EXPLANATORY NOTES

TRAINOR

1:250 000 SHEET

WESTERN AUSTRALIA

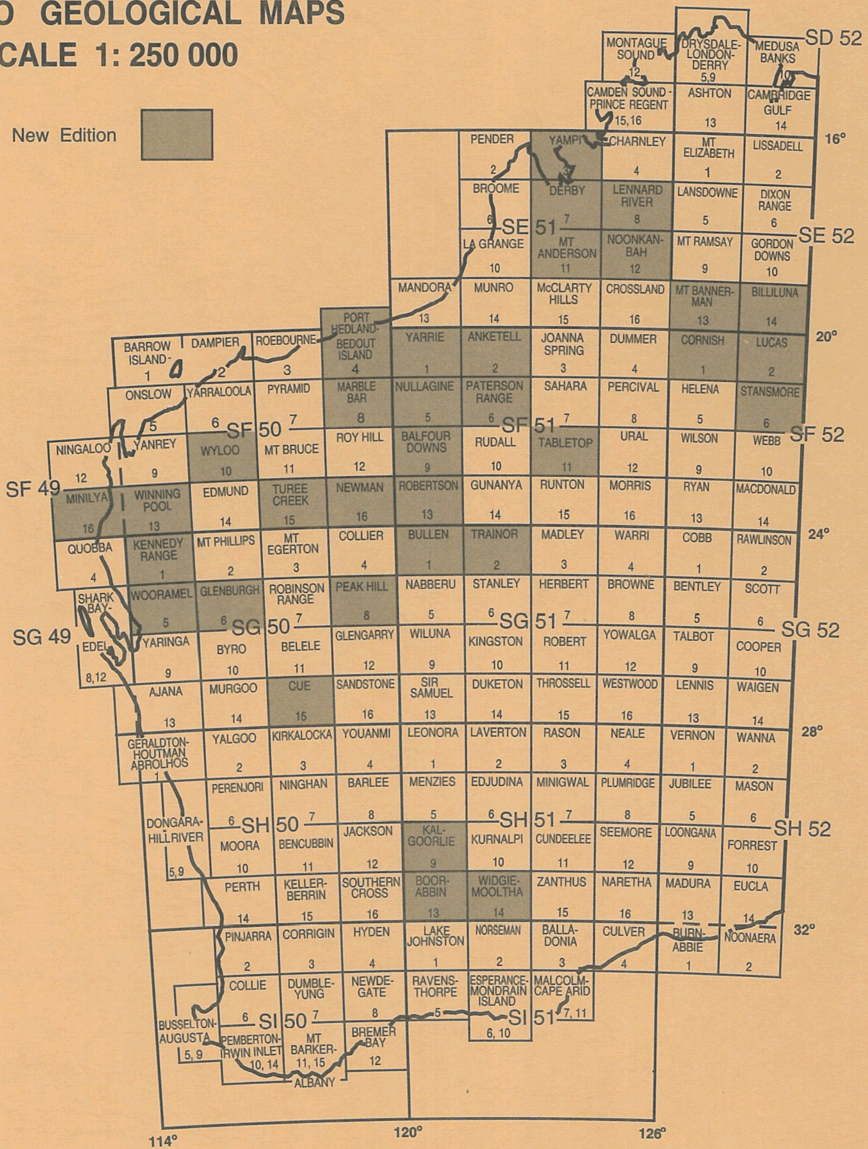
SECOND EDITION

SHEET SG 51-2 INTERNATIONAL INDEX

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DEPARTMENT OF MINERALS AND ENERGY

WESTERN AUSTRALIA
INDEX TO GEOLOGICAL MAPS
SCALE 1: 250 000

New Edition



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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
1:250 000 GEOLOGICAL SERIES — EXPLANATORY NOTES

TRAINOR

WESTERN AUSTRALIA

SECOND EDITION

SHEET SG51–2 INTERNATIONAL INDEX

by
I. R. WILLIAMS

Perth, Western Australia 1995

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by I. R. Williams

INTRODUCTION

The TRAINOR* 1:250 000 sheet (SG51-2) is bounded by latitudes 24°00'S and 25°00'S and longitudes 121°30'E and 123°00'E. The sheet takes its name from the Trainor Hills (latitude 24°15'S, longitude 122°15'E), which lie 20 km east of the abandoned Canning Stock Route (CSR**) Well No. 14. The Trainor Hills were named by Lawrence A. Wells, leader of the Calvert Scientific Exploring Expedition, in 1896 (Feeken et al., 1970).

TRAINOR is uninhabited and covers desert regions largely unsuitable for pastoral purposes. Glen-Ayle cattle station is the only pastoral lease to encroach onto the sheet and is confined to the southwestern corner of TRAINOR.

The region is very poorly serviced with tracks. A rough but well-worn four-wheel drive track follows the abandoned Canning Stock Route, which crosses the western half of the area in a north-northeasterly direction. Abandoned CSR Wells Nos 10 to 15 occur along this section of the Stock Route. Growing numbers of tourists, intent on experiencing the remoteness of the region, traverse the Canning Stock Route track during the winter months. The only other track on TRAINOR connects Piccaninny Bore, Joes Well, and Snell Bore (BULLEN) to the Canning Stock Route track south of CSR Well No. 10.

Weld Spring (CSR Well No. 9) lies 2 km south of the southern boundary of TRAINOR. It is linked by graded track to Glen-Ayle Homestead, 58 km to the southeast. The homestead, in turn, lies 280 km northeast of Wiluna, to which it is connected by a graded shire road. The mining centre of Wiluna is the nearest commercial centre to TRAINOR. Weld Spring is also linked directly to Wiluna by the rough and winding Canning Stock Route track, Cunyu Station tracks, and the graded Wiluna – Cunyu Homestead road, a distance of about 250 km.

During field work a rock cairn and the initials 'F. H.' (Frank Hann) carved on a nearby rock were found, which helped to correctly position Macintosh Hill (Department of Land Administration, 1989). Also, a close study of F. H. Hann's survey notebooks (1902), held in the J. S. Battye Library, Perth, helped to accurately fix the position of the Kelly Range, the name for which was previously applied incorrectly to hills on the adjoining BULLEN (Department of Land Administration, 1988).

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* Sheet names are printed in capitals to avoid confusion with identical place names.

** CSR is used in the text as an abbreviation for Canning Stock Route when referring to numbered wells along this track e.g. CSR Well No. 10.

PREVIOUS AND CURRENT INVESTIGATIONS

A full account of the exploration and early geological investigations is given in the first edition of the TRAINOR Explanatory Notes (Brakel and Leech, 1980). The geological framework, evolved at that time, was incorporated in the Bangemall Basin Bulletin (Muhling and Brakel, 1985). The historical background and rationale for the production of a second edition of TRAINOR is the same as that already described for the adjacent 1:250 000 sheet, BULLEN (Williams, 1995). Areas of TRAINOR were remapped during the 1987, 1988, and 1989 field seasons as part of the reassessment of the region for the Savory Basin project (Williams, 1992). Field work consisted of ground inspections designed to visit areas not previously covered by the earlier reconnaissance ground and helicopter traverses. More detailed studies were also conducted on stromatolite occurrences in the Skates Hills Formation on the eastern side of TRAINOR (Grey, 1989). The second edition of TRAINOR incorporates the new Savory Basin stratigraphy as described by Williams (1992).

Geophysical data over TRAINOR have been collated and published by the Bureau of Mineral Resources (BMR), Canberra (now renamed the Australian Geological Survey Organisation). A total magnetic intensity map (BMR, 1988) and a gravity map (Bouguer anomalies), released in 1970, are available for TRAINOR at 1:250 000 scale. Recently (1991), the TRAINOR Bouguer-anomaly data were included in the WILUNA 1:1 000 000 gravity sheet (SG51).

The very poor access and difficult desert terrain hindered early systematic mineral prospecting and exploration. More recently, wide-ranging helicopter surveys and sampling programs have been carried out as part of the search for diamonds and base metals. WAMEX* open-file reports on this work are available through the Geological Survey Library.

CLIMATE, VEGETATION, PHYSIOGRAPHY

There are no meteorological stations on TRAINOR but it has been inferred from adjoining regions that the climate is arid (desert) with the highest rainfall in summer (Beard, 1974). However, the rainfall pattern appears to be erratic. Field observations during the last decade suggest that most rain falls in autumn and early winter. Rainfall decreases easterly across TRAINOR and is below 200 mm in the east. Potential evaporation averages over 4000 mm per annum, which is greater than in most parts of Australia. Summers are hot with a mean maximum temperature of 38.5°C (December–February). Winters are cool with a mean minimum temperature of 6.5°C (June–August).

TRAINOR lies mainly within the Keartland Botanical District of the Eremaean Botanical Province. Small areas along the southern margin fall within the Ashburton Botanical District (Beard, 1974; Fig. 1).

The Keartland Botanical District is largely a mixed shrub steppe on small areas of sand plain and between sand dunes. The shrubs are mainly *Acacia* species with some *Hakea* species. Scattered desert bloodwood (*Eucalyptus dichromophloia*) and mallee (*E. gamophylla* and *E. kingsmillii*) grow on the dunes. Spinifex (*Triodia* and *Plectrachne* species) and low ericoid shrubs such as *Thryptomene maisonneuvii* form the ground cover. The latter is more widespread in the southern part of TRAINOR. Low rocky hills, such as the Ward Hills and the Oldham and Cornelia Ranges, are covered with spinifex (grass steppe)

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* Western Australian Mineral Exploration Index

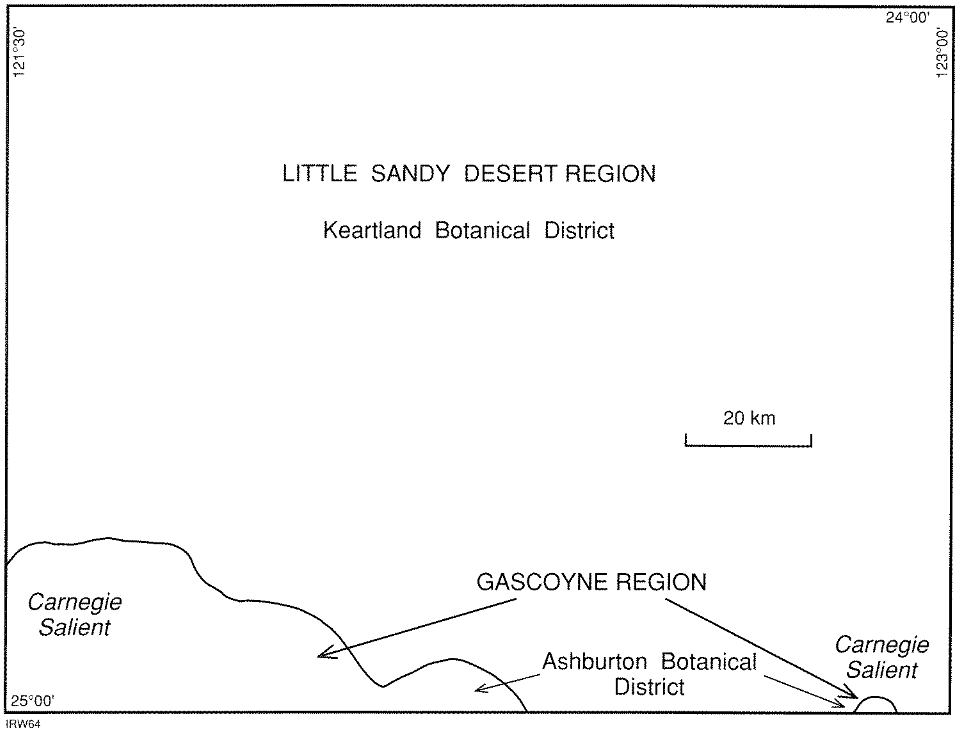

Figure 1. Natural regions on TRAINOR

and meagre, low *Acacia* species. Isolated hills and breakaways, like the Trainor Hills, are covered by a thick mulga scrub (*Acacia aneura*). Strings of salt lakes, occupying palaeodrainage systems, support saltbush (*Atriplex*) and samphire (*Arthrocnemum*) communities. Desert oaks (*Casuarina decaisneana*) are scattered along calcreted palaeodrainage lines.

Low mulga woodland (Acacia aneura) and mulga parkland (*A. aneura*, *A. pruinocarpa*, and spinifex) characterize the Ashburton Botanical District (Beard, 1974). A distinctive striped airphoto pattern identifies this unit on TRAINOR.

The Keartland Botanical District corresponds in area to the Little Sandy Desert Natural Region (Beard, 1970), which, in turn, is underlain by the Savory Basin. The Little Sandy Desert mainly consists of well-vegetated sand dunes, 200 to 1000 m apart, and some small areas of dune-free sandplain. Dune types range from longitudinal (seif) dunes through chain dunes to widespread net-dune complexes. Anastomosing seif dunes are up to 30 km long and reach a maximum height of about 12–13 m. Overall dune heights on TRAINOR are a little lower than dunes further to the west on BULLEN. In general, net dunes are slightly lower than seif dunes at around 8–11 m, although complex net dunes in the Disappointment Palaeoriver valley in the northeast corner of TRAINOR only reach 5–7 m in height. The longitudinal dunes are most abundant in the northwest of TRAINOR whereas net-dune complexes predominate in the southern and eastern regions, particularly in areas interspersed with rocky island hills and ranges. The regional dune trend swings from 310–300° at the eastern side of TRAINOR to 270–240° along the western margin. In detail, trends are locally influenced by bedrock topography.

The Ashburton Botanical District corresponds to the Carnegie Salient of the Gascoyne Natural Region (Beard, 1975). In an earlier publication, Beard (1974) assigned the Carnegie Salient to the Murchison Region. The Carnegie Salient is distinguished by the almost complete absence of sand dunes. The region is broadly undulating and consists of low laterite hills and rocky outcrops bordered by low-slope colluvial washes that merge into well-defined drainage lines. The Carnegie Salient is underlain by rocks of the Bangemall Basin.

The landscape across TRAINOR is broadly undulating. Elevations range from 600 m in the northwest and southwest to 360 m in the floor of the Disappointment Palaeoriver in the northeast. Local relief is commonly less than 50 m, although rounded rocky hills in the central part, such as the Ward Hills, and northwesterly trending ranges in the southeast parts, such as the Cornelia and Oldham Ranges, rise over 100 m above the surrounding countryside. Low breakaways (20–40 m high) occur in the Trainor Hills, Brassey Range, and Kelly Range areas.

The east-sloping Ilgarari Palaeodrainage Basin occupies over 75% of TRAINOR. Although largely sand-filled, chains of small salt lakes and clay pans outline a strong orthogonal drainage pattern (315° and 045° directions). This is thought to reflect major joints in the underlying sedimentary bedrock. Extensive trunk-valley calcretes occur in the lower reaches of the Ilgarari Basin. The Ilgarari Palaeodrainage connects with the north-sloping Disappointment Palaeoriver northeast of the Cornelia Range (van de Graaff et al., 1977). Headwater regions of the Durba Palaeodrainage and part of the Savory Palaeodrainage encroach on the northern boundary of TRAINOR, whereas in the south a branch of the Kahrban Palaeodrainage lies west of the Brassey Range. Stream capture appears to have occurred in this area where the south-flowing Kahrban Palaeodrainage has intersected an east-northeasterly flowing branch of the Ilgarari Palaeodrainage. This beheaded drainage contains extensive trunk-valley calcretes (Fig. 2).

Further details of the physiography on TRAINOR can be found in the first edition Explanatory Notes (Brakel and Leech, 1980).

REGIONAL GEOLOGICAL SETTING

The distribution of tectonic units on TRAINOR is shown in Figure 3 and the geological history is summarized in Table 1.

The oldest rocks on TRAINOR have been assigned to the Middle Proterozoic Bangemall Group of the Bangemall Basin (Williams, 1992). They occur in the southwest corner and in two northwesterly elongated inliers, the Ward and Oldham Inliers, which lie in the central and southeastern parts of TRAINOR respectively (Fig. 3). The southwest corner is occupied by fluvial–deltaic sedimentary rocks of the Coonabildie Formation, which belongs to the Kahrban Subgroup of the Bangemall Basin (Muhling and Brakel, 1985). The Ward and Oldham Inliers contain marine-shelf sedimentary rocks of the Cornelia Formation. The lithologies in the Cornelia Formation are very similar to those described from the Collier Subgroup in the eastern part of the Bangemall Basin (Williams, 1992). Both the Coonabildie and Cornelia Formations were intruded by fine- to medium-grained dolerite sills prior to deformation, probably during the extensional phase of development of the Bangemall Basin.

The Coonabildie and Cornelia Formations are folded about northwest-trending axes. The intensity of deformation increases northwards, and pelitic rocks on the northern margin of the Ward and Oldham Inliers exhibit an axial planar cleavage accompanied by evidence of

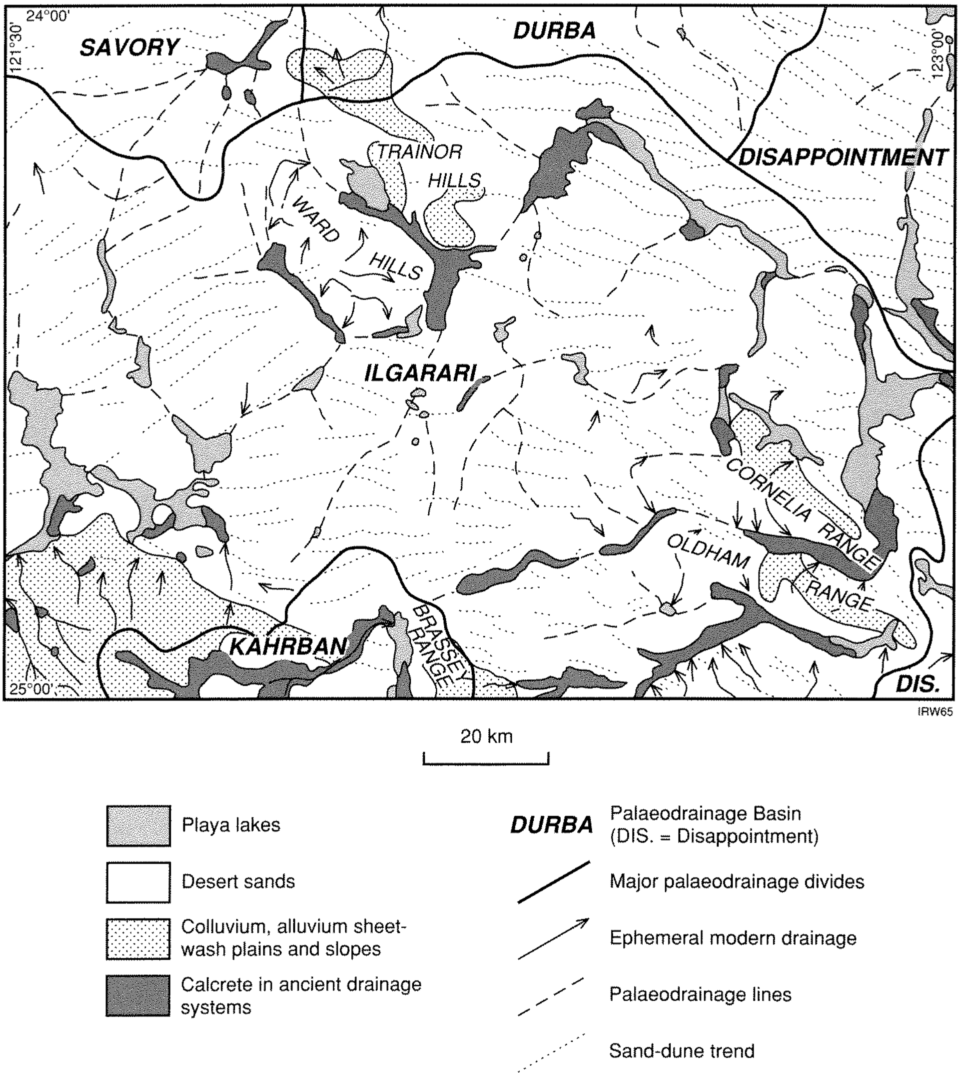

Figure 2. Palaeodrainage sketch map of TRAINOR

low-grade dynamic metamorphism. It is not clear whether this deformation is an eastward extension of the Edmund Fold Belt (Muhling and Brakel, 1985), which disappears beneath the Savory Basin unconformity 200 km to the west on BULLEN (Williams, 1995), or whether the northwesterly trending fold axes are the outcome of events connected with the Watrara Orogeny (c. 1250 Ma; Clarke, 1991) of the Paterson Orogen, which lies 200 km to the north. However, the northwest trend of the fold axes, the asymmetric fold profiles with northeasterly dipping axial planes, and the gradual increase in metamorphic grade northwards all tend to indicate that the structures are the product of interaction between the Paterson Orogen and the Bangemall rocks.

The deformation of the Bangemall Group was followed by uplift and erosion. These events were succeeded by several tectonic and sedimentary events not recorded on TRAINOR. To the northwest, the Bangemall Basin is unconformably overlain by the Middle Proterozoic

Table 1. Summary of Precambrian geological history on TRAINOR

Tectonic unit		*Geological event*	*Age*
Bangemall Basin	1.	Deposition of the Bangemall Group (Coonabildie and Cornelia Formations) on unknown basement	c. 1400–1250 Ma
	2.	Intrusion of dolerite sills	
	3.	Folding, faulting, increase in metamorphic grade northwards, ?Watrara Orogeny	c. 1250–1200 Ma
	4.	Uplift and erosion	
Karara Basin	5.	Deposition of Karara Basin sediments	c. 1000–900 Ma
	6.	Folding, uplift, and erosion	
Savory Basin	7.	Deposition of the Savory Group: Brassey Range, Glass Spring, Jilyili, Spearhole, Mundadjini, and Skates Hills Formations	c. 890–810 Ma
	8.	Intrusion of high-level dolerite and basalt	
	9.	Blake Movement: brittle faulting	c. 750 Ma
	10.	Deposition of the Savory Group: Boondawari Formation	c. 670 Ma
	11.	Intrusion of dolerite to form large bodies	c. 640 Ma
	12.	Minor deformation	
	13.	Deposition of the Savory Group: McFadden Formation and Durba Sandstone	
	14.	Paterson Orogeny: minor folding, faulting	c. 600 Ma
	15.	Intrusion of dolerite to form dykes	

Yeneena Group (c. 1200–1000 Ma) of the Yeneena Basin (Williams, 1990a). The Yeneena Group is a cover sequence on the Rudall Complex and both units are part of the Paterson Orogen. After deformation and uplift of the Yeneena Group a second sedimentary basin, the Late Proterozoic Karara Basin (c. 1000–900 Ma), developed on both the Rudall Complex and Yeneena Basin to the northeast of TRAINOR (Williams, 1990b). Sedimentary rocks of the Karara Basin in fault contact with Savory Basin rocks probably underlie Quaternary cover in the extreme northeast corner of TRAINOR. The Karara Basin deposits were also folded, uplifted, and eroded before the deposition of the Savory Basin deposits.

Rocks of the Late Proterozoic Savory Group of the Savory Basin unconformably overlie the sedimentary rocks of the Bangemall Basin on TRAINOR. The fluvial–deltaic Brassey Range Formation, which occupies the region between the Oldham Inlier and the southern edge of the Savory Basin, is the oldest unit in this part of TRAINOR. Palaeocurrent measurements indicate a strong northwesterly directed flow towards the initial depocentre of the Savory Basin, the Blake Sub-basin (Williams, 1992). The Brassey Range Formation is believed to have formed coeval with the shallow marine-shelf Glass Spring Formation and the deltaic Jilyili Formation, which are separated from the Brassey Range Formation by the Kelly Fault on the eastern margin of the Blake Sub-basin. High-level, fine-grained dolerite and basalt sills and dykes intruded the Brassey Range Formation early in the history of the Savory Basin.

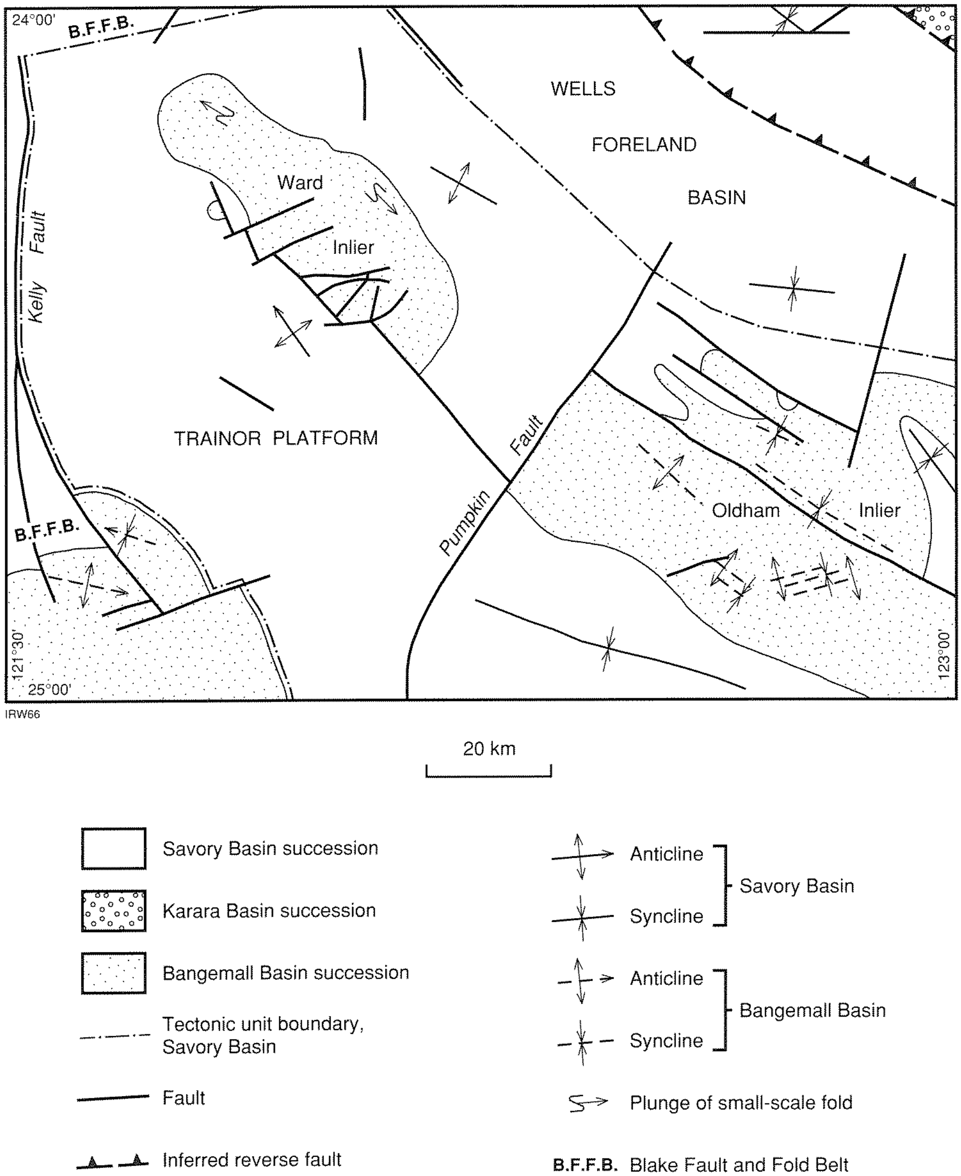

Figure 3. Tectonic sketch map of TRAINOR

The deposition of the fluviatile Spearhole Formation, west of the Ward Inlier, coincided with a radical change in the provenance of the clastic material entering the Savory Basin: from the east-southeast for the older Brassey Range Formation to southwest and west for the Spearhole Formation (Williams, 1992). Uplift and erosion of the Cornelia Formation along the western side of the Ward Inlier also contributed clastic material to the Spearhole Formation in this area. The Spearhole Formation unconformably overlies the Brassey Range Formation.

The Spearhole Formation is disconformably overlain by the near-shore tidal, deltaic, and evaporite-bearing Mundadjini Formation. The Mundadjini Formation, together with its coeval equivalent, the fluvial, beach, and near-shore Skates Hills Formation, lies at the base of the Savory Group on the northern side of the Ward and Oldham Inliers, and Williams (1992) suggested that this indicates migration of the depocentre of the Savory Basin to the northeast.

The TRAINOR region was largely stable during the Blake Movement (Williams, 1992), which generated north-northeasterly trending fold axes and faults in the western half of the Savory Basin. The Kelly Fault, on the western edge of TRAINOR, acted as a hinge line, and isolated most of TRAINOR from tectonic activity (Williams, 1992).

The transgression and deposition of the glacial marine Boondawari Formation northeast of the Ward Inlier marked the recommencement of sedimentation on TRAINOR. The Boondawari Formation sits unconformably on the Mundadjini Formation but is absent further east where the Skates Hills Formation is disconformably overlain by the younger McFadden Formation. The Boondawari Formation occupies the area between the Ward and Oldham Inliers. In this region the glacial diamictite contains clasts that suggest that the inliers may have provided a local source of detrital material. Large, coarse-grained dolerite bodies were emplaced in the Boondawari and Mundadjini Formations on TRAINOR at c. 640 Ma (Williams, 1992).

The McFadden Formation unconformably overlies or is in faulted contact with the Boondawari Formation, and disconformably overlies the Skates Hills Formation further east. It is a shallow marine-shelf deposit and palaeocurrent studies indicate current directions from the northeast, the direction of the Paterson Orogen. However, along the southern margin of the formation, palaeocurrent data indicate current directions from the south, possibly the Oldham Inlier. On GUNANYA the distribution of the McFadden Formation was influenced by the incipient Wells Foreland Basin (Williams, 1992), which developed during the Paterson Orogeny. Aeromagnetic data suggest that buried faults may occur in the northeast corner of TRAINOR. These faults appear to parallel structures in the Paterson Orogen. Where they are exposed on GUNANYA they are typically steep reverse faults with a southwest-directed movement.

Scattered outcrops of Durba Sandstone in the northeast of TRAINOR are the youngest sedimentary rocks of the region. They unconformably overlie the McFadden Formation and appear to be derived from the south.

The youngest Proterozoic event recorded on TRAINOR is the intrusion of north-northeasterly trending dolerite dykes.

PRECAMBRIAN GEOLOGY

BANGEMALL BASIN

On the first edition of the geological map of TRAINOR, the region was subdivided into supposed older (Early to Middle) Proterozoic rocks (17% of the area) and Middle Proterozoic rocks assigned to the Bangemall Basin (83% of the region; Brakel and Leech, 1980). The older Proterozoic rocks included small sandstone outcrops along the northeast margin of TRAINOR that were assigned to the Yeneena Group. A second, larger area of deformed sandstone, siltstone, and shale in the southeast part of TRAINOR lies unconformably beneath the Skates Hills Formation, and was assigned to the Bangemall Group. This older unit was called the Cornelia Sandstone (Brakel and Leech, 1980) and was equated to both the Yeneena Group in the north and the Scorpion Group to the southwest (on NABBERU). The region, occupied by the Cornelia Sandstone, was later called the Cornelia Inlier (Muhling and Brakel, 1985).

Brakel and Leech (1980) divided the Bangemall Group into four formations called the McFadden Sandstone, Skates Hills Formation, Calyie Sandstone, and Coonabildie Formation. The status of the overlying Durba Sandstone was uncertain, although it was still thought to be a Middle Proterozoic unit. However, the discovery of the Late Proterozoic Savory Basin (Williams, 1987, 1992) led to a radical rearrangement of stratigraphic units on TRAINOR. Only the Coonabildie Formation is retained as part of the Bangemall Group. The widespread Calyie Sandstone is replaced, on TRAINOR, by five formations: the Brassey Range, Glass Spring, Jilyili, Spearhole, and Mundadjini Formations of the Savory Group.

The Boondawari Formation was previously mapped as 'Permian glacigene diamictite' (Brakel and Leech, 1980). The earlier named Durba Sandstone, McFadden Sandstone, and Skates Hills Formation were retained for use in the Savory Group (Williams, 1992). The reassignment of the Skates Hills Formation to the Late Proterozoic Savory Group required a revision of the status of the Cornelia Sandstone that lies unconformably beneath it. The review of the geology on TRAINOR for the Savory Basin project found that the Cornelia Formation (now renamed) was more widespread than previously recognized. It occupied a structure called the Trainor Inlier by Williams (1990c). Further detailed mapping revealed that this inlier is divided into two inliers separated by the Boondawari Formation of the Savory Group. These inliers were subsequently called the Ward and Oldham Inliers (Williams, 1992). The Cornelia Formation was found to have many features in common with rock assemblages in the Collier Subgroup of the Bangemall Basin, which lies west of the Savory Basin.

To summarize, the Savory Group now occupies most of that region previously assigned to the Bangemall Group on TRAINOR. Of the original area assigned to the Bangemall Group on TRAINOR only the southwest corner remains. This area is occupied by the Coonabildie Formation of the Kahrban Subgroup. The expanded Cornelia Formation, once regarded as pre-Bangemall, is now correlated with the Collier Subgroup of the Bangemall Group. The isolated sandstone outcrops on the northeast margin of TRAINOR, previously assigned to the Yeneena Group, are included with the McFadden Formation of the Savory Group.

The stratigraphy of the Bangemall Group is summarized in Table 2 and this is compared with previously published stratigraphy in Table 3.

Coonabildie Formation (*ⱣMx*)

The Coonabildie Formation was first described on STANLEY (Commander et al., 1982) and later defined and assigned to the Kahrban Subgroup of the Bangemall Basin by Muhling and Brakel (1985). Scattered exposures of this formation, briefly described in the first edition Explanatory Notes (Brakel and Leech, 1980), occur in the southwest corner of TRAINOR. Brakel and Leech (1980) considered that the relationship between the Coonabildie Formation and overlying Calyie Sandstone was uncertain, but could be an unconformity. This was subsequently confirmed by the discovery that rocks, previously mapped as 'Calyie Sandstone' in this part of TRAINOR were actually of the Savory Group. It was already known that the Savory Group was unconformable on the Bangemall Group (Williams and Tyler, 1991).

The Coonabildie Formation on TRAINOR is a mixed succession of grey-brown to purple-brown, fine- to coarse-grained sandstone, purple-grey siltstone, purple micaceous siltstone,

Table 2. Summary of Proterozoic stratigraphy on TRAINOR

Group	*Formation*	*Thickness (m)*	*Lithology*	*Depositional setting*
	Durba Sandstone *ⱣSd*	>100; top eroded	Quartz sandstone; matrix-supported pebble and cobble conglomerate at base	Fluvial
	McFadden Formation *ⱣSf*	>1 500; top eroded	Quartz sandstone, feldspathic sandstone, quartz and lithic wacke, pebble conglomerate, siltstone	Sandy marine shelf
	Boondawari Formation *ⱣSb*	approx. 800	Diamictite (glacigene), sandstone, siltstone, shale, mudstone, conglomerate	Glacial marine
Savory Group	Skates Hills Formation *ⱣSs*	>200	Dolomite, stromatolitic dolomite, sandstone, siltstone, shale, polymictic conglomerate, chert, evaporite minerals	Fluvial, intertidal mudflat, sabkha, shallow marine
	Mundadjini Formation *ⱣSm*	>1 800	Sandstone, siltstone, shale, conglomerate, dolomite, some stromatolites, evaporite minerals	Fluvial, deltaic, intertidal mudflat, sabkha, near-shore marine
	Spearhole Formation *ⱣSp*	>1 100	Sandstone, pebbly sandstone, pebble to boulder conglomerate, siltstone	Fluvial, braided stream, fan delta
	Jilyili Formation *ⱣSj*	>1 000	Sandstone	Shallow-marine delta front
	Glass Spring Formation *ⱣSg*	>1 600	Sandstone, pebbly sandstone	Near-shore shallow marine-shelf
	Brassey Range Formation *ⱣSr*	>1 700	Sandstone, siltstone, micaceous siltstone, shale, sandy siltstone	Fluvial, deltaic
Bangemall Group	Cornelia Formation *ⱣMs*	>3 000	Sandstone, orthoquartzite, pebble conglomerate, glauconitic sandstone, siltstone, shale, wacke	Shallow marine-shelf
	Coonabildie Formation *ⱣMx*	>1 100	Sandstone, siltstone, shale, pebble conglomerate	Delta front

and grey shale. A few thin beds of pebble conglomerate are also present. Trough and planar cross-beds, mainly small-scale, are abundant in some sandstone units. There are also symmetrical wave ripples and asymmetrical current ripples in these rocks. Intraclast-bearing sandstone interbedded with siltstone, and interlaminations of siltstone and sandstone occur in some areas. Upward-coarsening sequences are abundant.

Muhling and Brakel (1985) proposed a prograde-delta environment for the deposition of the Coonabildie Formation. Palaeocurrent data indicate a unimodal east to west flow direction.

Table 3. Comparative stratigraphy for first and second editions of the geological map of TRAINOR

First edition (Brakel and Leech, 1980)		*Second edition (this publication)*	
Group	*Formation*	*Group*	*Formation*
Bangemall Group	Durba Sandstone	**Savory Group**	Durba Sandstone
	McFadden Sandstone		McFadden Formation
	Permian glacigene diamictite		Boondawari Formation
	Skates Hills Formation		Skates Hills Formation
			Mundadjni Formation
			Spearhole Formation
	Calyie Sandstone		Jilyili Formation
			Glass Spring Formation
			Brassey Range Formation
	Coonabildie Formation	**Bangemall Group**	Coonabildie Formation
Pre-Bangemall rocks	Cornelia Sandstone		Cornelia Formation

Cornelia Formation (*PMs*)

The Cornelia Formation (Cornelia Sandstone in the first edition Explanatory Notes, Brakel and Leech, 1980; Williams, 1990) is the only unit exposed in the Ward and Oldham Inliers, which lie in the northwest-central and southeast parts of TRAINOR. The formation is unconformably overlain by five successive formations of the Savory Group.

On the southwest margin of the Oldham Inlier, the Cornelia Formation is unconformably overlain, at a shallow angle, by the Brassey Range Formation, which is the basal formation of the Savory Group in this part of the Savory Basin. Further to the northwest the Spearhole Formation is mostly faulted against the Cornelia Formation on the southwestern side of the Ward Inlier. However, the Spearhole Formation unconformably overlies the Cornelia Formation 4 km northeast of CSR Well No. 13.

The northeast margin of the Ward Inlier shows steep- to vertical-bedded Cornelia Formation unconformably overlain by flat-lying Mundadjini Formation. This angular unconformity is well exposed 9 km north of CSR Well No. 14. Southeast of this locality the Boondawari Formation is postulated to unconformably overlie the Cornelia Formation at the southeastern end of the Ward Inlier. Finally, steeply dipping Cornelia Formation on the northern margin of the Oldham Inlier is unconformably overlain by shallow north-dipping Skates Hills Formation. This unconformity is well exposed at Phenoclast Hill.

The presence of coarse clastic detritus derived from the Cornelia Formation in the basal units of successively younger Savory Basin formations on both sides of the Ward and Oldham Inliers suggests that these Inliers were basement highs, contributing detrital material throughout most of the depositional history of the Savory Basin.

The Cornelia Formation, on the southwestern sides of the Ward and Oldham Inliers, consists mainly of white, grey, fawn, cream, and buff-coloured, fine- to medium-grained sandstone and orthoquartzite. Coarse-grained sandstone, quartz wacke, granule conglomerate, and thin-bedded pebble conglomerate with clasts of blue chert and quartzite are minor components. These rocks are interbedded with minor amounts of red siltstone, micaceous sandstone (detrital muscovite), and glauconitic sandstone. Interclast-bearing sandstone beds are widespread. Sedimentary structures include poorly defined tabular and trough cross-beds and less abundant symmetrical ripple marks. Most of these rocks are resistant to erosion and constitute the Ward Hills and Oldham and Cornelia Ranges.

In thin section, it can be seen that the sandstone is thoroughly recrystallized with quartz forming an interlocking mosaic. Scattered grains of chert and sericite may be derived from feldspar.

The Cornelia Formation is less well exposed northeast of the Ward Hills and the Cornelia Range. In these areas the Cornelia Formation includes interbedded fine- to coarse-grained sandstone, some orthoquartzitic, red micaceous siltstone, silty shale, purple shale, and cobble conglomerate. Sandstone is commonly subordinate to the finer grained rocks. This succession represents the lower part of the Cornelia Formation. The pelitic rocks in this lower unit are of very low metamorphic grade. Quartz veins are abundant in the pelitic rocks 27 km east of Phenoclast Hill.

Minor ripple marks, load casts, and synaeresis cracks occur in interbedded sandstone–siltstone units. Minor cross-bedding occurs in some sandstone units. Overall palaeocurrent directions are towards the west, similar to those in the Coonabildie Formation. A shallow marine-shelf environment is envisaged for the Cornelia Formation.

It should be noted that the sandstone-rich upper part of the Cornelia Formation is similar to the Collier Formation whereas the fine-grained lower units resemble the Backdoor Formation, which underlies the Calyie Formation in the Collier Subgroup of the Bangemall Group. These similarities led to the correlation of the Cornelia Formation with the Collier Subgroup of the Bangemall Basin (Williams, 1990c).

Mafic intrusions

Extensive, partly laterite-covered weathered mafic sills and irregular intrusions are prominent in the Coonabildie Formation in the southwest corner of TRAINOR. The large number of mafic bodies is reflected in the widespread high magnetic background shown in this region (BMR, 1988, total magnetic-intensity data). The Cornelia Formation contains thin mafic sills and dykes that are concentrated in the Ward Hills and Oldham Range areas.

In both regions the mafic rocks are grey to dark grey, fine- to medium-grained dolerite with a subophitic texture and a simple plagioclase, clinopyroxene, and magnetite assemblage. Although no samples were analysed from TRAINOR, the mafic rocks resemble others described from the Bangemall Group on the adjacent BULLEN (Williams, 1995) and STANLEY (Muhling and Brakel, 1985).

The chemical composition of the dolerites on BULLEN and STANLEY falls into the domain of continental tholeiite (Muhling and Brakel, 1985). It is postulated that the dolerites were emplaced during an early extensional phase in the development of the Bangemall Basin.

Structure

The structural evolution postulated in the TRAINOR first edition Explanatory Notes (Brakel and Leech, 1980) bears little resemblance to that currently proposed for the area (Williams, 1992). Most of the region now occupied by the Savory Basin, was previously grouped with the Bangemall Basin and placed within a tectonic unit called the Bullen Platform (Muhling and Brakel, 1985). The Cornelia Sandstone (now Cornelia Formation), then regarded as pre-Bangemall in age, was reported to have structural trends parallel to those in the Paterson Province (now called Paterson Orogen) to the north (Brakel and Leech, 1980). The revised stratigraphy for TRAINOR now assigns only the Coonabildie Formation in the southwest and the Cornelia Formation of the Ward and Oldham Inliers to the Bangemall Basin (see Fig. 3).

The Coonabildie Formation is broadly folded about poorly defined west-northwesterly trending axes, rather than the north-northeasterly axes postulated by Muhling and Brakel (1985). Dips are shallow and cleavage is absent. The Kelly Fault, downthrown to the west, intercepts the Coonabildie Formation northeast of McConkey Hill. The well-developed joint pattern in the sandstones in this area may be due to the widespread dolerite intrusions that pre-date the deformation.

The Cornelia Formation is more strongly deformed than the Coonabildie Formation. Large open, upright folds, trending northwest (about 310°), and plane-dipping southwest-facing units on the southwest side of the Ward and Oldham Inliers pass northeastwards to tight northwesterly trending folds with steep dips, northwesterly and southeasterly plunging fold axes, and steep northeasterly dipping axial planes. These folds are accompanied by a vertical to steep northeasterly-dipping axial planar cleavage. Numerous small-scale S-verging folds plunge 20–30° southeast in an area 15 km northeast of CSR Well No. 13, and small-scale Z-verging folds plunge 45° northwest in an area 10 km north-northwest of CSR Well No. 14. The cleavage is accompanied by evidence of very low-grade dynamic metamorphism with recrystallized quartz and sericitic micas in pelitic rocks.

The orthoquartzite and sandstone in the Oldham Range and Ward Hills are well jointed. Both areas contain small dolerite intrusions. In the vicinity of Phenoclast Hill a prominent 030° joint direction parallels quartz veins. Similar quartz veins, some containing iron oxides after pyrite, occur in the Cornelia Formation close to the Savory Group unconformity, 10 km northwest of CSR Well No. 14.

Several large faults parallel the northwesterly trending fold axes in the Cornelia Range area whereas northeasterly trending faults are abundant in the Ward Hills. These latter faults post-date the dolerite intrusions in this area. Although both fault directions intersect the overlying Savory Group, they are thought to be pre-existent basement faults reactivated during the development of the Savory Basin. The large Pumpkin Fault, a normal fault with a downthrow to the west, truncates the northwest end of the Oldham Inlier. Faulting also occurs along the southwestern margin of the Ward Inlier. Both faults were active during deposition of the Savory Group.

The folding in the Bangemall Group pre-dates the deposition of the Savory Group. The intensity of deformation and metamorphic grade increases northeastwards across the Ward and Oldham Inliers towards the Paterson Orogen. The Manganese Subgroup of the Bangemall Basin on BALFOUR DOWNS shows a similar increase in deformation and metamorphic grade to the northeast. This was also attributed to activity in the Paterson Orogen (Williams, 1989). The event, which terminated sedimentation in the Bangemall Basin in these regions, was possibly the Watrara Orogeny of the Paterson Orogen (c. 1250 Ma; Clarke, 1991).

KARARA BASIN

A very small area in the northeast corner of TRAINOR (see Fig. 3) is thought to be underlain by sedimentary rocks of the Late Proterozoic Karara Basin (Williams, 1990b, 1992). Although there are no outcrops on TRAINOR, bedding trends in exposures close to the boundary on GUNANYA suggest that sedimentary rocks of the Karara Basin extend southeast beneath sand cover in this area.

The contact between the McFadden Formation of the Savory Basin and folded sedimentary rocks of the Karara Basin on GUNANYA is inferred to be a fault. This linear contact, when extended southeast, crosses the northeast corner of TRAINOR (Fig. 3). Parallel faults on GUNANYA between the Savory Basin and units of the Paterson Orogen are compressional, steep reverse faults. The Karara Basin, an earlier foreland basin south of the Paterson Orogen, is also thought to be separated from the Savory Basin by a similar compressional fault (Williams, 1990b).

SAVORY BASIN

The recently defined Savory Group of the Savory Basin (Williams, 1992) occupies about 70% of the bedrock of TRAINOR. All these rocks were previously assigned to the Bangemall Group (Brakel and Leech, 1980). Nine formations of the Savory Group occur on TRAINOR. Three of these, the Durba Sandstone, McFadden Formation, and Skates Hills Formation, were originally included with the Bangemall Group (Muhling and Brakel, 1985) but are now placed in the Savory Group. Of the remaining six formations, only one, the Brassey Range Formation, has its type area on TRAINOR (Williams, 1992). The Mundadjini and Boondawari Formations were defined on ROBERTSON (Williams and Tyler, 1991) and the Glass Spring, Jilyili, and Spearhole Formations were defined on the adjacent BULLEN (Williams, 1992).

The stratigraphy is summarized in Table 2 and is compared with the stratigraphy described in the first edition Explanatory Notes in Table 3.

Brassey Range Formation (*ESr*)

The Brassey Range Formation (Williams, 1992) is named after the Brassey Range (latitude 25°00'S, longitude 122°15'E) on the southern boundary of TRAINOR. The formation unconformably overlies the Coonabildie Formation of the Bangemall Basin in the southwest corner of TRAINOR. The western limit of the formation is marked by the Kelly Fault that separates it from the Glass Spring and Jilyili Formations, which are coeval with and partly facies equivalents of the Brassey Range Formation. The Brassey Range Formation extends southeastwards from the Kelly Fault onto STANLEY, where it extends to the eastern edge of the sheet before being unconformably overlain by Phanerozoic rocks (Permian and Cretaceous) of the Officer Basin. Northeast of the Brassey Range the formation unconformably overlies the Cornelia Formation in the Oldham Inlier. North of the Brassey Range the formation is unconformably overlain by the Spearhole Formation.

In general, the formation is poorly exposed. Two type areas are given by Williams (1992): the Kelly Range (latitude 24°27'30"S, longitude 121°32'E) and unnamed hills 50 km east of the Brassey Range (latitude 24°58'S, longitude 122°42'E). The formation is characterized by a wide range of rock types. These include white to grey, laminated to thick-bedded, fine- to medium-grained sandstone and lesser red-brown, thick-bedded, coarse-grained sandstone. Cream, grey, and purple siltstone, micaceous siltstone, silty sandstone, and red, green, and purple shale and mudstone are interbedded with the sandstone units.

The high percentage of detrital mica, weathered feldspar, chert and lithic fragments, and pervasive clay matrix in many sandstones place them in the wacke category. Overall, the Brassey Range Formation is less mature than the Glass Spring and Jilyili Formations further west (Williams, 1992).

Trough and tabular cross-beds, some with asymptotic foresets, are abundant in the sandstones. The scale of the cross-beds is proportional to grain size: the largest cross-beds (3–4 m) occur in the coarser grained sandstones whereas small-scale cross-beds (less than 5 cm) occur in fine-grained sandstone and sandy siltstone. The few ripple marks seen are typically directional, asymmetric forms. Sandstone containing shale clasts is interbedded with siltstone and shale. Some thin sandstones exhibit load- and flute-casts. Flat-bedded sandstone, between cross-bedded sandstone, is commonly current striated.

Upward-coarsening sequences of shale, siltstone, sandy siltstone, and sandstone occur in the Kelly Range area. Here, green and red shale and mudstone are prominent amongst the finer grained rocks. In the Brassey Range, some upward-fining sequences of sandstone to silty shale occur together with graded-bedded, thick sandstones. Slump structures, convolute bedding, and oversteepening of cross-beds occur in both fine-grained and coarse-grained sandstones.

The wealth of sedimentary structures in the Brassey Range Formation points to a high-energy depositional environment. This, coupled with a broad west-northwest palaeocurrent direction (Fig. 4), supports a fluvial–deltaic environment of deposition for the Brassey Range Formation. The formation is restricted to the region between the Oldham Inlier in the north and the older rocks of the Bangemall and Nabberu Basins that form the south-southwest margin of the Savory Basin. Both these areas have contributed detritus to this fluvial–deltaic system. The high detrital mica and feldspar content suggests that granitic material, possibly from the Yilgarn Craton, may have also contributed detritus to this fluvial system.

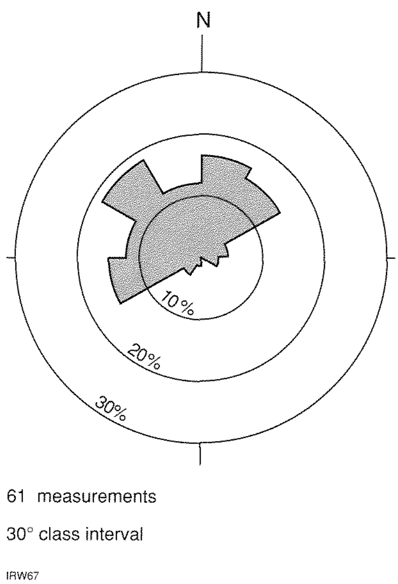

Figure 4. Palaeocurrent data for the Brassey Range Formation

In conclusion, the Brassey Range Formation is interpreted as a transverse fluvial–deltaic system flowing northwest to the Blake Sub-basin, which was the initial depocentre of the Savory Basin (Williams, 1992).

The Brassey Range Formation is intruded by high-level, fine-grained dolerite and porphyritic basalt to the east and southeast of the Brassey Range.

Glass Spring Formation (*ESg*)

The Glass Spring Formation (Williams, 1992) is restricted to a small area on the western margin of TRAINOR. The formation, which is widespread on BULLEN, extends only a short distance onto TRAINOR before it is terminated by the northerly trending Kelly Fault, which separates it from the Brassey Range Formation. Although contacts are not exposed on TRAINOR, the Glass Spring Formation unconformably overlies the Coonabildie Formation of the Bangemall Basin further south, and is conformably overlain by the Jilyili Formation to the north (Williams, 1992).

On TRAINOR the Glass Spring Formation consists mainly of coarse-grained, red-brown to purple-brown sandstone with occasional pebbles and cobbles. West of Macintosh Hill, small lenses and irregular patches of cobble conglomerate occur with the sandstone. The mature cobbles are rounded and consist of quartzite, vein quartz, and chalcedonic silica (?silcrete) clasts. Fifteen kilometres to the south-southeast of Macintosh Hill, adjacent to the Kelly Fault, well-jointed medium-grained sandstone and sandstone containing shale clasts are interbedded with purple siltstone.

Large tabular cross-beds, some with asymptotic foresets, are abundant. Some flat-bedded sandstone units, interbedded with cross-bedded sandstone, show current striae. Palaeocurrent directions are commonly north-northwest.

Further detailed descriptions of the Glass Spring Formation are given in the BULLEN Explanatory Notes (Williams, 1995).

Jilyili Formation (*ESj*)

The Jilyili Formation (Williams, 1992) is widespread on BULLEN but occupies only a very small area on TRAINOR north of Macintosh Hill, on the western boundary of the sheet. The eastern boundary of the formation on TRAINOR is marked by a splay fault of the Kelly Fault, which brings the formation into lateral contact with the underlying Glass Spring Formation (Fig. 3). The Jilyili Formation is disconformably overlain by the Spearhole Formation, but it should be noted that the poor, scattered outcrop in the vicinity of Macintosh Hill has made it difficult to assign the sandstone outcrops to specific lithostratigraphic units with any certainty.

On TRAINOR the Jilyili Formation consists of well-jointed, medium-grained, red-purple to red-brown sandstone and minor interbedded micaceous siltstone. Siltstone intraclasts occur in some sandstone beds. The formation contains rock types similar to those in the Brassey Range Formation of the Kelly Range area to the north. The coeval development of the Jilyili and Glass Spring Formations with the Brassey Range Formation has been described elsewhere (Williams, 1992). All three formations show evidence of strong west- to northwest-directed palaeocurrents. They constitute Depositional Sequence A of the Savory Basin, which has its provenance in the southeast (Williams, 1992).

Spearhole Formation (*ESp*)

The Spearhole Formation (Williams, 1992) is confined to an area west and southwest of the Ward Inlier. This is the eastern extent of a widespread formation on BULLEN and ROBERTSON adjoining TRAINOR to the west and northwest. A type area, west of the Ward Hills, is located at latitude 24°16'43"S, longitude 121°50'40"E*. Unlike the underlying Jilyili and Glass Spring Formations, the Spearhole Formation is not terminated by the Kelly Fault, although some displacement has occurred. The formation is faulted against the Cornelia Formation in the Ward Inlier where the fault appears to have been active during deposition of the Spearhole Formation. However, the unconformable relationship between the Cornelia and Spearhole Formations is seen in an area 4 km northeast of CSR Well No. 13. Here a narrow zone of conglomerate and sandstone, trending at right angles to the general strike of the Spearhole Formation, and partly modified by faults, overlies the Cornelia Formation. This narrow zone appears to be a channel or narrow valley incised in Cornelia Formation basement and filled with locally derived detritus. The clasts in the conglomerate consist of boulders, up to 2.5 m across, of orthoquartzite and fine-grained sandstone, which are identical to orthoquartzite and sandstone beds in situ in the underlying Cornelia Formation. Further west, the Spearhole Formation contains cobble conglomerate with the same type of orthoquartzite clasts interbedded with coarse-grained sandstone.

The Spearhole Formation is inferred to unconformably overlie the Brassey Range Formation to the southwest, although the contact is not exposed. Likewise, the contact with the overlying Mundadjini Formation is not exposed and, although interpreted to be disconformable on a regional scale (Williams, 1992), the abrupt termination of the northwest-trending Spearhole Formation against east-trending Mundadjini Formation near the northern end of the Ward Inlier suggests an unconformity between these two formations on TRAINOR.

The Spearhole Formation is mainly coarse- to very coarse-grained red-brown sandstone commonly containing scattered pebbles. Thin pebble bands and cobble-conglomerate beds are abundant west of CSR Well No. 13. Medium-grained sandstone and thick graded-bedded sandstone occur north of CSR Well No. 12.

Large trough and tabular cross-beds, up to 5 m thick, are abundant: some are asymptotic indicating high-energy conditions. Some pebbly sandstones are also cross-bedded. Palaeocurrent directions, measured from cross-beds, indicate a northerly direction roughly parallel to the western margin of the Ward Inlier.

The Spearhole Formation is interpreted as a fluvial, north-flowing braided-stream deposit with detritus largely derived from the southwest. However on TRAINOR, detritus also appears to have been derived from the Cornelia Formation of the Ward Inlier. A fault-controlled fan delta is envisaged for this area.

Mundadjini Formation (*ESm*)

The Mundadjini Formation (Williams and Tyler, 1991) extends into the northwest corner of TRAINOR from the adjoining BULLEN, ROBERTSON, and GUNANYA. It is the southeastern part of a widespread formation that occupies the central and northern parts of the Savory Basin. It unconformably overlies both the Cornelia Formation in the Ward Inlier and the Spearhole Formation. The former unconformity is well exposed in breakaways 9 km north of CSR Well No. 14. The Mundadjini Formation is unconformably overlain by the Boondawari Formation west of the Trainor Hills. Its relationship to the

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* Note: the type area in Williams (1992) was incorrectly located at latitude 24°16'43"S, longitude 121°35'40"E.

overlying McFadden Formation is unclear on TRAINOR, although regional relationships suggest it is faulted (Williams, 1992).

The Mundadjini Formation contains a wide variety of rock types. At the unconformity north of the Ward Hills, brown silty sandstone, quartz wacke, dark red-brown mudstone, and red-brown, coarse-grained sandstone with a clay matrix and scattered small lithic pebbles overlie the Cornelia Formation. The larger clasts in the sandstone are silty shale and micaceous siltstone identical to rock units in the underlying Cornelia Formation.

Ripple Hill (latitude 24°01'54"S, longitude 121°51'25"E) is a type locality for the Mundadjini Formation (Williams, 1992). Here a mixed sequence of clean, fine- to medium grained quartz sandstone overlies red-brown siltstone (some micaceous) and purple shale. The shale horizon contains discontinuous, thin-bedded, white carbonate. Single, bulbous, unidentified stromatolites are scattered through the carbonate unit. The fine- to medium-grained sandstone ranges from flaggy to thick bedded and is notable for the large number of ripple-marked surfaces. Both symmetric-wave and asymmetric-current ripples occur, and some have amplitudes up to 6 cm. Other bedding surfaces are covered with mud cracks. Matrix and clast-supported cobble and pebble conglomerate occurs in penecontemporaneous channels eroded in the sandstone–siltstone sequence. The clasts of the conglomerate are subangular to subrounded and consist of a mature assemblage of orthoquartzite, vein quartz, and sandstone, very similar to rock types recorded in the Ward Inlier to the south. Ripple Hill is characterized by upward-coarsening sequences from shale to sandstone. Medium- to coarse-grained sandstones east of Ripple Hill are cross-bedded, although this sedimentary structure is uncommon elsewhere in the Mundadjini Formation on TRAINOR. Halite pseudomorphs occur in fine-grained sandstone of the Mundadjini Formation in the southwest corner of GUNANYA close to the TRAINOR boundary, but evaporite minerals themselves have not been found. The Mundadjini Formation is intruded by a variety of dolerites, described below in the section on **Mafic intrusions**.

The Mundadjini Formation is interpreted as a mixed deltaic, tidal flat, shallow-water marine deposit with marine sabkha features developed in some areas (Williams, 1992).

Skates Hills Formation (*ESs*)

The Skates Hills Formation (Brakel and Leech, 1980; Muhling and Brakel, 1985) overlies the Cornelia Formation of the Oldham Inlier with angular unconformity in the southeastern part of TRAINOR. It is only on the northeastern and eastern sides of this inlier. Its absence from the southwest side, and the significance of the asymmetric distribution of the formation with respect to the Inlier, are discussed by Williams (1992). This basin-wide asymmetry is characteristic of marginal sag basins.

The Skates Hills Formation extends a short distance eastwards onto MADLEY where it was named after the Skates Hills (latitude 24°34'S, longitude 123°04'E). It is faulted against the Boondawari Formation to the west and is disconformably overlain by the McFadden Formation to the north (possibly a very low-angle unconformity). The Skates Hills Formation is correlated with the upper parts of the Mundadjini Formation to the northwest. The type section of the Skates Hills Formation (latitude 24°33'15"S, longitude 122°42'15"E) is about 6 km north-northeast of Phenoclast Hill (Muhling and Brakel, 1985). A type area for stromatolite-bearing dolomite lies 36 km southeast of Phenoclast Hill at latitude 24°48'34"S, longitude 122°57'50"E (Williams, 1992).

The Skates Hills Formation is a mixed unit with three main rock assemblages. The basal assemblage consists of polymictic cobble to boulder conglomerate with a fine-grained sandy matrix. It is patchily developed but is locally thick. Clasts are sandstone, orthoquartzite, vein quartz, and chert derived from the underlying Cornelia Formation. Conglomerates, up to 30 m thick, occur at Phenoclast Hill and 20 km northwest of Phenoclast Hill. They are interpreted as fluvial gravels filling channels incised in the underlying Cornelia Formation basement. Where the conglomerate is absent, red-brown, coarse-grained sandstone, granule sandstone, and thin pebble bands make up the basal assemblage. These units are locally overlain by maroon, cream, and grey fine-grained sandstone, micaceous siltstone, and shale. Overall, the basal unit is an upward-fining sequence.

The middle assemblage is mainly dolomite with interbedded, thin beds of fine-grained sandstone, siltstone, and shale, with blue and black (white weathering) chert. The dolomite is multicoloured ranging through grey, blue, buff, and cream to pink. Bedding ranges from thin laminations to thick beds up to 10 m thick (Brakel and Leech, 1980). A section, 21 m thick, lying 6 km north-northeast of Phenoclast Hill, consists of three dolomite beds separated by thin-bedded sandstone, siltstone, and shale. Some dolomites contain blue chert pods and lenses, whereas others contain cauliflower cherts, which are siliceous replacements of anhydrite nodules (Chowns and Elkins, 1974). The cauliflower cherts, together with gypsum-shaped voids in interbedded sandstones, indicate that evaporite conditions prevailed at some stages during deposition.

The dolomites of the Skates Hills Formation are characterized by numerous well-exposed stromatolites. Grey (1989) recorded and documented at least twelve localities on TRAINOR. *Acaciella australica* and *Basisphaera irregularis* have been positively identified (Grey, 1995). The best localities are 6 km north-northeast, 6 km northeast, 28 km northeast, and 36 km southeast of Phenoclast Hill. At the second locality, a thick-bedded, basal cliff-forming dolomite contains thin, blue chert beds but no stromatolites. It is overlain by thin to medium-bedded dolomite containing numerous bioherms and biostromes of *Acaciella australica*. This unit in turn is overlain by rubbly, exposed interbedded dolomite, shale, black chert, and scattered cauliflower chert after anhydrite. Silicified stromatolites, identified as *Basisphaera irregularis*, also occur in this horizon. This 20 m-thick dolomitic assemblage overlies interbedded siltstone and shale, and is capped by red-brown, medium-grained, cross-bedded sandstone.

The dolomite assemblage is interpreted as an upward-shallowing sequence that culminated in evaporitic, sabkha conditions. The carbonate-producing conditions were brought to a close by an influx of fluvial or shallow-marine sands. The upward-shallowing conditions in which the dolomite was deposited appear to be typical for the whole of the Skates Hills Formation.

The upper assemblage of the Skates Hills Formation consists of a thin succession of pink to red shale, siltstone, and flaggy fine- to medium-grained sandstone. Small planar cross-beds and a few symmetrical ripple-marked surfaces occur in the sandstone. Thin-bedded sandstone, interbedded with the siltstone and shale, typically has bottom structures such as flute- and load-casts.

The Skates Hills Formation indicates a wide range of depositional environments. These include fluvial deposits at the base, followed by beach deposits, intertidal and subtidal mudflat, and shallow near-shore marine conditions towards the top (Muhling and Brakel, 1985). Edgewise dolomitic conglomerate indicates strong tidal currents whereas evaporite minerals suggest sabkha conditions. The pink and red colour of the upper assemblage suggests that arid conditions prevailed for some time.

The identification of stromatolite taxa in the dolomite of the Skates Hills Formation has enabled important biostratigraphic correlations to be made between the Savory Group of the Savory Basin and the Amadeus Basin succession in the Northern Territory. Grey (1989) showed that the Skates Hills Formation can be equated, and is coeval, with the Loves Creek Member of the Bitter Springs Formation in the Amadeus Basin. Whether the Skates Hills Formation was physically linked, via the Proterozoic rocks of the Officer Basin, to the Amadeus Basin, or whether it formed a separate, contemporary basin is unknown.

Boondawari Formation (*ESb*)

The Boondawari Formation (Williams, 1987; Williams and Tyler, 1991) occupies the central part of TRAINOR, which lies 100 km southeast of the main exposures of the Boondawari Formation in the Boondawari Creek area on ROBERTSON and GUNANYA. Movement on the Marloo Fault has cut out the Boondawari Formation from the area between these two regions of outcrop and brought the higher McFadden Formation into contact with the underlying Mundadjini Formation.

Most of the Boondawari Formation is poorly exposed, especially the contacts with adjacent formations. It occupies the area between the Ward and Oldham Inliers. It is separated from the Cornelia Formation of the Oldham Inlier by the Pumpkin Fault, but its relationship to the Ward Inlier is not exposed. The formation is also faulted against the Spearhole Formation to the southwest, and the contact with the underlying Mundadjini Formation is intruded by a large dolerite sill. To the north, it is unconformably overlain by the McFadden Formation.

Some exposures of glacigene diamictite and conglomerate, which are now assigned to the Boondawari Formation, were mapped as Permian Paterson Formation on the first edition of the geological map of TRAINOR (Brakel and Leech, 1980). However, the discovery of Late Proterozoic glacigene rocks in the Boondawari Creek area on ROBERTSON (Williams, 1987) necessitated a reassessment of the diamictites on TRAINOR. These are interbedded with and overlain by coarse-grained sandstone, siltstone, and shale, and are petrographically similar to rocks in the Boondawari Creek area. Although the succession on TRAINOR appears to be mainly flat lying, mild deformation is indicated by broad folds, faults, and kinking, siliceous veining, and slickensides. The latter resemble those along faults in the Boondawari Creek area. West of the Trainor Hills the glacigene assemblage is intruded by coarse-grained dolerite, petrographically similar to the Boondawari Dolerite, which has been dated at c. 640 Ma (Williams, 1992).

A type area for the Boondawari Formation on TRAINOR lies 29 km east of CSR Well No. 13 at latitude 24°27'46"S, longitude 122°16'19"E*. The diamictite is a purple- to dark chocolate-coloured mudstone to sandy mudstone, containing scattered cobbles and boulders up to 0.5 m. Many cobbles and boulders are striated, faceted, and polished. The clasts are predominantly sedimentary rocks with a minor igneous (mainly granitoid) and metamorphic rock component. Abundant large, white to grey orthoquartzite boulders resemble bedded orthoquartzites of the Cornelia Formation of the Ward and Oldham Inliers.

The diamictite is commonly overlain by a red-brown, coarse- to medium-grained flaggy sandstone, in many cases with a siliceous nodular weathered surface. This sandstone is interbedded with sandy siltstone and cobble conglomerate lenses. The latter appear to fill channels eroded in the sandstone. Clasts in the conglomerate are similar to those in the diamictite. The coarse sandstones are planar cross-bedded, with a general palaeocurrent direction to the north. Poorly exposed blue silty mudstone and white-weathering purple siltstone and shale occur in the Trainor Hills.

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* The type area in Williams (1992) was incorrectly located at latitude 24°17'46"S, longitude 122°16'19"E.

Williams (1987) correlated the Boondawari Formation with similar Late Proterozoic glacial rocks in the Amadeus Basin. More recent studies concluded that the intergrading sandstone–diamictite of the Boondawari Formation closely resembled the intergrading of the Pioneer Sandstone and Olympic Formation in the Amadeus Basin (Walter et al., 1994).

Although a glacial-marine environment was postulated for the deposition of the Boondawari Formation (Williams, 1992), the occurrence of sandstone and conglomerate interbedded with the diamictite may be more consistent with deposition at the margin of a retreating terrestrial glacier or ice sheet (Walter et al., 1994). This depositional setting may be particularly applicable to the TRAINOR occurrences, because many boulders in the diamictite resemble rocks in the adjoining Ward and Oldham Inliers. However, no glaciated surfaces or pavements of Proterozoic age have yet been detected within or adjoining the Savory Basin (Williams, 1992).

McFadden Formation (*ESf*)

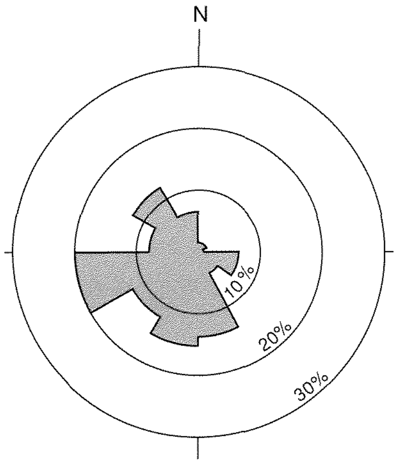
The McFadden Formation (Williams and Williams, 1980) occupies most of the northeast quarter of TRAINOR. The formation is widespread on GUNANYA, adjacent to TRAINOR, where it derives its name from the McFadden Range. It is also the main formation along the northeast margin of the Savory Basin.

The linear contact with the Karara Basin in the extreme northeast corner of TRAINOR is presumed to be a fault. Although there are no exposures in this area, the contact is postulated from outcrops on adjoining GUNANYA and MADLEY. The formation is unconformably overlain by Phanerozoic rocks (Permian and Cretaceous) of the Officer Basin on the western edge of MADLEY. On TRAINOR the formation is faulted against the Mundadjini Formation and it is inferred to disconformably or unconformably overlie the Boondawari and Skates Hills Formations. In both cases, outcrop is sparse because of widespread sand cover. The McFadden Formation is unconformably overlain by the Durba Sandstone.

On TRAINOR the McFadden Formation is an arenaceous unit that becomes coarser grained northwards. The sandstones are laminated to thick bedded, medium to coarse grained, and commonly flaggy. They are interbedded with feldspathic sandstone, and quartz and lithic wacke. The wacke is poorly sorted and contains up to 20% clay as the matrix. Many quartz sandstones in this region also have a high clay content. Brakel and Leech (1980) suggested that the clay may have been derived from volcanic ash.

The sandstones are progressively cleaner southwards. The red-brown sandstones overlying the Skates Hills Formation are medium to coarse grained and lack the interbedded wacke component. Further north, the McFadden Formation consists of purple-red to purple-brown coloured, medium- to coarse-grained sandstone and wacke, commonly with a friable weathered surface. Purple siltstone and pebble conglomerate also become more common northwards.

The McFadden Formation contains many large to very large cross-beds. These include trough and tabular forms with both planar and asymptotic foresets. Although measured cross-beds are up to 5 m thick they are commonly smaller than those on GUNANYA (Williams and Williams, 1980). Some flat-bedded sandstone between cross-bedded units contains ripple marks and current striae. The cross-beds indicate dominant palaeocurrent directions towards the south-southwest (Fig. 5). However, cross-bedded quartz sandstones in the lower part of the McFadden Formation, overlying the Skates Hills Formation, indicate palaeocurrent directions towards the northwest.



91 measurements

30° class interval

IRW68

Figure 5. Palaeocurrent data for the McFadden Formation

The McFadden Formation belongs to Depositional Sequence D, which has its provenance in the mixed igneous, metamorphic, and sedimentary rocks of the Paterson Orogen (Williams, 1992). However, on TRAINOR, the northwesterly directed current, the clean nature of the quartz sandstone, and the dominance of reworked sedimentary clasts in the scattered pebble bands in the southern part of the formation suggest that some detritus may also have been derived from the Oldham Inlier.

The origin of the large cross-beds in the McFadden Formation is uncertain, and several possibilities have been discussed (Williams, 1992). On TRAINOR, they are possibly the product of migrating sandy offshore current-ridges or megaripples in shallow-water shelf conditions.

Durba Sandstone (*ESd*)

A few small outliers of Durba Sandstone (Brakel and Leech, 1980) are scattered along the northeast margin of TRAINOR. The formation lies unconformably on the McFadden Formation and is the youngest formation of the Savory Group.

The basal unit of the Durba Sandstone is a polymictic pebble to cobble conglomerate up to 1 m thick. The clasts are well rounded and consist of a mature assemblage of sandstone, orthoquartzite, vein quartz, and red and grey chert. The conglomerate is overlain by red-brown, coarse- to medium-grained sandstone, with a few scattered pebbles. The highest units exposed on TRAINOR are fine- to medium-grained sandstones containing a few siltstone clasts. Planar cross-beds up to 1.5 m across occur in the medium- to coarse-grained sandstone, and asymmetric and interference ripple-marks occur on some surfaces.

The Durba Sandstone is an upward-fining sequence, and Muhling and Brakel (1985) proposed a fluvial origin. The strong unimodal palaeocurrent direction to the north supports this interpretation. It also suggests that the sandstone may have been derived from rocks of the Bangemall Basin exposed in the Oldham Inlier to the south.

Mafic intrusions

Three groups of mafic intrusive rocks occur in the Savory Group on TRAINOR. The oldest group consists of high-level, fine-grained dolerite and porphyritic basalt sills and dykes, probably emplaced during the early extensional phase of basin development. The second group consists of large coarse-grained dolerite intrusions, correlated with the Boondawari Dolerite, dated at around c. 640 Ma, on ROBERTSON. The third group includes fine- to medium-grained dolerite dykes cutting all the Proterozoic rocks and structures of the regions.

High-level intrusions

The basal Brassey Range Formation contains several fine-grained dolerite sills in the Brassey Range. Although most of the dolerite is deeply weathered or ferruginized, fresh exposures occur at the base of laterite-capped breakaways. The dolerite is fine grained with a subophitic texture marked by plagioclase, clinopyroxene, and magnetite.

A network of thin veins and dykes (up to 6 m thick) and small sills of porphyritic basalt occur in sandstone of the Brassey Range Formation, 39 km east of Brassey Range. The sandstone in this area contains dislocations, shear zones, and fractures related to the emplacement of the porphyritic basalt. Some of the larger dykes contain slivers of sandstone. Evidence of contact metamorphism is present in sandstone adjacent to the larger intrusions. The unweathered basalt is dark grey and consists of small plagioclase phenocrysts set in an aphanitic groundmass.

Similar fine-grained dolerite and basalt sills occur north of Sunday Well and around Mount Normanhurst on STANLEY to the south. The Brassey Range Formation has a high total magnetic intensity (BMR, 1988). This suggests that mafic intrusions may be abundant in the formation beneath the widespread sand cover.

An unusual, altered basalt sill occurs on the northeast side of Ripple Hill in the Mundadjini Formation. It consists of large relict phenocrysts of plagioclase and clinopyroxene, now replaced by carbonate and a very pale-green phyllosilicate, set in a matrix of bladed and skeletal plagioclase. Trains of opaque minerals form curved, frondlike plumes in the relict pyroxenes. The high ratio of relict pyroxene to plagioclase indicates that this rock was more mafic than other basalts cutting the Savory Group. This occurrence may be an apophysis from one of the large dolerite intrusions that are abundant in this area.

Large dolerite intrusions

A large, 800 m-thick body of coarse-grained dolerite is discontinuously exposed in an area southwest of CSR Well No. 15. This arcuate body extends for about 30 km from the southwest end of the Trainor Hills, where it intrudes the contact between the Mundadjini Formation and overlying Boondawari Formation, to an area about 20 km west of CSR Well No. 15.

A second, poorly exposed dolerite within the Mundadjini Formation can be traced over a distance of 30 km beneath sand and laterite cover southwest of Ripple Hill. A third body, also within the Mundadjini Formation, lies 12 km west-northwest of Ripple Hill.

The dolerite consists of coarse, little-altered clinopyroxene or orthopyroxene, primary brown hornblende, fine- to medium-grained, partly altered plagioclase (labradorite), minor quartz, and rare olivine. Skeletal and intergranular magnetite and biotite are accessories. Textures are commonly intergranular, although subophitic and seriate textures have also been noted.

A diagnostic feature of these bodies is the widespread occurrence of small, granophyric patches. Quartz occurs in both intergranular textures and as a constituent of the granophyric patches. The coexistence of quartz and granophyric patches with olivine in the dolerites suggests that wall-rock contamination of the dolerite may have occurred during passage through the thick sedimentary pile.

These dolerites are correlated with the granophyric quartz-rich Boondawari Dolerite on ROBERTSON, which has given a poorly defined Rb/Sr whole-rock isochron of c. 640 Ma (Williams, 1992). The dolerites appear to be slightly silica-enriched tholeiites. Chemical analyses of four dolerite samples are given in Table 4.

Late mafic dykes

The group of late mafic dykes includes fine- to medium-grained dolerite dykes that post-date all other Proterozoic rocks on TRAINOR. They are typically weathered. They are part of a dyke swarm described on BULLEN (Williams, 1995), which is Suite 7 (d_7) of the southeast Pilbara region (Williams and Tyler, 1991).

One prominent set of dykes can be traced intermittently from the Brassey Range, on the southern margin of TRAINOR, north-northeast to the Calvert Range on GUNANYA and beyond. This set consists of a number of discontinuous dykes that are typically subparallel and en echelon. The dykes are up to 10 m wide and occupy the floors of narrow valleys in the sandstone hills. The dolerite is typically deeply weathered, but the white-weathering saprolitic rock often preserves a doleritic texture.

Airphoto lineaments between Lake White and the Brassey Range, emphasized by vegetation, are interpreted as a dyke swarm with north-northeasterly trending dykes that continue towards the Ward Inlier and north-northwesterly trending dykes that are confined to the Brassey Range Formation. Although it is possible that the two dyke directions represent contemporaneous intrusion, it is also possible that the north-northwesterly trending dykes are related to the older basalt and fine-grained dolerite sills and dykes described in the first group.

Structure

It has already been mentioned that the previous tectonic subdivisions of TRAINOR (Brakel and Leech, 1980; Muhling and Brakel, 1985) bear little relationship to current understanding of the Savory Basin. It is now known that the Savory Basin unconformably overlies the Bangemall Basin and that it had an independent tectonic history (Williams, 1992). The Savory Group on TRAINOR is unevenly divided in area between the Trainor Platform, Blake Fault and Fold Belt, and the Wells Foreland Basin, the three tectonic units proposed for the Savory Basin (Fig. 3; Williams, 1992).

The Trainor Platform is the major tectonic unit on TRAINOR and occupies a broad northwest-trending zone through the central parts of the sheet. In this area the Savory Group unconformably overlies and surrounds a central core of Bangemall Group rocks in

Table 4. Chemical analyses of coarse-grained dolerite intrusions (Group 2) in the Savory Basin on TRAINOR

Sample number (a)	*96002* *24°06'37"S* *122°03'17"E*	*96009* *24°12'05"S* *122°10'45"E*	*96014* *24°18'11"S* *122°12'22"E*	*96038* *24°05'52"S* *122°01'33"E*
		Percent		
SiO_2	54.1	54.8	54.1	53.7
Al_2O_3	13.3	14.3	13.6	16.1
Fe_2O_3	2.82	3.76	2.73	2.57
FeO	8.51	7.65	8.25	7.20
MgO	5.97	3.51	5.92	4.14
CaO	7.96	7.16	7.97	8.89
Na_2O	2.59	3.14	2.68	2.79
K_2O	1.56	1.88	1.55	1.54
H_2O^- (b)	0.37	0.41	0.37	0.18
H_2O^+ (b)	1.51	2.11	1.71	0.67
CO_2 (b)	0.28	0.30	0.28	0.18
TiO_2	1.20	1.41	1.18	1.08
P_2O_5	0.13	0.16	0.13	0.12
S	0.10	0.11	0.09	0.09
MnO	0.21	0.21	0.21	0.19
O=S (c)	0.05	0.05	0.05	0.05
Other (d)	0.18	0.20	0.19	0.17
Total (e)	**100.8**	**101.1**	**100.9**	**99.6**
		Parts per million except where indicated		
Ba	266	357	293	264
Ce	44	56	47	40
Cr	26	<4	26	7
Cu	49	51	51	59
Ga	19	20	20	21
Hf	7	5	7	6
La	21	27	23	24
Li (f)	16	21	20	18
Nb	8	7	<7	8
Ni	44	22	39	29
Pb	11	11	14	16
Pd (g)	<5	<5	<5	<5
Pt (g)	<10	<10	<10	<10
Rb	76	90	77	74
Sc (f)	33	29	33	28
Sn	<4	<4	4	4
Sr	147	159	160	173
Th	10	12	10	10
U	2	3	2	2
V	283	290	276	249
Y	33	38	32	30
Zn	97	107	105	89
Zr	156	181	149	141
K/Na	0.67	0.68	0.65	0.61
K/Rb	170	173	167	172
Rb/Sr	0.51	0.57	0.48	0.43

Analyses carried out using X-ray fluorescence spectrometry unless otherwise noted
(a) Geological Survey of Western Australia sample number
(b) Classical chemistry
(c) Calculated
(d) Sum of trace elements expressed as oxides
(e) Sum of components — O=S is deducted
(f) ICP emission spectrometry
(g) Classical chemistry — parts per billion

the Ward and Oldham Inliers. The Trainor Platform is the most stable and least deformed part of the Savory Basin. It is bounded to the west by the north-trending Kelly Fault. This fault separates the northwesterly trending structures of the Trainor Platform from the northeasterly fault and fold trends of the Blake Fault and Fold Belt. The northeast boundary of the Trainor Platform on TRAINOR is the southwest boundary of the McFadden Formation.

The Brassey Range, Skates Hills, and Boondawari Formations, and the southeast extensions of the Spearhole and Mundadjini Formations overlie the Trainor Platform. The platform is characterized by northeast-dipping beds, and broad open folds plunging gently to the northwest. Sparse, brittle faults are typically extensional, and trend northeast or northwest. The northeast direction typically truncates the northwest direction. The large northeast-trending Pumpkin Fault is downthrown to the northwest. A series of northwest-trending faults along the southwestern side of the Ward Inlier appear to be growth faults that were active during deposition of the Spearhole Formation. Later reactivation along these faults may account for some open northwest-plunging folds in the Spearhole Formation in this area. The northwest-trending faults have been offset by later east-trending faults. Most large faults in the Trainor Platform are probably reactivated basement faults.

The Blake Fault and Fold Belt lies west of the Kelly Fault, occupying only a very thin strip along the western margin and the northwest corner of TRAINOR. The Kelly Fault is part of the hinge line that marks the eastern boundary of the half-graben that initiated the Blake Sub-basin of the Savory Basin. The Blake Sub-basin contains the oldest rocks in the Savory Basin. Although the dominant movement on the Kelly Fault is a downthrow to the west, some slickensides indicate that sinistral strike-slip movement also occurred. The Kelly Fault now separates the fluvial Brassey Range Formation in the east from the shallow marine-shelf Glass Spring Formation and overlying deltaic Jilyili Formation to the west. Originally, these three formations were probably closely related in space and time and differed only in their depositional environment. Although the Spearhole Formation is dislocated by the Kelly Fault, it also overlaps it, and, together with the overlying Mundadjini Formation, continues west and northwest into the Blake Sub-basin.

The Wells Foreland Basin occupies the northeast quarter of TRAINOR. It contains the McFadden Formation and scattered outcrops of Durba Sandstone. This tectonic unit is a shallow, northwest-elongated basin formed in response to southwesterly directed compression generated during the Paterson Orogeny. The incipient Wells Foreland Basin was caught up, along its northeast margin, in the closing stages of this southwesterly directed compressional movement (Williams, 1992). Deep-seated steep reverse faults are postulated to extend southeast onto TRAINOR by extrapolation of known faults on GUNANYA to the north. This includes the sand-covered, faulted contact with the Karara Basin (Fig. 3). Steep reverse micro-faults with south-directed movement occur in the McFadden Formation.

The poor outcrop of the Savory Group on TRAINOR makes description of the structural history of the Savory Basin difficult.

SUPERFICIAL DEPOSITS

The descriptive, morphologic scheme used for the Cainozoic superficial deposits on TRAINOR is the same as that used on the adjacent BULLEN (Williams, 1995). Three major groups recognized in this scheme were mapped on TRAINOR: unconsolidated recent alluvial and eolian deposits; unconsolidated transitory alluvial and colluvial depositional and erosional deposits; and older consolidated, mainly chemical deposits. The first group can be divided into three geomorphic units — alluvium (*Qa*), mixed lacustrine (*Ql*, *Qd*), and eolian (*Qs*, *Qd*, *Qp*).

Unconsolidated silt, sand, and gravel (*Qa*) occupy both broad drainage lines and narrow incised creeks in the southwest corner of TRAINOR. Here, ephemeral drainages, such as Gum Creek, drain northwest from rounded bedrock hills and low laterite-capped breakaways to saline palaeodrainage valleys. This largely sand-dune free area overlies Bangemall Group bedrock. Coarse gravel and sand occurs in short, steep creeks and incised gullies in and adjacent to the rocky Ward Hills and the Oldham and Cornelia Ranges. The rapid run-off from these rocky hills prevents windblown sand from blocking the channels, which eventually disappear amongst the sand dunes. Some of the larger creeks find their way to clay pans and salt lakes that lie in the palaeodrainage valleys.

The salt lake (playa; *Ql*) and mixed lacustrine and eolian units (*Qd*) are widespread along the floors of the major palaeodrainage lines on TRAINOR. The salt lakes are typically smaller but more numerous on TRAINOR than on BULLEN. The largest, Lake Aerodrome and White Lake, are bare, red-brown surfaces underlain by saline and gypsiferous mud, silt, and sand. Salt (halite) encrustations occur in the lowest levels of the lakes. Lunette kopi dunes (flour gypsum and silt) rim the larger salt lakes.

The mixed lacustrine and eolian unit (*Qd*) consists of strings of small clay pans, samphire swamps, and salt pans separated by red windblown desert sand and cream-coloured lake-derived gypsum dunes. The unit is confined to the palaeodrainage valleys. Saline silt and sand-filled channels and creeks occur in the headwaters of the Kahrban Creek west of the Brassey Range and in a broad palaeodrainage valley east of the Ward Hills. Sections of the Disappointment Palaeoriver and the palaeodrainage valley northeast of CSR Well No. 12 are completely choked with red desert sand.

Windblown sand (*Qs*), in dunes and sheets, is widespread on TRAINOR. This region is part of the Little Sandy Desert (Beard, 1970). The sand is medium to coarse grained and consists of subangular iron-stained or coated quartz grains. No information is available as to the depth of sand on TRAINOR. Overall, sand dunes are slightly lower than on BULLEN but more complex in form.

The ironstone pebble veneer on sand plain (*Qp*) is a lag deposit. It is widespread in areas where dunes are absent or poorly developed. The formation of the unit is dependent on the breakdown of laterite-capped breakaways or weathering of buried laterite profiles. The laterite, in turn, favours sandstone-poor areas, such as the Coonabildie Formation in the southwest, the Boondawari Formation, and large dolerite sills such as occur north of the Ward Hills.

Brakel and Leech (1980) argued that the extensive sand cover on TRAINOR was primarily derived from the breakdown of Proterozoic sandstone rather than windblown sands from eroded Phanerozoic rocks of the Officer Basin to the east. The recent work in the Savory Basin supports this view and shows a close relationship between the distribution of sand (the Little Sandy Desert) and the Late Proterozoic sandstones of the Savory Basin (Williams, 1992).

The second group (unconsolidated transitory alluvial and colluvial depositional and erosional deposits) consists of unconsolidated low-slope sheet-wash deposits (*Qw*), commonly adjacent to the main drainage lines, and regions undergoing recent erosion adjacent to and overlying bedrock (*Qc*). The latter unit includes scree and talus deposits. Unconsolidated low-slope sheet-wash deposits are mainly confined to the southwest corner of TRAINOR where it overlies the Coonabildie Formation, and between CSR Well Nos 14 and 15 northeast of the Ward Hills. In both areas it is associated with laterite and ironstone-pebble-veneered sand deposits (*Qp*). The sheet-wash deposits are distinguished by a vegetation-striped airphoto pattern, the origin of which is discussed in the Explanatory Notes for BULLEN (Williams, 1995). Scree, talus, and quartz-pebble-veneered surfaces (Qc) occur adjacent to the rocky Cornelia and Oldham Ranges. Windblown sand (*Qs*) covers this unit at the eastern end of the ranges.

All the units discussed above involve currently active processes and can be assigned to the Holocene (Recent) Series of the Quaternary System.

The third group on TRAINOR (older consolidated, mainly chemical deposits) includes trunk-valley calcrete (*Czk*) and laterite (*Czl*). The calcrete is a hard, grey-white to bluish limestone, typically fragmented and recemented at the surface. In some areas minor opaline silica replacement is evident. The calcrete is confined to palaeodrainage lines and is particularly well developed in the Kahrban Creek drainage and in the Oldham Range area.

Laterite occurs scattered throughout TRAINOR. It includes massive, brecciated, and pisolitic forms capping low breakaways, and more ferruginous, earthy forms in the soil profile. The laterite is common over weathered dolerite sills. This is particularly evident in the southwest corner of TRAINOR and northeast of the Ward Hills.

The age of the calcrete and laterite on TRAINOR is unknown although it is traditionally considered to be middle Tertiary. Further description of the superficial deposits on TRAINOR is given in the first edition Explanatory Notes (Brakel and Leech, 1980).

ECONOMIC GEOLOGY

Over the last fifteen years, specific areas of TRAINOR have been targeted for base-metal, uranium, and diamond exploration with few positive results. In the past, the difficult sand-dune terrain and poor access has retarded prospecting and ground-level exploration. More recently, broad-based geochemical and geophysical surveys have been carried out. These have included rock, lag, and loam sampling, and particular emphasis has been placed on the search for diamonds. In some areas ground-based gravity and magnetic surveys have followed up specific anomalies detected using airborne techniques.

One such anomaly, 54 km east of CSR Well No. 15, was unsuccessfully investigated for copper–uranium mineralization in the early 1980s (CRA Exploration Pty Ltd, 1982). Several diamond searches over the last fifteen years have produced few positive results (Dampier Mining Co. Ltd, 1980; CRA Exploration Pty Ltd, 1987, 1989). The only discovery of interest lies northwest of McConkey Hill in the southwest corner of TRAINOR where one micro- and two macro-diamonds were found in loam samples. Subsequent follow-up work proved negative (CRA Exploration Pty Ltd, 1987). The sampled area overlies the Coonabildie Formation of the Bangemall Group close to the Savory Group unconformity. The Kelly Fault crosses the area of interest.

A large circular magnetic structure, 15 km in diameter and 2 km wide, crosses the northwest corner of TRAINOR. The bulk of this anomaly lies on GUNANYA to the north. A ground survey located deep-weathered mafic (basic) igneous rocks within shallow-dipping, medium-grained sandstone and interbedded siltstone. A search for kimberlitic indicator minerals proved negative (CRA Exploration Pty Ltd, 1989). Brief reports on exploration work on TRAINOR are available from the WAMEX open-file system in the Geological Survey Library.

The discovery of halite, gypsum, and barite in the Mundadjini Formation and anhydrite and gypsum in the Skates Hills Formation at a number of scattered localities in the Savory Basin suggests that these formations may be prospective for evaporite deposits.

The Savory Basin has recently been correlated with the Late Proterozoic component of the Amadeus Basin (Williams, 1992), which has known oil and gas occurrences (Schroder and Gorter, 1984; Roe, 1991). This correlation suggests that the Savory Basin may be prospective for hydrocarbons because it may have potential source rocks, is unmetamorphosed, and is structurally favourable.

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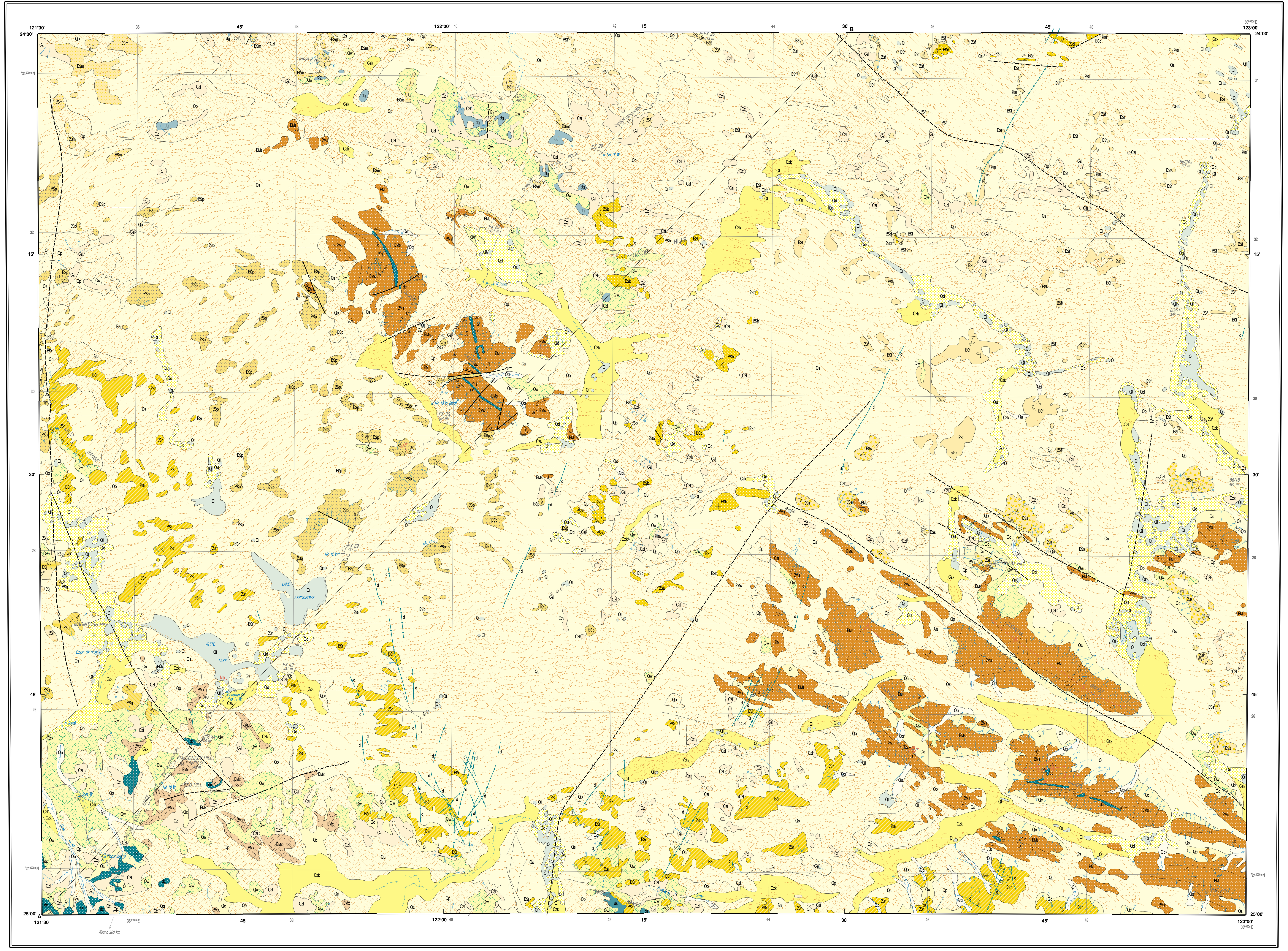
TRAINOR

AUSTRALIA 1:250 000 GEOLOGICAL SERIES

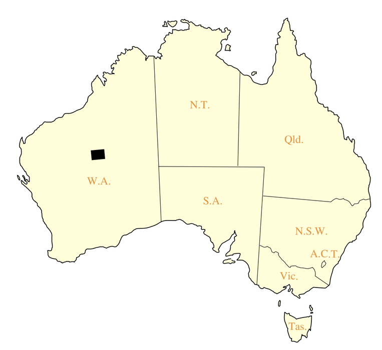
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SG 51-02

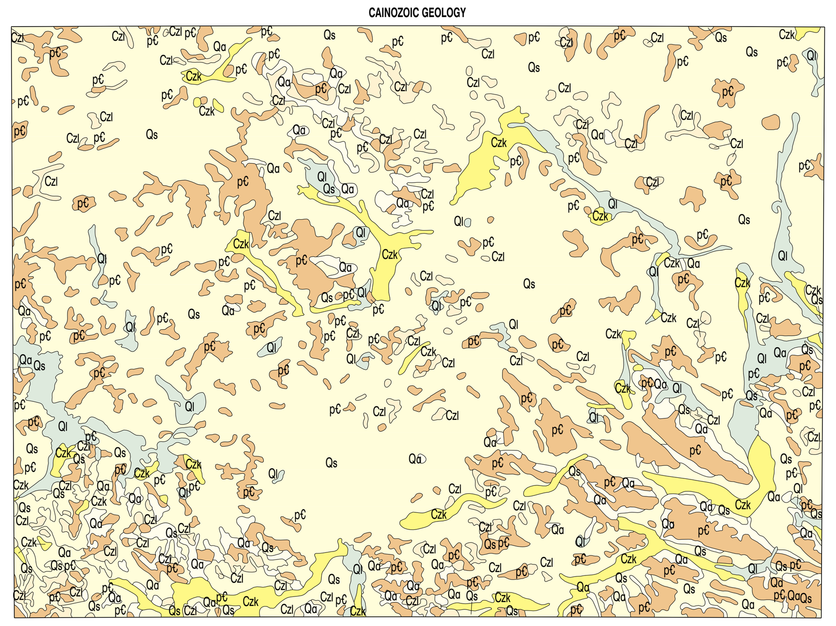


SYMBOLS

- Geological boundary, accurate
- Fault
  - accurate
  - inferred
  - inferred and concealed
  - reverse, inferred and concealed
- Fold, showing direction of plunge
  - anticline
  - syncline
  - minor, asymmetric
- Bedding, showing strike and dip
  - inclined
  - vertical
  - horizontal
- Way-up indicator
  - cross-bedding
- Direction of movement of sediment-bearing currents, from cross-bedding
- Cleavage, showing strike and dip
  - inclined
- Mineral lineation, showing direction of plunge
- Air photo lineament
- Stromatolite locality
- Track
- Yard — Yd
- Horizontal control; major, minor
- Bench mark, height accurate — FX 47 554 m
- Sand dune
- Watercourse, ephemeral
- Bore — B
- Well — W
- Windpump
- Rockhole, gnamma hole — RH GH
- Abandoned — (abd)
- Position doubtful — (PD)
- Industrial mineral occurrence
  - salt (in playa lakes) — Na



CAINOZOIC GEOLOGY



Qa Alluvium, colluvium	Qs Eolian sand	Czl Laterite
Ql Lacustrine and associated deposits	Czk Calcrete	p€ Precambrian bedrock

SCALE 1:1 000 000

0 10 20 30 40 50 Kilometres

REFERENCE

CAINOZOIC — QUATERNARY

Qa Ql Qd Qs Qp Qc Qw

- Qa — Alluvium—clay, silt, sand, and gravel; in drainage channels and adjacent flood plains
- Ql — Lacustrine deposits—clay, mud, and silt, mostly saline; commonly gypsiferous
- Qd — Mixed lacustrine and eolian deposits—clay, mud, silt, and sand; some saline; gypsum dunes (kopi)
- Qs — Eolian sand—in sheets and dunes; longitudinal (seif), chain, net, and pyramidal dunes
- Qp — Eolian sand—in sheets and interdunal areas; sand with ironstone pebble veneer, derived from Czl
- Qc — Colluvium and minor alluvium—quartz pebble and rock fragment veneer on sand and silt adjacent to bedrock; scree deposits
- Qw — Colluvium and alluvium—clay, silt, sand, and gravel on broad sheetwash areas; distinctive striped air photo pattern to vegetation

Czk Czl

- Czk — Calcrete—carbonate in sheets, mainly confined to palaeodrainage lines; some secondary silicification at surface
- Czl — Laterite—massive, pisolitic, pebbly, and nodular ferruginous deposits; overlies leached bedrock

- d — Fine-grained dolerite dykes, kaolinized weathered outcrop; various ages

LATE PROTEROZOIC (SAVORY BASIN)

- dg — Medium- to coarse-grained dolerite, granophyric in places; in sills, dykes, and irregular intrusions
- ds — Basalt, amygdaloidal basalt, and fine-grained dolerite; in sills and dykes

Savory Group

- ᵽSd — **DURBA SANDSTONE:** medium- to coarse-grained sandstone, with minor basal conglomerate lenses
- ᵽSf — **McFADDEN FORMATION:** laminated fine- to coarse-grained sandstone, feldspathic sandstone, quartz wacke; minor conglomerate, siltstone
- ᵽSb — **BOONDAWARI FORMATION:** glacigene diamictite, sandstone, siltstone, shale, calcareous shale

*c.*610 Ma

*c.*810 Ma

ᵽSm ᵽSs

- ᵽSm — **MUNDADJINI FORMATION:** fine- to coarse-grained sandstone, conglomerate, siltstone; minor shale, mudstone, stromatolitic dolomite, evaporite
- ᵽSs — **SKATES HILLS FORMATION:** thin-bedded stromatolitic dolomite, chert, evaporite, fine- to medium-grained sandstone, siltstone, shale, conglomerate
- ᵽSp — **SPEARHOLE FORMATION:** coarse- to medium-grained sandstone, pebbly sandstone, siltstone, conglomerate lenses

ᵽSj ᵽSg ᵽSr

- ᵽSr — **BRASSEY RANGE FORMATION:** fine- to medium-grained sandstone, siltstone, shale, minor coarse-grained sandstone
- ᵽSj — **JILYILI FORMATION:** fine- to medium-grained sandstone
- ᵽSg — **GLASS SPRING FORMATION:** medium- to coarse-grained sandstone

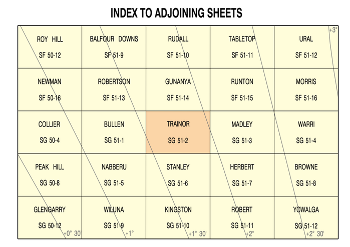
MIDDLE PROTEROZOIC (BANGEMALL BASIN)

- dc — Fine- to medium-grained dolerite; in sills, dykes, and irregular intrusions

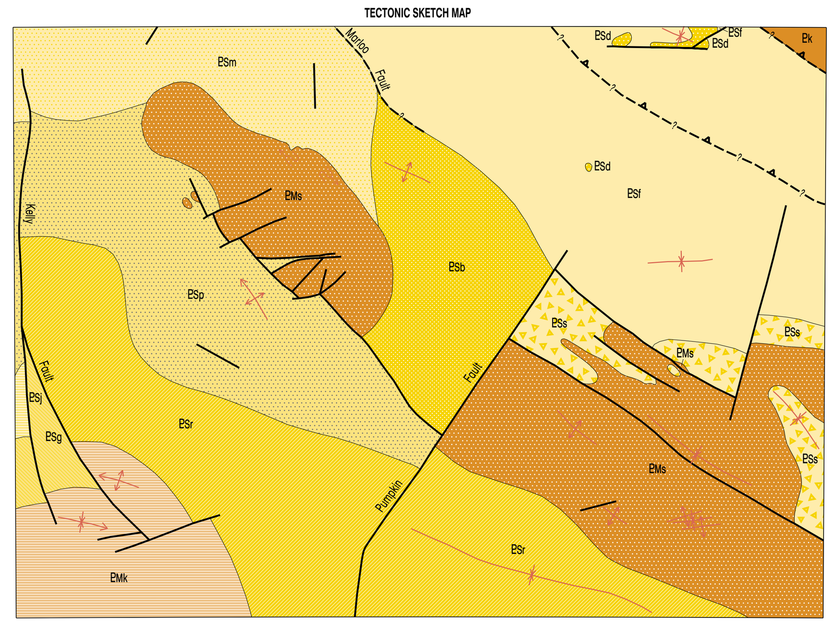
*c.*1300 Ma — Bangemall Group — Kahrban Subgroup

- ᵽMs — **CORNELIA FORMATION:** fine- to medium-grained sandstone, siltstone, mudstone; minor glauconitic sandstone, pebble conglomerate
- ᵽMx — **COONABILDIE FORMATION:** coarse- to fine-grained sandstone, micaceous siltstone, shale

INDEX TO ADJOINING SHEETS



TECTONIC SKETCH MAP



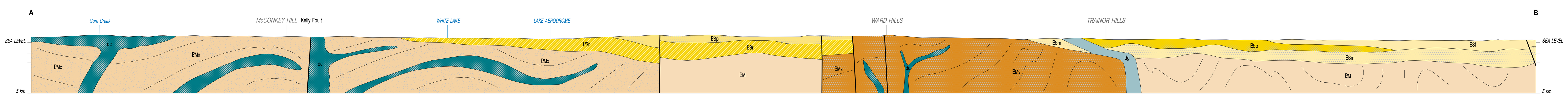
ᵽSd Durba Sandstone	SAVORY BASIN	ᵽSs Skates Hills Formation	SAVORY BASIN	ᵽk Karara Formation	KARARA BASIN
ᵽSf McFadden Formation		ᵽSp Spearhole Formation		ᵽMs Cornelia Formation	BANGEMALL BASIN
ᵽSb Boondawari Formation		ᵽSj Jilyili Formation		ᵽMk Kahrban Subgroup	
ᵽSm Mundadjini Formation		ᵽSg Glass Spring Formation			
		ᵽSr Brassey Range Formation			

SCALE 1:1 000 000

0 10 20 30 40 50 Kilometres

DIAGRAMMATIC SECTION

NATURAL SCALE



ᵽM Undifferentiated Bangemall Group rocks

Bedding trend

SCALE 1:250 000

5000 0 5 10 15 20 25 30

Metres — Kilometres

TRANSVERSE MERCATOR PROJECTION

Grid lines indicate 20 000 metre interval of the Australian Map Grid Zone 51

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