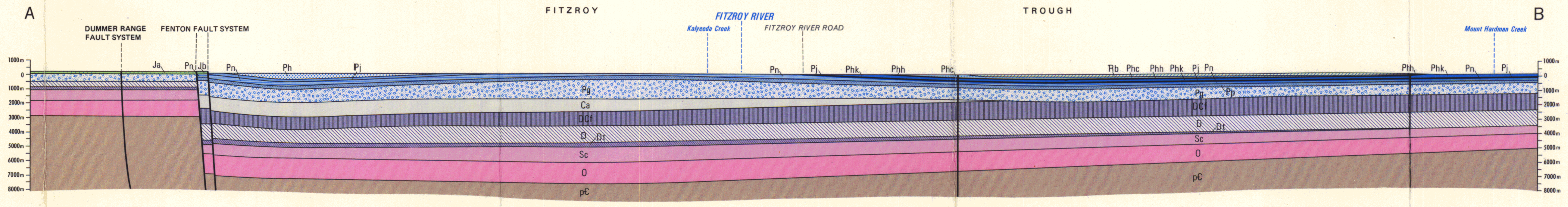
RELIABILITY DIAGRAM

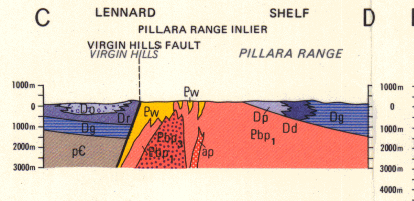


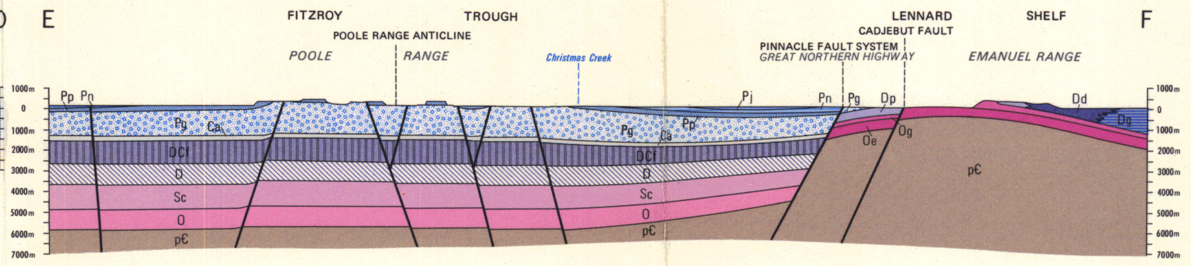
Geology: B Detailed reconnaissance: numerous traverses and airphoto interpretation; C General reconnaissance: many traverses and airphoto interpretation. Gravity: A Detailed survey; B Reconnaissance

SCHEMATIC SECTIONS

Cainozoic sediments omitted







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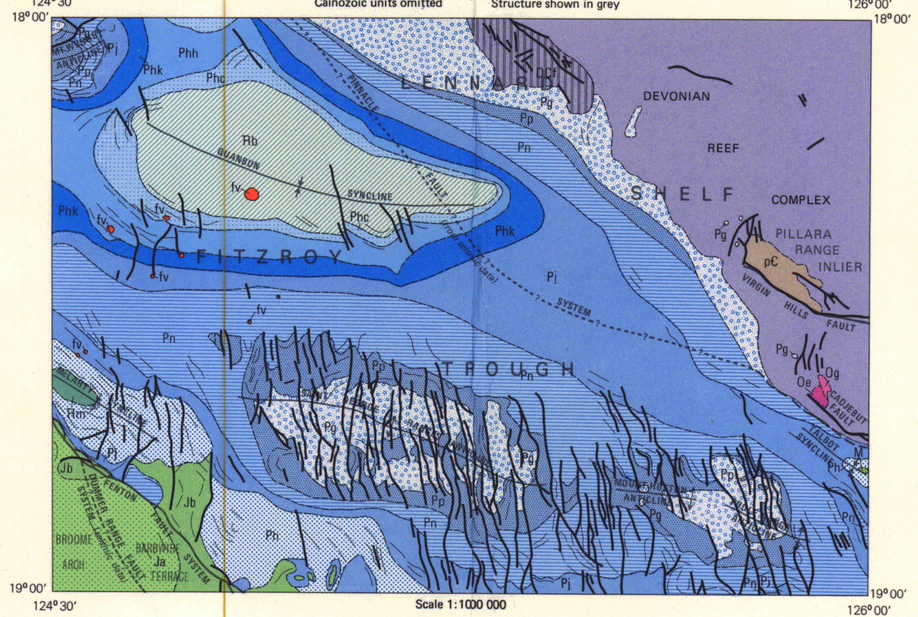
SIMPLIFIED GEOLOGY

Cainozoic units omitted. Structure shown in grey



SECOND EDITION 1980

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SHEET SE 51-12

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