Preliminary interpretation of deep seismic reflection lines 10GA–CP2 and 10GA–CP3: crustal architecture of the Gascoyne Province, and Edmund and Collier Basins

by

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Introduction and aims of the seismic survey

The Capricorn Orogen in Western Australia records both the punctuated assembly of the Pilbara and Yilgarn Cratons to form the West Australian Craton, and over one billion years of subsequent intracratonic reworking and basin formation (Cawood and Tyler, 2004; Sheppard et al., 2010). The orogen is over 1000 km long, and includes the passive margin deposits of both the Pilbara and Yilgarn Cratons, variably deformed and metamorphosed granitic and metasedimentary rocks of the Gascoyne Province, and both the sedimentary and low-grade metasedimentary rocks that overly these three tectonic units (Frontispiece 1; Plate 1; Cawood and Tyler, 2004; Sheppard et al., 2010).

A deep seismic reflection survey through the Capricorn Orogen, consisting of three lines (10GA–CP1, 10GA–CP2, and 10GA–CP3; Frontispiece 1), was acquired during 2010 by Geoscience Australia and Australian National Seismic Imaging Resource (ANSIR), in collaboration with Geological Survey of Western Australia (GSWA). All three lines were processed by the Seismic Acquisition and Processing Section of the Minerals and Natural Hazards Division, Geoscience Australia. Details of the data acquisition and processing are provided by Kennett et al. (2011).

The southern two lines, 10GA–CP2 and 10GA–CP3 (Frontispieces 1–3), provide a transect through the Gascoyne Province, and Edmund and Collier Basins, totalling 383 line-km. Both lines are oriented approximately north–south, and are perpendicular to the major faults and regional-scale structures (Frontispiece 1–3; Plate 1). The geology of the Gascoyne Province, and of the Edmund and Collier Basins, are documented in detail by Johnson et al. (2011a) and Cutten et al. (2011), respectively. Because of the lack of road access, it was not possible to have a single, continuous survey line through the region. Instead, the end of line 10GA–CP2 is offset from 10GA–CP3 by ~80km along the strike of the orogen (Frontispiece 1; Plate 1). Line 10GA–CP2 starts at the contact between the Edmund Group and Ashburton Basin, crosses the Talga Fault, and finishes within the Dalgaringa Supersuite to the north of the Errabiddy Shear Zone. Line 10GA–CP3, designed to cross the Errabiddy Shear Zone, begins in the Dalgaringa Supersuite and finishes within the Narryer Terrane of the Yilgarn Craton (Frontispiece 1; Plate 1). Considering that the surface geology and geological history of the Gascoyne Province, and of the Edmund and Collier Basins are relatively well understood (e.g. Johnson et al., 2011a; Cutten et al., 2011), the main aim of lines 10GA–CP2 and 10GA–CP3 within the broader objectives of the Capricorn Orogen transect (Kennett et al., 2011) were to establish:

1. the location and orientation of the major crustal terrane-bounding faults, including the suture between the Yilgarn Craton and Gascoyne Province (located at the Errabiddy Shear Zone), and the suture between the Pilbara Craton and the Gascoyne Province (possibly located at the Talga Fault)
2. the depth and shape of the Minnie Creek batholith, and other Proterozoic granite intrusions
3. the deep crustal structure of the Edmund and Collier Basins, and nature of major growth faults; e.g. the Talga Fault.

Here, we report the results of an initial geological interpretation of these two seismic lines, and the resulting implications for the crustal architecture of the Gascoyne

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Province, and Edmund and Collier Basins, as well as the processes related to the punctuated assembly of the West Australian Craton and multiple periods of subsequent crustal reactivation and reworking.

Preliminary interpretation of seismic lines 10GA–CP2 and 10GA–CP3

Both seismic lines (Figs 1 and 2) provide images through the crust and upper mantle, down to 20 seconds two-way travel time (s TWT) (~60 km). The crust in both lines is moderately reflective and several major crustal structures can be identified. The location and character of the Mohorovičić discontinuity ('the Moho') varies considerably across the two lines. Under the Gascoyne Province, in 10GA–CP2, the Moho is deep and undulating, varying between 12 and 15.3 s TWT (36–46 km), and continues this trend into the northern part of 10GA–CP3, where the Moho is at 15 s TWT (~45 km) deep. In the south of 10GA–CP3, we interpret the presence of a double Moho, formed by the thrusting of the Glenburgh Terrane under the Narryer Terrane along the Cardilya Fault (Korsch et al., 2011). The upper mantle, below the Moho, is essentially non-reflective within both seismic lines. Features such as granite batholiths and sedimentary basins can be observed in the upper 0–5 s TWT (~15 km) of the crust (Figs 1 and 2).

The Gascoyne Province has been divided into several fault- or shear-bounded, easterly–southeasterly trending structural and metamorphic zones (Frontispieces 2–3; Sheppard et al., 2010). Although each zone shares a common, province-wide tectonostratigraphic assemblage, each has also been shaped by a characteristic and unique combination of deformational, metamorphic, and magmatic events, which reflects different responses to the multiple reworking events in the Gascoyne Province (Sheppard et al., 2010; Johnson et al., 2011a). Some of the major zone-bounding structures have also affected rocks of the Edmund and Collier Basins (Cutten et al., 2011). The major structures that define the boundaries of each zone are prominent in both regional gravity and aeromagnetic images (Frontispeices 2 and 3), although the attitudes, depth extents, and kinematic histories of these structures are not yet well known. The most important structures are the Collins and Talga Faults; the composite Minga Bar and Minnie Creek Faults; the Ti Tree, Chalba, and Errabiddy Shear Zones; and the Cardilya Fault (Frontispieces 1–3; Plate 1); although not all were intersected during this seismic survey. All the major structures imaged dip moderately to the south, and generally steepen in the upper crust. Some structures, such as the Ti Tree Shear Zone, Lyons River Fault, Godfrey Fault, Talga Fault, and Cardilya Fault, transect the entire crustal profile and root in the Moho (Figs 1 and 2). In line 10GA–CP3, the Errabiddy Shear Zone dips moderately to the north, where it soles onto the south-dipping Cardilya Fault (Fig. 2).

Crustal terranes and seismic provinces

On the basis of seismic character and surface geology, Korsch et al. (2011) identified three terranes and seismic crustal provinces within the two lines, most of which are separated by major structures that coincide with the mapped surface faults or shear zones that define the major zone boundaries of the Gascoyne Province (Johnson et al., 2011a). The seismic character of these terranes and seismic provinces is described in detail by Korsch et al. (2011), and as such, only a summary of their geometric relationships is presented here.

Within line 10GA–CP3, the Narryer Terrane, which forms part of the northern Yilgarn Craton, is separated from the Glenburgh Terrane by a series of anastomosing, north-dipping faults known as the Errabiddy Shear Zone, and a single, moderately south-dipping fault called the Cardilya Fault (Figs 1 and 2). These two fault systems also segment the Glenburgh Terrane into two crustal elements:

1. The Dalgaringa Supersuite, including the Nardoo Granite, which, at the surface, represents the exhumed mid-crustal portions of a continental-margin arc known as the Dalgaringa Arc (Johnson et al., 2010, 2011a,b), and which occurs structurally above both the Errabiddy Shear Zone and the Cardilya Fault (that is, the hangingwall).

2. The remainder of the Glenburgh Terrane, including the basement gneisses into which the continental-margin arc magmas were intruded, which occur in the footwall of the Cardilya Fault, lying structurally below the Narryer Terrane.

The lower crust beneath the Glenburgh Terrane is only very weakly reflective, and has been interpreted as a distinct crustal entity from the overlying Glenburgh Terrane (Korsch et al., 2011). This portion of crust, termed the MacAdam Seismic Province (Korsch et al., 2011), is up to 5.5 s TWT (~16.5 km) thick, and is bounded by the Lyons River Fault in the north and the lower crustal component of the Glenburgh Terrane in the south (Figs 1 and 2). As this crust is not exposed at the surface, neither its age nor composition are known.

Within line 10GA–CP2, the Glenburgh Terrane is separated from the Bandee Seismic Province by the moderately south-dipping Lyons River Fault (Fig. 1). This fault splays into the Ti Tree Shear Zone, with both faults dissecting rocks of the Moorarie and Durlacher Supersuites, plus the sedimentary rocks of the Edmund Basin, in the upper crust (Figs 1 and 2).

Since rocks of the Bandee Seismic Province are not exposed at the surface, it is impossible to determine if this province is similar to the Glenburgh Terrane in terms of its age, lithological makeup, and composition. Its differing seismic character suggests that it may in fact be a separate terrane, forming part of the southern extension of the Pilbara Craton (Thorne et al., 2011a; Korsch et al., 2011).

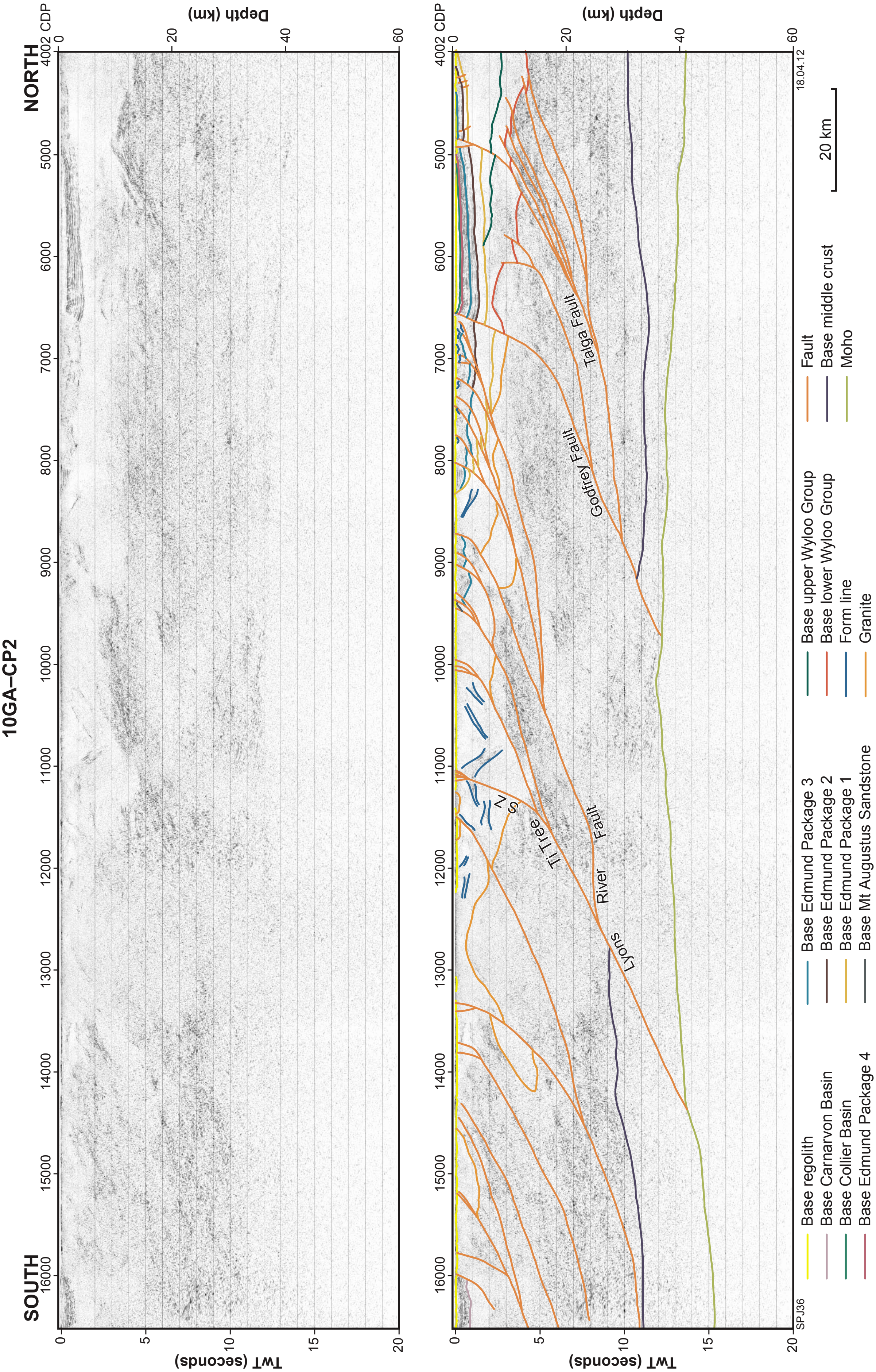

Figure 1. Migrated seismic section for line 10GA–CP2 across the Gascoyne Province, showing both uninterpreted and interpreted versions. Display is to 60 km depth, and shows vertical scale equal to the horizontal scale, assuming a crustal velocity of 6000 m/s.

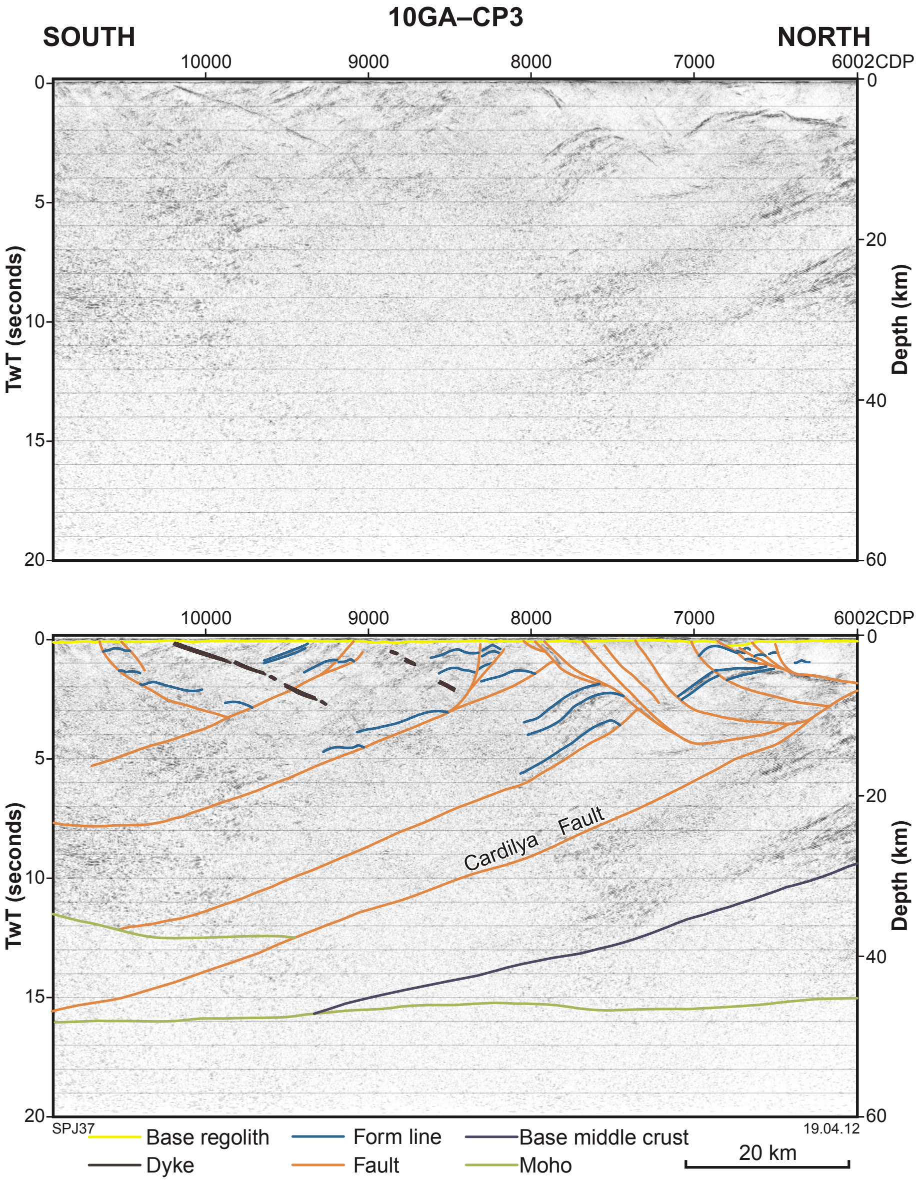

Figure 2. **Migrated seismic section for line 10GA–CP3, showing both uninterpreted and interpreted versions. Display is to 60 km depth, and shows vertical scale equal to the horizontal scale, assuming a crustal velocity of 6000 m/s.**

Towards the northern end of 10GA–CP2, the Bandee Seismic Province is cut by the moderately south-dipping Talga and Godfrey Faults, which transect the entire crustal profile, and root in the Moho.

Suture zones

The geological history of the Gascoyne Province indicates that the West Australian Craton was assembled from at least three distinct and unrelated tectonic blocks (the Pilbara and Yilgarn Cratons, and the Glenburgh Terrane of the Gascoyne Province), thus requiring the presence of two suture zones (Occhipinti et al., 2004; Johnson et al., 2010, 2011a,b). This punctuated assembly history records the collision, or accretion, of the Glenburgh Terrane with the southern margin of the Pilbara Craton during the 2215–2145 Ma Ophthalmian Orogeny, followed by the collision of this combined entity with the northern margin of the Yilgarn Craton during the 2005–1950 Ma Glenburgh Orogeny (Occhipinti et al., 2004; Johnson et al., 2010, 2011a,b).

Pilbara Craton and Bandee Seismic Province – Glenburgh Terrane suture

Due to the extensive cover of the Ashburton, Edmund, and Collier Basins, the suture between the Pilbara Craton – Bandee Seismic Province and Glenburgh Terrane is

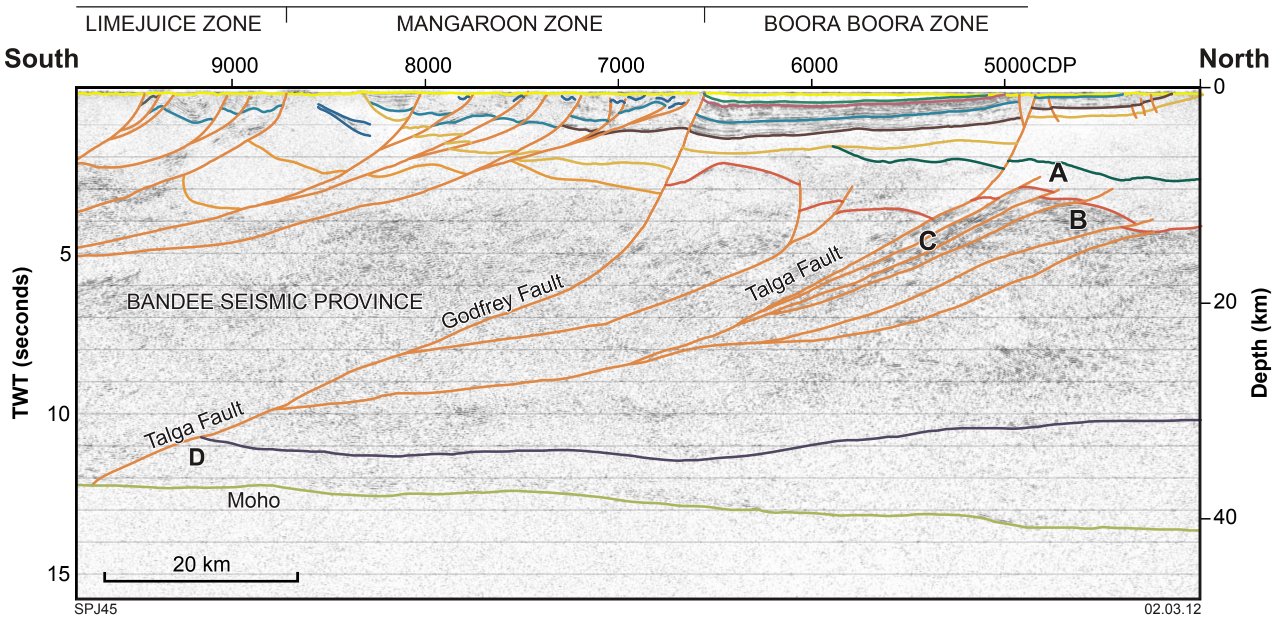

Figure 3. Interpreted migrated seismic section of part of line 10GA–CP2, showing the attitude and orientation of the Talga and Godfrey Faults.

not exposed (Frontispiece 1; Plate 1), although prior to the present seismic and magnetotelluric (MT) surveys, various geophysical data (Abdulah, 2007; Selway, 2008; Selway et al., 2009; Kennett, 2011) with limited horizontal resolution had implied that the suture was a vertical, or steeply north-dipping, structure approximately coincident with the mapped surface expression of the Talga Fault. However, in line 10GA–CP2 (Fig. 1), the Talga Fault does not appear to separate crust of differing seismic character (that is, it may be an intra- seismic province fault), and so is not likely to represent a suture zone. If not this structure, then the suture is probably located further south, at the Lyons River Fault, which separates the Glenburgh Terrane from the Bandee Seismic Province (Korsch et al., 2011).

The Talga Fault

In contrast to the various pre-existing geophysical data (Abdulah, 2007; Selway, 2008; Selway et al., 2009; Kennett, 2011), the seismic data presented in line 10GA–CP2 show the Talga Fault to be a listric, south-dipping structure, which joins with the Godfrey Fault before intersecting the Moho at 12.3 s TWT (~37 km) (Figs 1 and 3).

Although this fault does not appear to separate crust of differing seismic character, several other lines of evidence suggest that it may be a significant structure relating to the collision between the Pilbara Craton and the Glenburgh Terrane. The offset of seismic reflections across the fault in 10GA–CP2 show that its present expression is as a south-dipping listric fault that offsets rocks as young as the 1620–1465 Ma Edmund Group. The current listric nature of the fault is most likely a late Paleoproterozoic to Mesoproterozoic feature, formed by the reactivation of older structures to accommodate the deposition of sediments in the Edmund Basin (see below and Cutten et al., 2011). From 3–7 s TWT (9–21 km), the Talga Fault is parallel to, and forms part of, an imbricate set of faults (area A in Fig. 3) that reorient (area C in Fig. 3) a region of horizontal seismic reflections to the north (area B in Fig. 3), indicating that it is a zone of intense deformation. The faults offset only the lower stratigraphic units of the lower Wyloo Group, suggesting that they are of Ophthalmian age (equivalent in age to the c. 2210 Ma Cheela Springs Basalt in the lower Wyloo Group; Martin et al., 1998; Martin and Morris, 2010), whereas the northward-directed thrust sense of movement is parallel to the transport direction of exposed northward-verging thrusts in the Ophthalmia Fold and Thrust Belt (Tyler, 1991; Thorne et al., 2011b). Furthermore, non-reflective lower crust on the north side of the Talga–Godfrey Faults (area D in Fig. 3) does not occur to the south, implying that, at least in the lower crust, the Talga–Godfrey Faults offset and juxtapose crust of differing seismic character.

Therefore, the Talga Fault appears to be a major crustal shear zone that forms part of a north-verging fold and thrust system active during the Ophthalmian Orogeny.

The Lyons River Fault

The Glenburgh Terrane is well exposed in the Mooloo Zone, and fragmentary outcrops are present in the southern part of the Limejuice Zone (Johnson et al., 2011a–c; Frontispiece 1; Plate 1). Basement to the 1820–1775 Ma Moorarie Supersuite and 1680–1620 Ma Durlacher Supersuite in the northern part of the Gascoyne Province (i.e. the Bandee Seismic Province) is not exposed, and thus, the northerly extent of the Glenburgh Terrane is unknown. A recent MT survey showed no significant electrical contrast between the Glenburgh Terrane in the south, and unexposed basement north of the Limejuice Zone, and it was concluded that the Glenburgh Terrane extended north up to the Talga Fault, thus forming basement to the entire Gascoyne Province (Selway, 2008; Selway et al., 2009).

Although the seismic character of the upper and middle crust of both the Glenburgh Terrane and Bandee Seismic Province are relatively similar in line 10GA–CP2, the Glenburgh Terrane is characterized by a non-reflective lower crust, the MacAdam Seismic Province (Korsch et al., 2011). In contrast, the lower crust of the Bandee Seismic Province south of the Talga Fault is highly reflective, locally showing gentle folding in the seismic reflections (area A in Fig. 4). The contact between the two regions is defined by the Lyons River Fault, the Ti Tree Shear Zone, and a zone of strong seismic reflections parallel to these faults (areas B and C in Fig. 4). Furthermore, there is a significant step in the Moho where the Lyons River Fault intersects the upper mantle (Fig. 4).

These observations suggest that the Lyons River Fault represents a major crustal suture in the central part of the Gascoyne Province (Korsch et al., 2011). At the surface, this structure is represented by the Lyons River, Minnie Creek, and Minga Bar Faults (Frontispiece 1–3; Plate 1); nevertheless, all three faults have been extensively reworked during younger orogenic and magmatic events (Sheppard et al., 2005, 2010; Johnson et al., 2011a). Thus, direct age constraints for the timing of collision/accretion of the Bandee Seismic Province – Pilbara Craton with the Glenburgh Terrane along this structure are poor. The upper age limit can be defined by the youngest rocks of the Halfway Gneiss, which forms the basement to the Glenburgh Terrane, at c. 2430 Ma (Johnson et al., 2011a,c). The younger age limit is taken to be 2240–2125 Ma, the depositional age of the Moogie Metamorphics, which unconformably overlie the Glenburgh Terrane. These metasedimentary rocks were sourced partly from the Fortescue, Hamersley, and Turee Creek Groups on the southern margin of the Pilbara Craton (Johnson et al., 2011a–c) and thus, the Bandee Seismic Province and Glenburgh Terrane must have been sutured by this time. Based on these observations, the Lyons River Fault is likely to form the principal Ophthalmian-aged suture between the Pilbara Craton – Bandee Seismic Province and the Glenburgh Terrane.

Glenburgh Terrane – Yilgarn Craton suture

Based on both geological (e.g. Johnson et al., 2011a) and geophysical observations (Hackney, 2004; Selway, 2008; Selway et al., 2009; Reading et al., 2012), the Errabiddy Shear Zone is interpreted to be the suture between the Glenburgh Terrane and the Narryer Terrane of the Yilgarn Craton. A previous MT survey across this zone showed a clear electrical contrast between the Gascoyne Province and Yilgarn Craton, with the contact dipping 45° to the south (Selway, 2008; Selway et al., 2009). Regional gravity anomalies and geoid lows in this area have been interpreted to indicate thickened crust under this part of the orogen (Hackney, 2004); passive seismic data not only confirm the existence of this thickened crust, but also indicate the presence of a double crust or double Moho in the region (Reading et al., 2012).

The seismic data presented from 10GA–CP3 (Fig. 2) and the southern part of line 10GA–CP2 (Fig. 1) show that the Narryer Terrane is separated from the Glenburgh Terrane by the north-dipping Errabiddy Shear Zone, and the south-dipping Cardilya Fault, the two fault systems intersecting at CDP 6300 on line 10GA–CP3 at 3.3 s TWT (~10 km) depth. The Cardilya Fault transects the entire crust, can be imaged down to 15.5 s TWT (~46.5 km), and is interpreted to offset the Moho, which under the Narryer Terrane is much shallower at 12.5 s TWT (~37.5 km) depth (Figs 2 and 5). These results are comparable to those obtained by passive-seismic methods (Reading et al., 2012). At the northern end of line 10GA–CP3, the footwall of the Cardilya Fault is marked by a thick package, up to 3 s TWT (~9 km) thick, of strong seismic reflections (area A in Fig. 5) that are parallel to the fault. Similar packages are also observed adjacent to the boundary with the MacAdam Seismic Province (area B in Fig. 5).

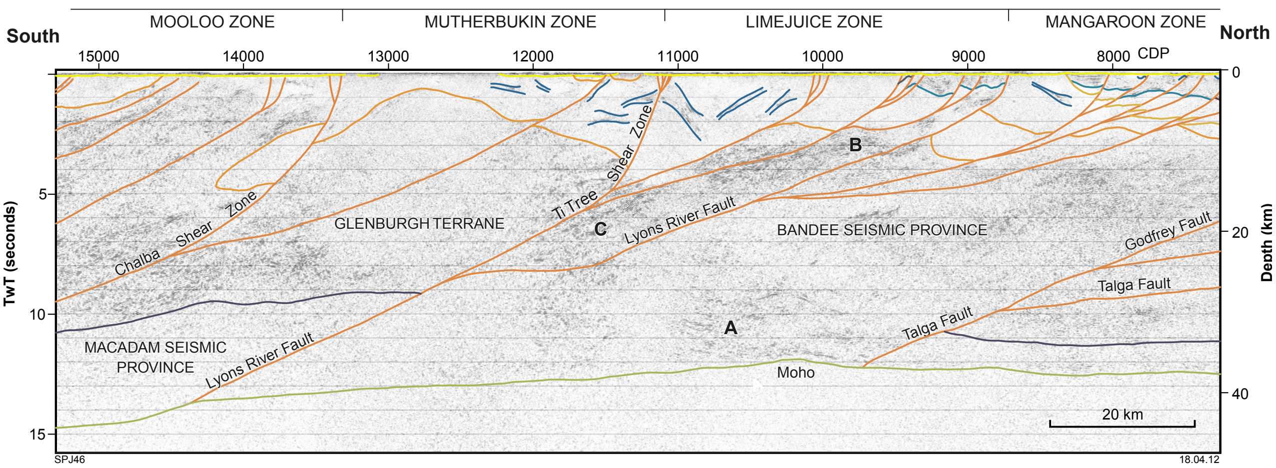

Figure 4. **Interpreted migrated seismic section of part of line 10GA–CP2, showing the location of the suture zone between the Glenburgh Terrane and Bandee Seismic Province at the Lyons River Fault.**

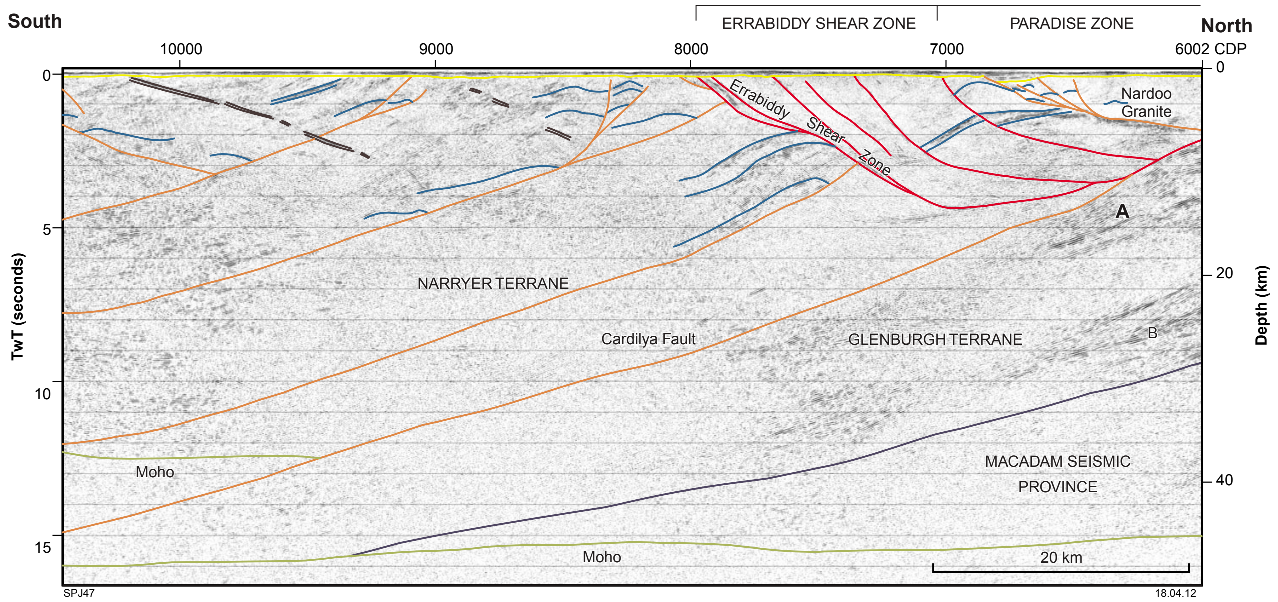

Figure 5. Interpreted migrated seismic section of part of line 10GA–CP3, showing the relationships between the Errabiddy Shear Zone and Cardilya Fault.

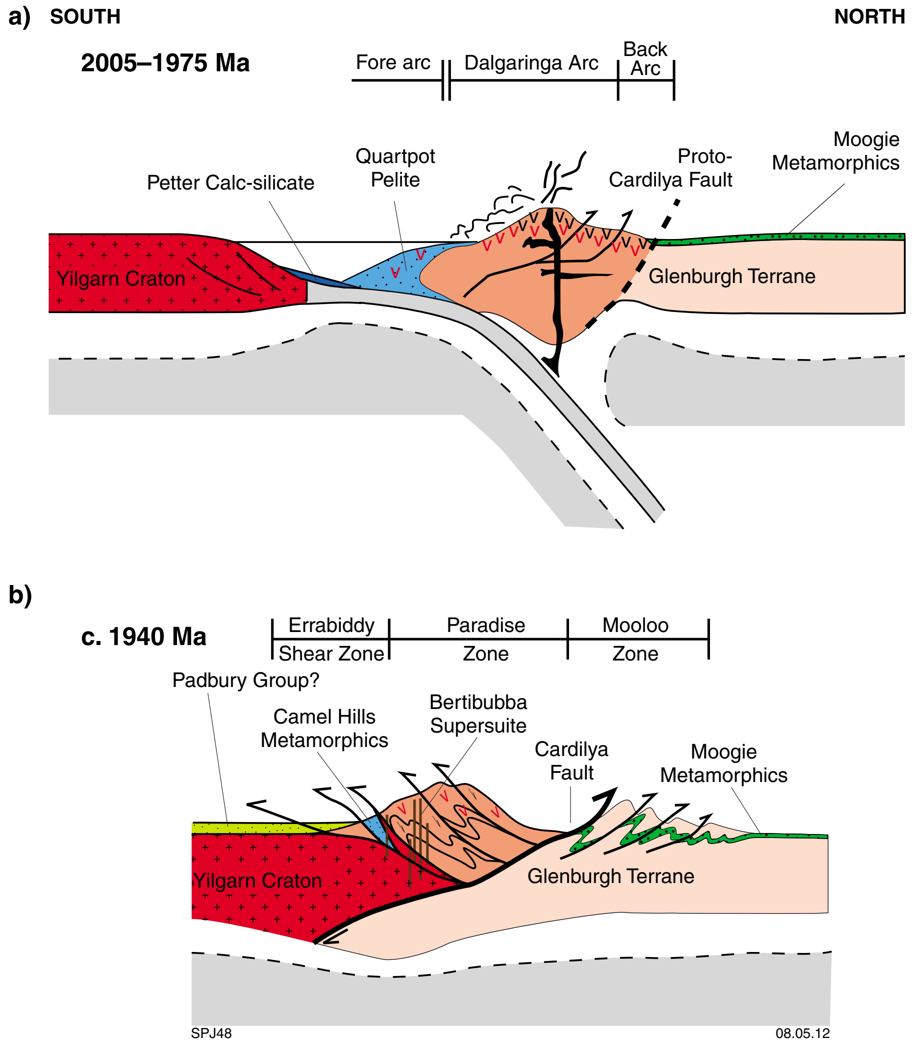

Figure 6. Schematic cross sections, showing the evolution of the Dalgaringa Arc and the formation of the Errabiddy Shear Zone and Cardilya Fault.

These areas are interpreted to represent strongly deformed parts of the Glenburgh Terrane. Lithological variations within the Errabiddy Shear Zone, such as imbricate slices of Narryer Terrane, or intrusions of the Bertibubba Supersuite (Johnson et al., 2011a), cannot be differentiated seismically. However, areas of low seismic reflectivity north of CDP 6800 in the upper 3.5 s TWT (~10.5 km) of the crust most likely represent composite plutons of weakly deformed Nardoo Granite (Sheppard et al., 2004, 2010; Johnson et al., 2011a).

The crustal architecture of this suture zone, as imaged in line 10GA–CP3, is significantly complex, something predicted in part by the surface geology (see fig. 3 of Cawood and Tyler, 2004; Sheppard et al., 2004) and geophysical data (Hackney, 2004; Selway, 2008; Selway et al., 2009; Reading et al., 2012). Although both major terrane-bounding structures are related to the Glenburgh Terrane – Yilgarn Craton collision, their geometric relationships suggest that the Cardilya Fault post-dates the formation of the Errabiddy Shear Zone. The imbrication of lithologies from the Glenburgh Terrane and Yilgarn Craton along the Errabiddy Shear Zone suggest that this earlier structure is probably the suture zone. This interpretation is consistent with the presence of continental-margin arc magmatic rocks of the Dalgaringa Supersuite to the north of the north-dipping Errabiddy Shear Zone, implying northward-directed subduction under the southern margin of the Glenburgh Terrane (Sheppard et al., 2004; Johnson et al., 2010, 2011a,b). Following the initial collision and interleaving of lithologies along the Errabiddy Shear Zone, this zone was reworked by the Cardilya Fault, which underthrust the southern margin of the Glenburgh Terrane beneath the Narryer Terrane (Sheppard et al., 2003; Cawood and Tyler, 2004). The geological history of this fault is poorly known from surface mapping, as it is both poorly exposed, and has been extensively intruded by younger magmatic rocks of the 1820–1775 Ma Moorarie Supersuite (Frontispiece 1; Plate 1). However, the fault that occurs between the magmatic-arc rocks of the Dalgaringa Supersuite, and the basement gneisses of the Glenburgh Terrane into which they were intruded (Frontispiece 1; Plate 1), is located in the former back-arc region of the Dalgaringa Arc. The proto-Cardilya Fault may have been established during a period of back-arc crustal thinning (Fig. 6). During the collision, this thinned crust may have ruptured, resulting in the underthrusting of the Glenburgh Terrane beneath the Yilgarn Craton (Fig. 6).

Alternatively, the Narryer Terrane may have been obducted onto the Glenburgh Terrane at the present site of the Cardilya Fault during the collision. During the post-collisional phase of the Glenburgh Orogeny, there was backthrusting along the Errabiddy Shear Zone, with a slice of the Glenburgh Terrane being thrust back to the south over the upper part of the Narryer Terrane.

Batholiths and granite intrusions

Within both the Glenburgh Terrane and upper crust of the Bandee Seismic Province, the upper 5 s TWT (~15 km) of the crust is defined by numerous, irregular, and seismically non-reflective bodies (Figs 1, 2, and 7), which are indicated by the mapped surface geology (Frontispiece 1; Plate 1) to be granite plutons of the 1820–1775 Ma Moorarie Supersuite and 1680–1620 Ma Durlacher Supersuite.

In the Mutherbukin Zone (Frontispiece 1–3; Fig. 7; Plate 1), a single pluton belonging to the 1680–1620 Ma Durlacher Supersuite is imaged between the Chalba and Ti Tree Shear Zones (CDPs 11075–13325). The pluton has a concave, presumably intrusive, basal contact with the underlying Glenburgh Terrane (Fig. 7). The pluton ranges in thickness from 0.6 s TWT (~1.8 km) in the centre of the Mutherbukin Zone, to 3.8 s TWT (~11.5 km) at its northerly contact where it is truncated by the Ti Tree Shear Zone. The pluton thins rapidly by about 2 s TWT (~6 km) on the southern side of the Chalba Shear Zone, where it has been downthrown across this fault to the south. Weak seismic reflections within and beneath the intrusion are parallel to the concave basal contact, suggesting that the shape and orientation of the pluton is due to folding during the Mutherbukin Tectonic Event (Johnson et al., 2011a). Prior to folding, the pluton would have been a flat-lying or gently dipping, tabular body greater than, or equal to, 11.5 km at its thickest.

In the Limejuice Zone, the Minnie Creek batholith (Frontispiece 1; Fig. 7; Plate 1; Johnson et al., 2011a) is imaged north of the Ti Tree Shear Zone at CDP 11075, and is interpreted to continue northward, underlying rocks of the Edmund Basin in the Cobra Syncline to CDP 8975 (Figs 3 and 8). North of the Edmund Fault at CDP 9450, the batholith is cut by numerous listric normal faults, which have produced a series of rotated (southwest-side down) half grabens. The Minnie Creek batholith has not been imaged north of these half grabens (between CDP 8975 and the Lyons River Fault at CDP 8725), where the area is dominated by rocks of high seismic reflectivity (Fig. 8). The base of the Minnie Creek batholith is mostly interpreted as a fault contact, but between CDP 10400 and 9900, the batholith has a relatively sharp, flat, possibly intrusive contact with the underlying Glenburgh Terrane. In this section, the batholith has a thickness of 2.25 s TWT (~6.75 km), but its maximum thickness, immediately north of the Ti Tree Shear Zone, is 6 s TWT (~18 km); nevertheless, as the basal contact in this region is tectonic in origin, it is possible that the Minnie Creek batholith has been thickened during folding or faulting.

At several localities within the batholith (e.g. CDP 11000, 10500, and 10300), planar regions of highly seismically reflective material dip at moderate angle toward the batholith centre. At the surface, these bodies have been shown to be kilometre-scale rafts of low-metamorphic grade pelitic and semipelitic schist belonging to the 1840–1810 Ma Leake Spring Metamorphics (Frontispiece 1; Plate 1; Johnson et al., 2011a). These rafts are also evident in the northern part of the Durlacher Supersuite pluton to the south of the Ti Tree Shear Zone (e.g. at CDP 11200 and CDP 11500), although none are exposed at the surface. These packages, some of which are up to 8 km in length, most likely represent vestiges of a formerly coherent sedimentary succession (Leake Spring Metamorphics), into which the granites were intruded. The preservation of these tabular metasedimentary packages suggest that the batholith may have formed by a series of

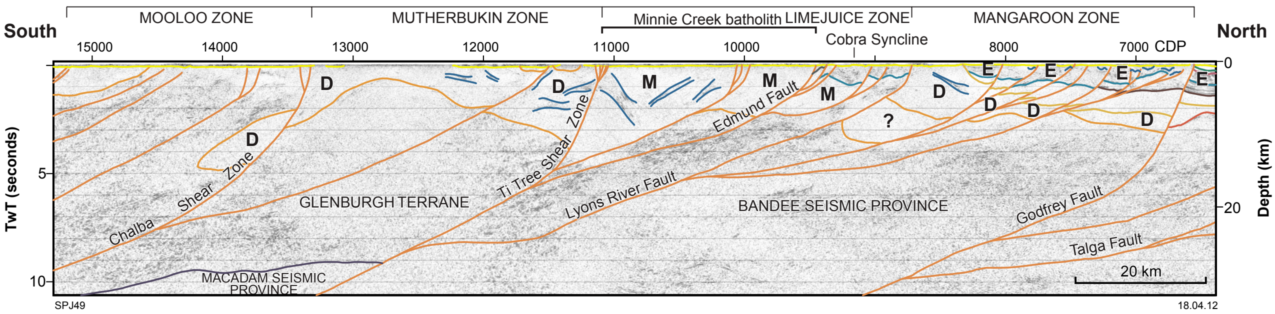

Figure 7. Interpreted migrated seismic section of part of line 10GA–CP2, showing the location and shape of granitic plutons and batholiths in the upper 15 km (5 s TWT) of the crust. Abbreviations used: D — Durlacher Supersuite; E — Edmund Group; M — Moorarie Supersuite.

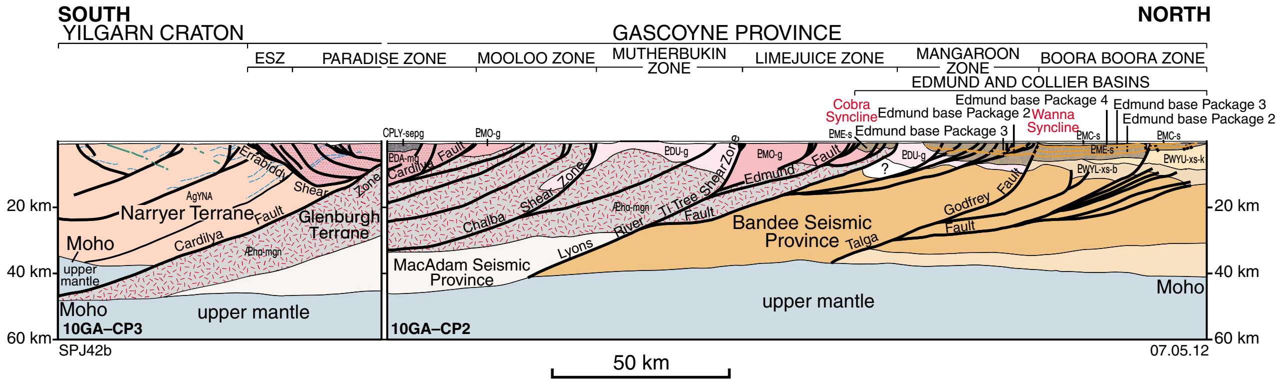

Figure 8. Geological interpretation of seismic lines 10GA–CP2 and 10GA–CP3

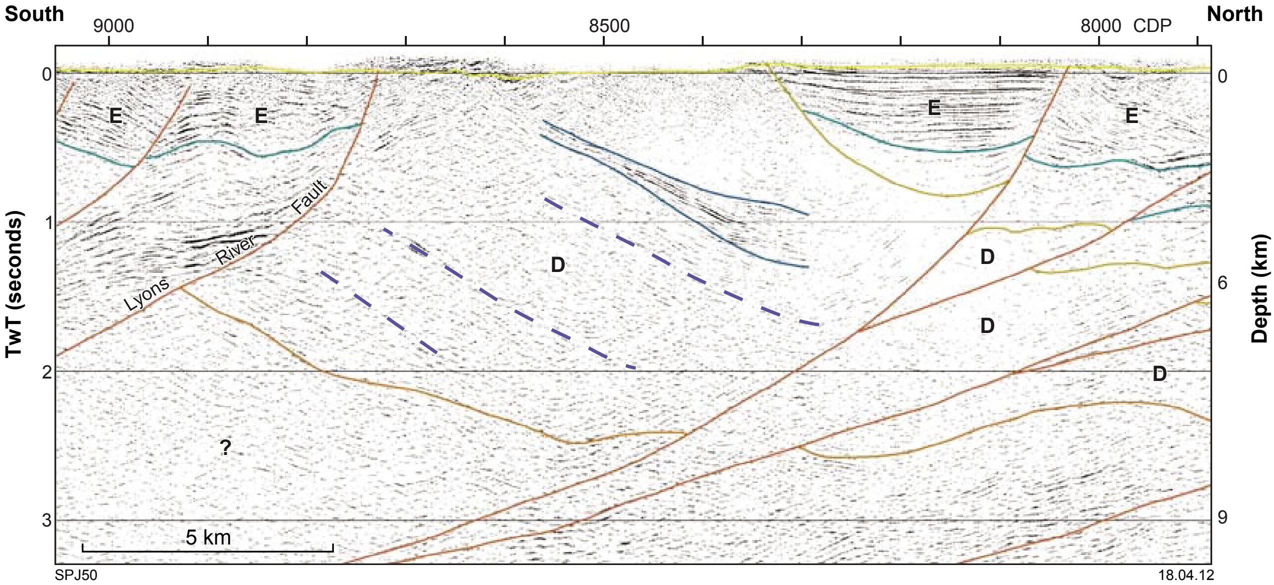

Figure 9. Interpreted migrated seismic section of part of line 10GA–CP2, showing the architecture of the Mangaroon Zone, including the raft of metasedimentary material that is parallel to other weak seismic reflections (shown as dashed blue lines) within the granitic body. Abbreviations used: D — Durlacher Supersuite; E — Edmund Group.

sheet-like plutons, an interpretation supported in part by field evidence, which indicates that many of the granites in the Moorarie Supersuite in the Limejuice Zone have sheet-like geometries (Sheppard et al., 2010).

In the Mangaroon Zone, the seismic reflection data presented in seismic line 10GA–CP2 (Figs 1 and 7) show weakly reflective crust, interpreted as granite plutons of the 1860–1620 Ma Durlacher Supersuite, bounded by the Lyons River Fault in the south (CDP 8720), and the Godfrey Fault to the north (CDP 6575; Fig. 7). The area north of CDP 8300 is covered by extensive sedimentary rocks of the Edmund Basin, and there are no surface exposures of basement rocks in this region (Frontispiece 1; Plate 1). The largest volume of granitic material occurs in the central part of the Mangaroon Zone, between CDP 8750 and 8300, where it is ~2.5 s TWT (~7.5 km) thick (Fig. 9). The granite contains a 6 km long package of moderately north-dipping, seismically reflective material (CDP 8550–8300) similar to the metasedimentary rafts in the Minnie Creek batholith further south. The reflective package also parallels numerous other weak seismic reflections that occur throughout the granite body (Fig. 9), which are interpreted to reflect relict sedimentary or lithological layering of the 1760–1680 Ma Pooranoo Metamorphics. The presence of parallel seismic reflections down to ~2.0 s TWT indicates that the Pooranoo basin was at least ~6 km thick.

Farther north, in the area underlying the Edmund Basin (south of the Godfrey Fault; Fig. 7), it is difficult to determine if the non-reflective packages are granites of the Moorarie or Durlacher Supersuites, and for simplicity they are tentatively shown as a continuation of the interlayered granitic and metasedimentary material of Durlacher Supersuite and Pooranoo Metamorphics. Rare outcrops of strongly deformed granite belonging to the Moorarie Supersuite (the Gooche Gneiss; Frontispiece 1; Plate 1), formed a basement onto which the Pooranoo Metamorphics were deposited (Sheppard et al., 2005, 2010).

Architecture of the Edmund and Collier Basins

Line 10GA–CP2 crosses the Edmund and Collier Basins (Frontispiece 1; Plate 1), revealing the subsurface architecture necessary to understand their depositional and tectonic evolution. Although the succession in the Collier Basin, which is only present in the Wanna Syncline, is relatively thin (<0.25 s TWT; ~750 m), both basins are well imaged in line GA10–CP2 (Fig. 10). The maximum thickness of the Edmund Basin is 2.25 s TWT (~6.75 km) on the southern side of the Godfrey Fault. A relatively large package, up to 1 s TWT (~3 km) thick, of highly seismically reflective material occurs between the base of Package 2 and the top of Package 4 (Fig. 10); these reflections are interpreted to be abundant dolerite sills of the c. 1465 Ma Narimbunna Dolerite and c. 1070 Ma Kulkatharra Dolerite, which intrude the upper parts of the Edmund Basin (Cutten et al., 2011).

Three principal structures, the Talga, Godfrey, and Lyons River Faults, appear to have controlled the depositional architecture of the Edmund Basin (Fig. 10). Extensional movement on these faults formed three half graben structures, into which sediments of the Edmund Basin were deposited (Martin and Thorne, 2004), and across which significant sediment thickness variations are evident. On the Pingandy Shelf, to the north of the Talga Fault (Fig. 10), the maximum thickness of Packages 1 and 2 are ~0.5 s TWT (~1.5 km), whereas to the south they increase to ~1.25 s TWT (~3.75 km). Across the Godfrey Fault, Packages 1 and 2 increase from 2.0 s TWT (~6 km) to >2.75 s TWT (~8.25 km) thick. Packages 1 and 2 are consistently thicker in the hangingwall of the basin-bounding extensional faults, suggesting that extensional downthrow on these major faults was toward the southwest. Packages 1 and 2 are not present south of CDP 8300, presumably having been incised and eroded away prior to the deposition of Packages 3 and 4 (Martin et al., 2008; Cutten et al., 2011). In this region, Package 3 is at least 1 s TWT (~3km) thick.

Between the Godfrey Fault (CDP 6575) and the Edmund Fault (CDP 9465), the Edmund Basin (Package 3) is intensely folded, with numerous imbricate thrust faults truncating the limbs of the tight, upright folds (Fig. 10). This corridor of intense deformation has been mapped in the surface geology (Frontispiece 1; Plate 1), and does not appear to have significantly affected rocks of the Collier Basin, suggesting either that the deformation is related to the pre- Collier Basin, 1385–1200 Ma Mutherbukin Tectonic Event, or that the Godfrey Fault acted as a backstop to the northward-propagating thrust system during the 1030–955 Ma Edmundian Orogeny.

The seismic data show that the depositional architecture and subsequent structural inversion of the Edmund Basin was controlled by pre-existing major crustal structures in the underlying Gascoyne Province. Reactivation of these structures as extensional faults accommodated the deposition of the sediments in the Edmund Basin, whereas subsequent reactivation as thrust faults inverted the basin.

Summary

Figure 8 (also see Plate 2) shows a complete cross section through the Gascoyne Province, based on the interpretation of seismic reflection data presented in lines 10GA–CP2 (Fig. 1) and 10GA–CP3 (Fig. 2). The main suture zones are shown to be the Lyons River Fault, separating the Pilbara Craton – Bandee Seismic Province from the Glenburgh Terrane, and the Errabiddy Shear Zone – Cardilya Fault, which separates the Glenburgh Terrane from the Narryer Terrane (Yilgarn Craton). Therefore, the West Australian Craton can be shown to consist of three separate tectonic units, juxtaposed at two suture zones, as originally proposed by Occhipinti et al. (2004), Sheppard et al. (2004), and Johnson et al. (2011b). Plutonic rocks of the 1820–1775 Ma Moorarie Supersuite and 1680–1620 Ma Durlacher Supersuite are imaged in the upper crust of the Glenburgh Terrane and Bandee Seismic Province (Fig. 8). At the northern end of line 10GA–CP2 (Fig. 8), the depositional architecture of the Edmund and Collier Basins has also been resolved, and indicates that deposition of these basins was controlled by the reactivation of older, crustal-scale faults.

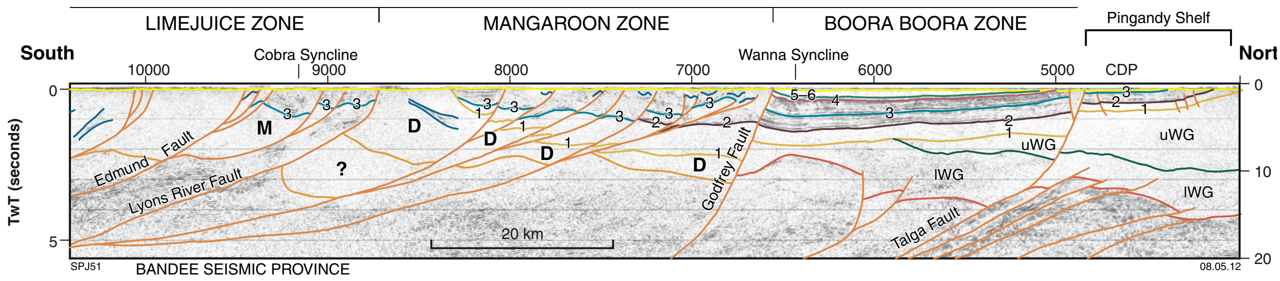

Figure 10. Interpreted migrated seismic section of part of line 10GA–CP2, showing the extent of the Edmund Basin. The base of individual packages of the Edmund Group are also shown. Abbreviations used: M — Moorarie Supersuite; D — Durlacher Supersuite; lWG — lower Wyloo Group ; uWG — upper Wyloo Group

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