Mesoproterozoic stratigraphy in the Oldham Inlier, Little Sandy Desert, central Western Australia

by R. M. Hocking[1], K. Grey, L. Bagas, and M. K. Stevens

Abstract

The Ward and Oldham Inliers form a basement high in the northwestern part of the Officer Basin (formerly 'Savory Basin'), and contain rocks previously included in a single unit, the Cornelia Formation. The Cornelia Formation is now divided into the steeply dipping Cornelia Sandstone, the steeply dipping shaly Quadrio Formation, and the moderately folded Oldham Sandstone. These formations have not been dated, but the Quadrio Formation and Cornelia Sandstone, although adjacent to the Oldham Sandstone, appear to be older because they dip more steeply, are relatively more tightly folded, and show a greater degree of silicification and quartz stockworking. The Quadrio Formation and Cornelia Sandstone probably correlate with the base-Mesoproterozoic Edmund Group, and the Oldham Sandstone with the ?late Mesoproterozoic Collier Group of the Bangemall Basin. However, the Quadrio Formation and Cornelia Sandstone also resemble shale and sandstone units included in the Mesoproterozoic–Neoproterozoic Throssell Group in the Paterson Orogen. The Throssell and Edmund Groups contain significant metallic mineralization of different types, and the Quadrio Formation contains barium and gold anomalies, so likely stratigraphic correlations for all three units are of economic interest.

KEYWORDS: Cornelia Sandstone, Oldham Sandstone, Quadrio Formation, Throssell Group, Bangemall Group, Officer Basin, Paterson Orogen, stratigraphy, tectonics, mineralization

Introduction

Sedimentary rocks in the Ward and Oldham Inliers (Fig. 1) in the Savory region (Little Sandy Desert) of the northwest Officer Basin were previously assigned to the Cornelia Formation ('Cornelia Sandstone' of Brakel and Leech, 1980; amended by Williams, 1992). The stratigraphic relationships and age of these rocks have been problematic since initial mapping in the 1970s (Brakel and Leech, 1980), and were not resolved by a reassessment in the 1980s after the unconformity separating the Bangemall and 'Savory' (now Officer) Basins was discovered (Williams, 1990, 1992, 1995). The drilling of the petroleum exploration well GSWA Trainor 1 on the northern margin of the Oldham Inlier (Fig. 2) provided pertinent data (Stevens and Adamides, 1998), but did not clarify the age or relationships. Recent reconnaissance work in the Oldham Inlier partly resolves the stratigraphic relationships of the Oldham Inlier rocks, and indicates that a substantial redefinition of the Cornelia Formation is necessary. This will help unravel the complex tectonic and stratigraphic history of the rocks in the southern Little Sandy Desert, and provide pointers for future mineral exploration.

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Geological setting

The Ward and Oldham Inliers in the southern Little Sandy Desert are composed of well-indurated sandstone with lenses of siltstone, shale, and conglomerate, previously referred to as the 'Cornelia Sandstone' (Brakel and Leech, 1980) or Cornelia Formation (Williams, 1992). This unit was at first thought to be older than the Collier Group (Muhling and Brakel, 1985), and then a correlative of the group (Williams, 1990, 1992). The inliers are onlapped by or faulted against the Neoproterozoic Sunbeam Group and overlying Boondawari Formation (Fig. 2; Bagas et al., 1999) of the northwest Officer Basin.

The Sunbeam Group is dominated by shallowly dipping, moderately indurated quartz sandstone, with a basal cobble conglomerate and a higher interval of stromatolitic carbonate in the Skates Hills Formation. Most clasts in the basal conglomerate are highly silicified sandstone, derived from the Cornelia Sandstone and probably the Oldham Sandstone to the south.

The Skates Hills Formation contains the *Acaciella australica* Stromatolite

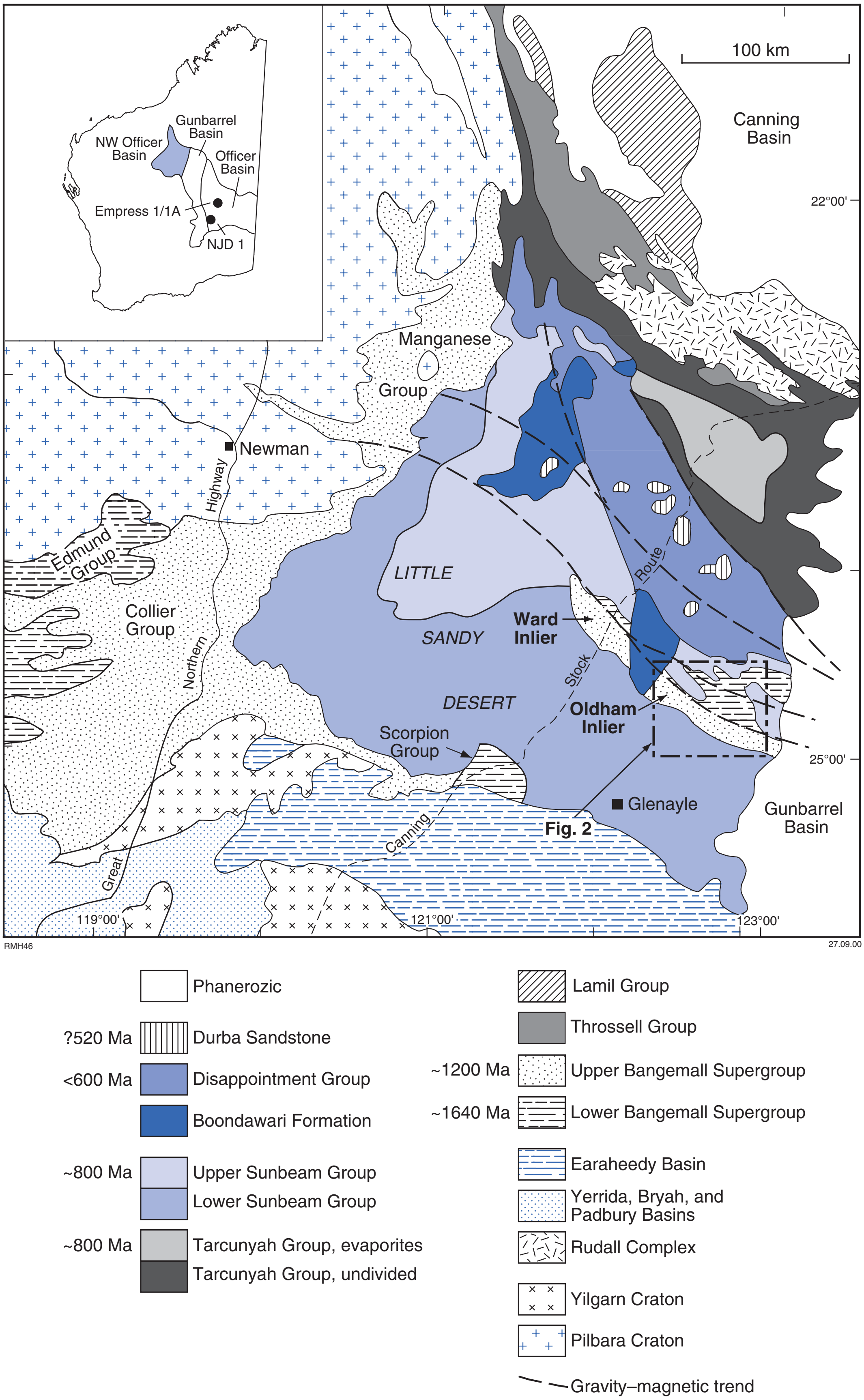

Figure 1. Regional setting of the Oldham Inlier (modified from Bagas et al., 1999)

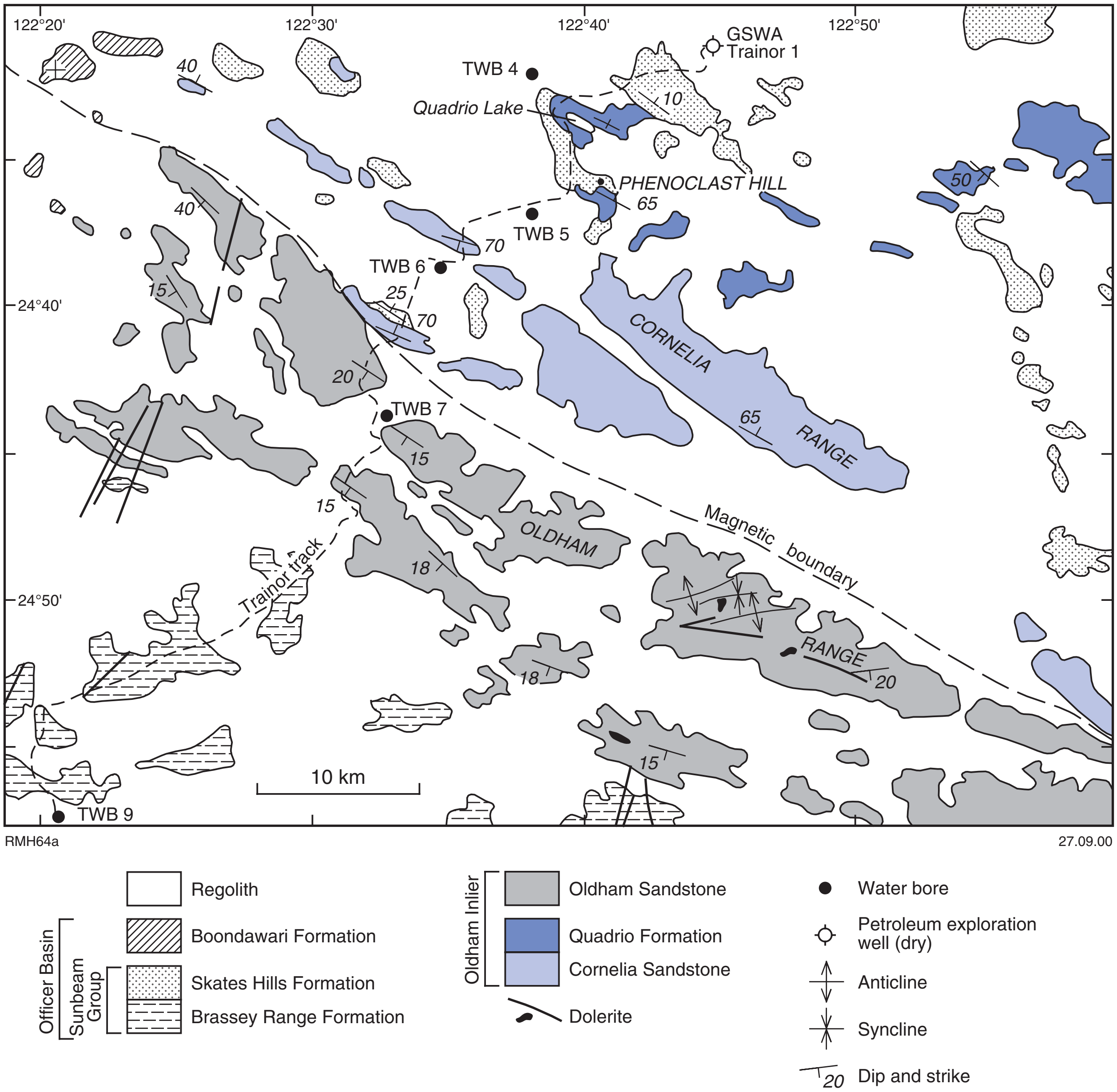

Figure 2. Outcrop geology of the Oldham Inlier (modified from Williams, 1995)

Assemblage, which can be confidently assigned to Supersequence 1 (Grey, 1995; Hill et al., 2000). Neoproterozoic palynomorphs typical of Supersequence 1 were recovered from a water bore (TWB 9, Fig. 2) in the Brassey Range Formation (Grey and Stevens, 1997). An almost identical assemblage was recovered north of the Oldham Range from TWB 6 (Grey and Stevens, 1997; Fig. 2), which was spudded into rocks then mapped as Cornelia 'Formation'. Further work indicates that at that locality, gently dipping Neoproterozoic rocks fill a shallow successor syncline in an older steeply dipping syncline of Cornelia Sandstone.

Revised stratigraphy

Recent mapping, accompanied by Landsat and airborne magnetic image interpretation, shows that three distinct units were previously included in the Cornelia Formation. These units are here assigned to a revised Cornelia Sandstone and two new units, the Quadrio Formation and Oldham Sandstone (Table 1). Full definitions of these units are given by Hocking et al. (2000a).

Differentiation of the Oldham and Cornelia Sandstones is based on changes in bedding orientations and a strong change in magnetic character along the northern margin of the Oldham Range (Fig. 3). The change coincides with an observed fault in sandstone, 18 km southwest of Quadrio Lake

Table 1. Stratigraphic history of the Oldham Inlier

Williams (1995) and earlier stratigraphy	*Proposed stratigraphy*	*Lithology*	*Age and correlation*
Cornelia Formation	Oldham Sandstone	Silicified sandstone; moderately dipping	?1.2 Ga, ?Collier Group
	Quadrio Formation	Shale, minor sandstone; subvertical	?1.6 Ga, ?Edmund Group
	Cornelia Sandstone	Intensely silicified sandstone; steeply dipping	?1.6 Ga, ?Edmund Group

(Fig. 2). Rocks in the Oldham Range to the south, defined as the Oldham Sandstone (Hocking et al., 2000a), are silicified, cross-bedded, and rippled quartz sandstone commonly dipping at about 15° to the southwest. Sandstone north of this change in magnetic character has a subdued magnetic intensity (Fig. 3), is marginally more silicified than the Oldham Sandstone, dips at much steeper angles, and has a more pronounced quartz stockwork. Therefore, the name Cornelia Sandstone is restricted to the steeply dipping sandstone intervals north of the Oldham Range (Hocking et al., 2000a). Both formations were probably deposited on a fluvial plain, perhaps coastally situated in places as some sandstone beds are well sorted and appear to have been winnowed by waves. Either formation could be the source of many clasts in the basal conglomerate of the Skates Hills Formation at Phenoclast Hill.

The third unit, named the Quadrio Formation (Hocking et al., 2000a), outcrops in the northeastern part of the Oldham Inlier, at and north of Phenoclast Hill (Fig. 2). The Quadrio Formation is a steeply dipping, shale-dominated unit that youngs to the north. The base is obscured by the unconformably overlying Skates Hills Formation, although it appears to grade upwards from the Cornelia Sandstone at the northwestern end of the Cornelia Range (based on aerial photograph

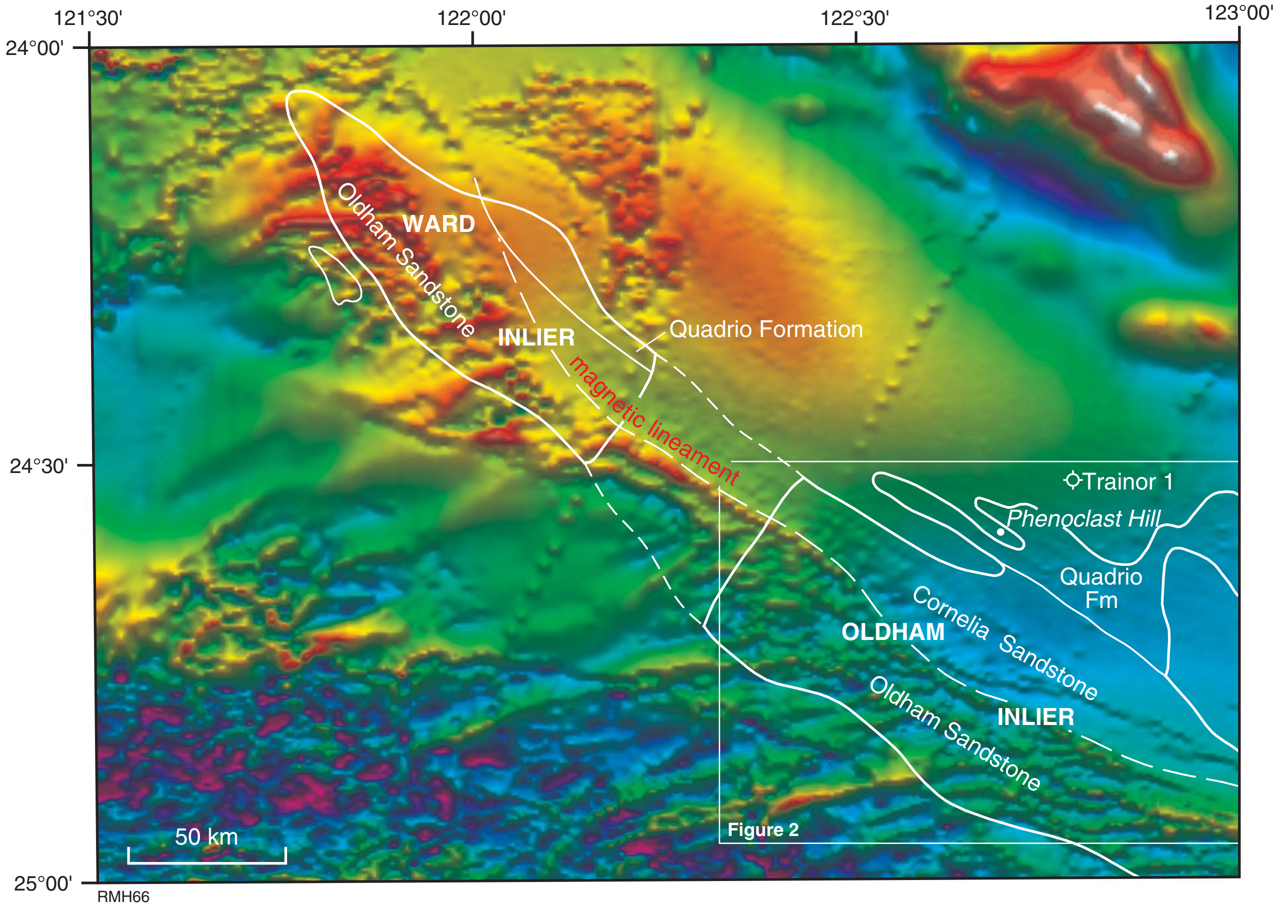

Figure 3. Total magnetic intensity image of the Oldham Inlier area

interpretation). Around Quadrio Lake it consists of ferruginized shale and siltstone that grades upwards into banded and laminated chert in a prominent ridge north of the lake. The chert is, in turn, overlain by about 100 m of recessive siltstone. Three coarsening-upward cycles grading from siltstone to rippled and hummocky cross-stratified sandstone, each 10 to 20 m thick, cap the siltstone. These are interpreted as offshore to foreshore shallowing-up cycles. They are capped by another siltstone dipping at up to 80°, which continues 3 km northeastwards to where it is overlain by the flat-lying Skates Hills Formation. The formation is interpreted as a low-energy offshore deposit, with a shallowing phase that could not be sustained. On the southern side of Quadrio Lake, epigenetic barite–hematite stockwork cutting through the Quadrio Formation contains anomalous gold values (Hocking et al., 2000b).

Trainor 1 succession

The Quadrio Formation is similar to the interval below 83 m in Trainor 1 (Stevens and Adamides, 1998), about 5 km north of the youngest exposed Quadrio Formation (Fig. 2). Rocks below 83 m in Trainor 1 dip at about 40° and are predominantly dark, well-indurated mudstone to siltstone, with thin turbiditic mass flows and slumps (Stevens and Adamides, 1998). The lithology, level of induration, and orientation in Trainor 1 are very similar to the exposed Quadrio Formation and, on this basis, the interval below 83 m in Trainor 1 is included within that formation. In both outcrop and the subsurface, this unit is dissimilar to the sandstone-dominated units in the Oldham Range (Oldham Sandstone) and Cornelia Range (Cornelia Sandstone).

Hypothetically, the Trainor 1 succession below 83 m has a maximum age of deposition of about 511 Ma (Early Cambrian), based on $^{206}Pb/^{238}U$ sensitive high-resolution ion microprobe (SHRIMP) ages of 511 ± 14 Ma, 696 ± 20 Ma, and 699 ± 20 Ma from detrital zircons at 574 m (Nelson, 1997). Even though 13 of the SHRIMP dates obtained from four zircon grains must be rejected for the Quadrio Formation to be older than about 850 Ma, an early Phanerozoic age requires a highly complex geology for which there is no corroborating evidence. It is difficult to fit a deep-water turbiditic environment, with no evidence of fossils, into the known Phanerozoic palaeogeography (Hocking, 1994; Jackson and van de Graaff, 1981; Kennard et al., 1994). Additionally, the presence of thermally overmature Phanerozoic rocks sandwiched between thermally mature Neoproterozoic rocks is difficult to explain without invoking a highly complex system of faulting. Less than 10 km to the south, unequivocal Neoproterozoic rocks (stromatolitic carbonates of the Skates Hills Formation) overlie outcrop that can be positively assigned to the Quadrio Formation. The zircon ages, therefore, must be regarded as suspect until the dates can be verified from additional samples and a realistic model is devised to explain their anachronism.

We interpret the lower unit in Trainor 1 as part of the Quadrio Formation, which it resembles in lithology, orientation, and degree of deformation. We consider that the Trainor 1 succession and the outcropping Quadrio Formation are significantly older than the Neoproterozoic succession of the Officer Basin, which unconformably overlies them with considerable angularity.

Correlation and age

None of the three units discussed here (the Oldham Sandstone, redefined Cornelia Sandstone, and Quadrio Formation) contain any features that provide an unequivocal correlation to other Proterozoic rocks in the region (Fig. 4). The Cornelia Sandstone and (probably) the Oldham Sandstone were well indurated, folded, and eroded to form the clasts within the conglomerate in the Skates Hills Formation of Supersequence 1 age (c. 800 Ma). There is an angular unconformity of up to 80° between the Quadrio Formation and Cornelia Sandstone below, and the Skates Hills Formation and Brassey Range Formation above. The Oldham Sandstone dips uniformly at about 15° to the southwest, whereas the Cornelia Sandstone and Quadrio Formation are folded with dips typically greater than 60°. These relationships partly constrain possible correlations. The Cornelia Sandstone and Quadrio Formation share a similar structural style, orientation, and magnetic character, and there is no indication from outcrop or Landsat imagery of a significant fault between the two. We therefore tentatively assume that they are of similar ages.

None of the three units can correlate with the Coonabildie Formation (formerly 'Kahrban Subgroup'; Williams, 1990; revised by Hocking et al., 2000a), about 50 km to the south, because recent mapping indicates that the Coonabildie Formation is the basal portion of the Sunbeam Group (c. 825 Ma; Bagas et al., 1999) and is conformable beneath the Brassey Range Formation, which is unconformable on the Oldham Sandstone. Correlation of any or all units with the Earaheedy Group (Capricorn Orogen, c. 1800 Ma; Jones et al., 2000), which outcrops 100 km to the south (Figs 1 and 4), is unlikely because the lithofacies are quite dissimilar. Probable lateral changes in the lithofacies in the Ward and Oldham Inliers do not match the regional facies patterns observed in the Earaheedy Group.

The most obvious correlation for the Oldham Sandstone is with the Collier Group, and for the Cornelia Sandstone and Quadrio Formation is with the Edmund Group (Fig. 4). The Collier Group is exposed about 100 km to the southwest (upper Bangemall Supergroup, Fig. 1), where its lithology, and degree of silicification and quartz veining are similar to the Oldham Sandstone. The Collier Group and its correlative to the north, the Manganese Group, were deformed by the Miles Orogeny of the Paterson Orogen, the maximum possible age of which is about 1150 Ma (Bagas et al., 1995). The Quadrio Formation resembles shales in the Edmund Group (?Discovery or Kiangi Creek Formations; Fig. 4), the nearest exposures of which are about 300 km to the west (lower Bangemall Supergroup, Fig. 1). Deposition of the Edmund Group began at about 1645 Ma (Martin et al., 1999). The Quadrio Formation could also correlate with the dolomitic and sandy Scorpion Group (exposed about 130 km to the southwest; Fig. 4) if the basin shallowed southward. The Scorpion Group (Hocking et al., 2000a) is a coastal-

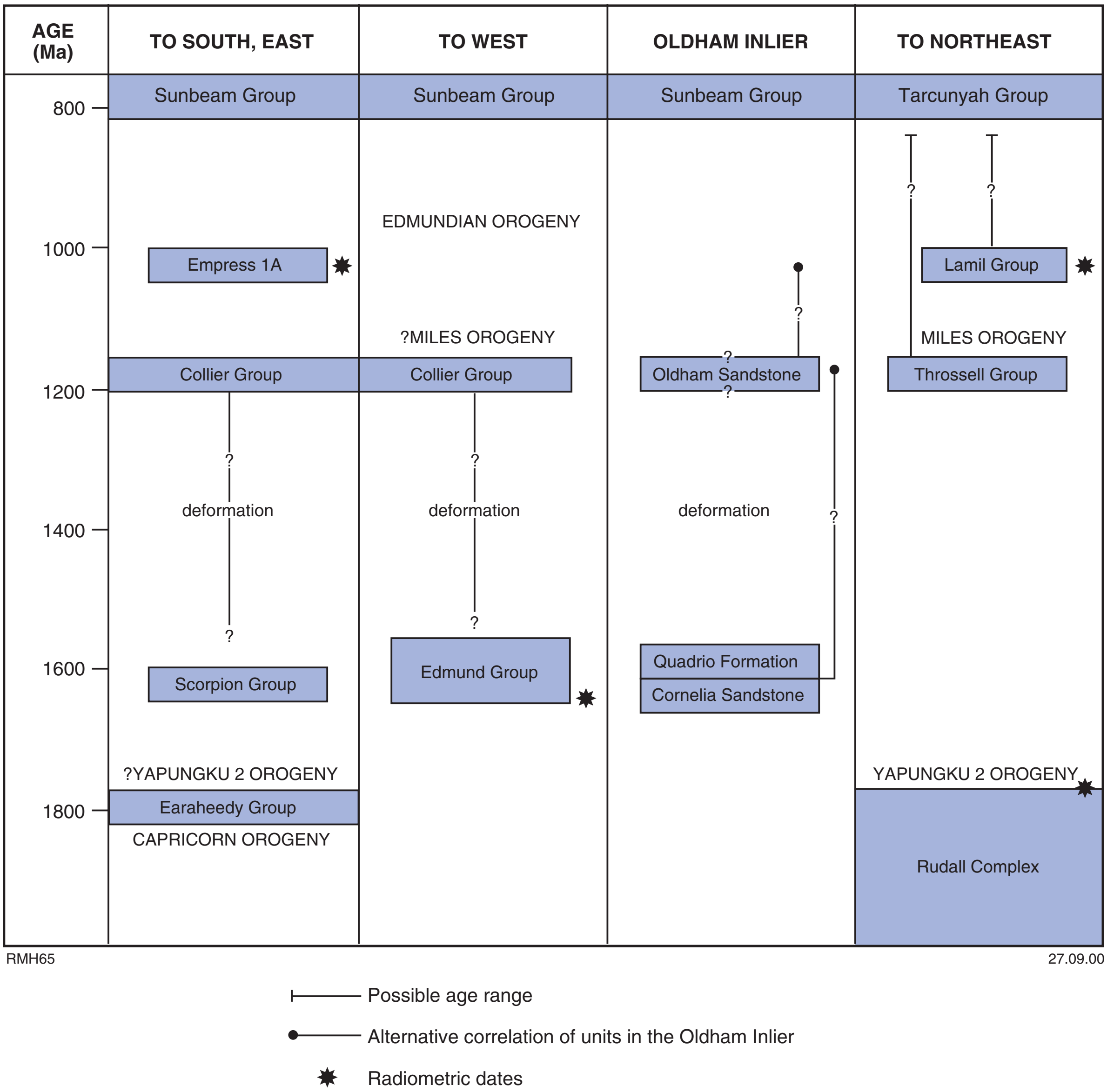

Figure 4. Regional stratigraphic relationships. Possible age ranges are indicated by bars, with units placed at the points that constrain their ages

facies, dolomite-rich succession that was previously correlated with the Edmund Group (Williams, 1990) and contains stromatolites similar to those in the lower Edmund Group.

An alternative correlation is between the Quadrio Formation and the Mesoproterozoic–Neoproterozoic Throssell Group (Fig. 4), which is exposed about 250 km northeast of the Oldham Inlier (Fig. 1; Bagas et al., 2000). The Throssell Group is a succession metamorphosed to greenschist facies (Hickman and Bagas, 1998) that consists of a basal sandy interval (Coolbro Sandstone) overlain by carbonaceous shale, siltstone, turbidite, and carbonate units (Broadhurst Formation), and may be of similar age to the Collier Group. The Quadrio Formation resembles, both in lithology and metamorphic grade, the Broadhurst Formation, and the Cornelia Sandstone resembles the Coolbro Sandstone. If this correlation is correct, then the Throssell Group may extend at least as far as the Ward and Oldham Inliers. The southward provenance of the Coolbro Sandstone lessens the likelihood of this correlation. The position of the Oldham Sandstone in this correlation scheme is unclear. It might relate to the interval at the base of drillhole Empress 1A (Figs 1 and 4), where pre-Supersequence 1 volcanic rocks interbedded with mudstone have a K–Ar age of 1058 ± 13 Ma (Stevens and Apak, 1999), and possibly to drillhole NJD 1 in the southern Officer Basin (Fig. 1), which also contains a similar succession at the base of the hole.

Regional implications

The recognition of three distinct units in the Oldham Inlier, all younger than and dissimilar to the Earaheedy Basin succession, and probably correlating with the Bangemall Supergroup or perhaps the Throssell Group, means that there is an extensive Mesoproterozoic basement to the northwestern Officer Basin, above possible Palaeoproterozoic rocks. The Little Sandy Desert area remained an active trough through the Mesoproterozoic and early Neoproterozoic.

The abrupt change in magnetic character and the relationship of the Cornelia and Oldham Sandstones indicate the presence of a south-facing high-angle reverse fault between the two, along the northern side of the Oldham Range. This fault is at the southern edge of the set of high-angle reverse faults that probably extend southeastward from the Rudall Complex to the Musgrave Complex (Myers and Hocking, 1998).

Accepting the correlations with the Edmund and Collier Groups implies the following events. A compressional event between about 1600 and 1200 Ma uplifted and folded the Cornelia Sandstone and Quadrio Formation. This is presumably the same event that caused uplift and erosion of the Edmund Group to the west, prior to deposition of the Collier Group. A second compressional episode after 1150 Ma (possibly related to the Miles Orogeny) thrust the Quadrio Formation and Cornelia Sandstone south-southwestward over the Oldham Formation, before deposition of the Sunbeam Group began at about 830 Ma. There is little indication of later faulting related to the c. 550 Ma Paterson and Petermann Ranges Orogenies (Bagas et al., 1995), as the Sunbeam Group is commonly subhorizontal and little faulted in the southern Little Sandy Desert. Some older structures were reactivated, as in the syncline around water bore TWB 6, where gently dipping Neoproterozoic rocks fill a shallow successor syncline in an older steeply dipping syncline of Cornelia Sandstone. The Oldham and Ward Inliers were probably emergent during the earliest stages of Supersequence 1 deposition, as the Oldham Inlier is locally onlapped by Skates Hills Formation, which belongs near the middle of Supersequence 1.

Mesoproterozoic to Neoproterozoic successions elsewhere contain significant mineralization, such as the Telfer gold deposit in the Lamil Group (Bagas, 2000), Nifty and other copper and base metal deposits in the Throssell Group (Hickman et al., 1994), manganese and copper in the Manganese Group (Williams, 1989), copper in the Camel–Tabletop Fault Zone of the Paterson Orogen (Bagas and Lubieniecki, 2000), and the Abra lead–zinc deposit in the Edmund Group (Cooper et al., 1998; Martin and Thorne, 2000). The potential for correlation between the Oldham and Cornelia Sandstones and Quadrio Formation, and any of these mineral-bearing stratigraphic units, together with the anomalous gold values in veins cutting the Quadrio Formation, and the possibility of associated base metal mineralization (Hocking et al., 2000b) indicate the need for more-detailed evaluation of the isolated outcrops in the Ward and Oldham Inliers. In addition, the association of mineralization with barite (Hocking et al., 2000b) also raises the prospectivity of other barite occurrences in the region.

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