NORTHERN TERRITORY GEOLOGICAL SURVEY

1:250 000 Geological Map Series
Explanatory Notes

ELKEDRA SF53-7
# 1:250 000 GEOLOGICAL MAP SERIES

## EXPLANATORY NOTES

### ELKEDRA SF53-7

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Figure 1 Location and access.
ABSTRACT

This report, based on mapping in 1982-83 and stratigraphic drilling in 1983-85, describes the geology and mineral resources of the Elkedra 1:250 000 map sheet area (ELKEDRA*).

Early Proterozoic rocks form the Davenport Range in the northwestern part of ELKEDRA. They consist predominantly of a 10 000 m thick sequence of ridgeforming quartz arenites, associated shallow-water sediments, and felsic and mafic volcanics which together constitute the Hatches Creek Group. This sequence was intruded by a series of comagmatic mafic and felsic sills, folded and refolded into large elongated dome-and-basin structures, regionally metamorphosed to lower greenschist facies, and intruded by the 1660 Ma Elkedra Granite.

Flat-lying, poorly exposed, late Proterozoic and Palaeozoic sediments of the epicontinental Georgina Basin sequence unconformably overlie Early Proterozoic rocks across the remainder of ELKEDRA. The basal sediments of this sequence are restricted to deeper troughs in the basin, and consist of red beds of probable Vendian age. An Early Cambrian alluvial fan sequence, the Andagera Formation, occurs in and around the Davenport Range. In the main basin a shoaling carbonate unit, the Errarra Formation, is the oldest Cambrian deposit, conformably overlain by subtidal organic-rich sediments of the Middle Cambrian Arthur Creek Formation. The Arthur Creek Formation interdigitates laterally to the west with shoal, supratidal and evaporitic sediments of the Chapalow Formation. Both formations are conformably overlain by supratidal to shallow-marine carbonates of the Middle to Late Cambrian Arrinthuranga Formation. Disconformably above this are Late Cambrian shallow-marine sandstones of the Tomahawk beds followed by an erosional hiatus. The aeolian to shallow freshwater Dulcie Sandstone of Early to Middle Devonian age crops out in southwestern ELKEDRA. The Georgina Basin sequence is up to about 1500 m thick in ELKEDRA, thickening towards the southeast.

Faulting and minor warping affect the early Palaeozoic rocks in some areas and were probably synchronous with the Carboniferous Alice Springs Orogeny.

Remnants of a clastic sequence of possible Mesozoic age are preserved in the southeastern part of ELKEDRA.

Deep weathering profiles, with silcrete and ferricrete duricrusts, developed during the Tertiary. Quaternary soils, sand, colluvium and alluvium blanket much of the area.

A few shows of wolframatite have been found in the Early Proterozoic basement. In the Georgina Basin sequence the Arthur Creek Formation has been investigated for phosphorite and turquoise in the past and is a good potential source for hydrocarbons of varying maturity, being both oil-prone and gas-prone. Oil stains and bleeds have been encountered in drill holes in the adjacent Chapalowe Formation and overlying Arrinthuranga Formation and there is potential for base metal mineralisation in the same units. Several Palaeozoic formations and Tertiary river channels have good groundwater supplies.

INTRODUCTION

These explanatory notes describe the geology and mineral resources of ELKEDRA, which covers an area of 17 050 km² between latitudes 21°00' and 22°00' south and longitudes 135°00' and 136°30' east (Figure 1).

The area contains two major geological units: a folded Early Proterozoic basement located in the northwestern corner of the Sheet, and a flatlying Late Proterozoic to Palaeozoic sequence of mainly Cambrian age. The Early Proterozoic rocks are part of the Tennant Creek Block and the Palaeozoic sequence represents part of the western margin of the Georgina Basin.

The first 1:250 000 geological map of ELKEDRA was published by the Bureau of Mineral Resources (BMR) in 1966. Revision of this work began in 1981 when BMR and the Northern Territory Geological Survey (NTGS) undertook a joint geological survey, known as the Davenport Project, in the southern part of the Tennant Creek Block, including the northwestern corner of ELKEDRA. This survey evaluated the gold-tungsten potential of the area, known as the Davenport province, and led to a complete redefinition of the Early Proterozoic Hatches Creek Group (Blake and others, 1985). The revised Early Proterozoic geology has been published by BMR as a special Elkedra region 1:100 000 map and commentary (Blake and Horstfall, 1987).

Mapping of the surrounding Palaeozoic sequence was initiated by NTGS as a separate project in 1983. In ELKEDRA the work was supplemented by the drilling of six stratigraphic core holes, resulting in a significant revision of the Palaeozoic stratigraphy. Two earlier informal units (Sandover beds, Mceta beds; Smith and Milligan, 1966) have been discarded, two new formations (Andagera, Chapalowe) are defined, and a third, unnamed formation of possible Mesozoic age has been recognised.

In addition three new subsurface units have been discovered (a clastic unit of Late Proterozoic age, a dolostone unit equivalent to the Errara Formation, and an evaporite-rich unit defined as the Hagen Member). The distribution of several formations, particularly the Arrinthuranga Formation and Tomahawk beds, is substantially revised. Of economic significance has been the discovery of many small hydrocarbon shows, believed to originate from the Arthur Creek Formation.

The following account and accompanying 1:250000 map incorporate the results of both projects but with added emphasis on the Palaeozoic geology.

Terms used are as defined in Bates and Jackson (1980). Plutonic rocks have been classified according to Streckeisen (1973). Proterozoic subdivisions with time boundaries at 1600 and 900 Ma follow the recommendations of Plumb and James (1986).
Figure 2 Physiographic divisions.
Habitation and access

The area is sparsely settled and supports a beef cattle industry. Permanent habitation is confined to four pastoral lease homesteads at Elkeda, Ammaroo, Annitowa and Ooratippa. Small aboriginal settlements have been established in three localities: the Iruvja community near the northern boundary of Utopia pastoral lease, the Ampalawatja community just west of Honeymoon Bore on Ammaroo pastoral lease and the Atmungurra community, also on Ammaroo, at the Sandover River crossing to Bluebush Bore.

The main access from Alice Springs is the Sandover Highway, a good gravel road which enters the southwestern corner of ELKEDRA and crosses in an easterly direction (Figure 1). All homesteads are linked by graded roads to the Highway. Near Ammaroo homestead a formed gravel road heads north and west via Murray Downs to connect with the sealed Stuart Highway south of Wauchope. Tracks to waterbores and along fences provide reasonable access to much of the area. The rest of the country is accessible by 4-wheel drive vehicle but is impeded by steep-sided ridges in the northwest and by dense mulga (Acacia aneura) scrub in the west.

Climate

The climate is semi-arid with long hot summers and mild winters. Temperatures show marked seasonal and diurnal fluctuation, the mean maxima and minima ranging from 36°C to 23°C in January and 22°C to 7°C in July (Slatyer, 1962). Average annual rainfall is 275 mm, of which about 250 mm falls between November and March and about 25 mm during the winter months; the rainfall is unreliable and droughts are common. Humidity values show little fluctuation, ranging between 20-30%.

Topography and drainage

The topography of ELKEDRA is largely influenced by the two major geological units. The folded Early Proterozoic strata in the northwest form the upland topography of the Davenport Range whereas the flatlying Georgina Basin sequence across the remainder of ELKEDRA is covered by a mature peneplain with low isolated hills and plateaus (Figure 2).

The Davenport Range consists of broad and sinuous strike ridges, approximately 60-120 m high, separated by wide flat valleys. The ridges have bevelled crests which slope very gradually to the east and southeast. This bevelled surface, known as the Ashburton Surface, is the oldest and highest of the two surfaces recognised in the region by Hays (1967); in ELKEDRA its elevation ranges from a maximum of about 600 m above sea level in the northwestern corner to just under 500 m near Tosca Mine. Its age was regarded as pre-Cretaceous by Hays (1967) and Mabbutt (1967), and is inferred to be Cambrian or older by Stewart and others (1986) who interpret the surface as pre-Andagera Formation. This is discussed further under 'Andagera Formation'.

The peneplain over the Georgina Basin has a gradual slope from west to east, declining approximately 100 m in 150 km. Five different components can be recognised. Three of these — the soil plains, low dissected plateaus and low isolated hills — constitute the second surface recognised by Hays (1967), termed the Tennant Creek Surface. The other two components, consisting of extensive areas of more recent sandplain and floodplain, are superimposed over this surface as shown in Figure 2.

The Tennant Creek Surface is a product of a long period of erosion and deep weathering in the Tertiary (Langford-Smith, 1983). This Tertiary erosion has produced a flat tree-covered, deeply weathered soil plain on the southern margin of the Davenport Range, relieved by a few low ridges and very low stony rises partly covered with a lateritic gravel. Towards the southeastern end of the Davenport Range the plain becomes a subdued plateau, with a relief of 10-30 m, dissected by a close-branching pattern of short valleys.

Another mature poorly drained plain is developed over dolostone in OORATIPPA to the south of the Sandover River, at an altitude of about 330 m above sea level. It is punctuated by occasional sandstone buttes up to about 10 m high, and in the extreme southeastern corner passes into a slightly elevated area of benches sandstone and dolostone mesas.

The sandplain covers much of the southern and eastern part of ELKEDRA and is relieved by the low scarp of the Dulcie Range in southern AMMAROO and by low dissected hills on ANNITOWA pastoral lease. Northwest-trending longitudinal dunes have developed in the northeast and central-south.

ELKEDRA is drained by two east-flowing river systems, the Sandover-Bundey system and the Elkeda system. These rivers deposit their alluvium in the sandplains and have long been severed from their original destination, the Georgina River in Queensland, about 150-200 km east of ELKEDRA. The Sandover and Bundey rivers are part of a braided alluvial fan derived from the Harts Range, south of ELKEDRA. Relicts of several palaeochannels are evident. The Sandover River falls from 410 m at the southwestern corner to 290 m on a floodout at the eastern margin, a gradient of 0.7 m per km. The Elkeda River drains the Davenport Range, having a gradient of 1.5 m per km within the range, and 0.8 m per km across the sandplain to ANNITOWA, the lowest area on the map at about 260 m above sea level.

With these very low gradients, floodplains are developed along both river systems, particularly where the drainage channels have been diverted by areas of outcrop. The lower end of each floodplain is covered by aeolian sand.

Vegetation

The following description is summarised from Perry and others (1962) and Perry and Lazarides (1962).

In the Davenport Range and the dissected siltstone plateau to the southeast, the strike ridges and hills have shallow stony soils with sparse shrubby and low trees such as snappy gum (Eucalyptus brevifolia) over varieties of spinifex (Triodia sp.). The extensive red earth plains to the southwest of the ranges are well covered with mulga scrub (Acacia aneura); where limestones occur, Georgina gidyea (A. georginiae) is developed.

The dolostone plateaus and plains in ANNITOWA and OORATIPPA have little soil and are sparsely covered with low witchetty bush (A. kempeana) and gidyea over short grass or spinifex. The shallow drain-
age floors across the Ooratippra plain support mulga and coolibah (*E. microtheca*).

Sandplains have a cover of spinifex (*Triodia and Plectranche sp.*), with sparse shrubs and low trees, mainly *E. brefolia*. Alluvial depressions between sand dunes contain stands of mulga.

River and stream channels are lined with the river red gum (*E. camaldulensis*) and ironwood (*A. estrophiolutea*) and in parts with coolibah. Vegetation on the alluvial plains alongside the large river channels includes mulga, witchetty bush, gidya, coolibah and ghost gum (*E. papuana*) but where the channels flood into the sandplains the plains are mainly open with short grasses such as Mitchell grass (*Astragaluspectinata*).

**Previous geological work**

The first investigations were made at the turn of the century by geologists and explorers such as Brown (1896), Etheridge (1902) and Davidson (1905), who concentrated their efforts around the Davenport Range. This early work was followed by intermittent studies on Cambrian fossils (Whitehouse, 1936; Opik, 1956), regional geology (Hossfeld, 1954; Quinlan, 1962) and radiometric dating of Proterozoic granites (Hurley and others, 1961; Walpole and Smith, 1961).

Between 1956 and 1961 the whole area was mapped at reconnaissance scale by BMR (Smith, Stewart and Smith, 1961; Smith, Vine and Milligan, 1961; Smith and Milligan, 1963). This was followed by the drilling of four shallow coreholes, BMR ELKEDRA (formerly Grg 3,3A,4 & 5 (Milligan, 1963; Fehr and Nichols, 1963), and a stratigraphic well, BMR 13 (Sandover), to a depth of 1015 m (Lloyd and Bell, 1964; Smith, 1967). From this work the first edition of ELKEDRA was published (Smith and Milligan, 1966).

In 1963, as part of a survey covering the Georgina Basin, BMR completed an aeromagnetic survey over ELKEDRA with flight-line spacing of about 3 km (Wells and Milson, 1965; Wells and others, 1966). Helicopter-supported reconnaissance gravity surveys at approximately 11 km station spacing were completed in 1965 (Barlow, 1966). These data were later used in conjunction with additional traverses along roads and tracks in the northwestern part of ELKEDRA to produce a gravity map of the whole area (Murray and Smiley, 1983a).

When initial 1:250 000 mapping of the Georgina Basin was completed the stratigraphy was compiled in a single volume by Smith (1972).

Faunas from the Sandover beds (now included in the Arthur Creek Formation) were systematically described by Opik (1957, 1968, 1975, 1979), Shergold (1969) and Jell (1975).

More detailed investigations of the Georgina Basin were initiated by BMR in 1974 (Shergold, 1980). Studies relevant to ELKEDRA include work on the Arrinrungra Formation (Kennard, 1981; Draper, 1978a), rostrocench molluscs (Pojeta and others, 1977), Middle Cambrian stratigraphy (Shergold, 1979) and shallow crustal geology beneath the basin (Tucker and others, 1979). During 1982 BMR conducted an orientation geochemical stream sediment sampling program in the Davenport Range (Hoatson and Crichtshank, 1985).

Mineral occurrences have been examined by several mining companies and by BMR. An occurrence of gas encountered during water-boring operations northeast of Ammaroo homestead was investigated by Mackay and Jones (1956). As a follow-up, two exploratory wells, Ammaroo Nos. 1 & 2, were drilled nearby by Farmout-Place N.L. (Newton, 1963; Sprigg, 1957). Prospects for petroleum in the Georgina Basin were assessed by Draper and others (1978) and Cook (1982).

The Ammaroo turquoise deposit was discovered in 1967 and described by Morrison (1969) during an investigation for phosphate deposits on Ammaroo pastoral lease (Morrison, 1968). The phosphorite potential of the basin was discussed by Cook and Shergold (1984) and de Keyser and Cook (1972).

A galena show on Ooratippra pastoral lease was reported by Sturtfield (1960) and stimulated investigation of the surrounding area by Vam Ltd., CRA Exploration, Centamin N.L. and BHP Ltd, without success. Attention was drawn to the Ooratippra magnetic anomaly by Woynzbun (1978) and Moore (1979), and the lead-zinc potential of the Georgina Basin was reviewed by Draper (1978b).

Stockdale Prospecting Ltd, Amoco Minerals Australia and CRA Exploration have sampled stream sediments for diamonds.

**Geological work for Second Edition**

The Early Proterozoic rocks were mapped by D. H. Blake (BMR) and C. L. Horsfall (NTGS) in 1982, using 1982 colour aerial photographs at a scale of 1:25 000 in ELKEDRA and 1:50 000 in the western half of GEORGE CREEK. A preliminary 1:100 000 map and detailed report were produced by Blake and Horsfall (1984). This work has been published as a special Elkedra region 1:100 000 map and commentary (Blake and Horsfall, 1987).

The Palaeozoic sequence was mapped by NTGS in 1983 using 1982 colour aerial photographs at 1:50 000 scale; GEORGE CREEK and SANDOVER were mapped by L. Bagas, A. Ninow and Ooratippra by A. M. Walley, and Ammaroo and the Cambrian in ELKEDRA by N. Donnellan, with contributions by P. A. Stidolph. Field data were compiled on photo-scale sheets then generalised at 1:250 000 scale. Stratigraphic drilling was supervised by Stidolph in 1983 and D. G. Morris in 1984-85. B. Simons compiled the geophysics.

Some of the drilling results and revised Palaeozoic stratigraphy have been presented by Morris (1986a) and Morris and others (1986). A preliminary data record was prepared by Stidolph and others (1986). All new information from the above work was used by Stidolph to compile these Explanatory Notes.

**REGIONAL GEOLOGY**

As shown in Figure 3, the northwestern part of ELKEDRA occurs within the southern part of the Early Proterozoic Tennant Creek Block, an area which is also referred to as the Davenport province (Stewart and Blake, 1984). The remainder of ELKEDRA is covered by flat-lying sedimentary rocks of the Georgina Basin (Shergold and Druce, 1980).

The Early Proterozoic rocks are represented by the Hatches Creek Group, a 10 000 m thick sequence of
Figure 3 Regional geological setting.
shallow-water sediments and interlayered volcanics characterised by the presence of numerous quartz arenite formations. The base of this Group is not seen in ELKEDRA but further north, near Tennant Creek, it unconformably overlies the 1870 Ma Warramunga Group (Blake and Wyche, 1983; Wyche and Simons, 1987). The Hatches Creek Group was folded, intruded by granites at about 1660 Ma, then gradually eroded over a period of about 800 Ma to form part of an undulating cratonic basement on which the Georgina Basin sequence was deposited. The Davenport Range represents a topographic high on the basement surface.

The Georgina Basin sequence in ELKEDRA attains a maximum preserved thickness of at least 1000 m. The oldest sediments of this sequence, of probable late Proterozoic (Vendian) age, occur in a deeper trough in SANDOVER and are not exposed. The oldest exposed unit is the Early Cambrian Andagera Formation, deposited around the flanks of the Davenport Range in a terrestrial valley-fill and alluvial fan setting. The first widespread marine sediments are dolostones of the Early Cambrian Errarra Formation. These form thin outcrops along the southern margin of the basin in HUCKITTA (Freeman, 1986) and appear to extend northwards into ELKEDRA under younger cover. A sharp contact separates these dolostones from the overlying organic-rich calcareous siltstones of the Arthur Creek Formation which were deposited under subtidal, partly anoxic conditions. These siltstones grade laterally northwards into shallow-marine sediments of the Gum Ridge Formation (Walley, 1987) and westwards into more arenaceous, tidal to supratidal sediments of the Chabaiowe Formation. They are overlain gradationally by the Middle to Upper Cambrian Arrinthuranga Formation, a thick complex carbonate sequence deposited in an intermittently emergent epicontinental sea (Kennard, 1981). The Arrinthuranga Formation was disconformably overlain in Late Cambrian to Early Ordovician times by shallow-marine sandstones of the Tomahawk beds. Remnants of an unnamed clastic unit of possible Mesozoic age are preserved in the southeastern part of ELKEDRA. At the top of the sequence, in a synclinal structure along the southwestern margin of the basin, is the Dulcie Sandstone of Early to Middle Devonian age.

A number of northwest-trending faults, which are downthrown to the northeast, displace the Georgina Basin sequence. These were probably activated in the Carboniferous during the Alice Springs Orogeny (Shaw and others, 1984, p.471).

Ferricrete and silcrete occur throughout and developed during deep weathering in the Tertiary Period. Calcrete occurs over Cambrian carbonates and within alluvial soils.

Ridges in the Davenport Range are flanked by both Tertiary and Quaternary colluvium. Much of the eastern and southern parts of ELKEDRA are covered by Quaternary sand, soil and alluvium.

**STRATIGRAPHY**

**EARLY PROTEROZOIC**

The Hatches Creek Group and a number of small Proterozoic intrusions are exposed in the Davenport Range in the northwestern part of ELKEDRA. The geology of these rocks has been described in detail by Blake and Horsfall (1984) and is published in the map commentary which accompanies the 'Elkedra Region' 1:100 000 map sheet (Blake and Horsfall, 1987). The following summary of Proterozoic units has been adapted from these descriptions, using the revised stratigraphy.

Additional information was obtained from those stratigraphic drill holes and waterbore which have intersected Early Proterozoic rocks below Cambrian strata in the Georgina Basin (Appendix 4).

**HATCHES CREEK GROUP**

The name Hatches Creek Group was introduced by Sullivan (1953) and Hossfeld (1954), and its usage was subsequently broadened and formalised by Smith, Stewart and Smith (1961). Blake and others (1985) redefined the Group and subdivided it into three subgroups, twenty formations and two recognisable members, several of which were previously mapped as intrusive. Fourteen of these new formations occur in ELKEDRA.

The Hatches Creek Group is a generally conformable sequence, approximately 10 000 m thick in ELKEDRA, of ridge-forming quartz arenites (Plate 1), recessive siltstones and minor carbonate rocks, and felsic and mafic lavas. The sediments are shallow-marine to fluviatile and in ELKEDRA they alternate with three major and a number of minor episodes of subaerial to subaqueous volcanism. The sequence has been folded and refolded into large, open to tight synclines and anticlines, and elongate domes (see 'STRUCTURE', Figure 9).

The base of the Hatches Creek Group is seen to the northwest, in BONNEY WELL (Wyche and Simons, 1987), where the Group unconformably overlies folded felsic volcanics and turbidite greywackes of the Warramunga Group. The age of the Hatches Creek Group is uncertain but folding occurred before 1660 Ma, the approximate Rb-Sr whole rock isochron age for the Elkedra Granite, which intrudes the Hatches Creek Group near Tosca Mine in southwest ELKEDRA (Blake and others, 1985).

Distinctive features of the Hatches Creek Group are:

- The dominance and regional extent of clean, pale pink to pale grey, medium-grained, well-sorted quartz arenites, representing extensive shallow-marine deposits with some fluvial component. These arenites have varying proportions of interstitial kaolinitic or feldspathic material and show wide-spread cross-bedding.
- The regular eruption of a bimodal volcanic suite, predominantly rhyolitic and dacitic in the lower part of the sequence and basaltic in the upper part.
- The periodic deposition of silty, more impure sediments and rare carbonate deposits, possibly representing more glacial or interglacial conditions.
- The conformable layer-cake stratigraphy of much of the sequence, particularly the two upper subgroups, and the sharp, well-defined contacts between most units.

In outcrop all units have been affected by Tertiary weathering processes, the arenites being partly silicified and iron-stained to bleached, and the volcanics being deeply weathered and partly ferruginised at surface. Details of the stratigraphy are given in Table 1.
### Table 1 Stratigraphy of the Hatches Creek Group in ELKEDRA.

<table>
<thead>
<tr>
<th>UNIT</th>
<th>MAP SYMBOL</th>
<th>STRATIGRAPHIC RELATIONSHIPS</th>
<th>TOPOGRAPHIC EXPRESSION</th>
<th>DEPOSITIONAL ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROTEROZOIC</strong></td>
<td></td>
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<tr>
<td><strong>Hanlon Subgroup</strong></td>
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</tr>
</tbody>
</table>
| **Lennec Creek Formation** | (Ehi) | Conformable on Aljinjabo Sandstone  
Top not seen in map area | Gently undulating depressions and low strike ridges | Slightly deeper marine |
| Up to 1500 m  |            |                                             |                                         |                                  |
| Fine-grained feldspathic, lithic & kaolinitic arenite, partly micaceous siltstone; shale, minor quartz arenite, possible calcareous beds; medium-bedded to laminated, some cross-beds |                                             |                                         |                                  |
| **Aljinjabo Sandstone** | (Ehi) | Conformable on Errololo Sandstone  
2 to 3 narrow strike ridges separated by narrow depressions; low undulating hills | Shallow marine shelf, may include deltaic deposits |                                  |
| 500 m         |            |                                             |                                         |                                  |
| Quartzose & feldspathic arenite, kaolinitic micaceous arenite, thin-bedded siltstone, mudstone, shale, minor altered basalt, possible calcareous beds. Arenites are thin-bedded, medium- to fine-grained, cross-bedded, with some ripple marks, slump structures, and mudstone pellet layers. |                                             |                                         |                                  |
| **Errololo Sandstone** | (Ehe) | Conformable on Kudinga Basalt | Broad, flat-topped strike ridges | Possibly intertidal flats and subtidal |
| 200-800 m     |            |                                             |                                         |                                  |
| Feldspathic to lithic arenite, quartz arenite, minor kaolinitic arenite. Arenites are medium-grained, well-sorted, thin-to medium-bedded; very common cross-beds, some ripple marks and mudstone pellet layers; rare quartz pebbles |                                             |                                         |                                  |
| **Wauchope Subgroup** |            |                                             |                                         |                                  |
| **Kudinga Basalt** | (Ehh) | Conformable on Frew River Formation  
Flat terrain, narrow arenite ridges | Extruded onto broad fluvial plain or shallow marine shelf |                                  |
| 150-500 m     |            |                                             |                                         |                                  |
| Basalt, interbanded feldspathic and quartz arenite, some volcaniclastic arenite. Basalt is amygdaloidal (quartz, epidote, chlorite, calcite in amygdalae) and partially altered to chlorite, epidote, actinolite; arenites are medium- to thin-bedded, medium-grained, with cross-beds and rare ripple marks |                                             |                                         |                                  |
| **Frew River Formation** | (Phf) | Conformable on Coulters Sandstone  
Mainly flat valleys under Quaternary cover, some low hills; most outcrop on gullied foot-slopes | Very shallow-marine to intertidal or sabhka |                                  |
| 150-600 m     |            |                                             |                                         |                                  |
| Thin-bedded fine-grained arenite, micaceous cherty and calcareous siltstone, mudstone, limestone, dolostone. Stromatolites at NS3947, some carbonates are manganiferous & hematitic; arenites are kaolinitic, feldspathic or lithic, with common cross-beds, ripple marks and mudstone pellet layers |                                             |                                         |                                  |
| **Coulters Sandstone** | (Ehc) | Conformable to disconformable on Newlands and Arabulja volcanics  
Prominent broad bevelled strike ridges, narrow recessive band near middle of formation | Extensive shallow marine shelf |                                  |
<p>| 350-1000 m    |            |                                             |                                         |                                  |
| Quartz arenite; medium-grained, well-sorted, some gritty and pebbly beds with quartz clasts, very thick- to thin-bedded, abundant cross-beds, ripple marks, mudstone pellet layers, well-jointed; feldspathic and kaolinitic towards SE |                                             |                                         |                                  |</p>
<table>
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<tr>
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<tbody>
<tr>
<td>WAUCHOPE SUBGROUP (continued)</td>
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<td></td>
</tr>
<tr>
<td>Aralulu Volcanics (Phj)</td>
<td></td>
<td>Conformable on Unimbra Sandstone</td>
<td>Undulating recessive terrain and footslopes</td>
<td></td>
</tr>
<tr>
<td>Up to 500 m</td>
<td>Porphyritic felsic lava, minor tuff, possible ignimbrite; altered with equant feldspar phenocrysts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yeeradgi Sandstone (with Phj)</td>
<td></td>
<td>Interfingers with basal part of Phj</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-200 m</td>
<td>Micaceous and feldspathic to lithic arenite</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Newlands Volcanics* (Eha)</td>
<td></td>
<td>Conformable on Unimbra Sandstone, intruded by dacitic granophyre</td>
<td>Recessive undulating terrain. Outcrops occur as low hills and on flanks of arenite ridges and Cambrian mesas</td>
<td>Mainly subaerial onto part fluvial and part shallow-marine sediments</td>
</tr>
<tr>
<td>Up to 2000 m</td>
<td>Porphyrhetic dacitic and rhyolitic ignimbrite and lava, bedded tuff, tuffaceous sandstone, siltstone, shale, agglomerate, thin bands of quartz arenite. Volcanics are usually cleaved, lateritised, locally pyritic, with euhedral plagioclase and quartz phenocrysts, biotite-chlorite aggregates</td>
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<tr>
<td>Unimbra Sandstone (Phs)</td>
<td></td>
<td>Conformable to disconformable on Mia Mia Volcanics and Treasure Volcanics (Interfingers N of ELKEDRA). Intruded by dacitic granophyre</td>
<td>Prominent bevelled strike ridge</td>
<td>Shallow water on irregular volcanic surface</td>
</tr>
<tr>
<td>Up to 1500 m</td>
<td>Feldspathic and lithic arenite, minor quartz arenite and quartz greywacke, thin interlayered felsic lava; up to 25% kaolinitised clasts, medium- to thin-bedded, medium- to coarse-grained, poor to moderate sorting, gritty and pebbly bands, common cross-beds, local ripple marks and mudstone pellet layers</td>
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<tr>
<td>ORADIDGEE SUBGROUP</td>
<td></td>
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<tr>
<td>Mia Mia Volcanics (Ehm)</td>
<td>Base not seen in map area</td>
<td>Recessive undulating terrain</td>
<td>Possible subaqueous eruption</td>
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<tr>
<td>1000 m</td>
<td>Cleaved felsic volcanics, massive to poorly bedded, mainly tufts</td>
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<tr>
<td>Treasure Volcanics (Ph3)</td>
<td></td>
<td>Conformable on Kurinelli Sandstone; intruded by dacitic granophyre</td>
<td>Depressed terrain with low hills</td>
<td>Probable subaerial eruption</td>
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<tr>
<td>Up to 400 m</td>
<td>Porphyrhetic rhyolitic ignimbrite, minor massive and bedded tuff, agglomerate, cherty ashstone, lava. Ignimbrite has sodic plagioclase, microcline and quartz phenocrysts and biotite aggregates in eutaxitic texture with fiammee, relic glass shards and devitrified pumice and rhyolite fragments</td>
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<tr>
<td>Kurinelli Sandstone (Phk)</td>
<td></td>
<td>Conformable on Rooneyes Formation; intruded by dolerite and granophyre</td>
<td>Strike ridges separated by narrow valleys</td>
<td>Shallow water</td>
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<tr>
<td>700 m</td>
<td>Feldspathic, lithic and quartz arenites, minor siltstone; medium-bedded, medium-grained, well-sorted, abundant kaolinitised feldspar, common cross-beds, local ripple marks and slumped bedding</td>
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Table 1 (continued)

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<th>TOPOGRAPHIC EXPRESSION</th>
<th>DEPOSITIONAL ENVIRONMENT</th>
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<td><strong>Rooneys Formation</strong> <em>(Phn)</em></td>
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<tr>
<td>1000+ m</td>
<td></td>
<td>Base not seen; intruded by Elkedra Granite and dacitic granophyre</td>
<td>Low strike ridges</td>
<td>Deltic?</td>
</tr>
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<td>Greywacke and siltstone, thin-bedded, fine-grained, variably micaceous, grey to red in outcrop, minor feldspathic arenite and felsic volcanics. Some cross-beds and mudstone pellet layers, rare ripple marks. Metamorphosed to mica schist and hornfels within 100 m of Elkedra Granite</td>
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</table>

After Blake and Horsfall (1984)

+ Type sections in ELKEDRA:
  Lennee Creek Fm: base at NS070532, top at NS070548
  Kudinya Basalt: NS038754, top at NS042755
  Newlands Volcanics: from NS11064 to NS115592

Most units unconformably overlain by Cambrian strata.

Plate 1 Typical sandstone ridge, Hatches Creek Group. Steeply dipping Almijaban Sandstone showing characteristically sparse spinifex vegetation, rare spindly shrubs, and minimal soil cover (GR NS0973).

Ooradidgee Subgroup

In the central part of the Davenport province the Ooradidgee Subgroup is characterised by the interfingering relationship of its constituent formations. However, in ELKEDRA the sequence tends to be conformable. Here the basal unit is the Rooneys Formation, a poorly sorted fine-grained sequence of silty arenaceous sediments with minor felsic volcanic material, exposed in an anticlinal structure in the southeast near Tosca Mine. This formation is overlain by the shallow-water, relatively clean Kurinelli Sandstone which in turn is covered by rhyolitic ignimbrites and associated volcanic material of the Treasure Volcanics. Chemical analyses show that these volcanics are very consistent in composition (Blake and Horsfall, 1984). Contemporaneous with the Treasure Volcanics are the Mia Mia Volcanics, a formation of similar composition, developed in the Mia Mia dome in the south of FREW RIVER (Blake and others, 1986). The southern margin of this dome crosses into the northern part of ELKEDRA. These formations, together with the Epenarra and Edmerringee volcanics in FREW RIVER and BONNEY WELL (Blake and others, 1986; Stewart and Blake, 1984), make up the first major phase of volcanic activity in the Hatches Creek Group.

Wauchope Subgroup

The basal unit of the Wauchope Subgroup, the Unimbra Sandstone, is the oldest of three province-wide ridge-forming quartz arenite units. It was probably deposited in a shallow-marine environment. The Unimbra Sandstone is conformably overlain over a large area by a thick pile of dacitic and rhyolitic ignimbrites,
lavas and tuffs of the Newlands Volcanics. These volcanics form the cores of many domal and anticlinal structures in the region. In the extreme northwest is a separate, stratigraphically equivalent pile of felsic volcanics, the Arabulja Volcanics, which occur mainly in BARROW CREEK and BONNEY WELL. These units represent the second major episode of volcanism.

The entire volcanic suite is conformably overlain by the Coulters Sandstone, the second and most prominent of the province-wide, ridge-forming arenite units. The Coulters Sandstone was probably deposited on a broad shallow-marine shelf. It is conformably overlain by silty and stromatolitic carbonate sediments of the relatively thin, recessive Frew River Formation (Plate 2). The uppermost formation of the subgroup is composed of lava flows of the Kudinga Basalt which covers a wide area and is a good stratigraphic marker. These lavas represent the final major volcanic phase.

Dacitic granophyre and feldspar porphyry (Egy)
Sills of dacitic granophyre and dacitic porphyry conformably intrude rocks of the Rooneys Formation, Kurinelli Sandstone, Unimbra Sandstone and Newlands Volcanics. These sills are up to 8 km along strike and 200-300 m in thickness. They occur mainly in the southeast, around the Tosca and Rockhole anticlines, but also within the Elkedra Dome and along the Whisky Camp Anticline.

The intrusions, exposed as small rounded boulders, consist of small, partly altered sodic plagioclase phenocrysts and mafic clots of biotite-chlorite-epidote- 설명을 완료하기 위해 제공한 문헌의 내용을 이용하시기 바랍니다. 설명의 간략화를 위한 영어 문장 구축에 도움이 될 수 있도록 원문의 주요 부분을 영어로 풀어보겠습니다.

**Plate 2** Stromatolitic dolostone, Frew River Formation, Hatches Creek Group.
Locality at GR NS3947.

**Hanlon Subgroup**
The prominent Errolola Sandstone is the uppermost of the province-wide ridge-forming arenite units and forms the basal formation of the Hanlon Subgroup. It is succeeded conformably by the Al Jinjabon Sandstone and the Lennie Creek Formation which crop out in the centres of the major synclines. These two uppermost units in ELKEDRA represent a gradual change to a more argillaceous, possibly slightly deeper water environment. Minor basalt flows are intercalated with the Al Jinjabon Sandstone in the Gastralambium Syncline.

**Intrusive igneous rocks**
The Hatches Creek Group in ELKEDRA has been intruded by dacitic granophyre and feldspar porphyry, by a few small dolerites, and by the Elkedra Granite. In addition, granitic rocks of unknown extent have been intersected beneath Cambrian strata in several drill holes.

**Dolerite (Ed)**
Rare small sills of metadolerite have intruded the Hatches Creek Group in the southeast part of the Davenport Range. One occurs concordantly between Kurinelli Sandstone and Rooneys Formation east of Tosca Mine (GR NS5525), and another intrudes Coul ters Sandstone south of Newlands Bore (GR NS7026). The dolerites are composed of altered plagioclase laths, greenish biotite or amphibole, chlorite and opaque minerals.

**Elkedra Granite (Eg)**
As defined by Blake and others (1985) the Elkedra Granite is restricted to an area of about 12 km² in the vicinity of the Juggerkout prospect (GR NS4925). For the 1:250 000 scale map the term has been extended to cover other smaller outcrops of granitic rocks that occur nearby to the west and southeast of the main intrusion.

The Elkedra Granite intrudes Rooneys Formation in the core of the Tosca Anticline and has a metamorphic aureole about 100 m wide. The age of the intrusion has been isotopically dated by the Rb-Sr method, initially at 1695 Ma (Riley, in Compston and Arriens, 1968), and more recently at 1660 Ma (recalculated by Page, from Blake, written comm., 1987). A previous K-Ar date of 1430 Ma (Hurley & others, 1961) is no longer accepted.

The granite is a well-weathered, horizontally jointed rock, and forms either flat pavements, tors, or boulder-strewn hills. It is also exposed on the slopes of mesas capped by Cambrian strata.

The typical rock is a medium-to coarse-grained, equigranular to slightly megacrystic monzogranite composed of about equal amounts of strained quartz, oligoclase, and pink perthitic microcline, with about 10% muscovite and subordinate partially chloritised biotite. The intrusion is generally homogeneous but in places contains tourmaline and is cut by zones of fine-grained greisen, quartz-feldspar-tourmaline pegmatite and quartz-tourmaline veins.

The outcrops to the southeast of the main exposure are similar in appearance and composition but
tend to be weakly foliated or locally gneissose and include a few xenoliths.

A small area of deeply weathered tonalite or granodiorite crops out beneath Cambrian strata at the Tosca turquoise mine. It is composed of completely altered feldspar, 20% well-fractured quartz, and about 20% red-brown biotite arranged in clusters with opaque minerals and apatite.

Other granitic rocks
Granitic rocks were intersected in drill hole BMR 13 (Sandoover) at a depth of 1007 m (Smith, 1967; Lloyd & Bell, 1964) and in drill hole Ammaroo 2 at 233 m (Newton, 1963). The chips from BMR 13 (Sandoover) contained medium to coarse crystalline quartz, pink feldspar, biotite, and rare muscovite and scapolite. Some of the chips were well banded, indicating affinities with the gneissic terrain of the Arunta Block (Stewart and others, 1984).

Gravity data indicate another granitic body near Annitowa (see ‘GEOPHYSICS’). Drillers’ logs indicate that water bore R.N.6426, located on the Elkeda River floodout, penetrated ‘granite’ at a depth of 92 m (Appendix 4).

**LATE PROTEROZOIC**

**Unnamed clastic unit in ELK 3 (E-E)**
Late Proterozoic sediments are exposed along the southern margin of the Georgina Basin (Shergold and Druce, 1980; Freeman, 1986) but are not seen in ELKEDRA. However, a siliciclastic sequence of possible late Proterozoic age was intersected in drill hole NTGSELK3 (Appendix 3, Figure 13). The hole terminated at 288-291 m in dark grey to black, pyritic, carbonaceous laminated siltstone which was found to contain filamentous and spheroidal microfossils. Preliminary identification of the microfossils by Zang Wen-long (written comm., 1986) suggests a late Vendian or Ediacarian age.

This dark siltstone is conformably overlain by 97 m of red beds comprising interbedded siltstone, mudstone, sandstone and feldspathic sandstone. Most of these sediments are dark reddish brown, with some light greenish beds. The siltstone and mudstone are finely laminated, planar or undulose, alternating with fine-to-coarse-grained, partly feldspathic sandstone and some very thin granule conglomerate beds. Disseminated pyrite is locally a significant component.

This sequence was first thought to be a distal part of the Andagera Formation but is now regarded as a separate, slightly older deposit. It is conformably overlain by calcereous sandstone and dolostone of the Errara Formation. The transition from Vendian to Cambrian strata probably occurs within this unit or at the contact with the Errara Formation.

**PALAEOZOIC**

**Cambrian**

**Andagera Formation (Eld)**
This new formation, defined in Appendix 1, is a flat-lying sequence of conglomerate, sandstone and rare siltstone which unconformably overlies the Early Proterozoic basement. Most of these rocks were formerly regarded as the basal conglomerate-sandstone member of the Sandoover beds (Smith, Vine and Milligan, 1961; Smith and Milligan, 1966) and some, in the western part of ELKEDRA and in BARROW CREEK, were included in the Tomahawk beds (Smith and Milligan, 1964; 1966). The formation also occurs in FREW RIVER (Walley, 1987) and BONNEY WELL (Wyche and Simons, 1987).

In ELKEDRA the formation is distributed in and around the Davenport Range (Figure 4) where two broad lithofacies have been recognised, one mainly of conglomerate, the other of sandstone. Conglomerates prevail in the central and eastern parts of the range; sandstones predominate to the southeast.
Figure 4 Locality map of Andagera Formation.
In the central Davenport Range, the formation is preserved as terraces and mesas along the axes and flanks of extant valleys (Figure 5, profile AB). The base of the formation is slightly above the present valley floor, indicating that the conglomerates were deposited in palaeovalleys similar to the present ones, carved along less resistant units of the Hatches Creek Group. The conglomerate lithofacies once largely filled these palaeovalleys, locally to within a few metres of the present bevelled ridgetops which bound the valleys.

Around the southeastern part of the range, the post-Andagera erosion process has gone much further, isolating the formation on top of remnant mesas which in some areas overlie crests of the older Proterozoic ridges. This part of the formation once formed a much more extensive sheet on a relatively flat piedmont plain (Figure 5, profiles CD and EF; Plate 3).

The formation ranges from 5 m to 40 m in thickness and shows marked lateral variations in thickness and lithology, as illustrated by the reference sections in Figure 6. Section 3 has been selected as the type section and section 14 is the principal reference section for the sandstone lithofacies.

The conglomerate lithofacies is generally an upward-fining succession, consisting predominantly of thick-bedded to massive oligomictic cobble conglomerate, with thinner beds of sandstone near the top. The conglomerate is poorly sorted and is composed of subangular to well-rounded clasts up to boulder size in a matrix of sand and granules (Plate 4). Most of the clasts are quartzitic sandstone derived from nearby ridge-forming formations of the Hatches Creek Group, such as the Coulters, Errolola and Unimbra sandstones; vein quartz clasts are a minor component. Most conglomerates are planar bedded and many have a weak imbricate structure. Crude cross-beds, some with high angle foresets up to about 20°, are usually evident, particularly towards the top of upward-finng units. Sandstones near Tosca Mine contain parallel, sinuous-crested, interference and truncated ripples.

Near Rockhole Bore some of the coarse clast-supported conglomerates are clearly channel-fill deposits cutting into underlying strata; their clasts have numerous percussion marks, indicating high-energy water flow. At the same locality, many cobbles have indentations at cobble-to-cobble contacts, indicating

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Figure 5 Profiles across Andagera Formation.
Figure 6 Measured sections in Andagera Formation.
that significant compaction and pressure solution has occurred (Plate 5). This implies a significant thickness of sediment once overlay these conglomerates.

In the sandstone lithofacies, beds range from thin to very thick, and from clean and well-sorted to immature, with scattered pebbles and granules. Sedimentary structures include ripple marks and cross-beds. Fairly well-sorted pebble conglomerates are interbedded with the sandstone; many clasts have a notable angularity and are usually composed of vein quartz. Minor feldspar is present in basal outcrops near Andagera Creek. The quartz grains are usually coated with hematite. A thin siltstone bed is present in a few localities at the base of the formation and laminated interbeds of dusky red siltstone are developed in the middle of the sandstone sequence near Andagera Bore. No fossils have been found.

The sedimentary features and palaeotopography indicate high-energy fluviatile valley-fill deposits in the central part of the range and a more distal braided alluvial fan environment to the east. Generation of such deposits requires a source area of substantial relief. The ridges in northwestern ELKEDRA and southwestern FREW RIVER are up to 100 m higher than the most elevated part of the Andagera Formation in the present landscape (Figure 4), and may have formed a more substantial mountain range in the Early Cambrian, though Stewart and others (1986) argue that these bevelled ridges represent the maximum elevation at this time. Palaeogradients appear to slope southeasterwards (Figure 6). Walley (1987) has evidence for a number of small intermontane alluvial fan deposits in FREW RIVER which were probably generated by activation of fault zones in the Early or early Middle Cambrian, a period of tectonic instability and volcanism in central Australia (Shergold and Druce, 1980). The northwest-trending faults through the Davenport Range in ELKEDRA are part of a major fault lineament which extends many hundreds of kilometres (Figure 3), so movement on this zone could have triggered these deposits.

Plate 4 Framework-supported cobble conglomerate, Andagera Formation. Rounded orthoquartzite clasts, derived from Hatches Creek Group, in sandstone matrix (GR NS5445).

Plate 5 Compaction features exhibited on surface of cobbles within the Andagera Formation. The indentations have been produced by pressure solution on cobble-to-cobble contacts, indicating that significant compaction has occurred (GR NS6141).
The Andagera Formation is overlain disconformably by fossiliferous silicified siltstones of the Middle Cambrian Arthur Creek Formation but its relationship to the Early Cambrian Errarra Formation is unclear. About 16 km south of Andagera Bore, near GR NS6809, a very thin unit of silicifiedstromatolitic dolostone lies between Andagera Formation and Arthur Creek Formation. If this dolostone is a surface expression of the Errarra Formation then the dolostone part of the Errarra Formation is younger than the Andagera Formation. Thus the most likely correlation of the Andagera Formation, from drill hole NTGS ELK 3, which is only 14 km down the palaeoslope from this outcrop, would be the basal sandstone of the Errarra Formation or, possibly, the underlying red beds (Appendix 3, Figure 13, section JKL on map face). These stratigraphic relationships indicate that the Andagera Formation is probably Early Cambrian in age.

Errarra Formation (Ele)

The Errarra Formation is an Early Cambrian archaeocyath-bearing dolostone unit which crops out sporadically along the southwestern margin of the Georgina Basin in HUCKITTA. In the type section, defined by Freeman (1986), from drill hole NTGS HUC 1 (Figure 3), the formation is 129 m thick, composed of four units: (a) a basal granule conglomerate and silty shale 3 m thick, overlain by (b) 23 m of muddy micritic dolostone with siltstone laminae, (c) 36 m of silty sandstone and medium-coarse sandstone with patches of chert, and (d) 67 m of pale grey dolostone and limestone with intraclasts and local quartz sandstone beds. The archaeocyathan fauna is confined to (b) and indicates an Attabanian to early Botoman (ex Lenian) age (Kruse and West, 1980). In HUCKITTA the formation overlies various Early Cambrian and late Proterozoic units and is everywhere overlain by the Middle Cambrian Arthur Creek Formation.

Except for a thin silicified dolostone of uncertain affinity near GR NS6809 (see ‘Andagera Formation’), no outcrops of Errarra Formation are known in ELKEDRA. However, a dolostone unit, believed to be the northern equivalent of the Errarra Formation, has been intersected in five drill holes (Ammaroo 1 and 2, NTGS ELK 3 and 7, and BMR 13 Sandover) and a waterbore (R.N. 13987) beneath the Arthur Creek Formation. No archaeocyaths have been recognised but the lithologies are fossiliferous. They appear to equate with units (c) and (d) of the type section. Possible Errarra Formation occurs in a sixth drill hole, NTGS ELK 2, below 490 m where light brownish grey, vuggy bioclastic dolarenite shows evidence of alteration by secondary fluids (Appendix 3, Figure 14). However, biostratigraphic work is needed to resolve whether it is Errarra Formation, part of Arthur Creek Formation, or some other unit.

The formation unconformably overlies Early Proterozoic basement in four ELKEDRA drill holes and conformably overlies red sandstone and siltstones of Vendian to Early Cambrian age in the fifth (NTGS ELK 3). In all drill holes there is a sharp contact with the overlying Arthur Creek Formation, indicating a hiatus between them. In the west of ELKEDRA, where the sediments are virtually horizontal, the sequence appears to wedge out against the basement palaeoslope.

Stratigraphic logs are shown in Appendix 3, Figure 13. In all drill holes, sandstone is developed at the base and grades upwards into dolostone which forms the bulk of the formation.

The basal sandstone is medium- to coarse-grained with a dolomitic or calcareous cement and fines upwards into silty and sandy dolostone. It contains intervals of dolostone intraclasts and small amounts of pyrite. Thickness varies from 4 m to about 30 m.

The dolostone is pale yellow, brown or greenish-grey to dark-grey and carbonaceous, and consists of fine- to coarse-grained recrystallised dolarenite, very vuggy dolorudite and minor dololutite. The dolorudite is prominent in NTGS ELK 3 and consists of poorly sorted angular clasts of silty and stromatolitic dolostone and chert, in a dolarenite matrix. Thin undulous laminae of dark grey carbonaceous siltstone, with patches and blebs of pyrite, are distributed throughout. Small slumped lenses of tiny shell fragments contain remains of trilobites, brachiopods and hyoliths. Minor glauconite is present.

The Errarra Formation varies in thickness from 20 m to 77 m, thickening eastwards, and was probably deposited as a result of a marine transgression from the southeast up a gentle slope of low relief. Carbonate beds accumulated in tidal lagoons populated by stromatolites, archaeocyathan communities (in HUCKITTA) and a shelly fauna. These were subsequently largely destroyed by storm or wave action to form shoals of coarse-grained intraclastic carbonate.

Arthur Creek Formation (Emu)

The Arthur Creek Formation is a fossiliferous Middle Cambrian sequence of organic-rich siltstone, silty limestone and silty dolostone. It was first described in HUCKITTA (Smith, 1964a) and has been formally defined by Freeman (1986), based on a cored type section from drill holes NTGS HUC 1 and HUC 2 (Figure 3). In the type section the formation overlies the Errarra Formation with a sharp contact and is overlain gradationally by the Arrinthunga Formation.

In ELKEDRA, highly fossiliferous Middle Cambrian siltstone and limestone are exposed over an area of about 900 km² on a low-lying undulating plateau at the southeastern end of the Davenport Range. This sequence was previously known as the Sandover beds (Opik, 1956; Smith and Milligan, 1966) but on palaeontological and lithological evidence is now assigned to the Arthur Creek Formation. Stratigraphic drilling has confirmed that the Arthur Creek Formation is a widespread subsurface unit above the Errarra Formation and beneath the Arrinthunga Formation in the southwestern portion of the Georgina Basin, gradually thinning northwards from the type area in HUCKITTA to the western ELKEDRA.

The thickness of the formation ranges from 418 m in the type area to 159 m in BMR 13 (Sandover), at least 128 m in NTGS ELK 2 and 68 m in NTGS ELK 7. Drill holes Ammarray 1 and 2, and NTGS ELK 3, which were all collared below the top of the formation, penetrated thicknesses of 114–181 m. To the west, in Ammarray, the formation interdigitates laterally with the Chabalowee Formation and wedges out close to the western boundary of the sheet area. To the north, in northern ANNITOWA, it appears to grade into the Gum Ridge Formation which crops out in
FREW RIVER (Walley, 1987). The eastern limits of the formation are unknown, while to the southeast, on the eastern side of the Tarlton Fault, the unit is known as the Hay River Formation (Shergold and others, 1985; also see Figure 3).

The main outcrop in ELKEDRA occurs where the formation onlaps the Davenport palaeotopographic high, disconformably overlying the Andagera Formation and, in a few places, unconformably onlapping the Proterozoic basement. In general, the formation is near-horizontal or has a dip of 2-5° to the south and southeast but bedding structure is seldom clear in outcrop.

Beneath the main outcrop area the formation is deeply weathered to depths of 60-90 m. Here the calcareous matrix is almost entirely leached, and pyrite and carbon are completely oxidised, producing whitish to yellow-brown silstone and claystone. Chert (silification) is developed near surface and at rare intervals deeper in the weathered zone. Consequently, outcrop is poor, mainly a surface rubble of weathered silstone or silified silstone. Many of the rises or low mesas are capped by ‘grey billy’ silcrete consisting of black angular chert (silified silstone) fragments in a light grey silicified matrix. Thin coquinites, usually silicified, are present in several areas, particularly near the eastern margin of the outcrop area. Sporadic outcrops of thin biosparite and other limestones occur in open red soil country near Limestone Bore in AMMARROO.

Subsurface lithologies are shown in Appendix 3 (Figure 14). Most of the formation consists of calcareous and dolomitic silstone, silty limestone and dolostone with a characteristically high carbonate content. Two distinct facies are recognisable, anaerobic and aerobic.

The anaerobic facies occurs in the deeper parts of the basin, such as the basal 80 m of BMR 13 (Sandover) and the basal 60 m of NTGS ELK 3. It consists of dark grey to black, finely pyritic calcareous and dolomitic silstone and dolomitic mudstone with very fine millimetre-scale planar lamination. Each individual bed is graded. Carbonaceous content is very high (total organic carbon up to 14%; Morris, 1986a), and generally increases towards the base, giving a bituminous odour. Fossils are rare and are restricted to minor sponge spicules or shell material derived from upslope by debris flows. This facies was deposited in a marine euxinic environment under anaerobic conditions.

In contrast to the anaerobic facies the subtidal aerobic facies is highly fossiliferous and bioturbated throughout and has a lower organic carbon content. Dark grey to black thinly laminated to wavy-bedded calcilutite, dololutite and fine-grained calcarenite and dolarenite are interbedded with light grey bioturbic and peloidal medium-grained calcarenite and dolarenite. Nodular bedding or sedimentary boudinage is a distinctive feature, particularly in NTGS ELK 2. Quartz silt and sand content is variable and dolomite is dominantly detrital.

The abundant and diverse fauna consists of trilobites (Plate 6), brachiopods, hyoliths, chancelloridides, bradorinies and sponge spicules. Shell debris is concentrated on bedding planes, in lenticular coquina interbeds, in nodules formed by differential compaction and as fill in large burrows. Phosphatic brachiopod shells are common and non-phosphatic faunal debris has in places been phosphatised.

A prodigious fossil assemblage has been collected from sites throughout the outcrop area (Figure 7). Most studied are the trilobites, first described by Etheridge (1902). Detailed studies have been made of the orycecephalids (Shergold, 1969), xystiridurs (Opik, 1975), eodiscines (Jell, 1975) and agnostines (Opik, 1979). According to available data at least 26 trilobite species are recognised, grouped into seven families. Many of these species appear to be confined to the Sandover area. Those found elsewhere include ‘Acdagnostus’ scutalis, Xystiridae alera, Orycecephalus reynoldsii, Perinopsis (Iaenostos) elkedraensis and Pageia prolate in the Burton beds (Opik, 1957; 1975; 1979; Shergold, 1969; Jell, 1975); Xystiridae (Polydinites) verticosa in the Gum Ridge Formation in HELEN SPRINGS (Opik, 1975); and Orycecephalus reynoldsii in the Arthur Creek Formation in HUCKITTA (Shergold, 1969).

Four orders of inarticulate brachiopods (Lingulida, Acrotretida, Obolellida, Paterinida, Moore, 1965) and one articulate orthide brachiopod are represented in the Sandover area but none have been studied in any detail. Gatehouse (1967) described lithistide ‘rhizomorine’ (actually orthocladiine anthaspidellid; Kruse, 1983) sponge spicules from drill hole BMR 13 (Sandover). The phosphatic bradorine Ophiosea sp. nov. aff. spicatum was described by Opik (1968). Chancelloridides were identified near Discovery Bore by P. D. Kruse (pers. comm., 1986).
Hyolith coquinas, though very common in parts of the formation, have not been studied. A detailed list of all known fossils is given in Stidolph and others (1986). Specimens collected by NTGS are listed in Appendix 2.

According to Öpik (1975, 1979) the fossils in ELKEDRA range in age from the late Ordian stage to the immediately post-Templetonian Psychagnostus atavus biozone although the NTGS collection (Appendix 2) indicates an entirely Templetonian age (Shergold and Laurie, 1984). However most collected fossils are probably at least 100 m above the base of the formation so the basal, poorly fossiliferous anaerobic zone may well be Ordian.

The Arthur Creek Formation is a good potential source rock for hydrocarbons, and is prospective for phosphate and base metal deposits (see ‘MINERAL RESOURCES’).

Chabalowe Formation (Emc)
The Chabalowe Formation is a newly defined unit (Appendix 1) consisting of interbedded dolomitic sandstone, siltstone, claystone, dolostone and gysiferous beds. It occurs in the western part of ELKEDRA, in northern BARROW CREEK (Bagas, 1985), and may continue into the Wiso Basin. The name is taken from Chabalowe Bore in BARROW CREEK.

Outcrops are limited to leached ferruginised sandstone and chert rubble which form very low rises in thick mulga scrub country west of Honeymoon Bore. The chert is a lag of nodules derived from weathering of thin dolostone interbeds. These outcrops were previously mapped as part of the Tomahawk beds (Smith and Milligan, 1964; 1966). However, they lack fossils and bioturbation whereas typical Tomahawk beds are fossiliferous and very heavily bioturbated, and do not contain chert. In addition, in BARROW...
CREEK, Arrinthunga Formation has now been identified between outcrops of sandstone assigned to Chabalowe Formation and definite Tomahawk beds (Morris, 1986b).

The sequence has been intersected in five drill holes, three in ELKEDRA (NTGS ELK 4, ELK 6 and ELK 7, 7A; Appendix 3, Figure 15) and two in BARROW CREEK. The type section is from drill hole BC 5 (Figure 3).

In ELKEDRA, the formation is divisible into two units: a lower unit, 100 m thick, defined as the Hagen Member (Appendix 1), and an upper unit, 150–200 m thick.

The Hagen Member (emh) is characterised by the presence of abundant gypsum or anhydrite in an algal dolostone sequence. At the base is a coarse-grained intraclastic dolarenite which, in parts, is very vuggy and porous, the vugs being partly filled with calcite, hydrocarbons, fluorite, minor galena or pyrite. Oil stains and bleeds are common, accompanied by a strong petroliferous odour. The intraclastic dolarenite is overlain by algal laminate and dololutite with numerous interbeds of mosaic anhydrite and gypsum, particularly towards the top of the unit. Chert, in the form of interlaminations (sillified algal laminates) and concretions, is very common. Also present are intervals of dolomitic stromatolites, some thrombolitic dolostone, laminated greenish grey to red dolomite siltstone and shale, minor sandstone, sandy dolarenite and dolarenite. Intraformational brecciation is a common feature. Any outcrop of the Hagen Member would consist largely of chert rubble but little has been found in ELKEDRA. However, large tracts of chert rubble occur to the west in BARROW CREEK (Morris, 1986b).

The upper unit of the Chabalowe Formation has similar lithologies to the lower, the main differences being a marked reduction in the gypsum-anhydrite content and significant increase in clastic detritus. It consists of numerous fining-upward cycles of sandstone, siltstone, shale and dolostone, usually separated by erosional contacts. At the base of each cycle is fine- to medium-grained, occasionally coarse-grained, sandstone which is generally cross-bedded, very porous, and has a dolomitic to gypsiferous matrix. Each sand unit is capped by finer interbeds of siltstone, shale and dolostone which are generally thin-laminated and ripple-marked. Desiccation cracks may occur at the top of each cycle. Intraformational breccia, consisting of claystone or dolostone clasts in a sandy matrix, is very common. The fine-grained beds vary in colour from red, reflecting oxidising conditions due to subaerial exposure, to greyish-green with carbonaceous material and pyrite, reflecting submerged reducing conditions. The dolostones are predominantly algal laminates, dolarenite or mircrite and are commonly associated with nodular chert. Some dolomitic stromatolites are present and there are numerous vugs and cavities.

The lithologic features indicate deposition under near-shore tidal to supratidal conditions, initially a shoal, grading upwards to a sabkha environment, followed by increased terrigenous input and decreased salinity in a near-shore lagoonal setting.

In northern AMMAROO, the Chabalowe Formation grades laterally eastwards into, and partly overlies, the Arthur Creek Formation (Section F–H on Map face).

In the southwestern part of AMMAROO, and further northwest in BARROW CREEK, the formation unconformably overlies Early Proterozoic rocks. It is overlain gradationally by the Arrinthunga Formation, the contact being distinguished by the change from a sandstone-dominant to a carbonate-dominant sequence. These relationships indicate that the Chabalowe Formation is Middle Cambrian in age.

Arrinthunga Formation (EuA)
The Arrinthunga Formation, defined by Smith (1964a), is a thick well-bedded sequence of carbonate rocks, predominantly dolostones, underlying most of the eastern and southern portions of ELKEDRA. The principal areas of outcrop are in southeastern ORATIPPRA, where much of it was originally mapped as a dolostone unit in the Tomahawk beds, and in northern ORATIPPRA and ANNITOWA, where it was formerly known as the Meeta beds (Smith and Milligan, 1966). In the subsurface, the formation has been intersected in drill holes BMR 13 (Sandover), BM5 ELKEDRA (formerly Grg) 3A, 4 & 5, and NTGS ELK 1, 2 & 6.

The principal lithologies are peloidal, ooidal and intraclastic dolarenite, algal dolostone (cryptalgal laminates, columnar stromatolites and domal thrombolites) and dololutite (including mircrite). Limestones constitute about 10% of the total sequence. At certain intervals the carbonates are interbedded with quartz sandstone and terrigenous siltstone and mudstone, all of which contain varying amounts of carbonate detritus. These rock types are described in detail by Kennard (1981).

In the type area in HUCKITTA the formation is 975 m thick (Freeman, 1986) and has been subdivided into eight lithofacies by Kennard (1981). These facies, which also occur in ELKEDRA, range from high-energy ooid, grainstone and sandstone shoals, characterised by cross-bedding and ripple cross-lamination, to low-energy submerged algal mounds and shallow-water shelf, lagoonal and peritidal deposits of very fine dolarenite and dololutite. Near-shore facies include semi-emergent hypersaline algal flats, and terrigenous sandstone and shale beds with evaporite pans.

In ELKEDRA, the Arrinthunga Formation dips about 2° to the southeast and is thickest in the southeastern part of ORATIPPRA where 681 m was intersected in BMR 13 (Sandover) (Lloyd and Bell, 1964). To the west, it is 390 m thick in NTGS ELK 6. Corehole NTGS ELK 2 is a good reference section for the lowermost 360 m of the formation (Appendix 3, Figure 16).

The Arrinthunga Formation conformably overlies the Arthur Creek and Chabalowe formations. It can be subdivided into three units: Lower Carbonate, Middle Siliciclastic-carbonate and Upper Carbonate.

Lower Carbonate Unit
The lowest part of the Arrinthunga Formation, about 160–200 m thick, is predominantly carbonate. This unit is exposed as low, northeast-trending, spinifex-covered outcrops on Annitowa pastoral lease (formerly ‘Meeta beds’, Plate 7) and has been intersected in drill holes BMR 13 (Sandover) (Lloyd and Bell, 1964; Smith, 1967), and in NTGS ELK 1, ELK 2 and ELK 6 (Appendix 3, Figure 16).
brown and oxidised, with desiccation cracks, and there is a significant increase in gypsum, indicating a change to semi-emergent conditions.

Most of the Middle Unit is very poorly exposed. However, there is one prominent sandstone horizon (EU3) which crops out as a number of low hills and thin cappings in eastern ELKEDRA. These outcrops could represent a series of lensoid sand bodies occurring within the same stratigraphic interval. At ELK 2 the sandstone is 15–20 m thick and it possibly correlates with a sandstone interval 35 m thick in BMR 13 (Sandover) (Smith, 1967). The sandstone is well-sorted and fine- to medium-grained, containing mostly well-rounded quartz with minor feldspar and chert. It is cross-bedded, current-scoured and has numerous ripple marks. The ripple ridges strike ESE and indicate a bimodal current direction; many ripple crests are bevelled, indicating intermittent emergence (Plate 8).

Plate 7 Typical dolostone outcrop, Arrinthunga Formation (GR PS2221).

Lithologies consist mainly of fine- to coarse-grained, thin- to thick-bedded peloidal dolarenite, some ooidal dolarenite, and numerous intervals of laminated and columnar stromatolites and dololutite; large algal bioherms appear to be rare. The dolarenite beds are commonly cross-laminated and have numerous intraclast layers, typically at the base of each upward-fining cycle. Limestone is a minor component. In NTGS ELK 2 and ELK 1 the upper part of this basal unit is marked by development of chert and occurrence of laminae and lenses of quartz silt and very fine sand. These carbonates were almost totally submerged throughout deposition, as indicated by grey-green and black carbonaceous clay laminae. However, in the west (ELK 6), where the carbonate overlies the peritidal Chabalowe Formation, occasional red shales and desiccation features occur in the basal 40 m, indicating a gradual change from intermittent emergence to total submergence.

Middle Siliciclastic-carbonate Unit

The middle part of the formation is marked by a gradual increase of shale and quartz sandstone interbeds, a decrease in dolarenite, and a corresponding increase in dololutite, dolomitic mudstone and stromatolitic dolostone.

The Middle Unit has been intersected in NTGS ELK 6, where it is 60 m thick, and in BMR 13 (Sandover) where it is about 200 m thick. It also occurs in the top of NTGS ELK 1 and the uppermost 160 m of NTGS ELK 2. In ELK 2 and ELK 6 the shales are red-

Plate 8 Bevelled wave ripples in sandstone (EU3), middle siliciclastic-carbonate unit, Arrinthunga Formation (GR PS4340).

Upper Carbonate Unit

The upper part of the formation is not well exposed and lacks a fully cored reference section. It has been intersected in drill holes NTGS ELK 6 and BMR 13 (Sandover) (Appendix 3, Figure 16). ELK 6 does not provide a complete section as the top appears to have been eroded prior to deposition of the overlying Toma hawk beds. Both drill holes indicate that sedimentation in this unit began with an ooidal dolarenite sequence, about 140–170 m thick, which contains disseminated
pyrite, carbonaceous matter and glauconite. This indicates a second marine transgression and reappearance of higher energy shoaling conditions. In BMR 13 (Sandover), the ooid carbonates are overlain by 60 m of interbedded sandstone and dolostone, a sequence which can be correlated with outcrops on the upfaulted south side of the Ooratippra Fault. These outcrops consist of ooidal carbonates with subordinate sandstone, algal bioherms and dololutite, overlain by a 20 m thick sandstone equated with the Eurowie Sandstone Member (Euc) in HUCKITTA (Smith, 1964a). This sandstone contains halite casts and shrinkage cracks (Plate 9), indicating deposition in supratidal hypersaline conditions.

However, dates obtained on the fauna from the underlying Arthur Creek Formation suggest that the base of the Arrinhunga Formation youngs from the northwest to southeast. The overlying Tomahawk beds have been dated as Payntonian (Fojeta and others, 1977).

**Tomahawk beds (EOT)**

The Tomahawk beds, named by Smith (1964a), are a fossiliferous, shallow-marine, sandstone-dominated sequence which overlies the Arrinhunga Formation in two widely separated areas in ELKEDRA, one in the southwest near Bluebush Bore, the other in the southeast corner of Ooratippra.

At Bluebush Bore, the beds dip very gently (1–5°) to the southwest and are disconformably overlain by the Dulcie Sandstone. The total thickness is about 190 m, as revealed by cored drill hole NTGS ELK 6. Collared about 40 m below the disconformity at the top of the unit. The Tomahawk beds consist predominantly of medium- to coarse-grained sandstone with thin interbeds, laminae and partings of micaceous siltstone and shale, and occasional flat-pebble conglomerate of probable intraformational origin. Below the weathered zone (33 m in ELK 6), much of the sandstone has a slightly calcareous matrix and the shale and siltstone are dark greenish-grey to black and carbonaceous with common pyrite; near the surface the matrix is leached and porous. Trace fossils in the form of worm burrows and horizontal tracks and trails (including *Rusophycus*) are characteristic throughout, particularly in the upper part of the formation.

Three subunits have been recognised in the ELK 6 sequence as shown in Appendix 3 (Figure 17). The basal unit, about 70 m thick, rests on the Arrinhunga Formation with a sharp contact, marked by an abrupt change in downhole gamma and neutron logs. It is the most carbonate-rich part of the formation, containing minor thin interbeds of quartz-rich dolarenite and abundant glauconite. Bioturbation is common near the base and fragmented shell material occurs in some coarse-grained intervals.

The middle unit, about 40 m thick, has a much greater proportion of shale and siltstone, and has more abundant trace and body fossils. Like the basal unit, it is glauconitic.

The upper unit, about 75 m thick (35 m in drill hole ELK 6), represents a return to coarser-grained, more arenaceous sediment and is extremely bioturbated, with abundant vertical burrows, other trace fossils and various shelly fragments in coarser-grained intervals. It crops out as low hills and rises of leached, partly silicified, porous sandstone with occasional interbeds of micaceous siltstone and fossiliferous claystone. In addition to worm tubes, *Rusophycus* casts and well-formed tool markings, fossil remains include the trilobite *Tellerina*, the rostroconch mollusc *Cynatopegma semiplicatum*, an articulate brachiopod similar to *Eoorthis*, and various indeterminate trilobite, rubeiriod and gastropod fragments of probable Payntonian (latest Cambrian) age (J. Laurie, written comm., 1983)

In southeastern Ooratippra, quartz-rich dolostone (EOTd) crops out as medium to thick beds at the base of the formation, overlain by thin-bedded, deeply weathered quartz sandstone (EOTt) which contains a few dolostone interbeds. The sandstone forms small prominent hills and mesas on top of the dolostone and
also directly overlaps Arrinthunga Formation dolostones. Younger formations have been eroded from the area except on a few isolated mesas where thin caps of Mesozoic? conglomeratic sandstone remain. The maximum exposed thickness of the Tomahawk beds is 90 m (Appendix 3, Figure 17).

The dolostone is horizontally and evenly bedded and overlies the Arrinthunga Formation with a gradational contact. Small-scale bidirectional cross-bedding is common. Thin beds of shell debris contain fragments of hyoliths, possible brachiopods, echinoderms (primitive eocrinoid ossicles?), gastropods and rare possible siliceous sponge spicules. The dolostone is finely crystalline with up to 25% relict ooids and usually from 5 to 25% fine-grained quartz.

The exposed sandstone is a leached and highly porous quartz arenite composed of fine- to medium-grained, moderately well-sorted quartz grains with authigenic overgrowths, up to 5% feldspar and glauconite, and rare mica, opaques, tourmaline, chert and fossil fragments, including possible sponge spicules. The sandstone is very thin- to medium-bedded and cross-laminated, interbedded with reddish-purple to whitish siltstone and rubbly zones of bioturbation. Ichnofossils are common, including many types of grazing trails (Plate 10) and at least four different varieties of feeding burrows. Also present are resting traces (Rusophycus), crawling traces (Cruziana) and swimming-grazing trails (Monomorphichnus; Hantzsche, 1975).

A characteristic feature of many sandstone mesas is that bedding is very disrupted due to collapse of underlying strata. The beds are fragmented and faulted, and invariably dip inwards to a central point whereas adjacent dolostone beds retain their horizontal bedding intact (Figure 8, Plate 11). The contact between dolostone and sandstone in these areas is commonly discordant and marked by a narrow zone of

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**Plate 10** Arcuate grazing trails, Tomahawk beds. Host rock is a thin-bedded quartz sandstone at 28.5 m in measured section E17 (Appendix 3, figure 17). Locality at GR PR4268.

**Figure 8** Collapse structures in Tomahawk beds.

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**Plate 11** Bedding relationships, Tomahawk beds. Horizontally bedded dolostones with thin sandstone cap on left; hill of collapsed sandstone with fragmented, disrupted, leached beds on right (GR PR4367).
manganiferous ferricrete. A hole drilled by BHP (1977) into one of these collapsed areas about 500 m NNE of Gorey Bore (GR PR1974) showed that leached sandstones 18 m thick, with bedding angles of 20 – 40°, were underlain by a probable cavity 20 m deep. The cavity is filled with kaolinitised siltstone, with limonite at the base. Beneath the cavity is brecciated dolostone of the Arrinthuranga Formation. These collapse features are also common in HUCKITTA (Freeman, 1986).

The age of the Tomahawk beds in southeastern ORATIPPIPA, like those at Bluebush Bore, appears to be Payntonian. No fossils have been studied from this area but not far south, in the Tomahawk beds of northeastern HUCKITTA, the ribberiod molluscs Cymatopegma semiplicatum and Ribeiria buckitana have been identified (Pojeta and others, 1977).

The fauna, lithology, bioturbation, degree of sorting and cross-lamination indicate a littoral to sublittoral depositional environment. The presence of glauconite and thin organic pyritic silts suggest accumulation on a middle to outer marine shelf during episodes of reduced influx of sediment at a time of high sea levels (Van Houten and Purucker, 1984). Most samples of Cymatopegma semiplicatum examined by Pojeta and others (1977) were unornamented moulds lying parallel to bedding, suggesting minimal transport.

DEVONIAN

Dulcie Sandstone (Dud)
The Dulcie Sandstone was named by Smith (1964a) after the Dulcie Range in HUCKITTA. The formation forms low discontinuous, northwest-trending hills in the extreme southwest corner of ELKEDRA. Along the northeast margin of these hills, where the sandstone disconformably overlies the Tomahawk beds, there is a prominent scarp, generally 3 – 10 m high.

The formation dips about 3 – 5° to the southwest, and in ELKEDRA appears to be about 30 – 40 m thick. It is progressively covered to the southwest by Quaternary aeolian sand. The uppermost few metres of the underlying Tomahawk beds are thoroughly leached.

Virtually all outcrops consist of clean, white, medium- to very thick-bedded, strongly cross-bedded quartz sandstone. The cross-bed sets dip in many directions, typically at angles of 20 – 30°. In thin section the rock is a very well-sorted quartz arenite, composed almost entirely of fine- to medium-subrounded grains of quartz sand with authigenic overgrowths, and minor scattered tourmaline, zircon, muscovite and ferric oxide, with quartz dust and some kaolinitic material in the matrix.

Fish fossil fragments were found in a thin bed about 2 m above the basal contact, near the top of a low cliff about 2.3 km southeast of Bluebush Bore. They have not been identified but similar fish fossils have been collected by BMR palaeontologists from several localities in equivalent positions along strike between 40 and 75 km to the northwest. Preliminary information on these faunas by G. Young (written comm., 6.1.84) indicates phylactenid euarthrodires (including groenlandaspids), crossopterygians, and Wuttagoonaspis species. The fossil remains in ELKEDRA are probably part of this Wuttagoonaspis fauna, the type species of which is regarded as late Early to early Middle Devonian in age, i.e. a presumed Emsian –Eifelian age (Turner and others, 1981; Ritchie, 1973).

Wuttagoonaspis is believed to be a freshwater fauna which was restricted to central Australia at a time when Australia was in tropical latitudes (Turner and others, 1981, p. 65). Because of the fish fossils, the sandstones have been interpreted as shallow, freshwater, continental deposits (Hills, 1959; Smith, 1972).

A number of features indicate that much of the sandstone has an aeolian origin; these include the high angles and very divergent directions of the cross-beds, the very homogeneous medium grain size, the clean quartz arenite composition, and the presence of a very thin lag of grit on the extreme base of cross-bed sets.

In HUCKITTA, the Dulcie Sandstone has been divided into two units, from airphoto interpretation (Freeman, 1986). This distinction is not evident in the northern limb of the Dulcie Syncline, where the ELKEDRA outcrops are assigned to the lower part of the formation.

MESOZOIC?

Unnamed conglomerate-sandstone unit (M)

In the southeastern corner of ORATIPPIPA, a previously unrecognised unit of clastic sediments, 1 – 15 m thick, is preserved as a cap or as boulder remnants on top of several hills and mesas of Tomahawk beds sandstone. The unit is characterised by the presence of granule conglomerate but some outcrops are represented by erosional remnants of sandstone which are hard to distinguish from the underlying deeply weathered sandstones of the Tomahawk beds.

At the main locality (GR PR4572), the basal 5 m of the unit consists of a thick-bedded, trough cross-bedded conglomerate composed predominantly of angular quartz granules with rounded pebbles and cobbles of orthoquartzite, vein quartz, pegmatite and rare weathered granite. More significant, however, and unique to this locality, is the presence of large, very angular blocks up to 60 cm across of very fossiliferous quartz sandstone. The base of the conglomerate is upward-coarsening and the clasts are set in a very fine to fine quartz sand matrix with minor Feldspar, white mica and tourmaline. The conglomerate is overlain by fine-grained, cross-bedded quartz sandstone and siltstone interlayered with lenses of quartz-granule conglomerate.

The fossils in the large blocky clasts of sandstone include bivalves (Palaeonello smithii. Pojeta and others, 1977), gastropods (a large indeterminate macluritid species), large fragments of a very large asaphid trilobite, and brachiopods belonging to, or closely related to, the Middle Ordovician genus Orthobionites (J. Laurie, BMR, written comm., 1983). Also present are probable worm feeding burrows and “U”-shaped vertical dwelling burrows.

According to J. Shergold (BMR, pers. comm.), these sandstone blocks resemble the Middle Ordovician Carlo Sandstone (Draper, 1977). However, the nearest known preserved outcrop of Carlo Sandstone is 80 km to the SSE in the Tarlton Range so the source of these blocks must have long since been removed by erosion.

The unit overlies some 20 – 90 m of Tomahawk beds which indicates that an unknown thickness (300 m?) of upper Tomahawk beds and Lower to Middle Ordovician strata was eroded before the con-
glomerate was deposited. The source area would have included both lithified Carlo Sandstone and probable Early Proterozoic basement. There are no overlying beds to indicate an upper age limit but most outcrops have been affected by the same small-scale collapse folding as occurs in the Tomahawk beds, attributable to deep weathering and dissolution of underlying carbonate during Tertiary weathering.

The beds are tentatively correlated with mesa-forming Mesozoic rocks in southeastern TOBERMORY (Smith, 1965).

CAINOZOIC

TERTIARY

Ferricrete (Ti), silcrete (Ts), deeply weathered rock (Ta)
Most pre-Cainozoic outcrops show some evidence of ferruginisation or silification. The more significant ferricrete deposits, in the form of low rises of duricrust or chert-ferricrete rubble, have formed on a deeply weathered planation surface on the south side of the Davenport Range where the country rock is weathered to depths of about 80 m. Ferruginisation has particularly affected Cambrian arenaceous units and some of the recessive volcanic formations of the Hatches Creek Group. Silification has occurred on the same surface but is mainly prevalent on the siliter and more carbonate-rich strata of the Arthur Creek Formation (Plate 12). Massive silcrete is relatively uncommon. The sandstone outcrops of the Hatches Creek Group and the Dulcie Sandstone have a silicified coating, giving them a quartzitic appearance.

In eastern ELKEDRA, ferruginous duricrusts occur on mesas and isolated hills of the Tomahawk beds and the Arrinthuranga Formation sandstone member.

Silicified and ferruginised Cambrian rocks have been intersected in waterbores at depths of 20–70 m beneath Cainozoic alluvium along the Bundey and Sandover rivers (Appendix 4) indicating greater surf- face relief at the time of deep weathering. Drill hole NTGS ELK 1 intersected a lateritic regolith at 4–8 m beneath Quaternary sand.

Ferricrete is preferentially developed along fault zones which displace the Arthur Creek, Andagera and Arrinthuranga formations. In southeastern OORATIPPA, outcrops of black manganeseous ‘gossanous’ ferricrete, too small to show on the map, occur along many of the contacts between dolostone of the Arrinthuranga Formation and sandstone of the overlying Tomahawk beds.

TERTIARY TO QUATERNARY

Calcrite (Czk)
A thin calcrite crust is common over limestones and dolostones, particularly those of the Arrinthuranga and Frew River formations. A calcrite layer 3 m thick overlies Tomahawk beds near Bluebush Bore. Calcrite also occurs near exposures of Kudina Basalt (Blake and Horsfall, 1987).

Nodular or indurated layers of calcrite occur within alluvial soils at depths of 5–6 m along the Bundey, Sandover and Elkendra watercourses (Appendix 4).

Dissected fan deposits (Czk)
Fans of poorly consolidated alluvial and colluvial gravel, dissected by active watercourses, have accumulated on the flanks of the more prominent sandstone ridges and mesas in the Davenport Range. Those adjacent to the mesas consist largely of quartzitic sandstone cobbles, derived from erosion of conglomerate from the Andagera Formation.

Lag deposits (Czg)
Coarse nodular chert covers several low rises in the northeastern part of SANDBOVER. It is derived from near-surface dissolution of carbonates which occur at the top of the Lower Carbonate Unit of the Arrinthuranga Formation. The soft fine-grained limestone host is exposed in an excavation within one of these rises.

Plate 12 Brecciated silcrete overlying Arthur Creek Formation. Black angular fragments of silicified silstone occur in a matrix of sand grains and pale yellow-brown silica cement. This indicates initial silicification of silstone, then brecciation possibly caused by solution collapse, followed by a second period of silicification (GR NS5955).
**Fluvial deposits (Cza)**

Fluvial sediments of possible Tertiary age have been intersected in waterbores and drill holes along the Elkedra, Sandover and Bundey rivers. They grade upwards into Quaternary alluvium and are described under Qa.

**QUATERNARY**

The Quaternary has been subdivided on a morpho-stratigraphic basis after Grimes (1984).

**Colluvial deposits (Qc)**

Colluvial sand, soil and gravel forms gently sloping fans along ridges and hills in the Davenport Range. Waterbore data indicate that the colluvium is only 2–6 m thick, but greater thicknesses are likely close to the sandstone ridges. The fans are weakly incised by watercourses and grade downstream into alluvium.

**Sandplain and dunefields (Qs)**

Flat to gently undulating sandplain covers most of southern and eastern ELKEDRA. Longitudinal dunes up to 2 m high and many kilometres long, with a pronounced northwesterly trend, are developed within the plain. The sandplain and dunes consist of dark red aeolian sand and clayey sand and have been stabilised by a cover of spinifex and small bushy eucalypts. The depth of the sand is not known, except in the area north of the Sandover River on northern ORATIPPRA where it appears to be 4–10 m thick.

**Red earth soil plains (Qt)**

Red earth soils form a mantle up to 10 m thick over the mature deeply weathered plain on the southern side of the Davenport Range. The soils contain varying amounts of small ferricrete granules, derived mainly from lateritised sandstone and siltstone of the Chabal-owe and Arthur Creek formations which underlie the soil and form low rubbly rises within the plain. Most soils are covered with dense mulga (Acacia aneura) which has grown in a distinctive swaled pattern.

Within the mulga plain are areas of calcareous soils vegetated with gidyea (Acacia georginae), which overlie more calcareous and carbonate-rich Cambrian strata.

In southern ORATIPPRA, shallow residual earths vegetated with gidyea overlie dolostones of the Arrinthuranga Formation.

**Alluvial watercourses and floodplains (Qa)**

Alluvium and alluvial soils have accumulated along watercourses and spread over floodplains along the Sandover, Bundey and Elkedra rivers. The floodplains are dissected by meandering channels, up to 300 m wide, filled with sand and gravel. Many palaeochannels are discernible. Parts of the floodplain are covered by aeolian sand.

Waterbore information (Appendix 4) gives some idea of the subsurface extent of the alluvial deposits. The creeks that dissect the Davenport Range were formerly about 2–4 m deeper along their main channels and 15–25 m deeper in the lower reaches where they debouch onto the plain of the Georgina Basin. Beneath the Sandover River floodplain east of Ammaroo, and under the Bundey River floodplain, alluvial sand, silt, clay and river gravels are 30–90 m deep.

East of the Bundey-Sandover confluence, along the Sandover River towards Oratippra, most waterbores encountered Cambrian rocks at 5–20 m with deeper alluvial deposits apparently restricted to narrow channels. At the eastern end of the Elkedra River floodout in Annitowa, alluvium is 30–45 m deep, predominantly clay with sand and a few gravels, becoming thinner near the dolostone outcrops of the Arrinthuranga Formation. In drill holes BMR ELKEDRA 3 and 3A, the Quaternary sand and clays are underlain by a layer of partly chaledonic calcrite at 40–45 m, beneath which are 27 m of clays, sand and chert gravel (Milligan, 1963).

The age of the basal alluvial sediments is not known, but, being up to 90 m below present drainage level, it is likely to be late Tertiary rather than Quaternary.

**Mature alluvial plain (Qar)**

Qar represents more mature alluvial soils stabilised with mulga. These soils form the fringes of the Sandover and Bundey River floodplains and relics of abandoned drainage channels. Qar also indicates well-vegetated interdune swales formed by ponding of rainwater.

**Claypans (Op)**

Flat, poorly drained claypans are distributed in the lower reaches of floodplains and along relic drainage. Most are sparsely vegetated and sunbaked, but some form waterlogged sumps which support a dense plant community.

**STRUCTURE**

In the Early Proterozoic basement, the Hatches Creek Group forms a series of large synclines and antilines which have a dominant northwesterly trend. These folds have been refolded about northeasterly axes to produce complex arcuate domes and basins, outlined by resistant ridge-forming quartzitic sandstones (Figure 9). The main folds can be traced over 30–80 km along strike and have amplitudes of 5–12 km; they range from open to isoclinal and have steep axial surfaces (sections A–B and C–D on Map face). Most fold axes plunge between 10° and 50°. This folding is the result of an orogeny which affected the entire Davenport province sometime between 1800 Ma and 1650 Ma.

Numerous large and small faults, some marked by quartz veins, displace the Hatches Creek Group. Several major faults trend northwest across the middle of ELKEDRA. Within and southeast of the Davenport Range they offset the Hatches Creek Group, Andagera Formation and Arthur Creek Formation; in southeaster ELKEDRA, they displace the Arrinthuranga Formation and Tomahawk beds. The dip of these faults is unknown but nearly all have a downward displacement on their northeast side and an associated variable strike-slip component (Figure 9). Several are associated with prominent arcuate spur faults which curve to the north and northeast. These faults are part of suite of northwest-trending faults and monoclines which have similar characteristics (Figure 3).
Figure 9 Structure of Hatches Creek Group.

The age of this faulting is not known, but those faults that displace the Hatches Creek Group are believed to have formed during the late stages of deformation of the Hatches Creek Group (Blake and Horsfall, 1984; Stewart and Blake, 1984). Some of them must also have been reactivated much later, initially in the Early Cambrian when regional tectonism and volcanism could have triggered deposition of the alluvial fan deposits of the Andagera Formation (Walley, 1987), and again during the Alice Springs Orogeny at about 300 – 400 Ma (Shaw and others, 1984). Faulting attributable to the Alice Springs Orogeny has caused vertical displacements of about 50 – 200 m on the Supplejack Fault (Section JKL on Map face).

The Georgina Basin sequence is flat-lying and generally dips at less than 5° to the south and southeast. These slight dips could reflect differential compaction or the original slope of deposition. Alternatively, they could be due to very gentle regional folding associated with the Alice Springs Orogeny, producing a northwest-trending synclinal axis along the Dulcie Syncline, just south of ELKEDRA (Figure 3), and a corresponding anticlinal axis along the Davenport Range. A few minor anticlinal structures have warped the Arthur Creek Formation and can be explained by differential
compaction of siltstone and lenticular carbonate beds during diagenesis.

Collapse folding has affected the Tomahawk beds and Euowie Sandstone (see 'Tomahawk beds'). Warping of beds in the Arrinhrunga Formation may be due to incipient sinkhole development.

Joint sets are prominent in carbonates of the Arrinhrunga Formation.

METAMORPHISM

Studies by Blake and Horsfall (1984) showed that the Early Proterozoic rocks have been affected by low-grade regional metamorphism.

In the Hatches Creek Group, original textures are well preserved but minor changes are evident. Fine-grained sediments and felsic tuffs contain minor white mica, biotite and chlorite. In felsic volcanics, plagioclase phenocrysts have been albited. In basalt and dolerite, pyroxene and calcic plagioclase have been replaced by actinolitic amphibole, epidote, chlorite, albite and calcite.

Alteration in the Elkedra Granite is restricted to strain in quartz and some chloritisation of biotite.

Metamorphic aureoles a few metres wide border granophyre sills. An aureole about 100 m wide surrounds the Elkedra Granite, producing muscovite-biotite schist, needles of tourmaline and some altered aluminosilicate porphyroblasts in the adjacent Rooneys Formation.

Phanerozoic rocks have not been metamorphosed.

GEOPHYSICS

Gravity

ELKEDRA is covered by BMR gravity data at 11 km station spacing with additional traverses along roads and tracks in the northwest corner of the sheet area. The data have been processed and released as Bouguer anomaly contours (Murray and Smilok, 1983a, 1983b). The station spacing is inadequate for detailed interpretation but broad regional correlations can be made (Figure 10). ELKEDRA lies wholly within the Georgina Regional Gravity Shelf Province (Fraser and others, 1977) and consists of three units: the Ooratippra Gravity High, Ammaroo Gravity Depression and Sandover Gravity Low.
The Ooratippra Gravity High occurs in the southeastern corner of ELKEDRA (Figure 10) and is characterised by Bouguer anomaly values greater than 200 μm·s⁻². Modelling suggests that this gravity high is due to an increase in rock density at a depth of 2–3 km. The Ooratippra Gravity High coincides with a magnetic high (Figure 11) which is interpreted as having a similar depth to source. Drill hole BMR 13 (Sandover), drilled on the northern edge of this coincident high, intersected gneiss at 1007 m (Smith, 1967), indicating that this density and susceptibility contrast occurs within the Early Proterozoic basement about 1-2 km below the Palaeozoic unconformity.

A steep gravity gradient bounds the western edge of the Ooratippra Gravity High and extends south across HUCKITTA. This indicates the presence of a deep-seated north-trending fault at about 136° 00' which appears to coincide with the Putta Putta Fault (Freeman, 1986). The northern boundary of the gravity high, defined by northeast-trending Bouguer anomaly contours (Figure 10), also appears to be fault-controlled. This postulated northeast-trending fault has no surface expression and must be confined to the Early Proterozoic basement rocks.

Faults oriented northeast and northwest within the Ooratippra Gravity High have divided it into a series of gravity troughs and ridges. The gravity lows have been interpreted as representing thick sequences of late Proterozoic sediments (Fraser and others, 1977) but they could be due to granite.

Positive Bouguer anomaly values, with a contour pattern similar to that observed in southeastern ELKEDRA, occur north of the Mia Mia Dome in FREW RIVER. This led Fraser and others (1977) to define the Ooratippra Gravity High as extending across ELKEDRA into FREW RIVER and BONNEY WELL. However, between these two areas in ELKEDRA, the values are generally low (−250 to −350 μm·s⁻²) with isolated contour closures. This pattern is similar to that observed over the Sandover Gravity Low to the east, so the northern half of ELKEDRA has been redefined as being part of the Sandover Gravity Low (Simons, in Walley, 1987).

Fraser and others (1977) suggested that the low Bouguer anomaly values of the Sandover Gravity Low are caused by a thick sequence of Late Proterozoic sediments. However, the Hatches Creek Group predominates within the Sandover Gravity Low which indicates that the low values are due to the sandstone-dominant nature of this Group. Low Bouguer anomaly values at Annitowa in northeastern ELKEDRA are probably due to granite.

Low Bouguer anomaly values in the southern central part of ELKEDRA correspond to the Ammaroo Gravity Depression (Fraser and others, 1977). Modelling of detailed gravity results by Robertson Research (Australia) Pty Ltd (1982) suggested up to 5 km of post-Hatches Creek Group sediments could account for the observed gravity feature. However this does not accord with the aeromagnetic data which indicates that magnetic material, probably representing volcanic units of the Hatches Creek Group, occurs at depths of about 1 km. The preferred interpretation is that the Hatches Creek Group rocks underlying the Ammaroo Gravity Depression have been extensively intruded by less dense granitoids.

MAGNETICS
An airborne magnetic survey was flown by BMR in 1963 at an altitude of 600 m above sea level along lines 3.2 km apart (Wells and others, 1966). A total magnetic intensity contour map was compiled from this data (BMR, 1966).

The total magnetic intensity contours are disturbed over most of the map sheet, particularly in the northwest corner (Figure 11) where they trend northwest and reflect the interbedded magnetic volcanics and non-magnetic sandstone characteristic of the Hatches Creek Group. Elsewhere in ELKEDRA, the magnetic contours trend northeast.

Estimates based on total magnetic intensity profiles indicate that the depth to the magnetic units within the Hatches Creek Group increases to the south and east. Depth estimates greater than 1000 m are rare and suggest that the Ammaroo Gravity Depression does not represent a thickened sequence of post-Hatches Creek Group sediments.

The southeast corner of ELKEDRA is dominated by a large magnetic anomaly coinciding with the Ooratippra Gravity High (Figures 10 & 11). The anomaly has a relief of 2000 nT and an areal extent of approximately 1200 km². The depth to its source has been estimated at 2–3 km (Wells and Milsom, 1965; Robertson Research (Aust) Pty. Ltd., 1982) which is consistent with the estimated depth to the gravity anomaly. Smaller, superimposed magnetic anomalies yield depths of 1100 m (Wells and others, 1966), which is consistent with the depth to Early Proterozoic basement from drill hole BMR 13 (Sandover) (Smith, 1967).

GEOLOGICAL HISTORY
Deposition of the oldest exposed rocks in the area, the Hatches Creek Group, commenced sometime around 1900–1700 Ma with the eruption of basaltic and felsic lavas to the northwest of ELKEDRA, and deposition of fluvial, deltaic and shallow-water near-shore clastic sediments. The geological setting is uncertain but has been interpreted as an ‘extensional crustal regime’ (Blake and Horsfall, 1987) and as an ‘ensialic crustal rift’ (Stewart and Blake, 1984).

In ELKEDRA, the basal clastic sediments were covered by rhyolitic ignimbrites, lavas and pyroclastics from at least two volcanic centres. This first interdigitating phase of volcanism and sedimentation was followed by a period of widespread, relatively uniform sedimentation on a broad shallow-marine shelf, resulting in a thick, arenally extensive (750 000 km²) sequence of clean well-sorted sands across all the earlier deposits. A second episode of mainly explosive rhyolitic and dacitic volcanism, centred to the southeast of earlier eruptions, interrupted this sedimentation, blanketing the sands throughout northwestern ELKEDRA with more ignimbrites and pyroclastics. Thereafter sands continued to accumulate to even greater thickness, eventually grading upwards into finer silty sediments and localised sabkha deposits. A third episode of volcanism commenced with widespread basalt flows, followed by another pile of shallow-marine sandstone and more argillaceous sediments at the top of the sequence.
A major orogeny compressed the Hatches Creek Group sequence towards the northeast, forming major folds and associated high-angle thrusts (Stewart and Blake, 1984). A change in compressional direction produced complex refolding. The sequence was affected by very low-grade regional metamorphism. Towards the end of the orogeny, at about 1660 Ma, the Elkeda Granite intruded the base of the sequence. The region became part of a stable continental landmass and was subjected to a long period of erosion which produced a mature landscape of relatively low relief, the Ashburton Surface (Hays, 1967; Stewart and others, 1986). The Davenport Range was a topographic high on this surface.

In the late Proterozoic, a series of northwest-trending troughs or half-grabens were initiated just south of ELKEDRA, along the southern margin of the present Georgina Basin (Freeman, 1986). These troughs were filled with fluvial, glacial and shallow-marine sediments. In ELKEDRA, the sequence included red-bed shales and sandstones, deposited between about 750 Ma and 600 Ma.

In the Early Cambrian, or possibly Vendian, extrusive flood basalts were erupted in northern Australia from zones of crustal tension (Bultitude, 1976) linked to plate movement (Shergold and others, 1985). This activity could have reactivated fault movement in the Davenport Range area, triggering coarse fluvial deposits of the Andagera Formation which filled valleys and spread out as fans on the surrounding piedmont plain.

Late in Early Cambrian times the sea transgressed up a gentle slope from the southeast, resulting in deposition of carbonate shoals and algal-archaeocyathan communities of the Errarra Formation. By the early Middle Cambrian (Ordian), the sea probably covered most of the Davenport Range. Low-energy conditions prevailed and carbonaceous shales of the Arthur Creek Formation accumulated in the deeper, anoxic parts of the marine basin. As the sea shallowed, more oxic conditions evolved; in the relatively warm climate, organisms proliferated in a calcareous shale environment and phosphorite accumulated around basement highs. Carbonate shoals overlain by sabkha deposits of the Hagen Member were deposited along the shoreline west of ELKEDRA. Flooding of these supratidal flats and influx of terrigenous detritus produced tidal deposits of the upper Chabalowe Formation.

Near the end of the Middle Cambrian, the shallow-upwards sequence was succeeded by shallow-water submerged carbonate banks and shoals of the Arrinthunga Formation followed by a gradual influx of shale and sandstone, and proliferation of algal mats over
semi-emergent hypersaline flats and lagoons. One or two further cycles of inundation and re-emergence completed this thick Late Cambrian carbonate sequence.

Exposure and erosion removed part of the Arrin thrunga Formation prior to the next rise in sea level near the end of the Cambrian Period in Payntonian times. This produced fossiliferous shelf sandstone deposits of the Tomahawk beds.

Ordovician sediments may have covered the southeastern part of ELKEDRA, but, if so, these formations and the top of the Tomahawk beds were eroded in the Late Ordovician or Silurian. In the Early to Middle Devonian the fluvial and aeolian Dulcie Sandstone, containing a freshwater fish fauna, was deposited in a broad northwest-trending depression across the continental landmass, with much of the sand probably derived from reworking of the Tomahawk beds. The depression could have formed in response to early stages of crustal fracture, fault reactivation and downwarp initiated by the Alice Springs Orogeny which reached its peak in the Carboniferous, but which had only a marginal effect in ELKEDRA. Sedimentation in the Georgina Basin terminated with the onset of compressional events associated with the Alice Springs Orogeny. Just south of ELKEDRA, continued downthrow against northwest-trending faults in the Early Proterozoic basement caused broad ESE folding of the Dulcie Syncline.

Morris (1986a) estimated that peak oil generation from the Arthur Creek Formation coincided with the Alice Springs Orogeny. Lopatin modelling (the reconstruction of burial history of a geologic section at a given locality; Waples, 1980) based on organic geochemical data from drill holes NTGS ELK 7A and ELK 3, indicates that the hydrocarbon source rocks in these localities have been buried under 1000–1500 m of sediment in excess of what is preserved at the present day (Morris, 1986a). This means that, contrary to the ideas of Stewart and others (1986), the Davenport Range may have been covered by Late Cambrian and possibly younger sediments.

Erosion prevailed until the Jurassic and Cretaceous when widespread clastic sediments covered the Eromanga Basin. Possible remnants of these flat-lying sediments are preserved in southeastern ELKEDRA.

Deep weathering profoundly affected the landscape during warm and humid periods of the Early to Middle Tertiary (Langford-Smith, 1983), forming ferruginous and siliceous duricrusts underlain by deeply weathered profiles. Dissolution of Cambrian carbonates resulted in collapse of overlying sandstone strata into solution cavities. Palaeodrainage channels coincident with the Elk edra and Sandover rivers flowed into the Georgina River at least as far back as the Eocene and possibly during the Mesozoic (Langford-Smith, 1983). Onset of aridity towards the end of the Tertiary (Bowler, 1976; Langford-Smith, 1983) resulted in silting of this drainage, producing phreatic calcrite in the palaeochannels near the drainage sumps (Arakel and McConnell, 1982). Dune fields formed during the late Pleistocene, around 17 000 B.P. (Langford-Smith, 1983) and became stabilised about 13 000 B.P. (Bowler, 1976). A humid phase in early to mid-Holocene was followed by renewed stream activity, producing braided fluvial fans on the Bundey and Sandover floodplains. The region has been predominantly arid since that time.

**MINERAL RESOURCES**

ELKEDRA has been explored for a number of minerals, including lead-zinc in the various carbonate sequences, uranium in the Davenport Range, diamonds in stream sediments, and phosphorite in the Arthur Creek Formation. Mining activity has been confined to open pit excavations for turquoise at Tosca Mine and a little trenching along quartz reefs for tungsten. Good supplies of groundwater are present.

Morris (1986a) has reported on the hydrocarbon potential as indicated by NTGS stratigraphic drilling, showing that good potential source rocks exist in the southern part of ELKEDRA. Oil stains and bleeds, and shows of gas, were encountered within Cambrian sediments in a number of drill holes. Morris (1986c) has also reported on the potential for base metals in the Georgina Basin within the Northern Territory. The mineral resources and economic potential of the Davenport province have been summarised by Blake and Horsfall (1984).

The mineral deposits and their potential are discussed under commodity subheadings below.

**Copper-Lead-Zinc**

Copper-lead-zinc mineralisation has been sought in several carbonate sequences, both in the Early Proterozoic basement and the Georgina Basin, but nothing of significance has yet been found.

In the Early Proterozoic basement, Amoco Minerals Australia (Miller and Cartew, 1984) sampled the Frew River Formation of the Hatches Creek Group and found a zone, 250 m wide, of ferruginous calcareous siltstone which gave anomalous assay values of copper, zinc, cobalt and barium (up to 9300 ppm Cu, 1250 ppm Zn, 4800 ppm Co and 2.55% Ba). Within this zone, located about 5 km northeast of Supplejack Bore (GR NS5530), they found a number of discrete manganiferous iron oxide horizons, 5–10 m wide. Hoatson and Cruikshank (1985), in a limited orientation geochemical survey, found only weak Cu anomalies and near background Zn-Ag-Pb in crevices draining the Frew River Formation in northwestern ELKEDRA.

Smith and Milligan (1966) noted a report of a short narrow chalcocite-bearing vein in the western part of Elkedra pastoral lease. This is probably one of the small quartz veins containing secondary copper minerals in the Treasure Volcanics just west of the northwestern corner of ELKEDRA in Amelia Pound (Snelling, 1979). Blake and Horsfall (1984) reported a small prospect pit at GR NS4926 containing sheared sedimentary rocks of Rooney Formation impregnated with secondary copper minerals.

In the Georgina Basin, exploration has concentrated on the Arthur Creek and Arrin thrunga formations, and there is potential in the Chabalowe Formation.

Anomalous concentrations of copper are known from the base of the Arthur Creek Formation, e.g. up to 4000 ppm in the deeply weathered turquoise-bearing mudstones at Tosca Mine. They are associated with thin limonite bands, possibly after sulphides (Morrison, 1969).
A reconnaissance induced-polarization survey was commissioned by Vam Ltd to look for subsurface Pb-Zn mineralisation in the Arthur Creek Formation (Seigel Associates, 1970). Two areas, one in northern Ammaroo and the other on the eastern side of the Davenport Range, were followed up with brief ground reconnaissance but no mineralisation was found. Minor sphalerite, rare galena and some fluorite were observed in several NTGS drill holes through the Arthur Creek Formation; in ELK 7, the mineralisation is associated with hydrocarbon bleeds. Assay values of this core are given in Morris (1986c). Anomalous zinc values were found at 771–774 m (7800 ppm) and 832–835 m (2300 ppm) in BMR 13 (Sandover, BHP, 1977).

Small surface shows of galena were found in Oroatippra near Trackrider Bore (GR PR2569), within vuggy, siliceous and manganiferous dolostone of the Arrinthunga Formation (Sturmffes, 1960). The dolostone contains anomalous amounts of barium and fluorine (BHP, 1977). Geochemical sampling of the surrounding area by CRA Exploration showed that the whole of the Oaratippra area is moderately anomalous in lead, with concentrations up to 40 times background (Kostlin, 1970). Further investigations by Centamin NL and BHP Ltd showed that anomalous Pb-Zn values were concentrated on the near-horizontal disconformity surface between the mesa-forming sandstone of the Tomahawk beds and the underlying dolostone of the Arrinthunga Formation (Cotton, 1973; Chugg and Johnson, 1973; BHP, 1977). The disconformity is marked by a heavily ferruginised zone of hematite and goethite with manganiferous encrustations. Values ranged up to 14 000 ppm Pb and 830 ppm Zn (Cotton 1973). Two drill holes, TRD 1 and TRD 2, were drilled by BHP (1977) through the contact, intersecting anomalous zones at the disconformity (470–22 600 ppm Pb; 170–1160 ppm Zn) but no visible sulphides.

Traces of galena, in some cases with associated fluorite, occur in drill holes NTGS ELK 6 (at 220–240 m in ooid dolostone of Arrinthunga Formation) and ELK 7 (170–195 m in dolostone of Chabaloware Formation).

The coincident gravity-magnetic anomaly at Oaratippra (see ‘GEOPHYSICS’) was proposed as a target for Olympic Dam type mineralisation (Moore, 1979) but assessment by Ypma (1986) has downgraded its potential.

### Hydrocarbons

The NTGS drilling program has shown that the Arthur Creek Formation in the southern part of ELKEDRA is a good potential source of hydrocarbons (Morris, 1986a). This potential was first indicated when petroliferous gas was encountered in 1956 during drilling operations for water at Discovery Bore, located 21 km northeast of Ammaroo homestead (Mackay and Jones, 1956). Farmout Drillers NL followed up this discovery by drilling two shallow stratigraphic wells to basement in the vicinity of Discovery Bore: Ammaroo No. 1 to 186 m and Ammaroo No. 2 to 256 m (Newton, 1963). Bituminous limestone and shale of the Arthur Creek Formation with traces of petroliferous hydrocarbons were intersected in both holes.

The BMR drilled a deep stratigraphic hole, BMR 13 (Sandover), on Oaratippra to assist petroleum search in the Georgina Basin (Lloyd and Bell, 1964; Smith, 1967). A show of oil and gas was obtained between 899.7 m and 906.8 m from a calcareous, argillaceous and bituminous dolomite, assigned to the Arthur Creek Formation. A drill stem test of the interval recovered ‘22 cut ft gas cut mud at 61 lb/ft³ and a small volume of oil. Small quantities of bituminous material were observed in cuttings from the overlying Arrinthunga Formation at various depths between 368 and 784 m.

Three scout holes (P1, L2, L3) drilled by Vam Ltd in their search for phosphate to the north of Discovery Bore encountered a strong smell of natural gas issuing from black organic-rich shale of the Arthur Creek Formation (Morrison, 1968).

Four of the stratigraphic holes drilled by NTGS in 1983–85 intersected hydrocarbons, as summarised in Table 2. Samples from these drill holes were submitted to Amdel and the Baas Becking Geobiological Laboratory of BMR for source rock analysis and oil characterisation studies. Detailed Amdel results by D. McKirdy.

### Table 2 Hydrocarbon occurrences in NTGS drill holes.

<table>
<thead>
<tr>
<th>DRILL HOLE</th>
<th>DEPTH (m)</th>
<th>FORMATION</th>
<th>ORGANIC MATTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELK 2</td>
<td>280–285</td>
<td>Arrinthunga Arthur Creek</td>
<td>Minor oil and pyrobitumen Oil stains associated with fossil beds</td>
</tr>
<tr>
<td></td>
<td>365–450</td>
<td></td>
<td>V. carbonaceous, partly bituminous</td>
</tr>
<tr>
<td>ELK 3</td>
<td>80–114</td>
<td>Arthur Creek</td>
<td>Oil stains Oil stains, hydrocarbon odour.</td>
</tr>
<tr>
<td>ELK 6</td>
<td>483</td>
<td>Arrinthunga Chabaloware</td>
<td>Main zone at 791–797 m Fractures with oil bleed</td>
</tr>
<tr>
<td></td>
<td>694–819</td>
<td></td>
<td>Oil bleeds and stains in pores, small fractures and vugs Partly bituminous, strong odour; a few vugs with thick oil and pyrobitumen</td>
</tr>
<tr>
<td></td>
<td>819–823</td>
<td>Errarra</td>
<td>Oil bleeds</td>
</tr>
<tr>
<td>ELK 7</td>
<td>170–248</td>
<td>Chabaloware</td>
<td>Oil bleeds</td>
</tr>
<tr>
<td></td>
<td>248–300</td>
<td>Arthur Creek</td>
<td></td>
</tr>
<tr>
<td></td>
<td>300–301</td>
<td>Errarra</td>
<td></td>
</tr>
</tbody>
</table>
and T. O’Leary, and preliminary BMR results, by R. Summons, accompany the report by Morris (1986a).

Source rock analyses show that the total organic carbon content (TOC) of the Arthur Creek Formation varies from 0.1% to 14%. The rocks have potential hydrocarbon yields in the range 2–13 kg/tonne and contain good quality oil-prone Type II kerogen (hydrogen index 300 – 480; 40 – 80 where overmature) in which the main recognisable maceral is bituminite (in part vitrinite-like) of presumed algal/bacterial affinity (McKirdy and others, 1986). Samples from ELK 2 and ELK 7A are mature for oil generation; carbonaceous mudstone and limestone from ELK 3 (2–14% TOC) are overmature and hence gas-prone.

Oils analysed from the stained dolostone cores of the Chabalowe Formation in ELK 6 and ELK 7A are mature and of aromatic-intermediate composition, in which the gasoline range hydrocarbons display no sign of water-washing or biodegradation. Analyses indicate a marine origin from eukaryotic algal and bacterial remains deposited under anoxic to micro-oxic conditions. These oils can be tentatively correlated with carbonate source rocks in the Arthur Creek Formation.

Morris (1986a) regards the porous grainstone carbonates near the base of the Chabalowe Formation and very porous ooid dolostone of the Arrinthurra Formation as good potential reservoir rocks. The porous sandstone of the Chabalowe Formation and vuggy dolostone of the Errarra Formation are also potential reservoirs. Potential seals are evaporites in the Hagen Member and peritidal sediments within the Arrinthurra Formation.

**Phosphat**

Sedimentary phosphate deposits (phosphorites) were formed in organic-rich carbonate mudstone during the early Middle Cambrian in many parts of the Georgina Basin (Cook and Shergold, 1984) and are also present in the Arthur Creek Formation in ELKEDRA. Known deposits typically occur around the margins of the basin, on the flanks of basement highs.

Phosphorite was found in northern AMMAROO by Vam Ltd who drilled seven scout holes near Limestone Bore (Morrison, 1968). Phosphate was encountered in the following intervals within weathered calcareous siltstones and mudstones.

<table>
<thead>
<tr>
<th>Scoughole</th>
<th>Depth (m)</th>
<th>Field assay P₂O₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>P–2</td>
<td>33.5–35.0</td>
<td>under 20%</td>
</tr>
<tr>
<td>L–2</td>
<td>25.9–26.8</td>
<td>30%</td>
</tr>
<tr>
<td>L–4</td>
<td>26.8–28.6</td>
<td>15–20%</td>
</tr>
<tr>
<td>L–5</td>
<td>38.1–46.3</td>
<td>15–20%</td>
</tr>
<tr>
<td>L–5</td>
<td>46.3–51.8</td>
<td>5–10%</td>
</tr>
<tr>
<td>L–5</td>
<td>55.5–59.6</td>
<td>5–10%</td>
</tr>
<tr>
<td>L–5</td>
<td>23.5–33.5</td>
<td>2–8%</td>
</tr>
</tbody>
</table>

Phosphatic fossil debris is common in parts of the Arthur Creek Formation. Analysis of core from BMR 13 (Sandover) by BHP (1977) showed values of 2.7–4.0% P₂O₅ at 939–945 m in carbonaceous shale.

**Tungsten**

Wolframate was sought at the Juggler prospect (GR NS4925) where narrow quartz veins are exposed in a trench about 50 m long within a NNE-trending greisened zone in the Elkedra Granite. The veins are up to 20 mm wide and are impregnated with radiating black tourmaline, clusters of fine muscovite and a little feldspar.

At GR NS7027 a bulldozed cut has exposed a bifurcating quartz vein, about 2 m wide, which strikes at 295° within grey phylitic siltstone of the Newlands Volcanics; the quartz vein contains scattered crystals of wolframate.

A geochemical orientation survey undertaken by Hoatson and Crikshank (1985) showed that detrital scheelite is present in the vicinity of the Elkedra Granite. Low levels of W (21 ppm), Sn (12 ppm) and Bi (4 ppm) occur in the coarse sand fraction downstream from the Juggler prospect.

**Turquoise**

Turquoise of moderate to poor quality, much of it chalky, has been produced at the Tosca Mine, 34 km northeast of Ammaroo homestead. The host rocks are weathered mudstone and siltstone of the Arthur Creek Formation which form a near-horizontal sequence, 1–15 m thick. They overlie an undulating basement of steeply dipping quartzitic sandstone and purplish siltstone of the Hatches Creek Group (Kurinelli Sandstone and Rooney’s Formation) and a small body of weathered tonalite. In the northern part of the mine area, the siltstone overlies and abuts against a thin cobble conglomerate of the Andagera Formation.

Four main pits have been excavated in the siltstone sequence, exposing white to brownish-white kaolinitised mudstone underlain by dark red to purple mudstone. According to Morrison (1969), the main turquoise-bearing horizon is about a metre thick at the base of the mudstone, just above the unconformity. The turquoise occurs in lenses up to 100 mm thick within this horizon, generally as a single layer but more in some places. The host horizon is phosphatic and contains bands and stains rich in limonite or goethite which are thought by Morrison (1969) to represent oxidised chalcopyrite or pyrite layers. He also noted the presence of wavelite, detectable by scintillometer, in lenticular layers associated with the turquoise. The red beds were found to contain anomalous amounts of copper. About 60 tonnes of turquoise-bearing material have been mined from the pits but no overall production figures are available.

Poor quality turquoise was also found in the same formation 9 km to the southwest near the old Limestone Bore and also 4 km northwest of Rockhole Bore (GR NS5647).

**Construction materials**

Lateritic gravel, suitable for road construction, is available in gravel pits alongside the Sandover Highway. The gravel caps weathered siltstones of the Arthur Creek Formation. Calcrete and silcrete could also be used.

**Groundwater**

As surface water is limited to a number of semi-permanent waterholes along the Elkedra River, George Creek, and their tributaries in the Davenport Range, the principal source of water supplies is groundwater. The regional setting of these supplies has been
presented by Jones and Quinlan (1962). By the end of 1985 about 110 waterbore had been drilled, of which about 50 are currently in operation. Information on these bores, compiled from records held by the Water Resources Division of the Power and Water Authority in Alice Springs, is tabulated in Appendix 4.

Groundwater aquifers can be grouped into three geological environments: (i) the Early Proterozoic basement of the Davenport Range; (ii) the Cambrian strata of the Georgina Basin, and (iii) deep Cainozoic palaeochannels.

**Proterozoic aquifers:** Records show that groundwater in the Davenport Range, where available, is at relatively shallow depths, generally 20–60 m. The most successful bores have been in the limestone-bearing beds of the Frew River Formation which have yielded moderate supplies (1.0–2.5 L/s) of good quality to moderately saline water (800–1800 mg/L total dissolved solids). Aquifers are very limited in the other formations of the Hatches Creek Group but may occur in some fractured or deeply weathered zones. Bores sunk in the Newlands Volcanics have been particularly unsuccessful.

**Cambrian aquifers:** In the Georgina Basin the water table is deeper, generally between 50 and 120 m, with an average depth of weathering of about 80 m. Several of the Cambrian formations contain good aquifers and none are too saline for stock.

The Chabalowe Formation, comprising porous dolomitic sandstone, siltstone, carbonate rocks and some gypsiferous beds, has some large solution cavities. It has good aquifers with moderate to high yields (1–4 L/s) but the water is moderately saline (1100–2400 mg/L). High fluoride levels were encountered at Honeyman and Impalawatya bores (GR NS2604 and NS2305).

The Arthur Creek Formation, composed of relatively impermeable calcareous siltstone, generally does not yield useful quantities of water. Some good supplies (2.5–6 L/s) of drinkable water have been obtained by drilling on the southern margin of the main outcrop area where the siltstone grades into sediments of the Chabalowe Formation. These yields could have been influenced by aquifers in the Chabalowe Formation or in overlying Cainozoic palaeochannels. In bore R.N. 13987 (GR NS5702), drilled through the Arthur Creek Formation, the 5 L/s supply is derived from dolostone in the underlying Errarra Formation.

Aquifers in fractured and vuggy dolostone, limestone and some porous sandstone of the Arrinthrungra Formation supply most of the groundwater on Ooratippa and Annitowa pastoral leases. The quality is relatively good, ranging from 500 to 1600 mg/L and averaging about 900 mg/L dissolved salts. Aquifers have low to moderate yields (0.5–3.0 L/s) on Ooratippa and slightly better supplies (1.5–5.0 L/s) on Annitowa. In the northern part of Annitowa lease where the Arrinthrungra Formation could be underlain by the Gum Ridge Formation, bores are somewhat less productive.

The Tomahawk beds in southwestern ELKEDRA are potentially good sandstone aquifers. Two bores drilled into them supply moderate amounts of drinkable water.

**Cainozoic aquifers:** Tertiary palaeochannels underlie Quaternary alluvium along the Sandover and Bundey rivers at depths of up to 100 m. The watertable in these poorly consolidated gravel and river sand deposits may be less than 40 m deep. The water is of good quality (600–1000 mg/L dissolved salts) and is probably recharged by floods along the Sandover and Bundey rivers. Current yields are relatively low (0.7–1.0 L/s) but supplies are long lasting: those on Ammaroo along the Sandover River have been in use for many years. Larger yields may be present.

Along the Elkedra River the depth of Cainozoic palaeochannels is uncertain and may be above the piezometric surface.

**ACKNOWLEDGEMENTS**

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Special thanks are extended to field assistants, drafting personnel (S. Leyland, G. Evans, J. Watson, A. Brook and W. Pillar) and typing staff (L. Saxby and R. Edwards). The cooperation of pastoralists is acknowledged.

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APPENDIX 1

DEFINITION OF NEW STRATIGRAPHIC UNITS

**Andagera Formation**

**Symbol:** Eclid

**Proposers:** L. Bagas, N. Donnellan and P. A. Stidolph.

**Derivation of name:** After Andagera Bore (GR NS7725) and Andagera Creek.

**Distribution:** Around the margins of the Davenport Range and along some valleys within the range, mainly in the NW of ELKEDRA, also in SW of FREW RIVER, NE of BARROW CREEK and SE of BONNEY WELL.

**Type section:** 22 m of conglomerate overlain by sandstone, 17 km north of Iblumric Bore at GR NS2346. The top is a cap of silicified siltstone and the base a rubbly-covered unconformity over steeply dipping siltstone and sandstone of the Hatches Creek Group.

**Reference section:** 24 m of pebbly sandstone, conglomerate and siltstone exposed on the side of a mesa 2 km west of Andagera Bore at GR NS7525. Bas unconformably overlies Newlands Volcanics of the Hatches Creek Group; top is the crest of the mesa. Disconformably overlain by fossiliferous Arthur Creek Formation about 1.8 km to the NW.

**Lithology:** Varies laterally from a conglomerate-dominated lithofacies to a sandstone-dominated lithofacies. The type section, from the conglomerate lithofacies, consists of massive to thick beds of poorly sorted, well-imbricated, boulder to cobble orthoconglomerate at the base, fining upward to medium- and thin-bedded, planar and cross-bedded pebble conglomerate and sandstone. Clasts are quartzitic sandstone from the Hatches Creek Group, with minor vein quartz.

The reference section, from the sandstone lithofacies, is predominantly medium- to fine-grained, gritty and pebbly sandstone (sublitharenite) with lenses of pebble conglomerate at various intervals and some laminated interbeds of red siltstone. Bedding is thin to thick, almost horizontal, with sharp, planar contacts. Ripple marks are well developed. Pebbles consist of vein quartz and quartzitic sandstone. Parts of the lithofacies are feldspathic and have a ferruginised matrix.

**Thickness:** Ranges from 5 m to 40 m.

**Surface expression:** Occur as terraces on the floor and slopes of valleys, or as mesas.

**Relationships:** Unconformable on early Proterozoic Hatches Creek Group and Elkedra Granite. Overlain by partly silicified siltstone or siltstone rubble of the Arthur Creek Formation; contact is sharp and disconformable on a regional scale.

**Depositional environment:** Fluviatile deposits, ranging from proximal valley-fill conglomerate in the Davenport Range to more distal alluvial fan sediments at the SE end of the range.

**Age:** Inferred to be Early Cambrian. No fossils found. The overlying Arthur Creek Formation is early Middle Cambrian (late Ordian to Templetionian).

**Synonymy:** Formerly regarded as the basal conglomerate-sandstone member of the Sandover beds (Smith, Vine and Milligan, 1963; Smith and Milligan, 1966). Outcrops north of Iblumric Bore originally in the Tomahawk beds (Smith and Milligan, 1966).

**Correlatives:** Correlates with the basal unit of the Gum Ridge Formation (Smith, 1964b), now included in Andagera Formation (Walley, 1987).

**Chabalowe Formation**

**Symbol:** Emc.

**Proposers:** D. G. Morris, L. Bagas and P. A. Stidolph.

**Derivation of name:** After Chabalowe Bore (GR MS6250) in BARROW CREEK.

**Distribution:** Outcrops trend SE for 90 km from Chabalowe Bore in BARROW CREEK to Honeymoon Bore in ELKEDRA. Intersected in NTGS drill holes ELK 4,6,7,7A and BC 3,5A and 5.

**Holostratotype:** In NTGS BC 5, from 166.90 m to 327.43 m, located at GR MS155765 in BARROW CREEK (lat. 21°00'45"S, long. 134°11'15"E). Consists of 36 m of conglomerate and sandstone at the base, overlain by 160 m of typical lithology. The top is identified by gradation from sandstone-dominant to carbonate-dominant sequence; the base by an unconformity on coarse-grained Proterozoic granite.

**Parastratotype:** In NTGS ELK 7 and 7A, from 15.00 to 238.05 m, located at GR NS162052 in ELKEDRA. Top is not seen; upper 153 m is similar to holostratotype; lower 95 m constitutes gypsium-rich beds and dolostone of the Hagen Member (defined separately). Base is identified by gradation into dark carbonaceous and fossiliferous dolarenites and dolomitic siltstones of the Arthur Creek Formation.

**Surface expression:** Poorly exposed as low rises of ferruginised sandstone, minor chert and very rare dolostone, best seen about 8 km SSE of Chabalowe Bore in BARROW CREEK. No formalional boundaries seen on surface.

**Lithology:** The lithology of the holostratotype is summarised below:

39.5 m (166.00 – 205.50 m) Sandy dolarenite and dolomitic sandstone with minor interbeds of mudstone and dolomericrite. 85.0 m (205.50 – 290.53 m) Dolomitic sandstone, some sandy dolostone and rare dolarenite; minor interbeds of dolomericrite, dololutite, algal dolostone, partly carbonaceous siltstone and rare intraformational breccia. 24.2 m (290.53 – 314.77 m) Granule to pebbly conglomerate consisting of granitic, metavolcanic and quartzite clasts in a
sandy dolostone to dolomitic arkose matrix; sandstone with minor dolomite in matrix; minor dolarenite.
12.7 m (314.77 - 327.43 m) Conglomerate with clasts as above in a lithic arenite matrix.

The lithology of the parastratotype, from 15.00 m to 71.75 m in ELK 7 and from 65.61 m to 238.05 m in ELK 7A is as follows:
31.3 m (15.00 - 46.33 m) Interbedded dolomitic siltstone, claystone and fine-grained sandstone; minor medium- to coarse-grained sandstone.
31.5 m (46.33 - 77.81 m) Interbedded dolostone, claystone and siltstone; minor fine- to medium-grained sandstone and intraformational breccia
35.8 m (77.81 - 113.64 m) Fine- to medium-grained, porous sandstone with partly dolomitic matrix, dolostone with chert nodules, algal laminite, dolarenite, claystone, siltstone and intraformational breccia
39.5 m (113.64 - 153.48 m) Dolarenite, algal laminite, dolostone with chert nodules, dololutite, fine-grained sandstone, intraformational breccia.
95.3 m (153.48 - 248.76 m) Hagen Member — defined separately.

Thickness: 160 to 300 m

Relationships: In BARROW CREEK and SW of ELKEDRA is unconformable on early Proterozoic granite and Hatches Creek Group; in west-central ELKEDRA gradationally overlies and laterally interdigitates with Arthur Creek Formation. Gradationally overlain by Arrinrungra Formation.

Age: Middle Cambrian, based on lateral relationship with Arthur Creek Formation.


Correlatives: Correlated with interval 681-783 m in drill hole BMR 13 by Morris (1986a).

HAGEN MEMBER OF THE CHABALOWE FORMATION

Symbol: €nh

Proposer: D. G. Morris

Derivation of name: After Hagen Bore (GR NS158055)

Distribution: No known outcrop. Intersected in NTGS drill holes ELK 6 and 7A.

Type Section: In drill hole NTGS ELK 7A, from 153.48 m to 248.76 m, located at GR NS162052 (21°39'12"S, 135°9'12"E)

Lithology: The type section consists of the following:
15.4 m (153.48 - 169.31 m) Interbedded gypsum, gysiferous siltstone and chert (silicified algal laminite); minor anhydrite.
3.9 m (169.31 - 173.20 m) Dolostone, algal laminate, fine-grained dolarenite, minor dololutite
9.4 m (173.20 - 182.58 m) Massive gypsum (satin spar) interbedded with siltstone, chert and dolostone; minor anhydrite.
5.5 m (182.58 - 238.05 m) Partly stromatolitic dolostone, dololudite, dolarenite, dololutite, intraformational breccia.
10.7 m (238.05 - 248.76 m) Dolostone, silty dolarenite, dolomitic siltstone.

Relationships: The Hagen Member is a lenticular unit at the base of the Chabalowé Formation which is distinguished from the upper part by the abundance of evaporite minerals and much less terrigenous clastic detritus. The top of the member is identified by the uppermost thick massive gypsum and anhydrite bed, underlying the sandstone-dominant upper unit. The base is marked by a coarse-grained light grey unfossiliferous intraclastic dolarenite, gradationally overlying (and laterally interdigitating with) fine-grained, dark grey, highly fossiliferous silty dolarenite of the Arthur Creek Formation. Unconformably overlies Proterozoic quartzite in ELK 6.

Age: Middle Cambrian.

APPENDIX 2

FOSSILS COLLECTED FROM ARTHUR CREEK FORMATION

<table>
<thead>
<tr>
<th>NTGS NO.</th>
<th>GRID REF.</th>
<th>FAUNAS</th>
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<td>E271</td>
<td>PS073109</td>
<td>Hyoliths, lingulide and orthide (?)Bohemiella) brachiopods, trilobite fragments (Laurie, pers. comm.)</td>
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<td>E1217</td>
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<td>E1287</td>
<td>NS609355</td>
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<td>NS590362</td>
<td>Lyriaspis sp. indet.</td>
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<td>NS591325</td>
<td>Lyriaspis sp. indet., Peronopsis sp. indet., acrothelid brachiopod</td>
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<td>NS609200</td>
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<td>ELK 2</td>
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APPENDIX 3

STRATIGRAPHIC DRILL HOLES

All stratigraphic holes drilled in ELKEDRA to December 1986 are listed in Table 3. Those drilled by NTGS are graphically presented at a scale of 1:1000 in Figures 12-17 (excluding ELK 4 which was abandoned due to substantial core loss and re-drilled as ELK 7). The logs are arranged, in formations, from west to east across ELKEDRA. Figures 13 and 14 also include the relevant logs of Ammaroo No. 2 and BMR 13 (Sandoover), and Figure 17 shows a measured section of the Tomahawk beds from the southeastern part of ELKEDRA.

Table 3 Stratigraphic drill holes in ELKEDRA.

<table>
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<tr>
<th>NAME</th>
<th>INTERVAL (m) FROM</th>
<th>TO</th>
<th>THICKNESS (m)</th>
<th>FORMATION, GROUP</th>
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<td><strong>Cobble or boulder conglomerate</strong></td>
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<tr>
<td><strong>Carbonaceous siltstone, mudstone</strong></td>
<td><strong>Gypsiferous beds (some anhydrite)</strong></td>
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<tr>
<td><strong>Quartzite</strong></td>
<td><strong>Dacitic volcanics</strong></td>
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<tr>
<td><strong>Granite, gneiss</strong></td>
<td></td>
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</tr>
</tbody>
</table>

**Unconformity**

- Unconformity
- Chert, silicified bed
- Vugs
- Ooliths

**COLOUR (siltstone and claystone only)**
- Olive, greyish green
- Dusk red, reddish brown
- Greenish black, dark grey
- Yellowish orange

**STRUCTURES**

- Cross lamination
- Ripple marks
- Cross bedding
- Slumping
- Desiccation cracks
- Burrows

**FOSSILS**

- Bioturbated
- Macrofossil fragments
- Microfossils
- Trilobite
- Brachiopod
- Hyolith
- Sponge spicule
- Trace fossil

**MINERALS**

- Gypsum, anhydrite
- Glauconite
- Zn
- Sphalerite
- Pyrite
- Phosphatic
- Fe
- Ferruginous
- Hydrocarbon show
- Fluorite
- f
- Feldspathic
- Galena
- Chalcopryite

*Figure 12 Symbols used on stratigraphic sections.*
Figure 13 Stratigraphic sections: Proterozoic strata and Errarra Formation
Figure 14 Stratigraphic sections: Arthur Creek Formation.
Figure 14 (continued)
Figure 15 Stratigraphic sections: Chabalowe Formation.
Figure 15 (continued)

Log by D.G.M.
Figure 16 Stratigraphic sections: Arrinhrunga Formation.

Log by P.A.S.
Log by D.G.M.

Log by P.A.S.

Figure 16 (continued)
**Figure 17** Stratigraphic sections: Tomahawk beds.
<table>
<thead>
<tr>
<th>STATION</th>
<th>BORE NAME</th>
<th>REG. NO. OF BORE</th>
<th>GRID REF.</th>
<th>DEPTH (m)</th>
<th>YIELD (L/s)</th>
<th>STANDING WATER LEVEL (m)</th>
<th>STRATA (m) – from unchecked driller’s logs unless otherwise indicated</th>
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<td>AMMAROO</td>
<td>No.9 Depot</td>
<td>484</td>
<td>NR0884</td>
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<td>No.11 Bull Plain</td>
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<td>10817</td>
<td>NS4108</td>
<td>186</td>
<td>0.4</td>
<td>38</td>
<td>See Newton (1963); Sprigg (1957)</td>
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<td>NS4105</td>
<td>256</td>
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<td>45</td>
<td>See Newton (1963); Sprigg (1957). Log shown in Figs. 13 &amp; 14</td>
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<td>42</td>
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<td>15-21 fine to medium quartz sandstone;</td>
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<td></td>
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<td></td>
<td>21-42 weathered porphyritic sandstone (G log: PAS)</td>
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<td>0-5 laterite rubble; 5-30 weathered porphyritic sandstone (G log: PAS)</td>
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<td>13716</td>
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<td>0-9 or, 9-100 clay; after very weathered volcanic rock?;</td>
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<td>0-5 or, 9-100 rh?</td>
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<td>33-39 fine sandstone; 30-54 clay, dolomitic siltstone;</td>
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<td>54-57 dolostone; 57-60 chert, calc siltstone, clay;</td>
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<td>NS2305</td>
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<td>13-60 Emc</td>
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<td>STRATA (m) – from unchecked driller’s logs unless otherwise indicated.</td>
<td>STRATIG.UNIT</td>
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<td>0-6 gravel; 6-9 sandstone; 9-13 blue clay; 13-50 yellow &amp; brown ochre; 50-59 sandstone</td>
<td>0-6 Cz</td>
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<td>0-45 soil, sandy clay; 45-120 no return</td>
<td>6-59 Cma</td>
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<td></td>
<td>0-39 clay; 39-66 ‘slate’; 66-94 broken dolostone &amp; sandstone</td>
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<td>0-60 sandy clay; 60-98 broken dolostone &amp; sandstone</td>
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<td>0-24 sand; 24-70 sandy clay; 70-80 clay; 80-90 clay, gravel; 90-97 limestone, clay</td>
<td>0-90 Cz</td>
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<td>0-3 sandy clay; 3-11 limestone; 11-15 clay; 15-120 blue grey and black limestone</td>
<td>0-3 Qa</td>
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<td>0-20 siltstone, chert; 20-30 dolomitic sandstone; 30-48 dolostone; 48-63 sandstone; 63-82 dolostone; 82-86 calc sandstone, gravel; 86-137 pegmatite (G log: PAS)</td>
<td>0-86 Cme</td>
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<td>0-9 lateritic soil; 9-81 siltstone, fine sandstone, minor chert; 81-102 clay, chert, calc siltstone; 102-134 limestone, calc siltstone, chert (G log: PAS)</td>
<td>0-9 Qr</td>
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<td></td>
<td></td>
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<td></td>
<td>“sedimentary layers of limestone &amp; sandstone, bottomed on feldspar”</td>
<td>€ua</td>
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<td>0-18 calcite, soil; 18-73 dolostone; 73-106 calc &amp; dolomitic siltstone; silty &amp; sandy limestone (G Log: PAS)</td>
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<td>“Alluvium, jasper + limestone, weathered pugh, white sand”</td>
<td>73-106 €ua?</td>
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<td>0-2 sandy loam; 2-33 clay, limestone nodules; 33-45 hard limestone; 45-61 very hard limestone; 61-64 vuggy limestone</td>
<td>0-33 Cz</td>
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<td>No-76 limestone; 76-78 very hard limestone</td>
<td>33-64 €ua</td>
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<td>See log of NTGS ELK2 in Figs 14 and 16 in this report</td>
<td>0-14 €ua,</td>
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<td>ANNITOVA</td>
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<td>7168</td>
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<td>113</td>
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<td>0-9 sand; sandy clay; 9-46 clay; 46-78 clay; limestone, quartz; 78-98 clay; 98-113 clay, chert, limestone, quartz.</td>
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<td>Hughes</td>
<td>11924</td>
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<td>597</td>
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<td>152</td>
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<td>6-126 €ua?</td>
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<td>n.d.</td>
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<td>Same as BMR ELKEDRA 4 (Grg 4)(Milligan, 1963; Fehr and Nichols, 1963)</td>
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<td>10949</td>
<td>PS3346</td>
<td>107</td>
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<td>72</td>
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<td>9-107 €ua</td>
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<td>NR6894</td>
<td>97</td>
<td>–</td>
<td>n.d.</td>
<td>No log</td>
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<td>DOWNS</td>
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<td>0-50 clayey sand, silt; 50-56 silt with fragments of travertine, quartz, ironstone; 56-70 limestone, siltstone, sandstone; 70-83 limestone; 83-91 siltstone, limestone; 91-128 sandstone, limestone (G Log : DW)</td>
<td>56-128 €ua</td>
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<td>Alec</td>
<td>2891</td>
<td>NR5169</td>
<td>128</td>
<td>1.3</td>
<td>54</td>
<td>0-12 sandy clay; 12-37 silty sand; silt; 37-47 dolostone (G log: DW)</td>
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<td>11482</td>
<td>NR5269</td>
<td>47</td>
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<td>56-128 €ua</td>
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<td>0-15 soil; 2-24 white clay; 24-56 brown clay; 56-59 gravel</td>
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<td>Andagera</td>
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<td>NS7725</td>
<td>87</td>
<td>1.0</td>
<td>37</td>
<td>See Milligan (1963)</td>
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<td>Arganara</td>
<td>11479</td>
<td>NS6601</td>
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<td>0-5 earth; 5-44 yellow &amp; brown “sandstone”; 44-46 “drift sandstone”</td>
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<td>Bounday</td>
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<td>78-108 €ua?</td>
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<td>Gregory 1, 2</td>
<td>11480 14334</td>
<td>NR4980</td>
<td>110</td>
<td>1.2</td>
<td>61</td>
<td>93-108 poorly indurated medium sandstone &amp; sand (G log: PAS)</td>
<td>78-108 €ua?</td>
</tr>
<tr>
<td></td>
<td>Nyngan</td>
<td>11483</td>
<td>NR3768</td>
<td>46</td>
<td>0.8</td>
<td>30</td>
<td>No log</td>
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<td></td>
<td>Sandover road 84/1</td>
<td>13987</td>
<td>NS5702</td>
<td>196</td>
<td>5.1</td>
<td>78</td>
<td>0-3 red earth soil; 3-18 weathered siltstone, chert; 18-75 weathered siltstone; 75-135 carbonaceous silty limestone, siltstone; 135-150 calc carbonaceous siltstone; 150-196 dolostone (G log : AMW)</td>
<td>3-150 €ma 150-196 €le</td>
</tr>
<tr>
<td>STATION</td>
<td>BORE NAME</td>
<td>REG. NO. OF BORE</td>
<td>GRID REF.</td>
<td>DEPTH (m)</td>
<td>YIELD (L/s)</td>
<td>STRANDING WAT'ER LEVEL (m)</td>
<td>STRATA (m) – from unchecked driller’s logs unless otherwise indicated</td>
<td>STRATIG. * UNIT</td>
</tr>
<tr>
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<td>---------------------------</td>
<td>-----------------------------------------------------------------</td>
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<tr>
<td>A12/4</td>
<td></td>
<td>13328</td>
<td>NR5689</td>
<td>200</td>
<td>nil</td>
<td>nil</td>
<td>0-6 red soil; 6-22 calcrete; 22-31 lateritised soil, chert gravel; 31-75 weathered calc silstone; 75-200 no returns (G log : PAS)</td>
<td>0-31 Cz 31-75 Ėma</td>
</tr>
<tr>
<td>A12/5</td>
<td></td>
<td>14335</td>
<td>NR5694</td>
<td>103</td>
<td>6.0</td>
<td>n.d.</td>
<td>0-24 sandy soil, river gravel; 24-48 clayey sand, gravel; 48-54 sand; 54-72 clay &amp; gravel; 72-103 silstone, very fine sandstone, chert, coquina (hyoliths) (G log : PAS)</td>
<td>0-72 Cz 72-103 Ėma</td>
</tr>
<tr>
<td>ELKDRA</td>
<td>Ammaroo Road 83/6</td>
<td>13720</td>
<td>NS0338</td>
<td>61</td>
<td>nil</td>
<td>nil</td>
<td>0-14 sandy soil, gravel; 14-45 silstone, sandstone; 45-60 metaclastite (G log: PAS)</td>
<td>0-14 Oc 15-42 Ėmc? 42-61 Ėha</td>
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<tr>
<td></td>
<td>Centre</td>
<td>10779</td>
<td>NS5878</td>
<td>105</td>
<td>1.6</td>
<td>38</td>
<td>0-7 sand, gravel; 7-85 silstone; 85-98 sandstone; 98-105 hard quartzite</td>
<td>0-7 Qa 7-98 ? 98-105 Ėph?</td>
</tr>
<tr>
<td></td>
<td>Elkedra homestead</td>
<td>2156</td>
<td>NS4659</td>
<td>31</td>
<td>n.d.</td>
<td>n.d.</td>
<td>0-24 sand, gravel, clay; 24-41 brown sandstone</td>
<td>0-24 Cz 24-41 Ėph?</td>
</tr>
<tr>
<td></td>
<td>Elkedra No.2</td>
<td>929</td>
<td>NS6340?</td>
<td>116</td>
<td>0.7</td>
<td>n.d.</td>
<td>0-111 “slate &amp; shale”; 111-116 quartzite</td>
<td>0-111 Ėma?</td>
</tr>
<tr>
<td></td>
<td>Fitz</td>
<td>989</td>
<td>NS4132</td>
<td>88</td>
<td>n.d.</td>
<td>n.d.</td>
<td>No log</td>
<td>0-14 sand; 14-18 quartzite gravel; 18-47 silstone, chert &amp; sandstone; 47-52 red sandstone; 52-82 no return; 82-97 limestone (G log : PAS)</td>
</tr>
<tr>
<td></td>
<td>Gastro (A111/3)</td>
<td>10786</td>
<td>NS7274</td>
<td>97</td>
<td>0.8</td>
<td>69</td>
<td>0-9 soil; 9-18 quartzite gravel; 18-50 sandstone &amp; quartz; 50-117 limestone</td>
<td>0-18 Cz 18-117 Ėma?</td>
</tr>
<tr>
<td></td>
<td>Goodings (No.1)</td>
<td>167</td>
<td>NS7763</td>
<td>117</td>
<td>1.2</td>
<td>113</td>
<td>No log</td>
<td>0-8 gravel, clay; 8-40 boulders, clay; 40-63 quartzite</td>
</tr>
<tr>
<td></td>
<td>Newlands 1, 2.</td>
<td>2154</td>
<td>NS7033</td>
<td>62</td>
<td>n.d.</td>
<td>n.d.</td>
<td>0-7 sand, laterite at base; 7-34 limestone, sand, clay; 34-46 chert, limestone, sand; 46-52 chert; 48-52 lime sands; 52-63 sandstone, ironstone gravel; 63-92 limestone, sandstone, chert, sand; 92-63 granite</td>
<td>0-7 Qs, Qa 7-92 Ėmg 92-93 Ėg</td>
</tr>
<tr>
<td></td>
<td>Rockhole</td>
<td>–</td>
<td>NS5945</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>No information: same as Elkedra No.2?</td>
<td></td>
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<td>Supplejack</td>
<td>990</td>
<td>NS5530</td>
<td>93</td>
<td>n.d.</td>
<td>n.d.</td>
<td>0-8 gravel, clay; 8-40 boulders, clay; 40-63 quartzite</td>
<td>0-8 Ėga</td>
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<tr>
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<td>Trew</td>
<td>2155</td>
<td>NS8039</td>
<td>201</td>
<td>n.d.</td>
<td>n.d.</td>
<td>0-7 sand, laterite at base; 7-34 limestone, sand, clay; 34-46 chert, limestone, sand; 46-52 chert; 48-52 lime sands; 52-63 sandstone, ironstone gravel; 63-92 limestone, sandstone, chert, sand; 92-63 granite</td>
<td>0-7 Qs, Qa 7-92 Ėmg 92-93 Ėg</td>
</tr>
<tr>
<td></td>
<td>Whisky Camp</td>
<td>560</td>
<td>NS4244</td>
<td>63</td>
<td>1.2</td>
<td>46</td>
<td>0-8 gravel, clay; 8-40 boulders, clay; 40-63 quartzite</td>
<td>0-8 Ėg</td>
</tr>
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<td></td>
<td>New</td>
<td>6426</td>
<td>NS9457</td>
<td>93</td>
<td>1.0</td>
<td>87</td>
<td>0-7 sand, laterite at base; 7-34 limestone, sand, clay; 34-46 chert, limestone, sand; 46-52 chert; 48-52 lime sands; 52-63 sandstone, ironstone gravel; 63-92 limestone, sandstone, chert, sand; 92-63 granite</td>
<td>0-7 Qs, Qa 7-92 Ėmg 92-93 Ėg</td>
</tr>
<tr>
<td>A111/6</td>
<td></td>
<td>13009</td>
<td>NS1440</td>
<td>98</td>
<td>nil</td>
<td>nil</td>
<td>0-3 sand; 3-6 gravel (quartzite); 6-39 weathered basalt; 39-98 basalt (G log : PM)</td>
<td>0-6 Cz 6-98 Ėhb</td>
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<tr>
<td>A111/7</td>
<td></td>
<td>13326</td>
<td>NS1342</td>
<td>213</td>
<td>0.2</td>
<td>40</td>
<td>0-6 sandy clay; 6-60 “gravelly silstone &amp; sandstone”; 60-213 “quartz”</td>
<td>0-6 Qa 6-60 Ėldi/Czc? 60-213 Ėph?</td>
</tr>
<tr>
<td>STATION</td>
<td>BORE NAME</td>
<td>REG. NO. OF BORE</td>
<td>GRID REF.</td>
<td>DEPTH (m)</td>
<td>YIELD (L/s)</td>
<td>STANDING WATER LEVEL (m)</td>
<td>STRATA (m) – from unchecked driller's logs unless otherwise indicated</td>
<td>STRATIG. UNIT</td>
</tr>
<tr>
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<td>--------------------------------------------------------------------------------</td>
<td>-----------------</td>
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<tr>
<td>ELKEDRA</td>
<td>A111/8</td>
<td>13327</td>
<td>NS1440</td>
<td>159</td>
<td>seepage</td>
<td>70</td>
<td>0-12 sandy &amp; gravelly clay; 12-69 sandstone; 69-159 'quartz'</td>
<td>0-12 Qt 12-159 Qtc?</td>
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<tr>
<td></td>
<td>A111/9</td>
<td>13868</td>
<td>NS0542</td>
<td>110</td>
<td>1.7</td>
<td>62</td>
<td>0-3 sand, clay; 3-64 siltstone + sandstone; 64-100 sandstone, some limestone</td>
<td>0-3 Qt 3-100 Qtb</td>
</tr>
<tr>
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<td>A111/11</td>
<td>14309</td>
<td>NS2540</td>
<td>61</td>
<td>2.2</td>
<td>45</td>
<td>0-6 soil, gravel; 6-57 deeply weathered grey claystone, siltstone; 57-61 claystone + red very fine grained sandstone (G log : PAS)</td>
<td>0-6 Qt 6-61 Qtb</td>
</tr>
<tr>
<td></td>
<td>12 km north of Liburnic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0-6 soil, gravel; 6-30 deeply weathered basalt; 30-57 weathered basalt; 57-61 quartzite; 61-67 basalt (G log: PAS)</td>
<td>0-6 Qt 6-67 Qtb</td>
</tr>
<tr>
<td></td>
<td>A111/13</td>
<td>14310</td>
<td>NS0452</td>
<td>67</td>
<td>2.7</td>
<td>48</td>
<td>0-2 gravel, red soil; 2-6 siltstone; 6-24 sandstone, conglomerate; 24-66 porphyritic dacite (G log: PAS)</td>
<td>0-2 Qt 2-6 Qma 6-24 Qtl 24-66 Qtb</td>
</tr>
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<td>13329</td>
<td>NS1539</td>
<td>67</td>
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<td>nil</td>
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<td>0-2 Qt 2-6 Qma 6-24 Qtl 24-66 Qtb</td>
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<td>OORA-</td>
<td>No.13</td>
<td>1009</td>
<td>NR9088</td>
<td>47</td>
<td>n.d.</td>
<td>n.d.</td>
<td>0-11 soil, clay, gravel at base; 11-42 clay &amp; limestone boulders; 42-47 limestone</td>
<td>0-4 Qt 4-12 Qtb</td>
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<td>TIPPRA</td>
<td>No.14</td>
<td>489</td>
<td>PR0583</td>
<td>20</td>
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<td>–</td>
<td>0-4 clay; 4-12 quartzite</td>
<td>0-4 Qt 4-12 Qtb</td>
</tr>
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<td>No.14</td>
<td>1015</td>
<td>9</td>
<td>0.6</td>
<td>34</td>
<td></td>
<td>0-6 sand, gravel; 6-9 limestone; 9-13 silty limestone; 13-44 limestone; 44-46 grey clay; 46-50 limestone; 50-52 broken quartz; 52-53, grey rock, blue clay</td>
<td>0-6 Qt 6-53 Qtb</td>
</tr>
<tr>
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<td>No.14</td>
<td>3250</td>
<td>54</td>
<td>0.6</td>
<td>34</td>
<td></td>
<td>0-6 sand, gravel; 6-9 limestone; 9-13 silty limestone; 13-44 limestone; 44-46 grey clay; 46-50 limestone; 50-52 broken quartz; 52-53, grey rock, blue clay</td>
<td>0-6 Qt 6-53 Qtb</td>
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<td>No.15</td>
<td>1029</td>
<td>PR2886</td>
<td>239</td>
<td>1.0</td>
<td>43</td>
<td>0-19 clay, gravel; 19-31 quartz, limestone; 31-46 quartz, 'slate'; 46-55 'kaolinite'; 55-61 sandstone; 61-76 quartz, 'slate'; 76-229 white, blue, red clay; 229 limestone; 229-239 white clay</td>
<td>0-19 Qt 19-239 Qtb</td>
</tr>
<tr>
<td></td>
<td>No.16</td>
<td>490</td>
<td>PR4695</td>
<td>98</td>
<td>0.7</td>
<td>71</td>
<td>0-12 sand, clay; 12-24 gravel, quartz; 24-29 'jasper'; 29-76 clay, quartz; 76-98 sandstone, rare layers 'slate'</td>
<td>0-12 Qt 12-24 Qtb 24-29 Qtb 29-76 Qtb 76-98 Qtb 0-12 Qtb 12-24 Qtb 24-29 Qtb 29-76 Qtb 76-98 Qtb</td>
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<td>New No.16</td>
<td>2995</td>
<td>PR5194</td>
<td>35</td>
<td>1.5</td>
<td>27</td>
<td>0-3 soil, sandy clay; 3-15 travertine; 15-27 dolostone; 27-35 sandstone &amp; limestone</td>
<td>0-3 Qt 3-15 Qtb 15-27 Qtb 27-35 Qtb 0-3 Qt 3-15 Qtb 15-27 Qtb 27-35 Qtb</td>
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<td></td>
<td>Barnett</td>
<td>6405</td>
<td>PR2681</td>
<td>62</td>
<td>2.0</td>
<td>49</td>
<td>0-1 sand, clay; 1-12 limestone; 12-49 blue shale, grey sandstone; 49-62 limestone</td>
<td>0-1 Qt 1-12 Qtb 12-49 Qtb 49-62 Qtb</td>
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<td>BMR 13 (Sandoover)</td>
<td>10059</td>
<td>PR1983</td>
<td>1016</td>
<td>1.5</td>
<td>–</td>
<td>See Lloyd and Bell (1964), Smith (1967) Also see Figure 13, 14 and Table 2</td>
<td>0-1 Qt 1-12 Qtb 12-49 Qtb 49-62 Qtb</td>
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<tr>
<td>STATION</td>
<td>BORE NAME</td>
<td>REG. NO. OF BORE</td>
<td>GRID REF.</td>
<td>DEPTH (m)</td>
<td>YIELD (L/s)</td>
<td>STANDING WATER LEVEL (m)</td>
<td>STRATA (m) – from unchecked driller's logs unless otherwise indicated</td>
<td>STRATIG. UNIT</td>
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<tr>
<td>OORA- TIPRA</td>
<td>Buster</td>
<td>10791</td>
<td>PR4373</td>
<td>198</td>
<td>0.5</td>
<td>179</td>
<td>0-3 sand; 3-70 siltstone; 70-198 dolostone</td>
<td>0-3 Qs 3-70 €Ot; 70-198 €ua</td>
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<tr>
<td></td>
<td>Coles</td>
<td>5859</td>
<td>PR4191</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>0-22 sandy limestone; 22-44 clay; 44-59 hard limestone; 59-130 siltstone; 130-151 banded limestone</td>
<td>0-151 €ua</td>
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<td>Gorey</td>
<td>5860</td>
<td>PR1974</td>
<td>151</td>
<td>1.0</td>
<td>61</td>
<td>No log</td>
<td>0-10 Qa 10-130 €ua (+€ua?)</td>
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<td>Matrice</td>
<td>1503</td>
<td>PR3386</td>
<td>24</td>
<td>n.d.</td>
<td>12</td>
<td>0-10 loam, sand, gravel; 10-23 dolostone; 23-28 hard blue sandstone; 28-76 dolostone; 76-101 limestone; 101-108 sandstone; 108-113 limestone; 113-130 sandstone</td>
<td>0-10 Qa 10-130 €ua (+€ua?)</td>
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<td>Ooratippra homestead</td>
<td>4796</td>
<td>PR1280</td>
<td>130</td>
<td>3.0</td>
<td>124</td>
<td>No log</td>
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<td></td>
<td>Robbie</td>
<td>3797</td>
<td>PR4881</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>0-3 loam, clay, gravel; 3-6 dolostone; 6-31 limestone; sandy shale interbeds; 31-49 hard blue sandstone; 49-61 siltstone; 61-90 limestone; siltstone interbeds</td>
<td>0-3 Qa 3-90 €ua</td>
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<td>Rorke</td>
<td>4794</td>
<td>PR3380</td>
<td>90</td>
<td>0.7</td>
<td>79</td>
<td>0-4 sand, clay; 4-58 limestone</td>
<td>0-4 Qs 4-58 €ua</td>
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<td>Sandover road</td>
<td>13015</td>
<td>NR8690</td>
<td>88</td>
<td>2.6</td>
<td>50</td>
<td>0-10 sand; 10-88 very fine sandstone; chert; siltstone (trilobite frags at 66-84 m) (G log : PAS)</td>
<td>0-10 Qs 10-88 €ma</td>
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<td>Sandover road</td>
<td>13016</td>
<td>PR2287</td>
<td>46</td>
<td>1.5</td>
<td>34</td>
<td>0-10 sand; clay; 10-46 limestone</td>
<td>0-10 Qs 10-46 €ua</td>
</tr>
<tr>
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<td>Sandover road 81/3</td>
<td>13017</td>
<td>PR4405</td>
<td>58</td>
<td>1.0</td>
<td>34</td>
<td>0-4 sand, clay; 4-58 limestone</td>
<td>0-4 Qs 4-58 €ua</td>
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<td></td>
<td>Smith</td>
<td>5861</td>
<td>PR4183</td>
<td>75</td>
<td>1.5</td>
<td>59</td>
<td>0-6 sandstone; 6-14 sandstone; dolostone; 14-45 sandstone, chert; 45-75 blue dolostone, white limestone at 53-60</td>
<td>€ua</td>
</tr>
<tr>
<td></td>
<td>Trackrider</td>
<td>1789</td>
<td>PR2569</td>
<td>48</td>
<td>1.1</td>
<td>42</td>
<td>0-18 clay; 18-48 quartz</td>
<td>Cz/fault</td>
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<td></td>
<td>Weepita</td>
<td>3961</td>
<td>PR1074</td>
<td>n.d.</td>
<td>1.5</td>
<td>n.d.</td>
<td>No log</td>
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<td>UTOPIA</td>
<td>Bluebush</td>
<td>2650</td>
<td>NR0574</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>No log. See nearby drillhole NTGS ELK6 (Figs 15,16,17, this report)</td>
<td>0-3 Cz 3-150 €Ot</td>
</tr>
<tr>
<td></td>
<td>Irultja</td>
<td>11368</td>
<td>NR1169</td>
<td>76</td>
<td>1.7</td>
<td>31</td>
<td>0-22 sand, clay; 22-45 soft yellow sandstone; 45-76 dark brown siltstone</td>
<td>0-22 Qs, Qa 22-45 Dur? 45-76 €Ot?</td>
</tr>
<tr>
<td></td>
<td>Irultja</td>
<td>11369</td>
<td>NR1169</td>
<td>76</td>
<td>2.2</td>
<td>32</td>
<td>0-15 sand; 15-45 yellow sandstone; 45-76 grey siltstone</td>
<td></td>
</tr>
</tbody>
</table>

* G log: Geologist's log (PM = P. McDonald, PAS = P.A. Stidolph, AMW = A.M. Walley, DW = D. Woolley) n.d.: no data

Qa: Quaternary alluvium
Qc: Quaternary colluvium
Qr: Quaternary red earth soil
Qs: Quaternary sand
Cz: Cainozoic sediments
Cz: Cainozoic calcretes
€: Eurowie Sandstone
€b: Andagema Fm.
€c: Chabalowe Fm.
€d: Arthur Creek Fm.
€e: Gum Ridge Fm.
€f: Eerarra Fm.
€g: granite, pegmatite
€h: Hatches Creek Group
€i: Lennee Creek Fm.
€j: Aljinjabon Sandstone
€k: Kudinga Basalt
€l: Freew River Fm.
€m: Coulters Sandstone
€n: Newlands Volcanics