Geology of the Edmund and Collier Groups

by

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Introduction

Low-grade metasedimentary rocks of the Paleoproterozoic to Mesoproterozoic Edmund and Collier Groups represent the youngest depositional element within the Capricorn Orogen (Fig. 1). The succession comprises 4–10 km of mainly fine-grained siliciclastic and carbonate sedimentary rocks that were deposited in a variety of shelf to basinal environments (Martin and Thorne, 2004). Sediments in the Edmund Basin were deposited unconformably on granitic rocks of the Gascoyne Province sometime between c. 1620 and c. 1465 Ma. Sediments in the unconformably overlying Collier Basin were deposited across both the Gascoyne Province basement and locally deformed sedimentary rocks of the Edmund Basin sometime between c. 1200 and c. 1070 Ma. The Edmund Basin (Fig. 1) extends from the Pingandy Shelf in the north, and continues south across the Talga Fault as a rift-graben structure over 180 km in width (northeast–southwest) and 400 km in length (northwest–southeast). The Collier Basin is relatively restricted in the west, where it is only 30 km wide (Fig. 1); however, the basin widens significantly to the east to a maximum of ~200 km.

The main depositional and structural elements of the basins were controlled principally by movements on the Talga, Godfrey, Lyons River, Edmund, and Minga Bar Faults, and the Ti Tree Shear Zone (Frontispiece 1–3; Plate 1). Deposition within the Edmund Basin was controlled mainly by normal movements on the Talga Fault (Martin and Thorne, 2004), with the basin fill dramatically thickening to the southwest from the Pingandy Shelf. Deposition in the Collier Basin appears to have been less influenced by significant fault movements (Martin and Thorne, 2004). Subsequent basin inversion took place during the 1385–1200 Ma Mutherbukin Tectonic Event and the 1030–955 Ma Edmundian Orogeny (Frontispiece 1; Plate 1). Minor fault reactivation took place during the c. 570 Ma Mulka Tectonic Event. The structural architecture of the basins, including the Wanna, Cobra, and Ti Tree Synclines, and associated faults (Frontispiece 1–3; Plate 1), parallel the main northwest–southeast to east–west structural trends within the underlying Gascoyne Province basement (Johnson et al., 2011a), and indicate a regional-scale control on deformation and basin inversion.

Edmund and Collier Basins: stratigraphy and age constraints

The Edmund and Collier Groups comprise 4–10 km of siliciclastic and carbonate metasedimentary rocks that have been subdivided into 14 formations, grouped into six depositional packages (Figure 2 of this report, based on Martin and Thorne, 2004). Each package is separated by an unconformity or basal marine-flooding surface (Martin and Thorne, 2004).

The Edmund Group unconformably overlies granites of the 1680–1620 Ma Durlacher Supersuite of the Gascoyne Province (Sheppard et al., 2010), providing a maximum age of c. 1620 Ma for deposition. However, in the eastern part of the basin, the sediments are largely deposited on weathered granitic rocks of the 1820–1775 Ma Moorarie Supersuite (Occhipinti and Myers, 1999; Martin et al., 2005).

The Ullawarra Formation, within the uppermost package (Package 4) of the Edmund Group, locally contains volcaniclastic rocks, magmatic zircons from which have been dated, using the U–Pb SHRIMP technique, at 1463 ± 8 Ma (Wingate et al., 2010), and which provides a youngest age limit for deposition. The age of these volcaniclastic rocks are within uncertainty of those for voluminous dolerite sills of the Narimbunna Dolerite, dated between c. 1500 and c. 1465 Ma (Wingate et al., 2002, in prep.), which intrude the upper packages of the Edmund Group.

The depositional age of the overlying Collier Group is poorly constrained. Both the Edmund and Collier Basins are intruded by voluminous dolerite sills of the Kulkatharra Dolerite, which are related to the c. 1070 Ma Warakurna Large Igneous Province (Wingate et al., 2002). These sills therefore provide an upper age constraint for Collier Group deposition. The lower age constraint is provided by structural relationships that suggest that the sediments of the Collier Group were not affected by the 1385–1200 Ma Mutherbukin Tectonic Event (Johnson et al., 2011a); thus, deposition occurred between c. 1200 and c. 1070 Ma.

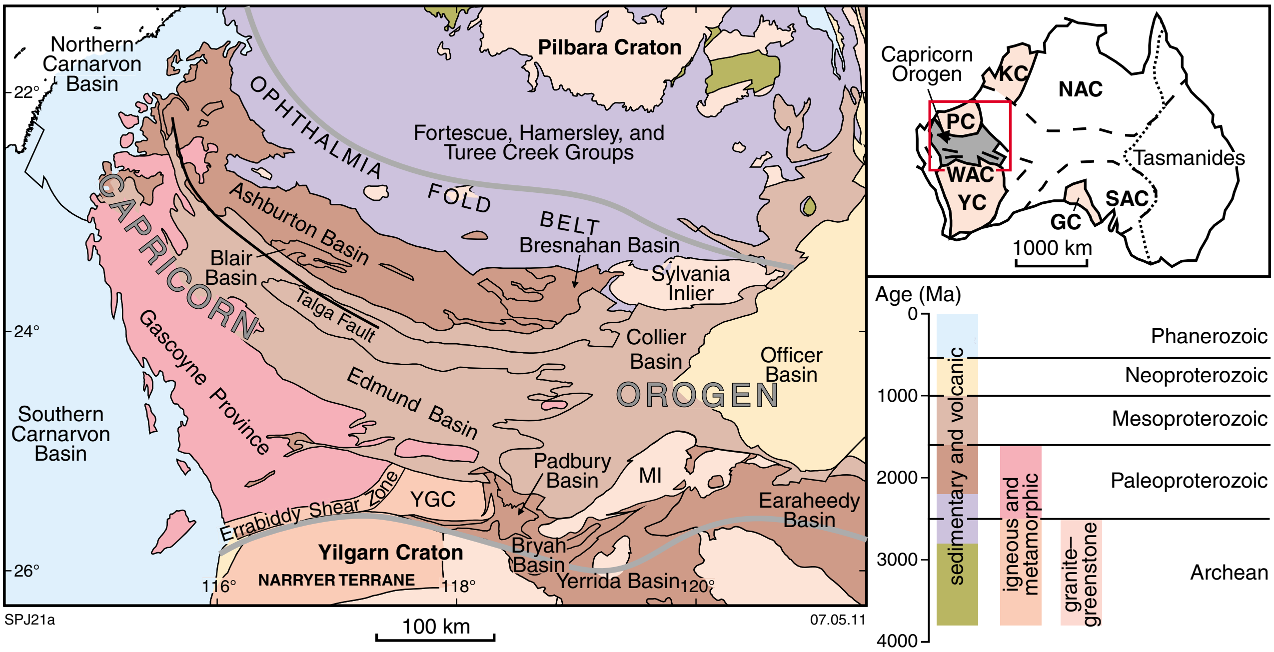

Figure 1. Location of seismic line 10GA–CP2 and the Edmund and Collier Basins in the Capricorn Orogen

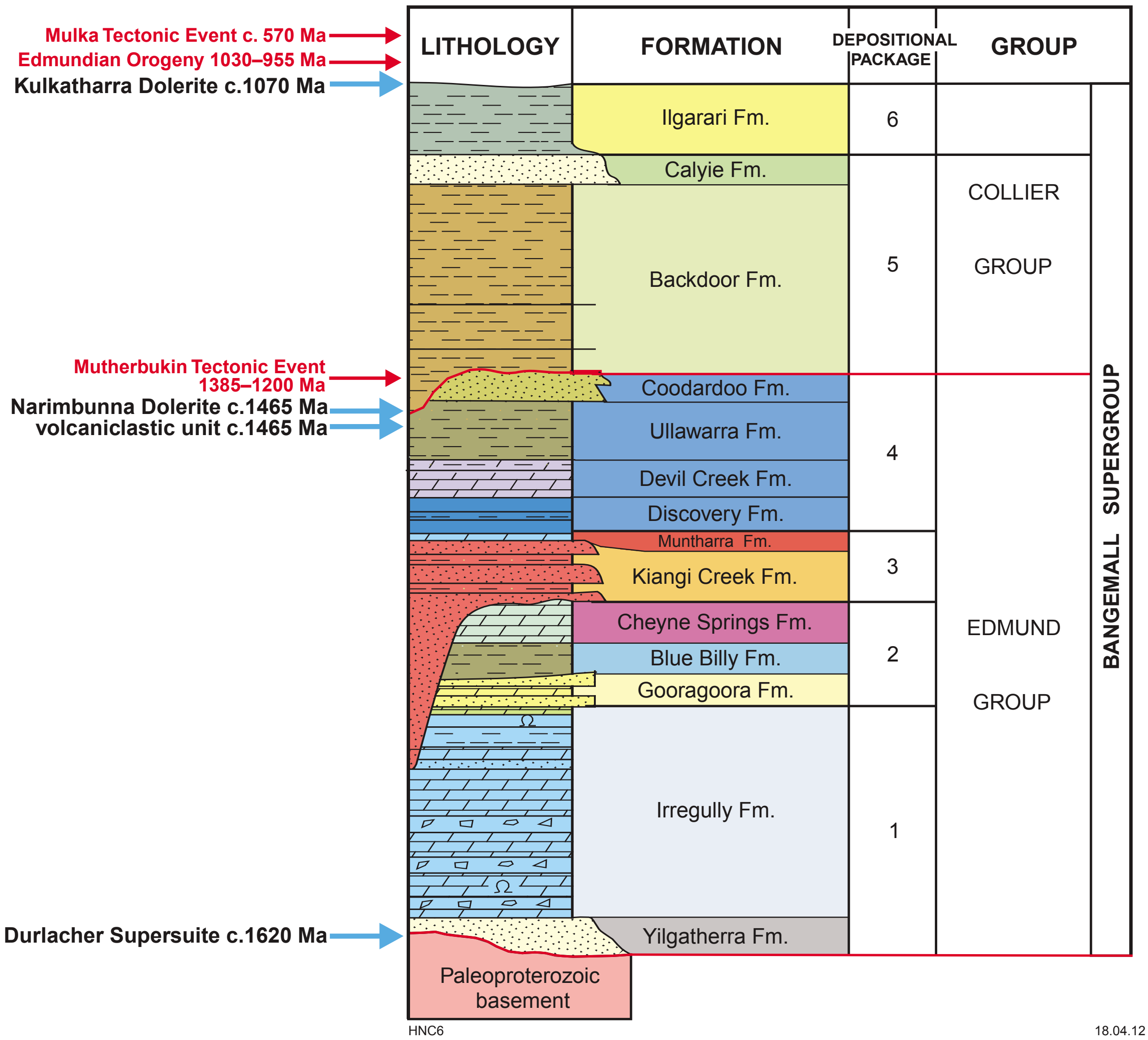

Figure 2. Stratigraphy of the Edmund and Collier Groups

U–Pb SHRIMP dating of detrital zircons from the Edmund Group reveal prominent age modes in the 1850–1600 Ma range, consistent with detritus from the northern Gascoyne Province and coeval sedimentary basins (Martin et al., 2008). Some samples also have prominent age modes in the 2780–2450 Ma range, consistent with detritus from the Fortescue and Hamersley Groups of southern Pilbara (Martin et al., 2008). In the Edmund Group, the dominant age modes become progressively older higher up in the succession, suggesting unroofing of the underlying basement rocks. In contrast, the dominant modes of the Collier Group become younger higher in the succession, recording progressive unroofing of the underlying Edmund Group. Ongoing Lu–Hf isotope studies of the same detrital zircon suite identified first-cycle transportation from the Gascoyne Province to the Wyloo and Capricorn Groups (2200–1800 Ma), and possibly on to the Besnahan Group (?1680 Ma), with second-cycle transportation from these older sedimentary basins into the Edmund Group (GSWA, unpublished results).

Edmund Basin

Package 1

Package 1 of the Edmund Group comprises mainly fluvial to shallow-marine sandstones and siltstones (Yilgatherra Formation), conformably overlain by siliciclastic and carbonate rocks (Irregully Formation). These were deposited in a half-graben formed by normal movements largely on the Talga, Lyons River, and Minga Bar Faults. On the Pingandy Shelf, these deposits are up to 400 m thick, and were deposited in fluvial to peritidal environments. Paleocurrent directions indicate that the sediments were sourced predominantly from the northeast (Martin et al., 2008). South of the Talga Fault, up to 3 km of sediments were deposited in fluvial, marine shelf, and marine-slope environments. Paleocurrent directions suggest that the sediments were sourced from local basement highs, with the predominant source to the southwest (Martin et al., 2008).

Package 2

Package 2 has an apparent conformable contact with the underlying Irregully Formation, and initially represents a prograding deltaic environment propagating from the northwestern part of the Edmund Basin. Planar-laminated siltstones grade upwards into fine- to coarse-grained, massive to trough cross-stratified sandstones (Gooragoora Formation) that range in thickness from 10–150 m. Deposition was controlled by continued normal movements, initially on the Talga Fault and later on the Lyons River Fault, and was accompanied by a rise in sea level. The basin then expanded to the southeast with the deposition of between 30–500 m of pyritic carbonaceous siltstones and turbidite sandstones (Blue Billy Formation) in a deep-water anoxic shelf environment. Infill of the basin led to the deposition of 50–300 m of siliciclastic and calcareous sediments (Cheyne Springs Formation) in a distal subtidal environment.

Paleocurrent directions in the prograding delta indicate that sediment was sourced from the northwest, although higher in the succession sediment supply was from the northeast and normal to the basin margin (Martin et al., 2008).

Package 3

The deposition of Package 3 followed an extended hiatus and considerable erosional thinning of the underlying sediments (Packages 1 and 2). In the eastern part of the Edmund Basin, conglomerates and coarse-grained sandstones of the basal Kiangi Creek Formation were deposited in an alluvial-fan environment. These deposits are truncated by an erosional marine-flooding surface, and overlain by pebbly sandstones and interbedded siltstones and sandstones deposited in a fan-delta environment. In the western part of the basin, these units pass into 50–2600 m of deep-shelf siltstones, and interbedded turbiditic sandstones with local amalgamated turbidites, mass-flow quartz sandstones, and planar-laminated carbonaceous siltstones. Here, deposition was controlled by progressive normal movements on the Talga, Lyons River, Edmund, and Minga Bar Faults. In the eastern part of the basin, sediment deposition was accommodated by normal movements on the Quartzite Well and Mount Clere Faults. On the Pingandy Shelf, a locally developed, 30–50 m thick, dolostone (Muntharra Formation) represents the shelf-edge to basinal carbonate deposition during the waning of coarse-grained sediment supply. Paleocurrent directions in all parts of the basin indicate that the sediments were sourced from the northeast.

Package 4

The basal sediments of Package 4 were deposited following a major transgressive event. Although these sediments have a sharp contact with the upper units of Package 3, they truncate the underlying units at a very low angle. The basal deposits comprise 50–365 m of silicified, pyritic carbonaceous siltstones and black cherts (Discovery Formation). They are interpreted as an anoxic deposit that accumulated below storm wave base. These sediments are overlain by locally stromatolitic, dolograinstones and dolomudstones of the Devil Creek Formation. Deposition appears to have been controlled by reactivation of the Talga Fault, as the units thicken southward from 80–450 m, and record a change from subtidal to slope and basinal facies. The Devil Creek Formation is transitional upwards into the planar- and ripple-laminated siltstones and mudstones, with minor dolostones and fine- to medium-grained sandstones, of the Ullawarra Formation. This unit grades into turbiditic sandstones and parallel-planar siltstones (Curran Member). A similar southward thickening of units, from 100 m on the Pingandy Shelf to ~600 m south of the Talga Fault, is also observed. In the eastern part of the basin, volcaniclastic sediments dated at 1463 ± 8 Ma (Wingate et al., 2010) occur within the Ullawarra Formation. The uppermost unit of Package 4 comprises up to 200 m of medium to very thick bedded turbidite sandstones and minor siltstones (Coodardoo Formation).

The deposition of Package 4 appears to have been controlled by the reactivation of the Edmund Fault and

Mount Clere Fault in the south, and the Talga Fault in the north. Late-stage reactivation along the Lyons River and Quartzite Well Faults accommodated deposition of the Coodardoo Formation in a northwest–southeast oriented basin. Paleocurrent directions indicate that sediments in the Ullawarra Formation were sourced from the southeast along the axis of an earlier larger basin, but were sourced from the northwest for the deposition of the Coodardoo Formation, indicating a smaller, narrower basin in the area of the Wanna Syncline at this time.

In the latest depositional phase of Package 4, the Edmund Basin south of the Pingandy Shelf was intruded by voluminous dolerite sills of the c. 1465 Ma Narimbunna Dolerite. These sills have inflated the thickness of the basin by up to 2 km.

Collier Basin

Package 5

Deposition of Package 5, within the Collier Group, followed a drop in sea level and a erosional period of at least 85 million years, based on the older age limit of c. 1380 Ma for the Mutherbukin Event (Rasmussen et al., 2010). The lowermost unit comprises ~1500 m of laminated siltstones, with minor thin beds of fine-grained sandstone and thin-bedded dolomudstones (Backdoor Formation). These units were deposited in a progradational shallow-shelf and marginal delta-front, and were in turn overlain by ~200 m of interbedded medium- to coarse-grained sandstones and siltstones (Calyie Formation) deposited in a delta-top to delta-front environment. Paleocurrent directions suggest that the sediment supply was from the northeast for the Backdoor Formation, but from the southeast for the Calyie Formation.

Package 6

Package 6 comprises up to 700 m of parallel planar-laminated pyritic and carbonaceous siltstones and fine-grained sandstones, with minor limestones, and calcareous siltstones and cherts (Ilgarari Formation). These rocks represent marine-shelf facies deposits, and were laid down following a basin-wide marine transgression.

Following the deposition of the Collier Basin, rocks of both the Edmund and Collier Groups were intruded by voluminous dolerite sills of the c. 1070 Ma Kulkatharra Dolerite, which form part of the Warakurna Large Igneous Province. The local presence of pepperites within the Backdoor Formation indicates that some of the dolerites were intruded into wet sediments, suggesting that deposition of the Collier Group was closer to c. 1070 Ma than to c. 1200 Ma (Martin, 2003).

Deformation history

Deposition of the Edmund Basin appears to have been ultimately controlled by the primary orientation and repeated reactivation of major crustal structures in the underlying Gascoyne Province basement (Sheppard et al., 2010; Johnson et al., 2011a–c). Following the termination of the Mangaroon Orogeny at c. 1620 Ma, extensional reactivation, principally on the Talga and Godfrey Faults, formed half grabens into which the sediments were deposited. Basin inversion took place during the 1385–1200 Ma Mutherbukin Tectonic Event, before the deposition of the Collier Group. Folding and faulting of both the Edmund and Collier Basins took place during the 1030–955 Ma Edmundian Orogeny and the c. 570 Ma Mulka Tectonic Event.

Mutherbukin Tectonic Event

Medium-grade metamorphism and deformation associated with the 1385–1200 Ma Mutherbukin Tectonic Event has been recognized in the basement rocks of the Gascoyne Province (Johnson et al., 2011a,c). Evidence in the Edmund Basin is more limited due to the low to very low grade nature of metamorphism; however, rocks of both the Edmund and Mount Augustus Basins contain abundant 1385–1300 Ma aged hydrothermal monazite and xenotime (Rasmussen et al., 2010; Tyler et al., 2011). In addition, magmatic xenotime from the Tangadee Rhyolite has been dated at c. 1235 Ma (Rasmussen et al., 2010), and pyrite from the mineralized zone of the Abra deposit has been dated using the Re–Os system at c. 1280 Ma (GSWA, unpublished data).

Surface geological mapping in the eastern part of the basin (Cutten et al., 2010; Thorne and Cutten, 2011) demonstrates that many faults within the Edmund Group have large, sinistral, strike-slip offsets, but only small offsets in the overlying Collier Group, suggesting pre-Edmundian Orogeny (1030–955 Ma) movements. These features are replicated in the Wanna Syncline, where the intensity of faults is significantly greater in the Edmund Group (Fig. 3) than in the Collier Group, suggesting that the Collier Group was deposited at <1200 Ma, following the 1385–1200 Ma Mutherbukin Tectonic Event.

Due to the brittle nature of faulting in the Edmund Group, direct age constraints on the fault movements themselves are rare. However, authigenic illite from a fault gouge that displaces sandstone and siltstone beds of the Kiangi Creek Formation (Fig. 4) has been dated at 1171 ± 25 Ma using the $^{40}K/^{40}Ar$ method (GSWA, unpublished data). These results demonstrate that faulting and hydrothermal fluid flow during the Mutherbukin Tectonic Event affected rocks of the Edmund Basin.

Edmundian Orogeny

In the Edmund and Collier Basins, the 1030–955 Ma Edmundian Orogeny was responsible for low to very low grade metamorphism, reverse faulting, and transpressional folding (Martin and Thorne, 2004; Martin et al., 2005). Martin and Thorne (2004) identified three distinct deformation events (D_{1e}, D_{2e}, and D_{3e}), although the latter (D_{3e}) is now considered to be related to the c. 570 Mulka Tectonic Event. It is currently unclear how the main folding and faulting events (D_{1e} and D_{2e}) in the Edmund and Collier Basins relate to regional amphibolite-grade metamorphism and deformation in the basement rocks of the Gascoyne Province (Sheppard et al., 2007). During this

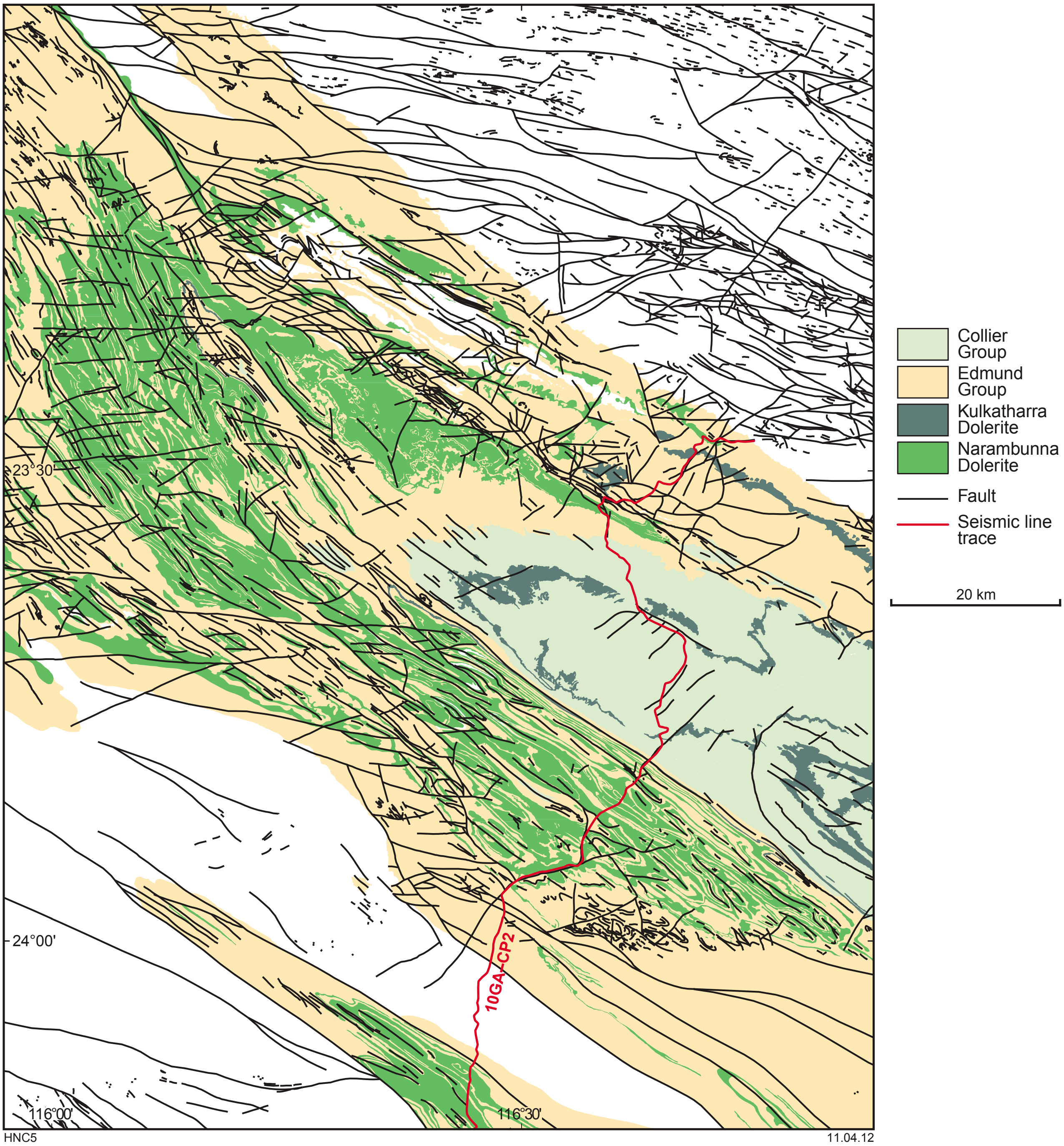

Figure 3. Map illustrating the greater abundance of fault traces in the Edmund Group as compared to the Collier Group.

Figure 4. Fault with 50 cm reverse displacement of sandstone and siltstone beds of Kiangi Creek Formation, and with a 5 cm fault gouge (Tangadee 1:100 000 map sheet; Thorne and Cutten, 2010).

event, the Gascoyne Province was intruded by leucocratic granites and pegmatites of the 1030–925 Ma Thirty Three Supersuite (Sheppard et al., 2010; Johnson et al., 2011a).

In the Edmund and Collier Basins, the fold and fault structures trend west–east to northwest–southeast, and are concordant with both the general basin architecture and the regional-scale structures in the underlying Gascoyne Province basement. The surface expression of these faults is usually limited to the presence of eroded valleys filled with regolith between offset ridges of Edmund–Collier strata. Because fault planes are very rarely exposed, it is difficult to determine if lateral offset is truly strike-slip, or only apparently so, due to normal or reverse offset (Fig. 5). Faults are often evident as zones of quartz veining up to 50 m wide, or as zones of brecciated quartz in an ironstone matrix (Fig. 6). Minor faults with well-developed slickensides or thin fault gouges are seen to offset strata rarely (Figs 4 and 7).

Folds are generally upright and open, but are tightened adjacent to faults, and generally plunge gently to the northwest or southeast. Martin et al. (2005) identified a main D_{1e} event resulting from northeast–southwest compression, although in the northwest, also documented local evidence of an earlier episode of north-northwesterly directed compression, possibly occurring during the Mutherbukin Tectonic Event. Here, reverse faulting and northeast-trending folds have been refolded by the main northeast–southwest D_{1e} compression. A D_{1e} axial planar cleavage is also locally developed, although absent in most rocks of the Edmund and Collier Groups. A later D_{2e} event is apparent from the often curvilinear axial traces of the F_{1e} folds, which Martin et al. (2005) identified as the result of a weak east-southeast to west-northwest compression.

Mulka Tectonic event

The Mulka Tectonic Event (c. 570 Ma) is evident from late-stage, dextral, brittle–ductile faults and shears, and associated quartz veins, developed in rocks of the Edmund and Collier Groups and the Gascoyne Province. These commonly have well-developed dextral strike-slip shear-sense indicators, and show dextral offset of dolerite dykes belonging to the c. 755 Ma Mundine Well Dolerite

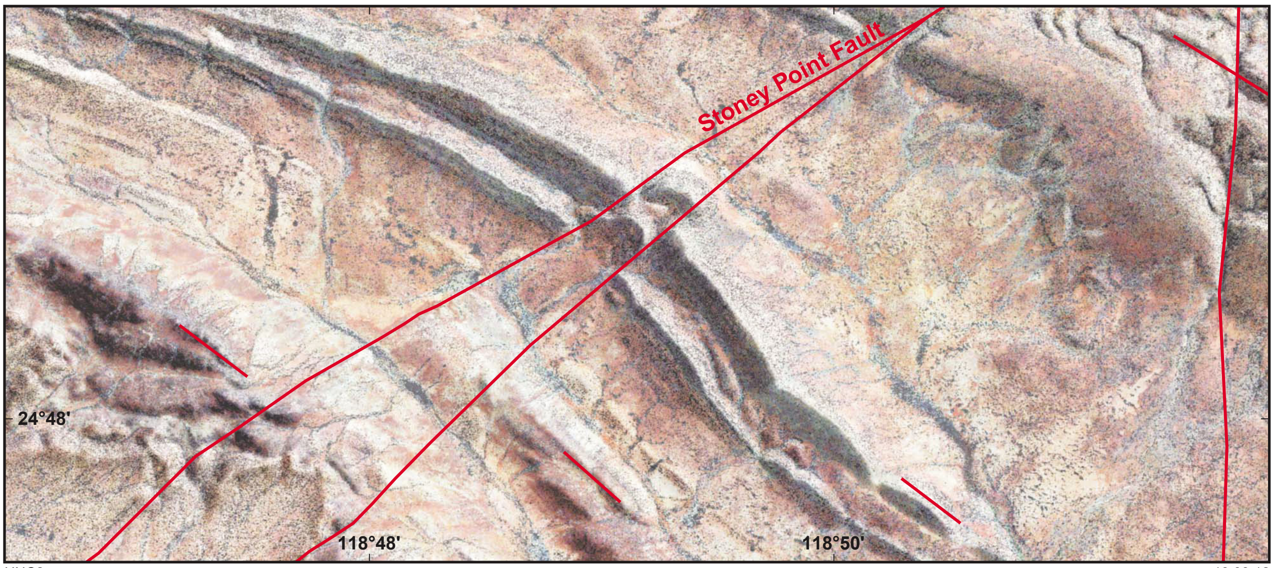

Figure 5. Hillshade-DTM image of northeast-trending fault offset (post- Edmundian Orogeny) on northeast margin of Calyie Syncline, displacing rocks of the Calyie Formation (CALYIE 1:100 000 map sheet; Cutten et al., 2010).

Figure 6. Brecciated quartz in an ironstone matrix, Quartzite Well Fault (MULGUL 1:100 000 map sheet; Thorne and Cutten, 2011)

Suite (Sheppard et al., 2010; Johnson et al., 2011a). Fault movement has been dated at c. 570 Ma, based on in situ $^{40}Ar/^{39}Ar$ geochronology on newly grown muscovite in a small dextral shear zone (Bodorkos and Wingate, 2007).

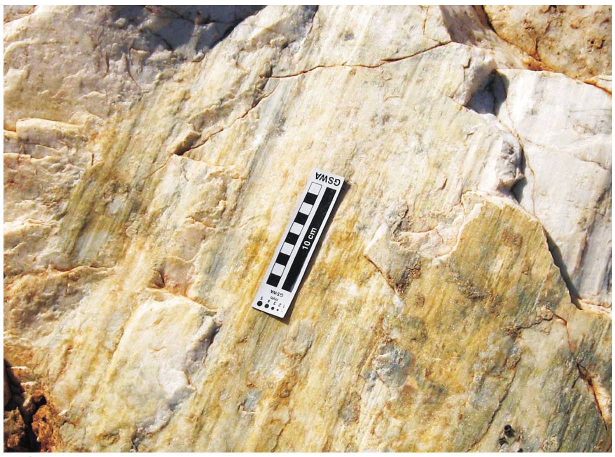

Figure 7. Slickensides showing reverse movement on an east-northeast trending fault, displacing rocks of the Yilgatherra Formation (MOUNT EGERTON 1:100 000 map sheet; Cutten et al., 2011).

References

Bodorkos, S and Wingate, MTD 2007, The contribution of geochronology to GSWA's mapping programs: current perspectives and future directions, *in* GSWA 2007 extended abstracts: promoting the prospectivity of Western Australia: Geological Survey of Western Australia, Record 2007/2, p. 10–11.

Cutten, HN, Thorne, AM and Blay, OA 2011, Mount Egerton, WA Sheet 2448: Geological Survey of Western Australia, 1:100 000 Geological Series.

Cutten, HN, Thorne, AM and Sheppard, S 2010, Calyie, WA Sheet 2648: Geological Survey of Western Australia, 1:100 000 Geological Series.

Johnson, SP, Thorne, AM, Cutten, HN, Tyler, IM and Blay, O 2011a, Geology of the Gascoyne Province, *in* Capricorn Orogen seismic and magnetotelluric (MT) workshop 2011: extended abstracts *edited by* SP Johnson, AM Thorne and IM Tyler: Geological Survey of Western Australia, Record 2011/25, p. 27–40.

Johnson, SP, Cutten, HN, Tyler, IM, Korsch, RJ, Thorne, AM, Blay, O, Kennett, BLN, Blewett, RS, Joly, A, Dentith, MC, Aitken, ARA, Goodwin, JA, Salmon, M, Reading, A, Boren, G, Ross, J, Costelloe, RD and Fomin, T 2011b, Preliminary interpretation of deep seismic reflection lines 10GA–CP2 and 10GA–CP3: crustal architecture of the Gascoyne Province, and Edmund and Collier Basins, *in* Capricorn Orogen seismic and magnetotelluric (MT) workshop 2011: extended abstracts *edited by* SP Johnson, AM Thorne and IM Tyler: Geological Survey of Western Australia, Record 2011/25, p. 49–60.

Johnson, SP, Sheppard, S, Thorne, AM, Rasmussen, B, Fletcher, IR, Wingate, MTD and Cutten, HN 2011c, The role of the 1280–1250 Ma Mutherbukin Tectonic Event in shaping the crustal architecture and mineralization history of the Capricorn Orogen, *in* GSWA 2011 extended abstracts: promoting the prospectivity of Western Australia: Geological Survey of Western Australia, Record 2011/2, p. 1–3.

Martin, DM 2003, Peperite in the Backdoor Formation and its significance to the age and tectonic evolution of the Bangemall Supergroup, *in* Geological Survey of Western Australia Annual Review 2002–03: Geological Survey of Western Australia, Perth, Western Australia, p. 53–59.

Martin, DM, Sheppard, S and Thorne, AM 2005, Geology of the Maroonah, Ullawarra, Capricorn, Mangaroon, Edmund, and Elliott Creek 1:100 000 sheets: Geological Survey of Western Australia, 1:100 000 Geological Series Explanatory Notes, 65p.

Martin, DM, Sircombe, KN, Thorne, AM, Cawood, PA and Nemchin, AA 2008, Provenance history of the Bangemall Supergroup and implications for the Mesoproterozoic paleogeography of the West Australian Craton: Precambrian Research, v. 166, no. 1–4 (Assembling Australia: Proterozoic building of a continent), p. 93–110.

Martin, DM and Thorne, AM 2004, Tectonic setting and basin evolution of the Bangemall Supergroup in the northwestern Capricorn Orogen: Precambrian Research, v. 128, p. 385–409.

Occhipinti, SA and Myers, JS 1999, Geology of the Moorarie 1:100 000 sheet: Geological Survey of Western Australia, 1:100 000 Geological Series Explanatory Notes, 20p.

Rasmussen, B, Fletcher, IR, Muhling, JR, Thorne, AM, Cutten, HN, Pirajno, F and Hell, A 2010, In situ U–Pb monazite and xenotime geochronology of the Abra polymetallic deposit and associated sedimentary and volcanic rocks, Bangemall Supergroup, Western Australia: Geological Survey of Western Australia, Record 2010/12, 31p.

Sheppard, S, Johnson, SP, Wingate, MTD, Kirkland, CL and Pirajno, F 2010, Explanatory Notes for the Gascoyne Province: Geological Survey of Western Australia, Perth, Western Australia, 336p.

Sheppard, S, Rasmussen, B, Muhling, JR, Farrell, TR and Fletcher, IR 2007, Grenvillian-aged orogenesis in the Palaeoproterozoic Gascoyne Complex, Western Australia: 1030–950 Ma reworking of the Proterozoic Capricorn Orogen: Journal of Metamorphic Geology, v. 25, p. 477–494.

Thorne, AM and Cutten, HN 2010, Tangadee, WA Sheet 2649: Geological Survey of Western Australia, 1:100 000 Geological Series.

Thorne, AM and Cutten, HN 2011, Mulgul, WA Sheet 2548: Geological Survey of Western Australia, 1:100 000 Geological Series.

Tyler, IM, Johnson, SP, Thorne, AM and Cutten, HN 2011, Implications of the Capricorn deep seismic survey for mineral systems, *in* Capricorn Orogen seismic and magnetotelluric (MT) workshop 2011: extended abstracts *edited by* SP Johnson, AM Thorne and IM Tyler: Geological Survey of Western Australia, Record 2011/25, p. 115–120

Wingate, MTD, Kirkland, CL and Cutten, HN in prep, 143445: dolerite sill, Waldburg Homestead; Geochronology Record: Geological Survey of Western Australia.

Wingate, MTD, Kirkland, CL and Thorne, AM 2010, 149019: felsic volcaniclastic rock, Tangadee Road; Geochronology Record 875: Geological Survey of Western Australia, 4p.

Wingate, MTD, Pisarevsky, SA and Evans, DAD 2002, Rodinia connections between Australia and Laurentia: no SWEAT, no AUSWUS?: Terra Nova, v. 14, p. 121–128.