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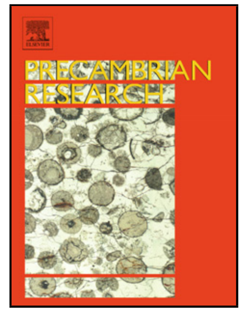

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PII: S0301-9268(15)00114-X
DOI: http://dx.doi.org/doi:10.1016/j.precamres.2015.04.002
Reference: PRECAM 4231

To appear in: *Precambrian Research*

Received date: 5-12-2014
Revised date: 2-3-2015
Accepted date: 2-4-2015

Please cite this article as: Spampinato, G.P.T., Ailleres, L.,Imaging the basement architecture across the Cork Fault in Queensland using magnetic and gravity data, *Precambrian Research* (2015), http://dx.doi.org/10.1016/j.precamres.2015.04.002

Imaging the basement architecture across the Cork Fault in Queensland using magnetic and gravity data

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ABSTRACT

The basement rocks in central Queensland are largely obscured by the Phanerozoic sedimentary succession and direct information comes only from sparse geological data. 2.5D forward modelling of regional aeromagnetic and Bouguer gravity data has been undertaken to unveil the crustal architecture at the junction of the Proterozoic Mount Isa terrane and the Phanerozoic Thomson Orogen in Queensland. The most prominent geophysical character is represented by the abrupt termination of positive NNW-trending geophysical anomalies of the Mount Isa terrane against NE-trending, low amplitude gravity and magnetic anomalies of the Diamantina River Domain of the Thomson Orogen. Potential field forward modelling indicates that the lower basement crust of the Thomson Orogen is petrophysically indistinguishable from the crust of the Proterozoic Mount Isa terrane. We interpret that the prominent gradients associated with the Cork Fault represent the displacement and burial of the Mount Isa terrane crust under the Thomson Orogen. In this context, the Cork Fault is inferred to represent a fundamental crustal discontinuity but does not represent the eastern margin of Rodinia because the Thomson Orogen is floored by Precambrian continental crust.

Initiation of the Cork Fault might have occurred as early as the Mesoproterozoic. At that time, the Cork Fault was a major structure that developed during the separation of the Mount Isa terrane and the Curnamona Province. It is inferred that this break-up occurred during initial N-S to NNW-SSE extension. The Cork Fault formed part of a network of major north- and south-dipping normal faults active at that time. The Cork Fault was repeatedly reactivated during the Neoproterozoic Rodinia break-up and during the Phanerozoic evolution of the Tasmanides. We suggest that the segment of the inferred 'Tasman Line' along the southern termination of the Mount Isa terrane should be regarded as a set of structures offsetting the Proterozoic crust rather than a simple lineament dividing the Proterozoic and the Phanerozoic Australian continent.

Key Words: Mount Isa terrane; Thomson Orogen; Gravity; Magnetic; Cork Fault; Tasman Line.

1 Introduction

The Cork Fault divides the Proterozoic Mount Isa terrane (Betts et al., 2006; Blake et al., 1984; O'Dea et al., 1997b) from the Phanerozoic Thomson Orogen (Finlayson et al., 1988; Glen, 2005; Glen et al., 2010; Murray and Kirkegaard, 1978) in Queensland and is one of the most distinguishable geophysical features on the Australian continent (Fig. 1). Because of its prominence, the Cork Fault has been interpreted to represent a major feature associated with the Neoproterozoic break-up of Rodinia (Finlayson et al., 1988; Gunn et al., 1997; Murray and Kirkegaard, 1978; Shaw et al., 1996; Veevers, 2000; Veevers and Powell, 1984). However, the architecture of the Cork Fault as well as the timing of its initiation is still poorly understood because the geological record of the fault is incomplete or sparsely preserved (Murray, 1994; Murray and Kirkegaard, 1978; Wellman, 1990).

In this study we use high resolution magnetic and gravity datasets to investigate the architecture of the Cork Fault and constrain the boundary between the Mount Isa terrane and the Thomson Orogen. Regional potential field datasets are increasingly used to unravel the crustal architecture of ancient tectonic systems in regions with little or no geological exposure (Betts et al., 2003a; McLean and Betts, 2003). The method, although ambiguous, provides insights into structural architecture and kinematics and can be used to map the geology of buried terranes (Gunn et al., 1997). 2.5D potential field forward modelling has been undertaken to determine the architecture and kinematics of the Cork Fault and associated structures. The results provide insights in understanding the Precambrian tectonic evolution of the Eastern Australian continent and have implications for unraveling the nature of the deep crust of the Thomson Orogen.

Insert Figure 1 here

2 Regional geology

2.1 The Mount Isa terrane

The Mount Isa terrane (Figs. 1 and 2) forms part of the Palaeoproterozoic North Australian Craton (Betts et al., 2006; Bierlein and Betts, 2004; Giles et al., 2006a; MacCready, 2006; Spikings et al., 2001). The exposed Mount Isa inlier (Fig. 2) preserves a geological record that spans more than 350 million years between ca. 1870 and 1500 Ma (Betts et al., 2006). The Mount Isa Inlier is divided in an Eastern and Western fold belts (Fig. 2a) in which sedimentation and subsequent deformation have been heterogeneous in time and space (Betts et al., 2006; MacCready, 2006; O'Dea et al., 1997b). Palaeoproterozoic supra-crustal rocks were deposited during multiple superimposed rifting and subsidence events (Betts et al., 2006; Bierlein and Betts, 2004; Blake, 1987; Giles et al., 2006a; MacCready, 2006; O'Dea et al., 1997a; O'Dea et al., 1997b; Spikings et al., 2001) and overlie basement rocks deformed and metamorphosed to amphibolite facies during the ca. 1900 - 1870 Ma Barramundi Orogeny (Betts et al., 2006; Blake, 1987; Etheridge et al., 1987; O'Dea et al., 1997b; Page and Williams, 1988).

The ca. 1790 - 1725 Ma Leichhardt Superbasin (Fig. 3) formed during an E-W crustal extension event (Betts et al., 2006; O'Dea et al., 1997a; O'Dea et al., 1997b) and was characterized by bimodal magmatism and clastic fluvial sedimentation (Jackson et al., 1990; O'Dea et al., 1997b). A following ca. 1725 - 1690 Ma NW-directed extensional event marks the imposition of the Calvert Superbasin (Fig. 3) (Jackson et al., 2000). The Calvert Superbasin is well represented in the Western Fold Belt and was characterized by significant felsic magmatism and deposition of fluvial to shallow marine rocks on SE-thickening half graben (Betts et al., 1999; Southgate et al., 2000). A ca. 1675 Ma switch in the regional extension direction resulted in the development of the Isa Superbasin (Fig. 3) (Betts et al., 2006; Hutton et al., 2012). The Isa Superbasin is interpreted to reflect a period of thermal subsidence (Betts and Lister, 2001; Betts et al., 2001; Betts et al., 1999) and fault reactivation (Andrews, 1998; Betts, 2001; Krassay et al., 2000; Scott et al., 1998) during NNE-SSW-directed extension (Gibson et al., 2008).

The ca. 1800 - 1600 Ma basinal evolution was terminated by the onset of the Isan Orogeny (Fig. 3) (Bell, 1983; Betts et al., 2006; Blake, 1987; Giles et al., 2006b; O'Dea et al., 2006; O'Dea et al., 1997b; Page and Bell, 1986). This shortening event strongly overprinted previous tectonic fabrics and resulted in reactivation of existing normal faults as reverse faults (Giles et al., 2006b). The early stage of the Isan Orogeny occurred during a ca. 1600 - 1580 Ma N-S- to NW-directed crustal shortening (Betts et al., 2006; Giles et al., 2006b; O'Dea et al., 2006). The following ca. 1570 - 1550 Ma Middle Isan Orogeny developed through a major E-W crustal shortening event (Giles et al., 2006b; O'Dea et al., 1997b). Crustal-scale upright folds and major N-S-trending reverse faults and thrusts were imposed at this time (Giles et al., 2006b; MacCready et al., 1998). The subsequent ca. 1550 - 1540 Ma wrenching tectonic stage defined the transition from ductile folding to brittle deformation (Giles et al., 2006b; O'Dea et al., 1997b). The ca. 1530 to 1500 Ma final stage of the Isan Orogeny is characterized by E-W- to ESE-directed deformation (Betts et al., 2006) and emplacement of A-type and I-type granites in the eastern part of the exposed inlier (Wyborn, 1998).

The Mount Isa terrane is considered to be cratonised after the Isan Orogeny and the architecture of the region has not changed since the Late Mesoproterozoic (Fig. 4) (Betts et al., 2006; O'Dea et al., 1997b).

Insert Figure 2 here

2.2 The Thomson Orogen

Neoproterozoic to Ordovician meta-siltstone, quartzite, schist and igneous intrusive rocks of the adjacent Thomson Orogen (Figs. 1 - 4) (Draper, 2006; Murray, 1994; Murray and Kirkegaard, 1978; Withnall et al., 1995) are concealed by Middle Palaeozoic to Mesozoic sedimentary successions (Glen, 2005; Murray and Kirkegaard, 1978). The basement rocks of the Thomson Orogen deposited predominantly in a deep water environment (Murray, 1994).

On the north-western margin of the Thomson Orogen and adjacent to the southern margin of the Mount Isa terrane, U-Pb SHRIMP analyses on detrital zircons from basement-intersecting drill holes (GSQ Machattie 1 and HPP Goleburra 1, Fig. 5) indicated a maximum depositional age of ca. 650 Ma (Carr et al., 2014). In the Maneroo Platform, drill hole AAP Fermoy 1 (Fig. 5) intersected Early to Late Cambrian (K-Ar and Rb-Sr analyses on muscovite phyllite) schistose and phyllitic basement rocks (Murray, 1994; Murray and Kirkegaard, 1978). U-Pb (SHRIMP) zircon analyses on basement samples from AAO Beryl 1, GSQ Maneroo 1 (Maneroo Platform), Dio Betoota 1 (western Thomson Orogen) and GSQ Eromanga 1 (central Thomson Orogen, Fig. 5) indicated a maximum deposition age of ca. 495 Ma (Brown et al., 2014; Carr et al., 2014).

Initial deposition is likely to have occurred during the Neoproterozoic to Middle Cambrian (Fig. 3) (Draper, 2006; Murray and Kirkegaard, 1978; Withnall et al., 1995). The rock package was subsequently deformed and metamorphosed by Middle to Late Cambrian tectonic event coeval with the Delamerian Orogeny (Draper, 2006; Murray and Kirkegaard, 1978). Renewed deposition and emplacement of volcanic rocks occurred during Late Cambrian to Middle Ordovician (Fig. 3) (Brown et al., 2014; Draper, 2006; Murray and Kirkegaard, 1978). At this time, rocks of north-eastern Australia have been interpreted to represent a back-arc igneous province associated with a convergent margin further east (Fergusson et al., 2007a). Middle Silurian (ca. 428 Ma) felsic magmatism occurred in the Thomson Orogen (Draper, 2006). The emplacement of intrusive bodies may have occurred during a Late Benambran contractional deformation (Champion et al., 2009; Draper, 2006) which has been recorded to the east (Fergusson et al., 2005; Fergusson et al., 2007b) and south (Foster and Gray, 2000; Glen, 2005; Glen et al., 2007) of the Thomson Orogen. However, Spampinato et al. (Unpublished results-a) suggested that Middle Silurian felsic magmatism might reflect a period of crustal extension due to the retreat of a congested plate margin located further southeast (Moresi et al., 2014).

Early Devonian intra-continental trans-tension resulted in the development of the widespread Adavale Basin (Figs. 3 and 4) (Evans et al., 1992; McKillop et al., 2007). During the Middle Carboniferous, the Adavale Basin was deformed and exhumed (Finlayson et al., 1990b). The remnant synclinal structures reflecting the deepest sedimentary deposition and recorded in deep seismic surveys (Leven et al., 1990; Wake-Dyster et al., 1983), are termed - from west to east - the Warrabin, Quilpie, Cooladdi and Westgate troughs (Hoffmann, 1988; Mathur, 1983; Pinchin and Senior, 1982).

Insert Figure 3 here

A hiatus of ca. 70 Myrs separates the Devonian sediments of the Adavale Basin from the Late Carboniferous - Middle Triassic Galilee Basin (Figs. 3 and 4) (Finlayson et al., 1988). The Galilee Basin is a large intra-cratonic basin which is predominantly filled by fluvial deposits. In the Lovelle Depression (Fig. 4) over 700 m of Permian and Triassic sediments accumulated over Precambrian and Early Palaeozoic metamorphic and granitic rocks

(Hawkins and Harrison, 1978). The Galilee Basin was inverted during the Hunter-Bowen Orogeny which resulted in the development of large-scale thrust faults (Van Heeswijck, 2010).

The Early Jurassic to Late Cretaceous Eromanga Basin unconformably overlies the northern part of the Mount Isa terrane, the basement rocks of the Thomson Orogen, the Devonian sedimentary sequences and the Galilee Basin (Finlayson et al., 1988; Mathur, 1983; Senior, 1978; Spence and Finlayson, 1983). Terrestrial to shallow marine sedimentary rocks of the Eromanga Basin extend over an area of approximately 1,200,000 km^2 and have been affected by minor deformation associated with Cenozoic shortening events which mostly reactivated the existing fault architecture (Leven et al., 1990; Moss and Wake-Dyster, 1983).

Insert Figure 4 here

3 Previous geophysical surveys

3.1 The Mount Isa terrane

In 2006, deep crustal seismic reflection survey was undertaken along six transects across North Queensland (Fig. 5). The survey has been conducted by the Geological Survey of Queensland (GSQ), Geoscience Australia (GA), the Predictive Mineral Discovery Cooperative Research Centre (PMD*CRC) and Zinifex Pty Ltd (now OZ Minerals). Signals were recorded to 20 seconds two-way travel time approximately equivalent to 60 km in depth. The aim was to determine, among other goals, a geodynamic framework of the North Queensland (Murray, 2007). In addition, two previous transects from the Mount Isa deep seismic lines shot by the Australian Geological Survey Organisation (AGSO) in 1994 were reprocessed to standardize the methodology and uniform the available data.

Insert Figure 5 here

The Mount Isa terrane is characterized by weakly reflective and seismically homogeneous crust extending to ~55 km depth (Fig. 6) (Korsch et al., 2012). The region can be divided in two broad tectonic domains having contrasting tectonic styles and regional vergences (Betts et al., 2006; MacCready, 2006; O'Dea et al., 1997b). The Eastern Fold Belt is characterized by west-directed deformations located above the crystalline basement rock (MacCready, 2006). The Western Fold Belt instead shows east-directed deformations that affect the basement rocks (MacCready, 2006). Seismic data indicate that major fault zones, including the west-dipping Mount Isa, Rufus and Quilalar faults in the Western Fold Belt (Korsch et al., 2008; O'Dea et al., 1997a) and the east-dipping Pilgrim and Cloncurry faults (Austin and Blenkinsop, 2010; Blenkinsop et al., 2008) in the Eastern Fold Belt (Figs. 2a and 6), controlled the architecture of the area. These are interpreted to represent major structures that accommodated the Late Palaeoproterozoic basinal deposition and were reactivated as reverse faults during the Early Mesoproterozoic Isan Orogeny (Betts et al., 2006; Blenkinsop et al., 2008; Gibson et al., 2006; MacCready, 2006; O'Dea et al., 1997b).

Insert Figure 6 here

3.2The Thomson Orogen

Over the period 1980 - 1986 the Australian Bureau of Mineral Resources (BMR) recorded deep reflection surveys across the central part of the Eromanga Basin (Fig. 5). The results provided new insights into the crustal architecture of the Thomson Orogen. ~1,400 km of new seismic reflection data were obtained and ~2,300 km of existing data over the Eromanga Basin were reprocessed (Moss and Wake-Dyster, 1983; Wake-Dyster et al., 1983).

Seismic data indicate that high angle thrust faults form the dominant deformation style (Fig. 7) (Finlayson et al., 1988). The top reflective zone at 1-2 seconds represents the shallow sedimentary sequences (Pinchin and Senior, 1982). The underlying basement rocks show heterogeneous seismic fabric and have been divided in a non-reflective upper crust extending between 2.5 and 8 seconds and a reflective lower crust between 8 and 12 seconds (Finlayson et al., 1990a; Finlayson et al., 1990b; Mathur, 1983, 1984, 1987). The bottom zone with no reflections and refraction velocities of 8.2 km/s is interpreted to represent the seismically homogeneous upper mantle (Mathur, 1983). The non-reflective character of the upper crust may be due to the severe deformation of meta-sedimentary and meta-volcanic rocks (Lock et al., 1986; Mathur, 1983; Spence and Finlayson, 1983). Mathur (1983) and Finlayson (1983) suggested that the reflectivity in the lower crust may be due to mafic intrusions related to an extensional event in the Early to Middle Palaeozoic. Glen et al. (2013) suggested that the lower crust may represent igneous oceanic crust equivalent to the crust that floors most of the Lachlan Orogen (Fig. 2) in the southern Tasmanides.

Insert Figure 7 here

3.3The Cork Fault zone

The architecture of the deep crust along the Cork Fault zone is unresolved because there are no deep seismic transects across the structure. However, several 4 seconds two-way travel time seismic surveys have been conducted within the region and a number of these cross the Cork Fault, providing insights into the shallow tectonic setting of the fault (Fig. 8).

In 1975, The Bureau of Mineral Resources (BMR) undertook a seismic survey in the western part of the Galilee Basin (Figs. 4 and 8). The seismic survey recorded ~320 km of continuous single-coverage reflection recording. The aim was to obtain information on the extent and thickness of the western part of the Galilee Basin (Harrison and Bauer, 1976). In the 1980’s, Esso Australia recorded ~6,436 km of lines to investigate the Galilee Basin and the Maneroo Platform of the Thomson Orogen (Fig. 8). In the 1982, Crusader Ltd completed a series of seismic surveys across a portion of the Eromanga – Galilee basins on the down thrown side of the Cork Fault / Holberton Structure complex (Fig. 8). Further seismic surveys were undertaken in the Galilee – northern Eromanga basins over the plateau area formed by the Nisbet Range and Kangaroo Mountains (Fig. 8). The Opalton Seismic Survey operated by Minora Resources NL is located south of the Lovelle Depression within the Galilee Basin and covers an area of ~5,990 km^2 (Fig. 8).

Insert Figure 8 here

Within the Cork Fault zone - Diamantina River Domain, the dominant structural grain trends northeast. The faulting pattern is generally more complicated within the basement rocks (Esso_Australia_Limited, 1984). The overlying horizons are conformable to the basement but do not show such a high fault rate or displacement (Esso_Australia_Limited, 1984). Faults are often terminated within the basement unit or show minor displacements in the overlying horizons, sometimes deforming last sediment packages through folding, which reflects reactivation episodes (Esso_Australia_Limited, 1984).

In the Maneroo Platform (Fig. 8), the basement is relatively shallow and is overlain by the Eromanga Basin. The Lovelle Depression is located along the junction of the Mount Isa terrane and the Maneroo Platform (Hawkins and Harrison, 1978). Immediately west to the Holberton Structure, previously recognized from geological mapping and coinciding with the south-eastern limit of the Galilee Basin, another NE-trending major structure was interpreted to represent the southern continuation of the Cork Fault (Harrison and Bauer, 1976). Whitin the BMR survey region, this fault coincides with a prominent magnetic gradient that trends NW-SE with amplitudes decreasing towards the SE. This fault appears to be sub-vertical and has a downthrown to the west of up to 300 m. The NE-trending Cork Fault separates the Lovelle Depression from the Maneroo Platform (Esso_Australia_Limited, 1984). Major movements in the Late Carboniferous determined a depocentre that accommodated sedimentation (Esso_Australia_Limited, 1984). The Cork Fault was interpreted to be active during the Early Permian and Late Permian and controlled the deposition of sedimentary sequences (Hawkins and Harrison, 1978). The Cork Fault along with the Holberton structure are reflected at surface as westerly-dipping monoclines, which reflects protracted fault reactivation and basin inversion (Esso_Australia_Limited, 1984).

On the northern margin of the Thomson Orogen, adjacent to the Cork Fault - Holberton Structure, shallowing of non-reflective basement rocks has been inferred (Esso_Australia_Limited, 1984). This variation in the relief of the Thomson Orogen basement rocks corresponds to an increase of NE-trending Bouguer gravity anomalies. In the northern Thomson Orogen, the Warbreccan Dome and Newlands Trend (Fig. 8) also form a prominent NE-trending structure.

3.4Tomographic data

Surface wave tomography imaging indicated that, within 250 km depth, the Archean and Proterozoic geological domains of the Australian continent, including the Mount Isa terrane, are characterized by high wave speeds (Fichtner et al., 2009; Fishwick et al., 2008; Kennett et al., 2004; Simons et al., 1999). In the Phanerozoic eastern Australia, including the Thomson Orogen, wave propagation appears relatively slow (Fishwick et al., 2008; Kennett et al., 2004), although the Thomson Orogen is characterized by higher wave speed lithosphere when compared to the rest of the Tasmanides (Fishwick et al., 2008; Kennett et al., 2004). In this scenario, the Cork Fault, separating the Proterozoic crust of the Mount Isa Terrane from the Phanerozoic Thomson Orogen, would represent a fundamental crustal boundary in which rock packages on either side of the fault are different. However, the higher speed velocities recorded in the Thomson Orogen suggest that the latter is floored by thinned Precambrian continental crust at depth and, thus, differs from the rest of the Tasmanides, where lower velocities may mostly reflect younger oceanic lithosphere (Fishwick et al., 2008; Fishwick et al., 2005; Kennett et al., 2004).

4 Methods

4.1Image interpretation

Aeromagnetic and gravity data interpretation is a powerful tool for regional geology and large-scale characterization in regions with little or no geological exposure (Aitken and Betts, 2009; Stewart and Betts, 2010b). The method provides insights into structural architecture and kinematics although it does not have unique solution (Betts et al., 2003b; Stewart and Betts, 2010b). However, geological and geophysical constraints such as seismic data, drill holes, geochemical data and observations in the surrounding areas may reduce significantly the ambiguity.

In 2006, the Geological Survey of Queensland started new acquisition of high resolution gravity and airborne geophysics data throughout Queensland including the Mount Isa terrane and Galilee/Thomson regions. Over 50% of Queensland has been covered by high resolution gravity data having 2 to 4 km station spacing. Aeromagnetic data were collected at a line spacing of 400 m and a ground clearance of 80 m (Chopping and Henson, 2009).

Magnetic and gravity datasets have been processed in order to enhance the geophysical signal and to assist in the geological interpretation. Image processing has been carried out using Oasis Montaj™ which allows viewing and processing of potential field datasets, grids and images within one integrated environment. In a total magnetic intensity (TMI) grid, the shape of the magnetic anomalies is function of the geometrical and petrophysical properties of the source bodies as well as the inclination and declination of the main magnetic field (the Earth's magnetic field). We have firstly applied a reduced to the pole filter to the TMI grid. This filter reconstructs the magnetic field of a given region as if it were at the pole. As a result, anomalies are brought over their source bodies and their shape can be associated with geometries or variation of magnetic susceptibility of the source bodies. Further filters were applied to the RTP magnetic and Bouguer gravity grids to enhance the geophysical signal and identify source bodies at different crustal levels. The vertical derivative filter has been applied to better determine the boundaries of the potential source bodies. This filter calculates the vertical rate of change in the magnetic or gravity signal. As a result, boundaries between source bodies have been sharpened and have been identified more accurately. The tilt derivative filter calculates the ratio of the vertical gradient and the total horizontal gradient irrespective of the amplitude or wavelength of the magnetic field. As a result, this filter can be applied as an edge detection method and also enhances weak magnetic anomalies. The tilt filtered grid has been superimposed onto the vertical derivative grid in order to highlight the structural architecture of the region and to interpret overprinting relationships. Low pass filter has been used to remove the noise that may arise when derivative filters are applied and to retain the longest wavelengths. GIS based structural and lithological interpretation mapping from these filtered grids was then undertaken.

4.2Forward modelling

Forward modelling technique allows testing the validity of the interpretation in 2 - 2.75 dimensions (Gunn et al., 1997). Geological models have been built using GM-SYS™ Profile Modelling which allows for comparison between the calculated (modelled) gravity and magnetic responses to observed measurements. Cross sections are extracted along selected profiles that orthogonally intersect the major structures in the study area. Rock packages are then divided in geological units and are assigned unique geometrical and petrophysical properties (McLean and Betts, 2003; McLean et al., 2008). This generates calculated magnetic and gravity profiles along the cross sections which are compared to the observed geophysical response. The parameters are adjusted until the calculated and observed geophysical profiles show an acceptable correlation (Blakely, 1995).

Total magnetic and Bouguer gravity data have been extracted along two profiles crossing the Cork Fault (profiles 1 and 3, Fig. 9). Profile n. 2 lies entirely within the Thomson Orogen (Fig. 9). The forward model n. 1 extends through the Warbreccan - Newlands trend and the Canaway Ridge because the architecture of the latters are well known from seismic reflection imaging and this allows a-priori structuring of the region. Profile n. 2 has been built along the Central Eromanga deep seismic surveys n. 7E and 7W (Fig. 5). The seismic data constrain the interpretation and provides a-priori structural modelling of the region. Although the forward models n. 3 is unconstrained, sparse data provided by basement-intersecting drill holes located in the vicinity of the profile and 4 seconds reflection seismic data within the area can been used to gain information about the geometries of the sedimentary succession and the shallow basement rocks. Furthermore, the southern ending of the forward model n. 3 intersects the constrained forward model n. 2. The intersection point can be used as a constrained reference point.

The forward models cover a total linear distance of ~725 km and have been modelled to 50 km depth. The Curie depth varies from ~40 km in the southern Mount Isa terrane to ~24 km in the northern Thomson Orogen (Maule et al., 2009).

5 Geophysical signature of the region

The Mount Isa terrane shows the highest amplitude geophysical signature (up to 2200 nT and 450 $\mu m*s^{-2}$) when compared to the surrounding regions. The adjacent Thomson Orogen is characterized instead by lower magnetic (between 180 and -650 nT) and Bouguer gravity (between 200 and -500 $\mu m*s^{-2}$) amplitudes and smoother magnetic texture. The Mount Isa terrane shows a prominent N-S- to NNW-trending structural grain while the Thomson

Orogen is characterized by a network of NE- and NW-trending anomalies mostly evident in the Bouguer gravity grid (Fig. 10). On the magnetic map, the boundary between the two provinces is defined by a prominent NE-trending anomaly that extends for more than 500 km and is associated with the Cork Fault (Fig. 9). In the RTP magnetic grid, The Cork Fault zone is defined by steep NW-oriented gradients of ~150 nT/km, decreasing towards the south. The prominent NW-oriented Bouguer gravity gradients (~50 $\mu m*s^{-2}$/km) which separates the high amplitude gravity anomalies of the Mount Isa terrane from the low intensity gravity anomalies of the Thomson Orogen (Fig. 10) define a prominent NE-trending gravity anomaly, although the latter occurs ~ 30 km south of the inferred Cork Fault zone.

Insert Figure 9 here

The Diamantina River Domain of the Thomson Orogen shows a persistent low magnetic signature with amplitude values comprised between -100 nT and -650 nT and Bouguer gravity anomalies of up to ~200 $\mu m*s^{-2}$ that decrease to ~ -350 $\mu m*s^{-2}$ towards the southeast of the domain (Figs. 9 and 10). An arcuate NE-trending high gravity belt with amplitudes between -100 and 200 $\mu m*s^{-2}$ but little magnetic expression characterizes the northern Diamantina River Domain and lies immediately adjacent to the Cork Fault (Figs. 10 and 11).

Insert Figure 10 here

Further south, a series of NE-trending structures are defined by NE-trending Bouguer gravity anomalies with amplitude values between -20 and -260 $\mu m*s^{-2}$. These structures include the NW-dipping Warbreccan Fault, which has been imaged in seismic data and delimits the north-western extent of the Devonian Barcoo Trough (Finlayson et al., 1988). On the RTP map, the Warbreccan Fault is less well defined and corresponds to a regional increase of magnetic anomalies above -100 nT. Finlayson et al. (1988) indicated that the trend of the Warbreccan Fault is approximately parallel to the edge of the Precambrian Craton (the Cork

Fault) and suggested that this fault initiated during the early tectonic history of the Thomson Orogen. Similar to the Cork Fault, the Warbreccan Fault is considered a major lithospheric structure and may penetrate the entire crust (Finlayson and Leven, 1987; Passmore and Sexton, 1984).

Short wavelength, magnetic anomalies are superimposed onto the regional magnetic signal. These anomalies show a variety of magnetic responses and appear to be focused along NE-trending structures, including the Cork Fault and the Warbreccan Dome - Newlands Trend. These anomalies are co-located with short wavelength, either positive or negative gravity responses.

Insert Figure 11 here

6 Regional interpretation

High amplitude geophysical anomalies located to the north of the Cork Fault might represent magnetic rocks of the Mount Isa terrane, which have been intersected by several drill holes at a shallow depth (~1 – 4 km) (Chopping and Henson, 2009). Spampinato et al. (Unpublished results-b) suggested that the intensely positive magnetic responses of the Mount Isa terrane are most likely related to Barramundi-aged basement rocks and meta-volcanic and meta-sedimentary rocks associated with the formation of the Leichhardt Superbasin. Regions with more subdued magnetic and gravity anomalies may reflect the distribution of the non-magnetic Calvert and Isa superbasins (Betts et al., 2004; Spampinato et al., Unpublished results-b) or shallow, low magnetic granitic intrusions. The N-S to NNW structural grain that characterizes the Mount Isa terrane correlates well with major N-S- to NNW-trending fault zones interpreted to accommodate the Palaeoproterozoic deposition and subsequently reactivated as reverse thrusts during the ca. 1600 - 1500 Ma Isan Orogeny (Betts et al., 2006;

Giles et al., 2006a; Giles et al., 2006b; O'Dea et al., 2006; Spampinato et al., Unpublished results-b; Wellman, 1992).

The Thomson Orogen is characterized by lower amplitudes and long wavelength anomalies suggesting thicker sedimentary sequences and deeper magnetic source bodies when compared to the Mount Isa terrane. Combined potential field and seismic interpretation indicate that Bouguer gravity anomalies below -300 $\mu m*s^{-2}$ define the distribution of the Devonian basinal sequences (Collins and Lock, 1990; Spampinato et al., Unpublished results-a). Long wavelength magnetic signatures are likely to reflect magnetic source bodies at mid- to low crustal level, above the Curie depth.

The steep regional gradients that characterize the Cork Fault reflect high petrophysical contrast between the crusts of the Mount Isa terrane and the Thomson Orogen. The prominent geophysical signatures that define the boundary of these two terranes are likely to reflect either two fundamentally different juxtaposed terranes or the burial of a magnetic crust beneath younger rock packages. In both cases, the Cork Fault marks a tectonic boundary between the cratonised Proterozoic Mount Isa terrane (Betts et al., 2006) and the Thomson Orogen which was a tectonically active region until the Carboniferous (Murray and Kirkegaard, 1978). ENE- to NE-trending, short wavelength positive magnetic and co-located high frequency gravity anomalies bounding the northern flank of the Cork Fault are interpreted to represent low density granitic intrusions or dense mafic rocks (Fig. 12). These granitic and mafic bodies do not trend N-S in alignment with the major structural fabric of the Mount Isa terrane and it is likely that the inferred emplacement of granitoids and mafic rocks occurred at the time of initiation or reactivation of the Cork Fault. K-Ar analysis on granitic rocks in drill holes CPC Ooroonoo 1 (Fig. 5) yielded a isotopic age of ca. 858 Ma (Murray and Kirkegaard, 1978), supporting that post-Mesoproterozoic tectonics affected the southern termination of the Mount Isa terrane, although post-Isan Orogenic events did not significantly change the architecture of the region (Betts et al., 2006). The NE-trending, high amplitude gravity anomaly lying the immediate south of the Cork Fault (Fig. 10) might reflect a belt of shallow and dense basement rocks (Fig. 12). This belt of high density rock shows poor magnetic expression, thus it is inferred that the shallow basement of the Diamantina River Domain must be formed by weakly magnetized rocks when compared to the rocks of the southern Mount Isa terrane. This belt bounds the NE-trending geophysical anomalies associated with the Cork Fault and this suggests that the two structures may be related. The positive regional gravity signature associated with the Warbreccan Dome - Newlands Trend is interpreted to represent shallowing of basement rocks of the Thomson Orogen, as confirmed by basement-intersecting drill holes and seismic data.

Insert Figure 12 here

Variation in the regional magnetic signature across the Warbreccan Fault suggests that the latter may represent a major structure within the Thomson Orogen. The orientation and extension of the Warbreccan Dome - Newlands Trend are comparable to that of the Cork Fault suggesting that these two structures may correlate. Short wavelength, positive magnetic and low amplitude Bouguer gravity anomalies focused along NE-trending structures may reflect source bodies at shallow crustal level and are interpreted to represent granitic intrusions (Fig. 12). The orientation and alignment of these intrusions suggest that their geometries are controlled by the regional structural architecture.

7 Forward models

7.1Parameters and seismic constraints

The crust and the upper mantle are modelled as six discrete layers to honour the constraining seismic data and to best represent the vertical heterogeneities in petrophysical characteristics at the scale of the models. The shallowest geological unit is represented by the sedimentary sequence of the reflective Eromanga, Cooper and Galilee basins (Pinchin and Senior, 1982).

In the Mount Isa terrane, the underlying poorly reflective basement rocks has been sparsely drilled at a shallow level and has been modelled to extend from approximately 1 km to approximately 42 km in depth. The basement crust of the Mount Isa terrane includes the Barramundi-aged crystalline basement as well as Palaeo- to Mesoproterozoic meta-sedimentary and meta-volcanic rocks, which have been mapped in the exposed inlier (Beardsmore et al., 1988; Blake et al., 1984; O'Dea et al., 1997b) and imaged in the 2006 Deep Seismic Transects (Korsch et al., 2008; MacCready, 2006). In the Thomson Orogen, the non-reflective zone underlying the reflective sedimentary rocks (Finlayson et al., 1990a; Finlayson et al., 1990b; Mathur, 1983, 1984, 1987) corresponds to the upper basement which extends from ~1 - 4 km depth to a maximum depth of ~20 km. Mathur (1987) indicated that the upper basement of the Thomson Orogen has a range of densities from 2.55 g/cm^3 to 2.85 g/cm^3. Best fit models are achieved dividing the upper basement of the Thomson Orogen in two discrete layers, which takes into account the density increases with increasing depth inferred from the seismic velocities (Mathur, 1987).

The transition to the lower crust is defined by an increase in reflectivity and seismic velocities (Finlayson et al., 1990a; Finlayson et al., 1990b; Mathur, 1983, 1984, 1987) and has been imaged to extend to approximately 39 - 45 km depth. The underlying upper mantle shows poor reflectivity in both the Mount Isa terrane (Korsch et al., 2012; MacCready, 2006) and the Thomson Orogen (Mathur, 1983). Deep seismic profiles show that the Moho under the Mount Isa terrane is deeper (~ 42 - 45 km depth) (Korsch et al., 2012; MacCready, 2006) than beneath the Thomson Orogen (~ 38 - 42 km depth) (Mathur, 1983). NW-oriented forward models n. 1 and n. 3 were created to intersect orthogonally the Cork Fault (Fig. 9).

The forward model n. 2 is oriented ENE and has been extracted along the 1983 BMR Deep Seismic Transects n. 7E and 7W (Fig. 9).

7.2Forward model n. 1

Profile n. 1 is ~310 km long and is oriented northwest to intersect the Mount Isa terrane, the Lovelle Depression in the Galilee Basin, the Cork Fault, the Diamantina River Domain, the Canaway Fault and the Adavale Basin within the Thomson Orogen (Fig. 13). Drill holes EAL Cork 1, EHN Holberton 1, AAP Mayneside 1, MAN Waterloo 1 and LOL Belmore 1 constrain the geometries of the shallow basement rocks (Fig. 9). The Central Eromanga deep seismic profiles n. 2, 5 and 6 and shallow seismic surveys (Fig. 5) provide information about the geometries under the Lovelle Depression, Barcoo Trough and Canaway Ridge and allow for a-priori structuring of the region.

The observed gravity profile (Fig. 13) shows a peak of ~150 $\mu m*s^{-2}$ associated with the crust of the mount Isa terrane, which regionally decreases towards the Diamantina River Domain with gradients of ~3 $\mu m*s^{-2}$/km. This trend is interpreted to reflect the deepening of a basement crust towards the southeast. To the south of the Diamantina River Domain, the Thomson Orogen shows gravity anomalies with amplitude values comprised between -420 and -130 $\mu m*s^{-2}$. Positive structures or shallowing of the upper basement under the depositional sequences are associated with relatively high intensity Bouguer gravity anomalies with amplitude values comprised between -300 and -130 $\mu m*s^{-2}$. The lowest amplitude values reflect regions where the sedimentary sequences are thicker. The Devonian Adavale Basin and Barcoo Trough are characterized by gravity anomalies below -300 $\mu m*s^{-2}$. By inference we interpret that regions characterized by low gravity anomalies ranging between -300 until -420 $\mu m*s^{-2}$ may reflect significant thickening (up to 4.5 km) of the sedimentary sequences and might contain remnants of the Devonian sedimentary deposition (Fig. 12).

Positive regional magnetic anomalies with peak amplitudes of ~620 nT decrease towards the southeast. The Cork Fault is associated with a steep gradient of ~20 nT/km that decreases towards the southeast. Under the Thomson Orogen, the observed magnetic profile shows low amplitude and smooth magnetic responses. The potential field forward model supports a scenario in which a magnetic crust is shallower in the Mount Isa terrane and deeper in the Thomson Orogen.

In the Thomson Orogen, variations in the relief of the upper basement is well represented in the observed gravity profile but correlates poorly with the magnetic signature along the profile, indicating that its magnetic contribution might be negligible. Instead, the long wavelength magnetic signature is likely to reflect magnetic source bodies at mid- to low crustal level, above the Curie depth.

The shallower unit has been modelled as a non-magnetic sedimentary sequence (D= 2.55 g/cm^3) extending up to 3.7 km depth. The shallow (within ~2 km of the surface), non-reflective basement crust of the Mount Isa terrane extends down to ~44 km depth (Curie depth) and is modelled with a magnetic susceptibility of 0.069 SI. To the southeast, the upper basement rocks of the Thomson Orogen (D= 2.73 and 2.79 g/cm^3) have been assigned zero magnetic susceptibility and regionally thicken towards the southeast. This two-layered block corresponds to the non-reflective upper basement rocks imaged in the seismic data. In the Thomson Orogen, a high density, two-layered block (D= 2.80 - 2.90 g/cm^3; S=0.069 SI) has magnetic susceptibility of 0.069 above the Curie depth and extends to a maximum depth of ~41 km. This two-layered block corresponds to the reflective lower crust imaged in the seismic data. The lower crust of the Thomson Orogen cannot be petrophysically distinguished from the basement crust of the Mount Isa terrane. Relatively short wavelength

(~25 km wide) positive geophysical anomalies under the Diamantina River Domain might be due to magmatic intrusions. Our preferred interpretation is that they represent remnants of the magnetized Proterozoic meta-sedimentary and meta-volcanic rocks of the Mount Isa terrane. The upper mantle (D= 3.25 g/cm^3) has been modelled to shallow under the Thomson Orogen and is non-magnetic because it lies well below the Curie depth.

Prominent SE- and NW-dipping listric structures are modelled to connect into a major detachment zone possibly extending to the Moho (Fig. 13). The Cork Fault is modelled as a high angle SE-dipping fault with listric geometry at depth.

Thrust faults which deform the sedimentary sequence and uplift the basement rocks are modelled from a series of positive gravity anomalies. High angle structures penetrating and offsetting the magnetic crust are associated with variations in both the regional magnetic and gravity signature. Shallow faults terminating at the upper crust result in positive gravity anomalies but have a minimal magnetic expression.

The connection between the east-dipping Canaway Fault (Finlayson et al., 1988) and a major SE-dipping fault is only apparent in the profile. Uplift of the upper basement and deformation of the sedimentary sequences are interpreted to reflect reactivation of structures that accommodated basinal deposition. The sedimentary rocks progressively thin towards the Canaway Ridge which is inferred to have been a structural high during the Devonian (Hoffmann, 1989) dividing the depositional sequences of the Barcoo Trough from those in the Adavale Basin.

Insert Figure 13 here

7.3Forward model n. 2

Profiles n. 2 (Fig. 14) is ~155 km long and it is oriented east - west to intersect the northern part of the Cooper Basin, the Harkaway and Windorah-Ingella faults. Towards the eastern end, the profile intersects also the Moothandella Fault, which represents the eastern limit of the Devonian Barcoo Trough. This profile lies entirely within the Thomson Orogen and crosses a major NW-trending magnetic anomaly that is prominent in the RTP magnetic grid (Fig. 9). The Deep Seismic Profiles n.7E and 7W have been used as constraints. The Central Eromanga Deep Seismic Transect n. 3 (Fig. 5) is located further south and runs parallel to the orientation of the forward model. This seismic profile intersects the southern continuation of NW-oriented structures that cross the modelled section thus providing additional constraints.

The observed gravity profile shows amplitude values ranging between -330 to -160 $\mu m{*}s^{-2}$ decreasing from west to east with a regional gradient of ~1 $\mu m{*}s^{-2}$/km. The regional gravity trend correlates with the deepening of the Moho eastward from 37 to 39 km depth. Regions showing thicker sedimentary sequences (D= 2.55 g/cm^3) are associated with lower gravity signature (up to -330 $\mu m{*}s^{-2}$) while shallowing of the upper basement rocks (D= 2.73 g/cm^3) are reflected by positive gravity anomalies.

The observed magnetic profile shows a prominent anomaly with peak amplitude of ~30 nT and a wavelength of ~100 km, decreasing towards the east and west with a gradient of ~1.3 - 1.4 nT/Km. The seismic data suggest that the reflective lower crust, which extends from ~19 - 22 km to ~37 - 39 km, is shallower beneath this prominent magnetic source body (Finlayson et al., 1990a). The best fit model is achieved with a lower crust consisting of densities ranging between 2.82 and 2.92 g/cm^3 and a magnetic susceptibility of 0.069 SI above the Curie depth.

The observed gravity and magnetic profiles show little correlation. In the western part of the profile, major shallowing of the upper basement is associated with positive gravity signature but corresponds to the lowest magnetic amplitude values. In the centre of the profile, the upper crust is modelled to be sub-horizontal, which reflects the near-flat trend of the observed gravity profile. However, regional peak anomalies in the magnetic profile occur. Thus, it is inferred that the non-reflective upper crust has a significantly lower magnetization when compared to the reflective lower crust. Positive magnetic shallow granitic rocks (D= 2.67 g/cm^3; S= 0.037 - 0.069 SI) lying at ~6 to 14 km depth have been modelled to take into account short wavelength variations in the observed magnetic profile. These modelled felsic intrusives are associated with low gravity anomalies.

The Harkaway, Windorah-Ingella and Moothandella faults are imaged as major high angle, west-dipping structures. Variations in regional gravity and magnetic anomalies in correspondence to these structures suggest that the latter displace the entire crust. Relatively short wavelength positive gravity anomalies are interpreted as reflecting positive flower structures consisting of east-dipping faults connecting into major west-dipping faults including the Windorah-Ingella and Moothandella faults.

Generally, the forward model along with the deep seismic data shows that west-dipping detachments appear to control the architecture of the region.

Insert Figure 14 here

7.4Forward model n. 3

Profile n. 3 is ~260 km long and extends across the Cork Fault to intersect the Mitakoodi Domain of the Mount Isa terrane, the Diamantina River Domain and the Warbreccan Dome - Newlands Trend of the Central Thomson Orogen. Drill holes GSQ Connemara 1, AEI Great Northern 1, IOR Canterbury 1 and the 1983 BMR Deep Seismic Transects n. 7E and 7W (Fig. 9) constrain the profile.

Regional Bouguer gravity anomalies ranging between -270 to 260 μm*s^{-2} decrease towards the southeast with a gradient of ~5 μm*s^{-2}/km. Since the Moho is regionally deeper in the Mount Isa terrane and shallower under the Thomson Orogen, this gravity trend is likely to mostly reflect the burial at depth of a dense basement crust beneath the Thomson Orogen.

Relatively short wavelength (~20 km wide), low gravity signatures may reflect the thickening of the sedimentary deposition that extends to a max depth of ~3.2 km. Shallowing of the upper basement is interpreted from large positive gravity anomalies and is associated - from south to north - with the Warbreccan Structure (~ -140 µm*s^{-2}), NE-trending structures in the Diamantina River Domain (~70 µm*s^{-2}) and the Mount Isa terrane basement crust (~250 µm*s^{-2}) north of the Cork Fault.

The regional magnetic anomalies show a prominent amplitude peak of ~820 nT coincident with the Mount Isa terrane. To the immediate south, a steep gradient of ~33 nT/km, decreasing towards the southeast, is interpreted to represent the termination of the Mount Isa terrane crust against the adjacent Thomson Orogen. Within the Thomson Orogen, the observed magnetic profile shows amplitudes values of ~10 nT and a smooth magnetic signature. Similar to profile N.1, best fit reconstruction suggests that the prominent gradient and the smooth texture represent the displacement and the burial at depth of a high density crust which has magnetic susceptibility of 0.069 above the Curie depth. This high density and magnetic crust links to the reflective lower crust of the Thomson Orogen, imaged in the seismic profiles N. 7W and 7E.

Similar to models 1 and 2, the topography of the upper basement crust beneath the Thomson Orogen correlates well with the trend of the observed gravity profile but show little magnetic expression, suggesting that along the profile the upper basement may be poorly magnetized or non-magnetic. The shallowest unit is represented by non-magnetic sedimentary sequences (D= 2.55 g/cm^3) which conceal the basement rocks. The basement crust under the Mount Isa terrane extends down to a depth of ~42 km and is magnetized (0.069 SI) above the Curie depth. The basement rocks of the Thomson Orogen can be divided in a non - magnetic upper crust (D= 2.72 - 2.79 g/cm^3), which thickens to the south and extend to a maximum depth of ~19 km and a magnetic lower crust (D= 2.80 - 2.90 g/cm^3; S=0.069 SI) overlying the Moho.

These two crustal blocks are inferred to correspond to the non-reflective upper basement and the reflective lower basement imaged in the deep seismic transects. The lower basement crust of the Thomson Orogen is petrophysically indistinguishable from the Mount Isa terrane crust. The Moho regionally deepens from the Thomson Orogen (~39 km depth) towards the Mount Isa terrane (~42 km depth). The non-reflective upper mantle (D= 3.25 g/cm^3) is non-magnetic because it is it is well below the Curie depth.

The Cork Fault is modelled as a major high angle, south-dipping listric fault. Major high angle structures, including the Warbreccan Fault, displace the entire crust and are modelled to connect into a major detachment surface. This results in variation of the regional gravity and magnetic signal. Positive gravity anomalies co-located with poor magnetic expression represent shallow structures that deform the non-magnetic, upper basement. They have been constrained to the upper crust in the modelling as they do not appear to affect the regional magnetic signature of the region.

Insert Figure 15 here

8 Validity of the interpretation

The boundary between the Mount Isa terrane and the Thomson Orogen is characterized by sharp magnetic gradients decreasing towards the southeast. In the Thomson Orogen, variations in thickness and displacement of the upper crust appear to have little effect on the magnetic trend. This suggests that the upper crust of the Thomson Orogen is significantly less magnetic than the Mount Isa terrane crust, which results in the prominent magnetic signature along the boundary. Instead, long wavelengths and low amplitude magnetic anomalies in the Thomson Orogen suggest greater depth to the source rocks. The constrained forward models indicate that the Thomson Orogen can be represented by a two-layered crust. The non-reflective, non-magnetic upper crust of the Thomson Orogen overlies a reflective and magnetic lower crust.

The basement rocks of the Mount Isa terrane and the lower crust of the Thomson Orogen are petrophysically indistinguishable. However, even though potential field data can discriminate rocks of different densities and magnetic susceptibilities, this is not necessary diagnostic of particular rock types. Many rock types show a wide range of magnetic susceptibility and can exhibit similar response on a survey grid (Clark, 1981).

The Cork Fault is interpreted to belong to a network of major NE-trending, north-dipping and south-dipping listric faults that displace the magnetic crust at depth. The steep magnetic gradients that characterize the Cork Fault result from displacement of the shallowest portion of the magnetic crust. In the Thomson Orogen, the thinning and burial at depth of the magnetic crust is reflected in the regional smoother magnetic signature. In this context, the Cork Fault would be a major SE-dipping normal fault which displaces the magnetic crust at depth. The high gravity structural belt bounding the southern termination of the Mount Isa terrane might represent a NW-dipping fault zone that connects into a major SE-dipping detachment surface that appears to control the architecture of the area. The NE-trending Warbreccan Dome - Newlands Trend is interpreted to be a major NW-dipping listric fault that connects into a major detachment surface. This structure is associated with regional variation of gravity and magnetic anomalies and inferred displacement of both the upper and lower crusts. We interpret the geophysical maps and 2.5D forward model profiles to suggest that the northeast-trending Warbreccan Dome - Newlands Trend and the Cork Fault might be related.

The basement crust is concealed by less dense and non-magnetic shallow depositional sequences of the Eromanga, Galilee and Adavale basins as confirmed by the sparse geological record. Regions showing significant thickening of the sedimentary rocks are inferred to contain remnants of the Devonian sedimentary sequence. The major listric faults appear to control the architecture of the area and have been repeatedly reactivated resulting in a series of vertical offsets, which decrease towards the upper units as imaged in the seismic data.

9 Discussion

The configuration of the Proterozoic supercontinent Rodinia as well as palaeogeographical reconstructions of the Australian continent are based on common geological character, tectonic elements and crustal age of nowadays divided geological provinces (Betts et al., 2008; Karlstrom et al., 2001; Li et al., 1995; Wingate et al., 2002). However, the lack of exposed piercing points and intense reworking of the Australian continent add ambiguities in the understanding of the Precambrian geodynamic evolution.

9.1 Timing of initiation and reactivation of the Cork Fault

The Cork Fault has been interpreted to represent a segment of the much debated Tasman Line (Direen and Crawford, 2003) which broadly divides the Proterozoic provinces of the Australian continent from Phanerozoic rocks of the Tasmanides (Fig. 2) (Fergusson et al., 2007a; Glen, 2005; Murray and Kirkegaard, 1978; Veevers, 2000). The Cork Fault is widely inferred to play a major role during the Neoproterozoic Rodinia break-up (Finlayson et al., 1988; Gunn et al., 1997; Murray and Kirkegaard, 1978; Shaw et al., 1996; Veevers and Powell, 1984) and, in most geodynamic reconstructions of the Proterozoic re-organization of the Australian continent, is also envisaged as an active feature (Betts and Giles, 2006; Gibson et al., 2008; Giles et al., 2004; Henson, 2011; Williams et al., 2010).

The forward modelled profiles indicate that the Cork Fault is a high angle, south-dipping listric fault dividing thick and shallow magnetic crust to the north from thinned and buried magnetic crust to the south. The Cork Fault can be consistently interpreted as an extensional fault. The time of initiation of the Cork Fault post-dates the ca. 1600 – 1500 Ma Isan Orogeny, since the fault abruptly terminates the N-S- to NNW-trending anomalies of the Mount Isa terrane. Therefore, the time of initiation is constrained between ca. 1500 Ma and ca. 650 Ma (maximum depositional age of Thomson Orogen basement rocks).

9.1.1 Time of initiation: the Palaeoproterozoic Mount Isa – Curnamona Province link

Lithological, metamorphic and metallogenic similarities as well as comparable geophysical features recorded in the Mount Isa terrane, the Curnamona Province and the Gawler Craton (Fig. 16) indicate that these terranes or parts thereof, might have shared the same tectonic history during the Palaeoproterozoic to Early Mesoproterozoic (Betts et al., in press; Betts and Giles, 2006; Betts et al., 2002; Giles et al., 2004; Henson, 2011). The ca. 1850 Ma Donington Suite, which is recorded in the eastern Gawler Craton, forms a N-S-trending granitoid belt (Hand et al., 2007) and temporally correlates with the Kalkadoon Batholith (Blake et al., 1990; Page, 1983; Page and Sun, 1998) of the Mount Isa terrane. Giles at al. (2004) argued that the Donington Suite and Kalkadoon Batholith could have formed one continuous belt at ca. 1850 Ma. The Palaeoproterozoic superimposed basinal evolution recorded in the Mount Isa terrane can be correlated with sedimentary successions preserved in the Curnamona Province, Georgetown-Yambo-Coen Inliers, Gawler Craton and McArthur Basin (Betts and Giles, 2006; Giles et al., 2004). The ca. 1700 - 1600 Ma Willyama and Maronan supergroups show remarkable similarities in timing, processes and sedimentary facies (Giles et al., 2004). Both successions were followed by a ca. 1600 - 1580 Ma major tectono-thermal event (Page and Laing, 1992; Page and Sun, 1998) including the Isan Orogeny in the Mount Isa terrane and the Olarian Orogeny in the Curnamona Province, respectively (Giles et al., 2004). The timing and the deformation style of the Isan Orogeny and the Olarian Orogeny show striking analogies as well (Giles et al., 2004; O'Dea et al., 1997b).

To honour the geological similarities between the two provinces, Giles et al. (2004) and Betts and Giles (2006) proposed a reconstruction in which the South Australian Craton (SAC, consisting of the Gawler Craton and Curnamona Province after Myers et al., (1996)), was rotated 52° counter clockwise about an Euler pole located at 136°E 25°S relative to its current position (Fig. 16a). Their reconstruction aligns the Palaeo-Mesoproterozoic orogenic belts including the ca. 1800 - 1700 Ma Strangways - Kimban orogenies (Collins and Shaw, 1995; Parker, 1993), the ca. 1700 - 1600 Ma Early Kararan - Leibig events in the wester Gawler Craton and in the southern Arunta Inlier (Daly et al., 1998) and the ca. 1620 - 1500 Ma Olarian, Wartaken and Isan orogenies (Betts et al., 2002; Betts et al., 2006; Giles et al., 2004; Stewart and Betts, 2010a).

Henson et al. (2011) observed that the shape of the boundaries that truncate the southern Mount Isa terrane - Arunta Province and northern Curnamona Province are superimposable. They inferred that a N-S structural grain characterizes both provinces and suggested that the Curnamona Province can be simply translated and restored next to the Mount Isa terrane (Fig. 16b). In their reconstruction, the Curnamona Province and the Mount Isa terrane are not directly juxtaposed since it is inferred that the two provinces may have been separated by attenuated crust.

Insert Figure 16 here

The inferred Late Mesoproterozoic re-organization that led to separation between the Mount Isa terrane and the Curnamona Province (Betts and Giles, 2006; Henson, 2011) is likely to be recorded at the southern margin of the Mount Isa terrane and would correspond to the time of initiation of the Cork Fault. The architecture of the Cork Fault and adjacent structures indicate N-S to NNW-SSE crustal extension, burial of the continental crust at depth and crustal attenuation within the Thomson Orogen. If this model is correct, then the Mount Isa crust may be - at least in part - represented under the Thomson Orogen and would correspond to the thinned and magnetic lower crust.

Gibson et al. (2008) indicated that there is no need for the Mount Isa terrane and the Curnamona Province to be contiguous during the Palaeoproterozoic and suggested that the two terranes occupied different part of a single continental scale rift system that extended from northern to southern Australia from ca. 1800 Ma to 1640 Ma (Fig. 16c). In this scenario, the Cork Fault acted as a transfer fault and was an active feature during the Early Mesoproterozoic Isan Orogeny.

However, recent detrital zircon ages, Hf and Nd isotopic data on the ca. 1760 - 1700 Ma cover sequences from the northern and western Gawler Craton have found that source characteristics are likely to be derived from the North Australian Craton (NAC) (Howard et al., 2011; Payne et al., 2006). This along with the well-established correlation of the ca.1720–1640 Ma basin systems between the Curnamona Province and North Australian Craton, implies that the SAC and the NAC where physically connected at ca. 1780 - 1720 Ma (Howard et al., 2011).

Although the geophysical anomalies at the southern margin of the Mount Isa terrane may reflect Late Mesoproterozoic extension, the V-shaped geophysical signature highlighted in Henson's work (2011) may result from a variety of tectonic processes rather than reflecting a single Mesoproterozoic event. For example, the north-western structural grain of the southern Arunta Inlier might have been imposed during the Late Palaeoproterozoic Aileron Event and Middle Palaeozoic Alice Springs Orogeny (Collins and Shaw, 1995; Floettmann et al., 2004; Lechler and Greene, 2006; Shaw et al., 1984). The northwest-trending geophysical signature in South Australia may reflect Neoproterozoic extensional event followed by several episodes of reactivation (Powell et al., 1994; Preiss, 2000)

In light of these observations, our favourite model is the one proposed by Betts & Giles (2006). Palaeomagnetic data provide independent support to Betts & Giles' (2006) model, although Wingate and Evans (2003) suggested that the Euler pole should be positioned west of the proposed position. Williams et al. (2010) correlated an interpreted suture along the eastern margin of the Curnamona Province to the Pilgrim Fault of the Mount Isa terrane (Fig. 9) where allochthonous crustal blocks were amalgamated to the Australian margin at ca. 2200 - 1720 Ma, further supporting Betts & Giles (2006) model.

9.1.2 The Grenville orogenic belt in North Queensland

On the north-western margin of the Thomson Orogen, U-Pb SHRIMP and Lu-Hf (LA-ICP-MS) analysis of detrital zircons on two samples from the basement-intersecting GSQ Machattie 1 and HPP Goleburra 1 drill holes (Fig. 5) have near unimodal zircon age peaks at ca. 1180 Ma and maximum depositional age of ca. 695 Ma (Brown et al., 2014; Carr et al., 2014). The zircons in these samples have relatively juvenile Hf isotopic signatures (εHf(t) values between 0 and +9) which are interpreted to indicate derivation from the Musgrave Province in central Australia (Brown et al., 2014) during late Neoproterozoic to Early Cambrian reworking (Camacho et al., 1997; Camacho and McDougall, 2000). Detrital-zircon SHRIMP U–Pb ages from Neoproterozoic to Early Cambrian (Fergusson et al., 2001; Fergusson et al., 2007; Withnall et al., 1996) metamorphosed sedimentary successions of the Anakie Inlier and Charters Towers Province are mainly 1000 – 1300 Ma with a minor 1500 - 1800 Ma component (Fergusson et al., 2001; Fergusson et al., 2007a). The existence of a Grenville-aged belt in north-eastern Australia (Blewett et al., 1998; Fergusson et al., 2001) provides a viable explanation for detrital zircon age signatures in the north-western Thomson

Orogen. Fergusson et al. (2001) suggested that an extension of a Late Mesoproterozoic (ca. 1050 – 1250 Ma) orogenic belt from the central Australian Musgrave Complex is the most likely source of the detrital zircons in the metamorphosed sedimentary successions of the Anakie Inlier and Charters Towers Province. In this context, the high density and magnetic lower crust of the Thomson Orogen can be formed - at least in part - by a Grenville-aged belt which extends from the Musgrave Block in the sub-surface. This Grenville-aged belt may link to the late Mesoproterozoic Agwamin Seismic Province which is overlain by the Greenvale and Charters Towers Provinces of the Thomson Orogen (Fig. 2) (Korsch et al., 2012). If this model is correct, then the inferred Mesoproterozoic break-up between the Mount Isa Terrane and the Curnamona Province is constrained between ca. 1500 Ma (post-Isan Orogeny) and ca. 1250 Ma.

Based on aeromagnetic data, Aitken and Betts (2008) indicated that the extension of the Musgrave block terminates against the southern Arunta Inlier and is unlikely to extend eastwards as suggested by the Musgrave structural grain which is a late overprint related to the ca. 580 Ma Petermann Orogeny. In this context, the uplifted Musgrave Block (Camacho et al., 1997; Camacho and McDougall, 2000) and Coen Inlier (Blewett et al., 1998) may have provided a source for the detrital zircon in north-western Thomson Orogen at the time of deposition (Late Neoproterozoic to Middle Cambrian). Alternatively, the burial of the magnetic crust at depth and the Neoproterozoic and Phanerozoic strong overprint may have obliterated the magnetic signature of Grenville-aged basement rocks within the Thomson Orogen.

9.1.3 Neoproterozoic reactivation

Geological evidence indicates that the Thomson Orogen was a tectonically active area during the Rodinia break - up (Fergusson et al., 2007a; Glen, 2005; Murray and Kirkegaard, 1978).

Early to Middle Cambrian deposition is recorded in the adjacent Anakie Inlier (Anakie Metamorphic Group) and Charters Towers Province (Wynyard Metamorphic) (Fergusson et al., 2001; Fergusson et al., 2007a; Withnall et al., 1995). Middle Cambrian deformation occurred in the northern Thomson Orogen and post-dates deposition of pre-Delamerian sedimentary successions (Draper, 2006; Murray and Kirkegaard, 1978; Spampinato et al., Unpublished results-a). Finlayson et al. (1988) suggested that the major NE-trending structures of the Thomson Orogen - including the Cork Fault - initiated during the Late Neoproterozoic and are associated with SE-directed rifting. Spampinato et al. (Unpublished results-a) correlated the Neoproterozoic architecture of the western Thomson Orogen and the south-eastern Arunta Inlier (Figs. 1 and 16b) (Greene, 2010) and indicated that the Rodinia break-up might have occurred further to the east of the Thomson Orogen (Fergusson et al., 2009), which instead recorded the interior extensional architecture in response to a NE-directed extensional event. In this model, the Cork Fault might have been reactivated as a Neoproterozoic strike-slip fault. If this model is correct, then the NW-trending structural grain in the western Thomson Orogen reflecting the west-dipping detachments imaged in the forward models and the BMR Deep Seismic Surveys might have occurred at this time.

Steeply dipping slate, phyllite and quartzite were intersected in several wells located over the NE-trending high gravity belt associated with the Warbreccan - Newland Structure and in the Maneroo Platform (Murray and Kirkegaard, 1978). Rb – Sr and K –Ar isotopic date on basement phyllite in AAP Fermoy 1 gave Cambrian ages (Harding, 1969; Murray and Kirkegaard, 1978). Late Cambrian crustal shortening is recorded in the Anakie Inlier and Charters Tower Province further to the east (Fergusson et al., 2001; Fergusson et al., 2007a; Withnall et al., 1995; Withnall et al., 1996). This suggests that a deformational episode coeval to the Delamerian Orogeny affected the northern Thomson Orogen (Draper, 2006; Spampinato et al., Unpublished results-a). This tectonic event is interpreted to have initiated or reactivated north-dipping faults that connect to the Cork Fault. The Neoproterozoic to Early Cambrian sedimentary sequences might have been inverted and uplifted (Fig. 17) resulting in the high gravity belt bounding the Cork Fault. However, the Late Ordovician to Early Silurian Benambran Orogeny, which is recorded in the Greenvale Province, Anakie Inlier and Charters Towers Province to the east (Fergusson et al., 2005; Fergusson et al., 2007b) and the Koonenberry Belt (Greenfield et al., 2011) and Lachlan Orogen (Burton, 2010; Cayley, 2011; Cayley et al., 2011; Foster and Gray, 2000) to the south of the Thomson Orogen along with the Carboniferous Kanimblan Orogeny that affected the Thomson Orogen (Finlayson, 1993; Leven and Finlayson, 1986; Leven et al., 1990) could have also reactivated the existing fault architecture and contributed to the inversion of meta-sedimentary basement rocks of the Thomson Orogen.

Insert Figure 17 here

10 Conclusions

Geophysical interpretation and potential field forward modelling across the Cork Fault indicate that the boundary between the Mount Isa terrane and the Thomson Orogen is not sharp. High angle, listric faults displace the magnetic crust which gradually deepens toward the southeast. The lower crust of the Thomson Orogen is petrophysically indistinguishable from the continental crust of the Mount Isa terrane. We suggest that the lower crust of the Thomson Orogen is attenuated continental crust with Precambrian affinities.

The timing of initiation of the Cork Fault might be dated to the Mesoproterozoic and may be related to the continental re-organization of the Australian continent that led to the separation of the Mount Isa terrane from the Curnamona Province. The mechanism of separation involves initial N-S to NNW-SSE extension and development of normal faults. During the Rodinia break-up, the Cork Fault might have been reactivated as a strike-slip fault, being in a favourable orientation and formed part of the NE-striking strike-slip faults and NW-oriented normal faults that accommodated the deposition of the Late Neoproterozoic to Early Cambrian stratigraphy. The northern part of the Thomson Orogen was likely affected by Early Palaeozoic deformational events. Deformation was controlled by the pre-existing fault network and resulted in the formation of a positive gravity belt that bound the southern termination of the Mount Isa terrane.

The protracted tectonic history of the Cork Fault results in a variety of geophysical responses that should be regarded as the expression of a complex interaction between several geological elements.

Acknowledgement

The 2006 Mount Isa Deep Crustal Seismic Survey (© Commonwealth of Australia – Geoscience Australia 2009) was acquired by Geoscience Australia under the Onshore Energy Security Program, in collaboration with the Queensland Geological Survey, the pmd*CRC and Zinifex which are gratefully acknowledged. Geoscience Australia is thanked and acknowledged for access to the Central Eromanga Basin Seismic Surveys (© Commonwealth of Australia – Geoscience Australia) which were conducted by The Bureau of Mineral Resources. TMI magnetic and Bouguer gravity grids (© Commonwealth of Australia – Geoscience Australia 2009) were thankfully obtained from Geoscience Australia. We would like to thank the reviewers of this paper for providing constructive feedback.

Figure captions

Fig. 1 Area of study over a TMI magnetic grid; on the bottom right, TMI magnetic map of the Australian continent. Values in the legend bar are in nT.

Fig. 2 a) tectonic subdivision of the Mount Isa Inlier, modified from Blake (1987) and O'Dea (1997b); b) Simplified tectonic map showing the position and extent of the Mount Isa Inlier along with its geophysical domain, modified from Wellman (1992); c) Distribution of some of the central and eastern Australian orogens, modified from Glen (2005).

Fig. 3 Time - space diagram illustrating the major depositional sequences and deformation events across the Mount Isa terrane and the Thomson Orogen from the Palaeoproterozoic to Late Palaeozoic; modified from Murray (1990), O'Dea et al. (1997b), Betts et al. (2006) and Foster and Austin (2008).

Fig. 4 Map of the geological domains and major structural features of the southern Mount Isa terrane and the Thomson Orogen.

Fig. 5 Location of some of the 2006 Deep Seismic Transects crossing the Mount Isa terrane; 1980 - 1984 BMR Central Eromanga deep seismic reflection profiles; basement-intersecting drill holes over a composite total magnetic and tilt derivative magnetic map. Values in the legend bar are in nT; modified from Korsch et al. (2009).

Fig. 6 interpreted seismic transects 06GA-M6; modified from Korsch et al. (2008).

Fig. 7 Deep Seismic Traverse n. 3 of the BMR Central Eromanga deep seismic sections along with the main structures; modified from Finlayson et al. (1990a).

Fig. 8 Approximate location of 4 seconds reflection seismic surveys.

Fig. 9 Location of the forward models 1 (Fig. 13), 2 (Fig. 14) and 3 (Fig. 15) and constraining drill holes over a composite RTP and vertical derivative magnetic map. Values in the scale bar are in nT.

Fig. 10 Bouguer gravity map of the boundary between the Mount Isa terrane and the Thomson Orogen. Values in the legend bar are in μm*s^{-2}.

Fig. 11 Vertical derivative Bouguer gravity map over a grey tilt and vertical derivative magnetic map of the boundary between the Mount Isa terrane and the Thomson Orogen. CoF= Cork Fault; WaF= Warbreccan Fault; CaF=Canaway Fault; HF=Harkaway Fault. Values in the legend bar are in μm*s^{-2} / m.

Fig. 12 Lithological map of the southernmost part of the Mount Isa terrane and the northern Thomson Orogen

Fig. 13 Forward model n. 1; MI= Mount Isa terrane; DR= Diamantina River Domain; MF= Major SE-dipping fault; CR= Canaway Fault; TO = Thomson Orogen basement; MC= Magnetic crust; NMC= Non-magnetic crust; Yellow line= Curie depth. Density is in g/cm^3 and susceptibility is in SI units.

Fig. 14 Forward model n. 2; HF= Harkaway Fault; WIF= Windorah-Ingella Fault; MF= Moothandella Fault; TO = Thomson Orogen basement; MC= magnetic crust; NMC= Non-magnetic crust; Curie depth= 24 km. Density is in g/cm^3 and susceptibility is in SI units.

Fig. 15 Forward model n. 3; MI= Mount Isa terrane; CF= Cork Fault; DR= Diamantina River Domain; WF= Warbreccan Fault; TO = Thomson Orogen basement; MC= Magnetic crust; NMC= Non-magnetic crust; Yellow line= Curie depth. Density is in g/cm^3 and susceptibility is in SI units. The density of the upper (non-reflective) Thomson Orogen is always 2.73 g/ cm^3 unless otherwise specified.

Fig. 16 Mid-Proterozoic reconstruction of the Australian continent after a) Giles et al. (2004); modified from Williams et al. (2010); b) Henson (2011) c) Gibson et al. (Gibson et al., 2008) d) Betts & Giles (2006).

Fig. 17 Sketch showing the inferred Late Cambrian shortening event within the Diamantina River Domain.

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Highlights

- The Cork Fault juxtaposes the Mount Isa Inlier and the Thomson Orogen.
- The deep crusts of the two provinces are petrophysically indistinguishable.
- The lower crust of the Thomson Orogen consists of thinned Precambrian crust.
- The Cork Fault does not represent the eastern margin of Rodinia.
- The Cork Fault was a post-1500 Ma S-dipping normal fault during N-S extension.

Figure1

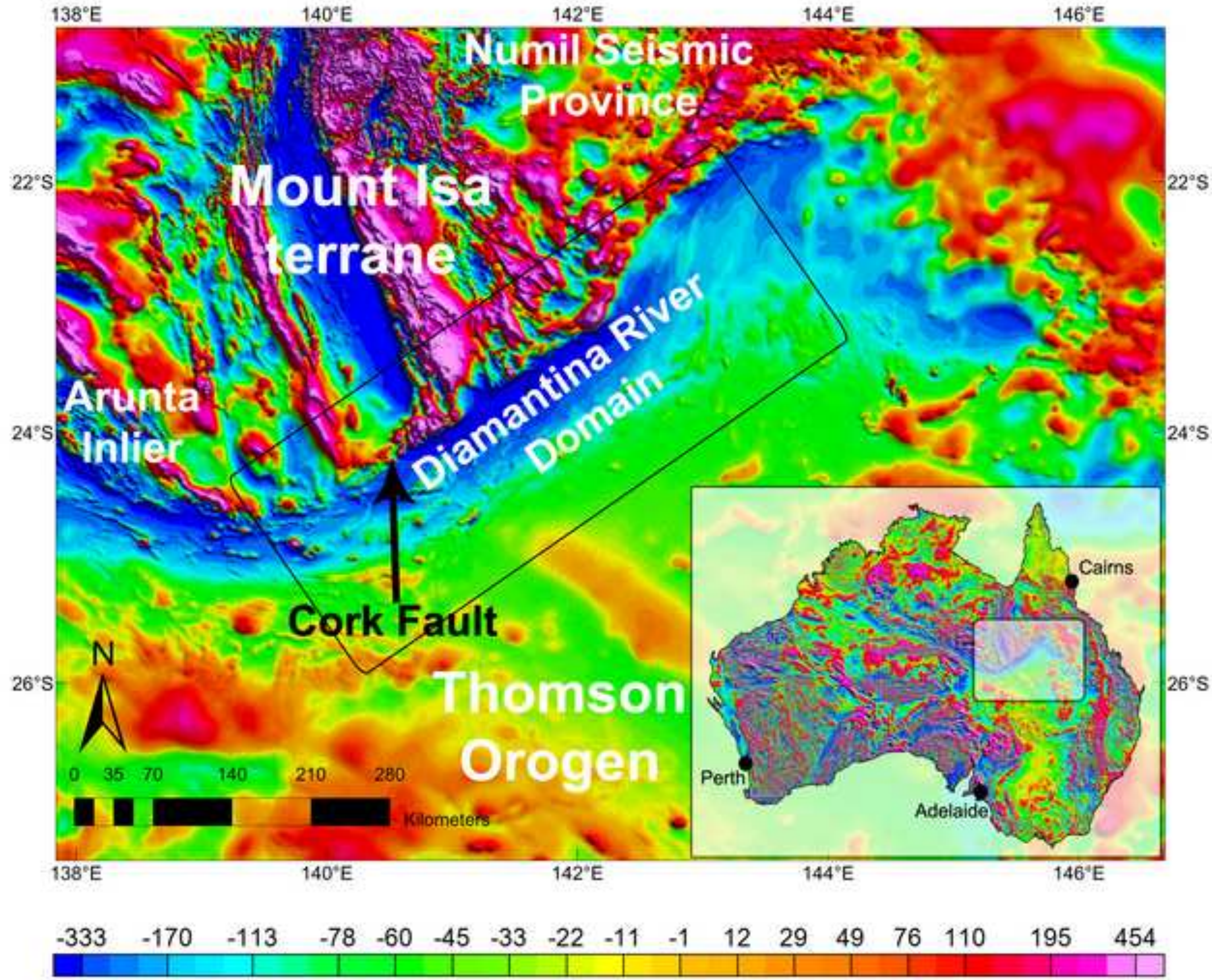
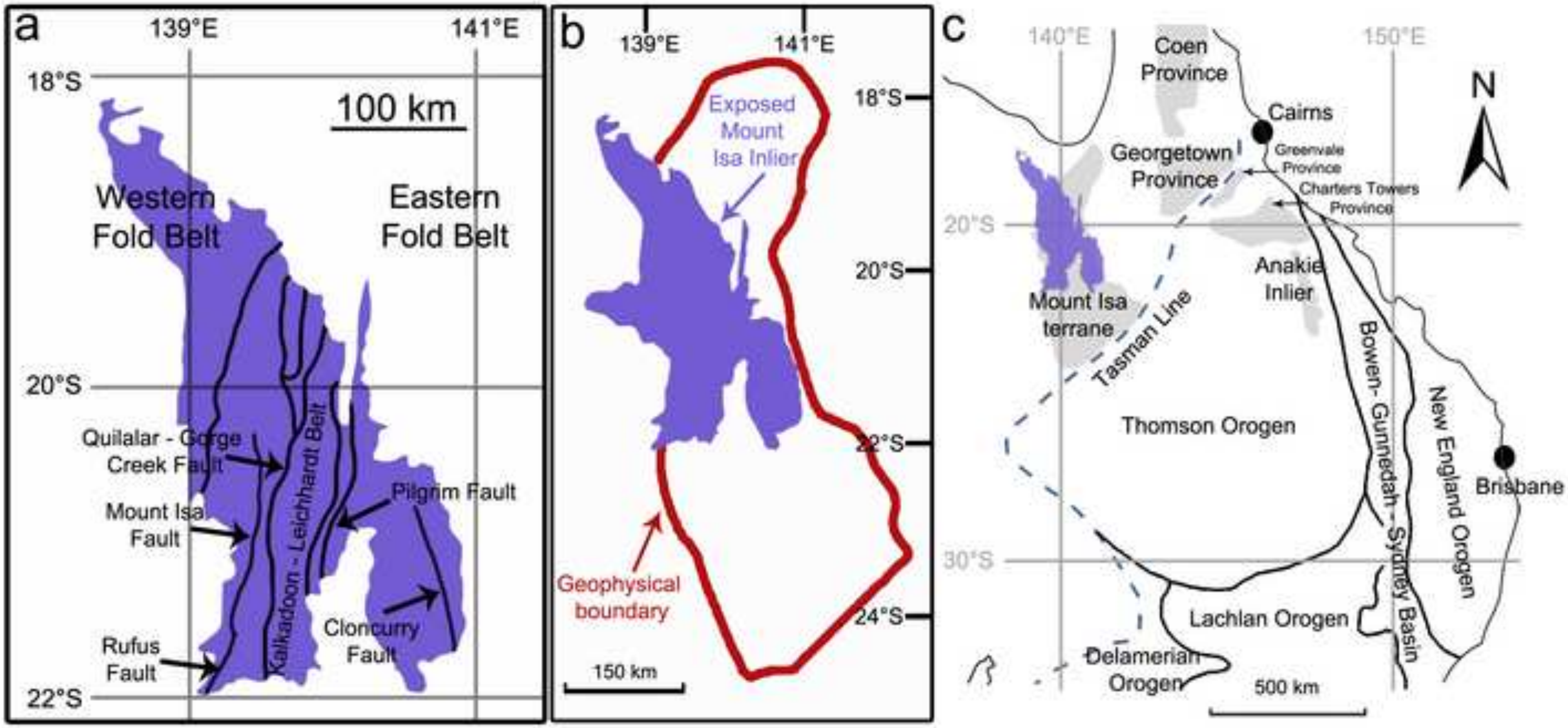

138°E
140°E
142°E
144°E
146°E
22°S
24°S
26°S
Numil Seismic Province
Mount Isa terrane
Arunta Inlier
Diamantina River Domain
Cork Fault
Thomson Orogen
N
0 35 70 140 210 280
Kilometers
Cairns
Perth
Adelaide
-333 -170 -113 -78 -60 -45 -33 -22 -11 -1 12 29 49 76 110 195 454

Figure2


a
139°E
141°E
18°S
100 km
Western Fold Belt
Eastern Fold Belt
20°S
Quilalar - Gorge Creek Fault
Kalkadoon - Leichhardt Belt
Pilgrim Fault
Mount Isa Fault
Cloncurry Fault
Rufus Fault
22°S
b
139°E
141°E
Exposed Mount Isa Inlier
18°S
20°S
22°S
24°S
Geophysical boundary
150 km
c
140°E
150°E
Coen Province
Cairns
N
Georgetown Province
Greenvale Province
Charters Towers Province
20°S
Anakie Inlier
Mount Isa terrane
Tasman Line
Thomson Orogen
Bowen- Gunnedah - Sydney Basin
New England Orogen
Brisbane
30°S
Lachlan Orogen
Delamerian Orogen
500 km

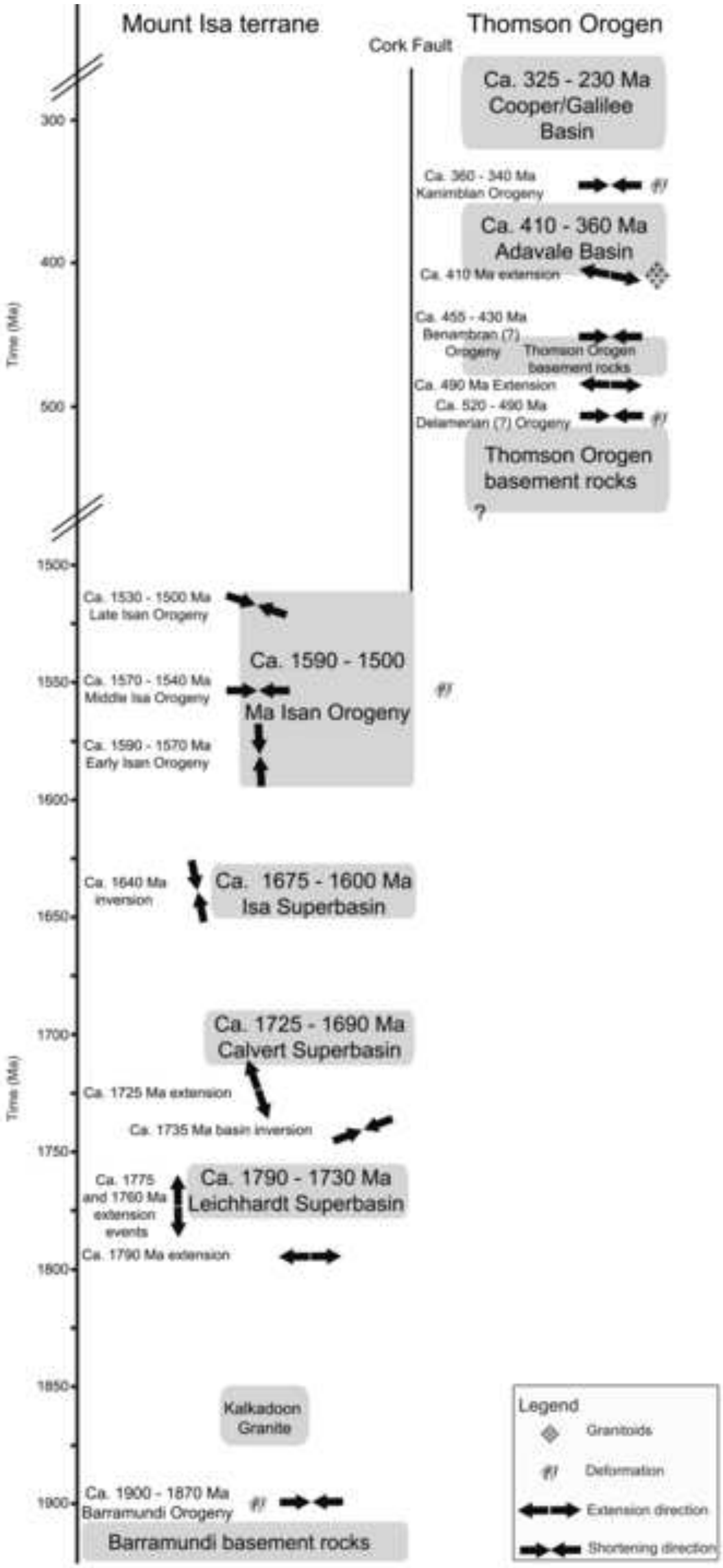
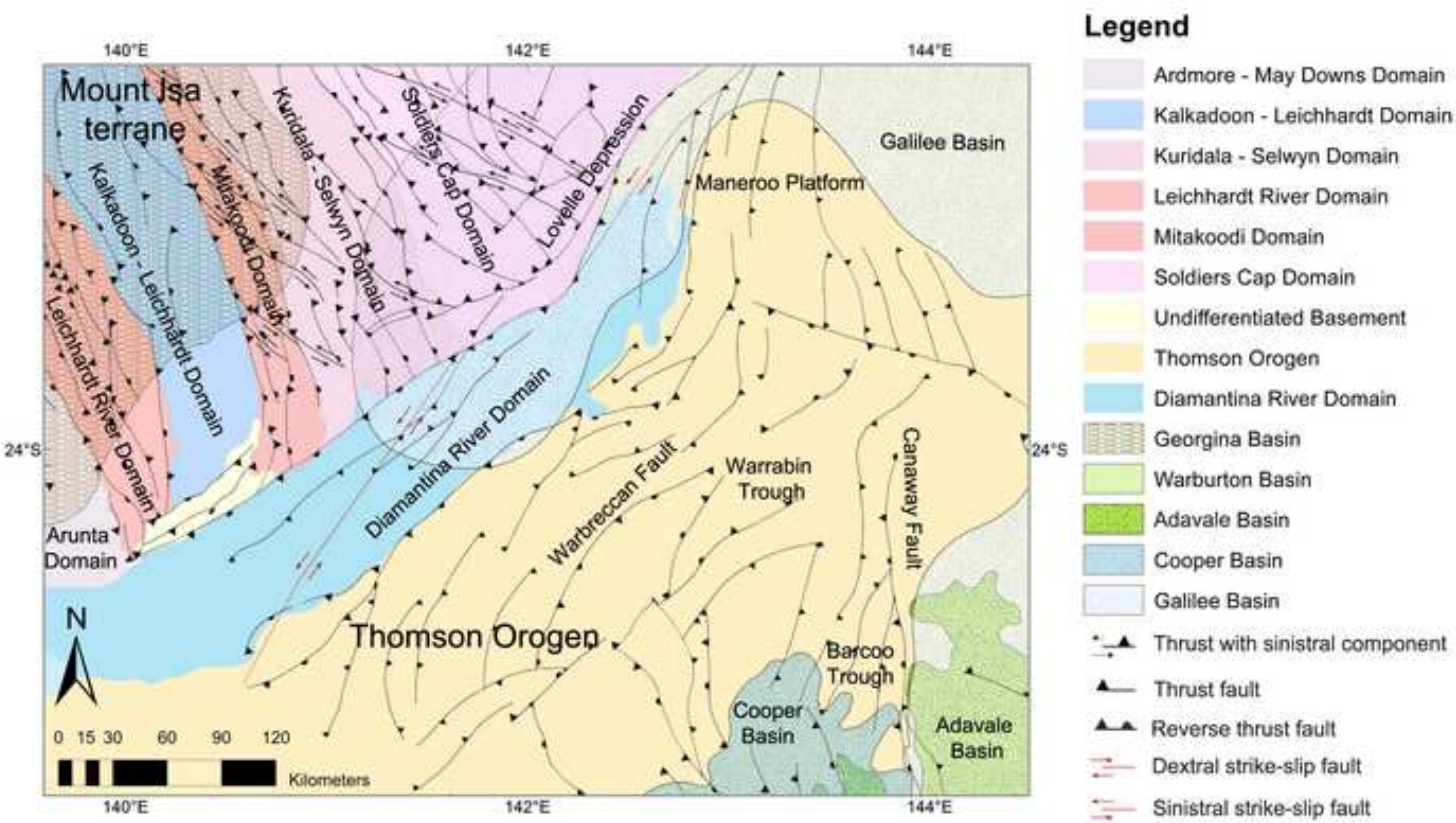

Mount Isa terrane
Thomson Orogen
Cork Fault
Time (Ma)
300
400
500
1500
1550
1600
1650
1700
1750
1800
1850
1900
Ca. 325 - 230 Ma Cooper/Galilee Basin
Ca. 360 - 340 Ma Kanimblan Orogeny
Ca. 410 - 360 Ma Adavale Basin
Ca. 410 Ma extension
Ca. 455 - 430 Ma Benambran (?) Orogeny
Thomson Orogen basement rocks
Ca. 490 Ma Extension
Ca. 520 - 490 Ma Delamerian (?) Orogeny
Thomson Orogen basement rocks
?
Ca. 1530 - 1500 Ma Late Isan Orogeny
Ca. 1590 - 1500 Ma Isan Orogeny
Ca. 1570 - 1540 Ma Middle Isa Orogeny
Ca. 1590 - 1570 Ma Early Isan Orogeny
Ca. 1640 Ma inversion
Ca. 1675 - 1600 Ma Isa Superbasin
Ca. 1725 - 1690 Ma Calvert Superbasin
Ca. 1725 Ma extension
Ca. 1735 Ma basin inversion
Ca. 1775 and 1760 Ma extension events
Ca. 1790 - 1730 Ma Leichhardt Superbasin
Ca. 1790 Ma extension
Kalkadoon Granite
Ca. 1900 - 1870 Ma Barramundi Orogeny
Barramundi basement rocks
Legend
Granitoids
Deformation
Extension direction
Shortening direction

Figure4



Mount Isa terrane
Kalkadoon - Leichhardt Domain
Mitakoodi Domain
Kuridala - Selwyn Domain
Soldiers Cap Domain
Lovelle Depression
Leichhardt River Domain
Arunta Domain
Diamantina River Domain
Maneroo Platform
Galilee Basin
Warbreccan Fault
Warrabin Trough
Canaway Fault
Thomson Orogen
Barcoo Trough
Cooper Basin
Adavale Basin
140°E
142°E
144°E
24°S
N
0 15 30 60 90 120
Kilometers
Legend
Ardmore - May Downs Domain
Kalkadoon - Leichhardt Domain
Kuridala - Selwyn Domain
Leichhardt River Domain
Mitakoodi Domain
Soldiers Cap Domain
Undifferentiated Basement
Thomson Orogen
Diamantina River Domain
Georgina Basin
Warburton Basin
Adavale Basin
Cooper Basin
Galilee Basin
Thrust with sinistral component
Thrust fault
Reverse thrust fault
Dextral strike-slip fault
Sinistral strike-slip fault

Figure5

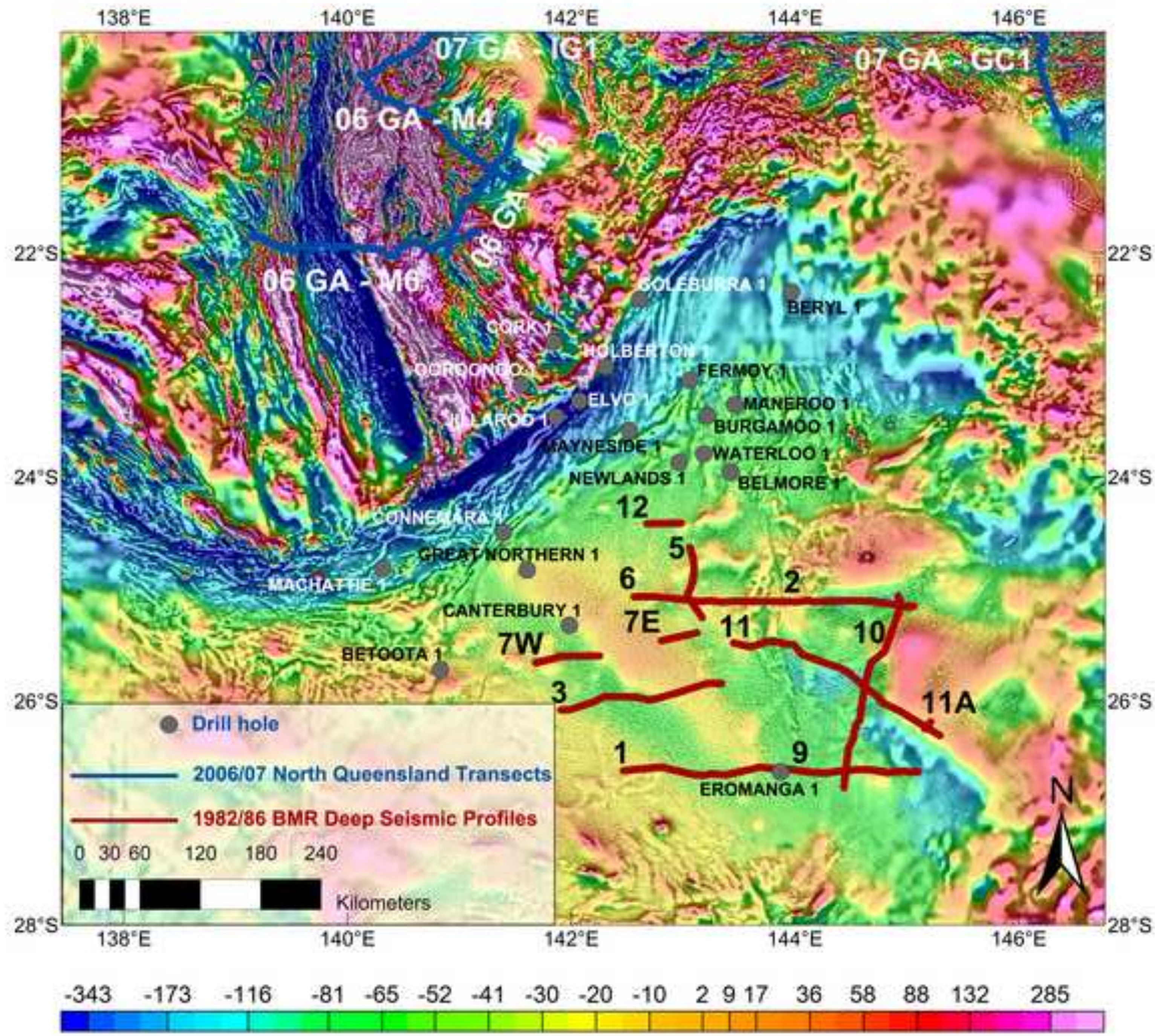

138°E
140°E
142°E
144°E
146°E
22°S
24°S
26°S
28°S
07 GA - IG1
07 GA - GC1
06 GA - M4
06 GA - M5
06 GA - M6
SOLEBURRA 1
BERYL 1
CORK 1
HOLBERTON 1
OOROONOO 1
FERMOY 1
ELVO 1
MANEROO 1
BURGAMOO 1
KILLAROO 1
MAYNESIDE 1
WATERLOO 1
NEWLANDS 1
BELMORE 1
CONNEMARA 1
GREAT NORTHERN 1
MACHATTIE 1
CANTERBURY 1
BETOOTA 1
EROMANGA 1
12
5
6
2
7E
11
10
7W
3
11A
1
9
Drill hole
2006/07 North Queensland Transects
1982/86 BMR Deep Seismic Profiles
0 30 60 120 180 240
Kilometers
N
-343 -173 -116 -81 -65 -52 -41 -30 -20 -10 2 9 17 36 58 88 132 285

Figure6

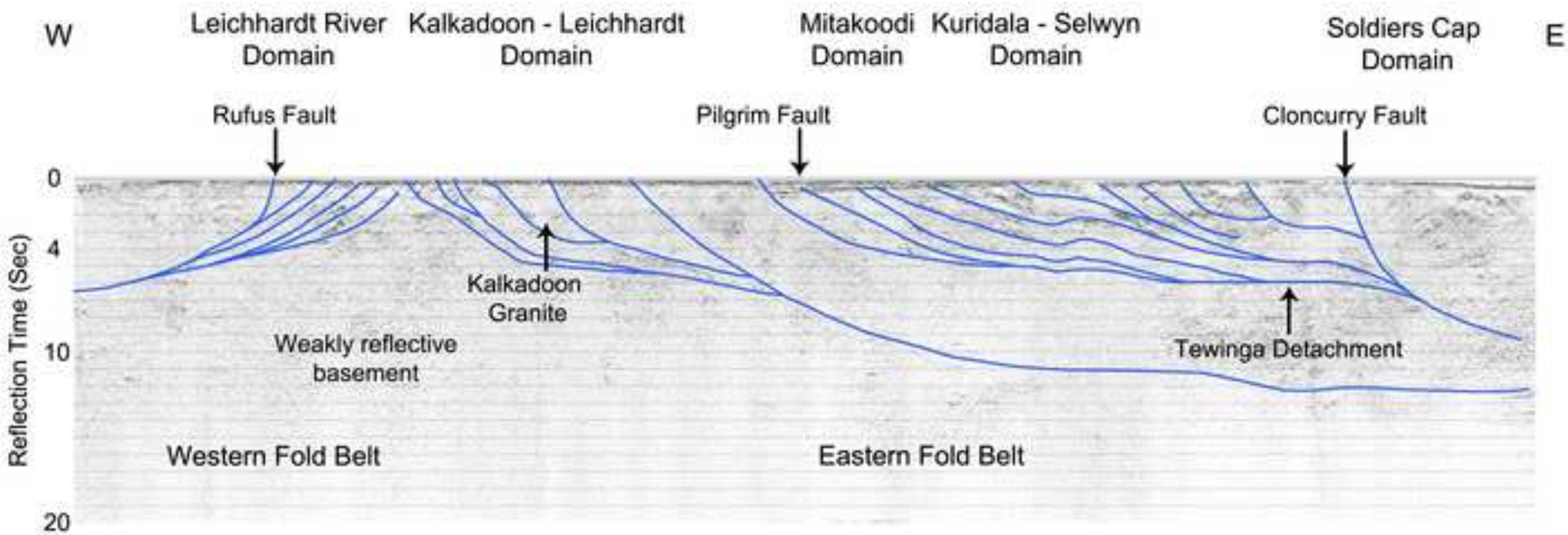

W
Leichhardt River Domain
Kalkadoon - Leichhardt Domain
Mitakoodi Domain
Kuridala - Selwyn Domain
Soldiers Cap Domain
E
Rufus Fault
Pilgrim Fault
Cloncurry Fault
0
4
10
20
Reflection Time (Sec)
Kalkadoon Granite
Weakly reflective basement
Tewinga Detachment
Western Fold Belt
Eastern Fold Belt

Figure7

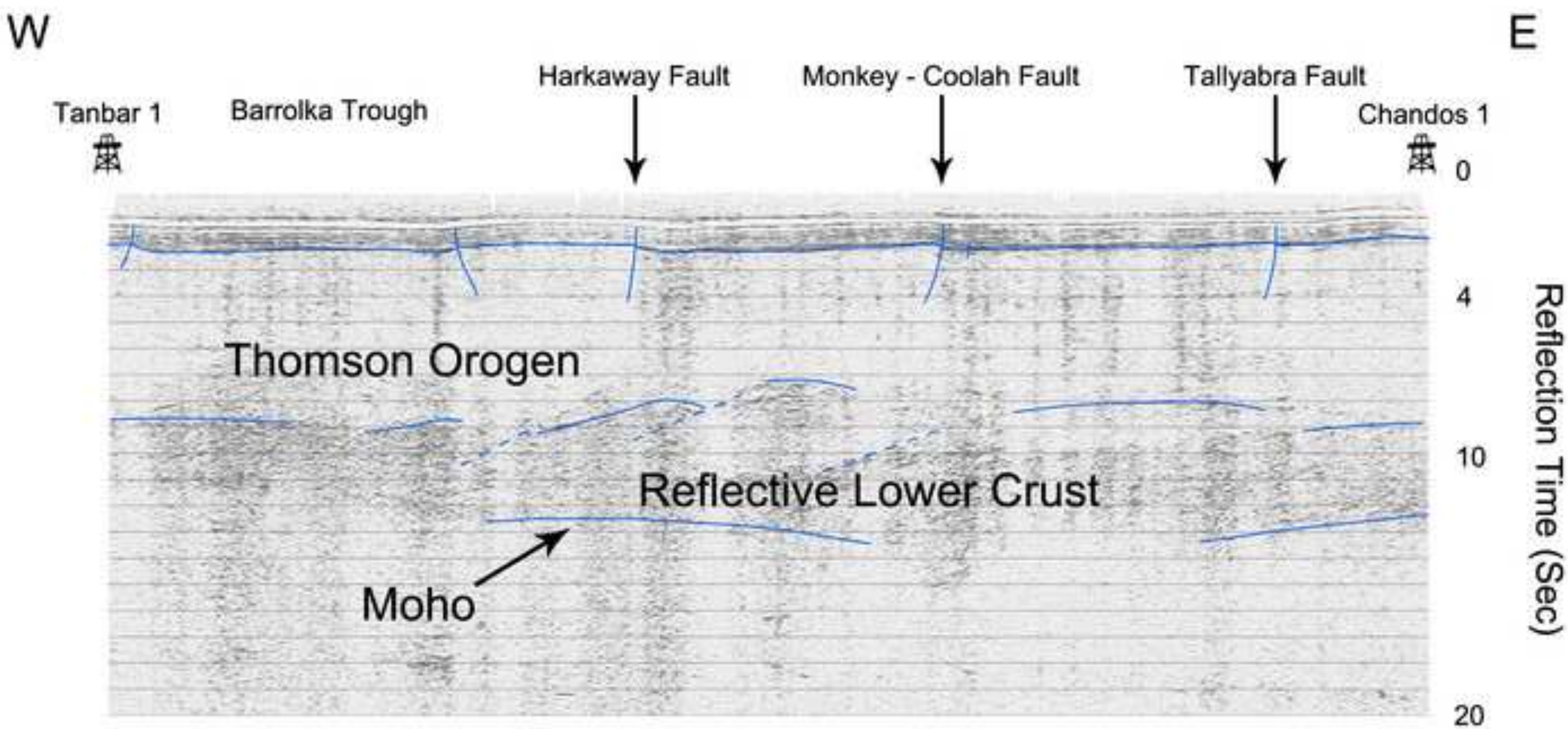

W
E
Harkaway Fault
Monkey - Coolah Fault
Tallyabra Fault
Tanbar 1
Barrolka Trough
Chandos 1
0
4
10
20
Reflection Time (Sec)
Thomson Orogen
Reflective Lower Crust
Moho

Figure8

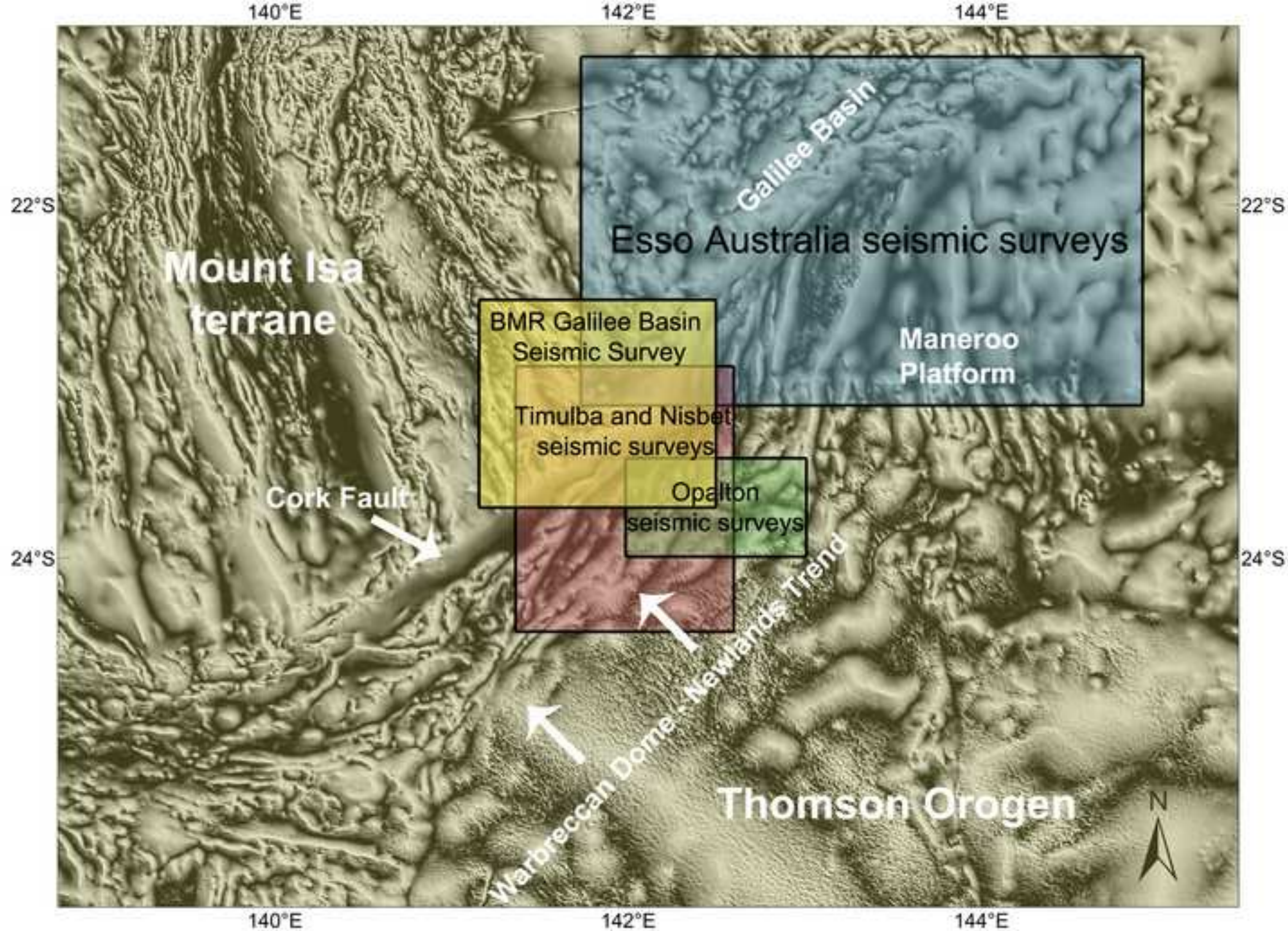
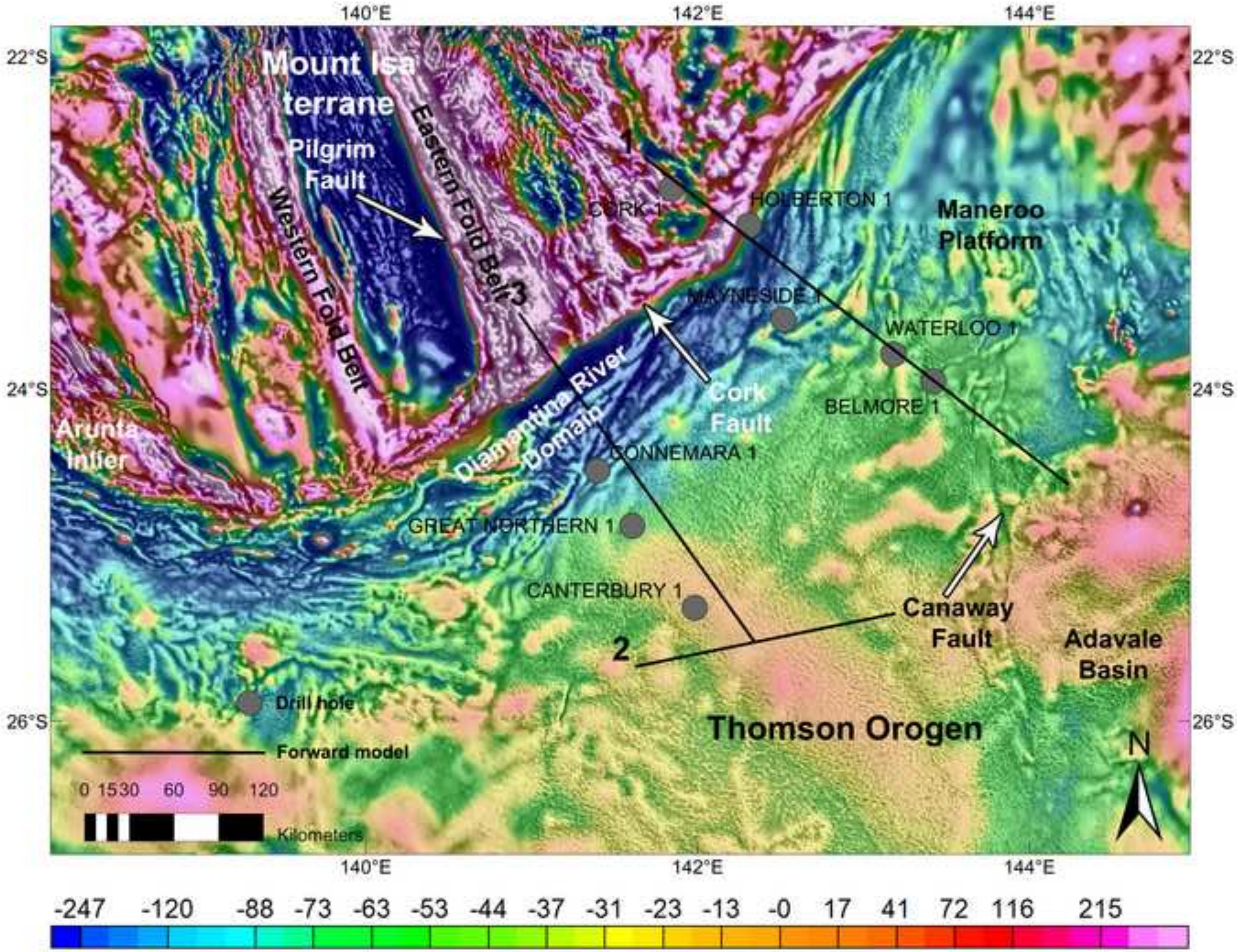

140°E
142°E
144°E
22°S
24°S
Galilee Basin
Esso Australia seismic surveys
Mount Isa terrane
BMR Galilee Basin Seismic Survey
Maneroo Platform
Timulba and Nisbet seismic surveys
Opalton seismic surveys
Cork Fault
Warbreccan Dome - Newlands Trend
Thomson Orogen
N

Figure9


140°E
142°E
144°E
22°S
24°S
26°S
Mount Isa terrane
Pilgrim Fault
Eastern Fold Belt
Western Fold Belt
1
2
3
CORK 1
HOLBERTON 1
Maneroo Platform
MAYNESIDE 1
WATERLOO 1
BELMORE 1
Cork Fault
Diamantina River Domain
Arunta Inlier
CONNEMARA 1
GREAT NORTHERN 1
CANTERBURY 1
Canaway Fault
Adavale Basin
Drill hole
Thomson Orogen
Forward model
0 15 30 60 90 120
Kilometers
N
-247 -120 -88 -73 -63 -53 -44 -37 -31 -23 -13 -0 17 41 72 116 215

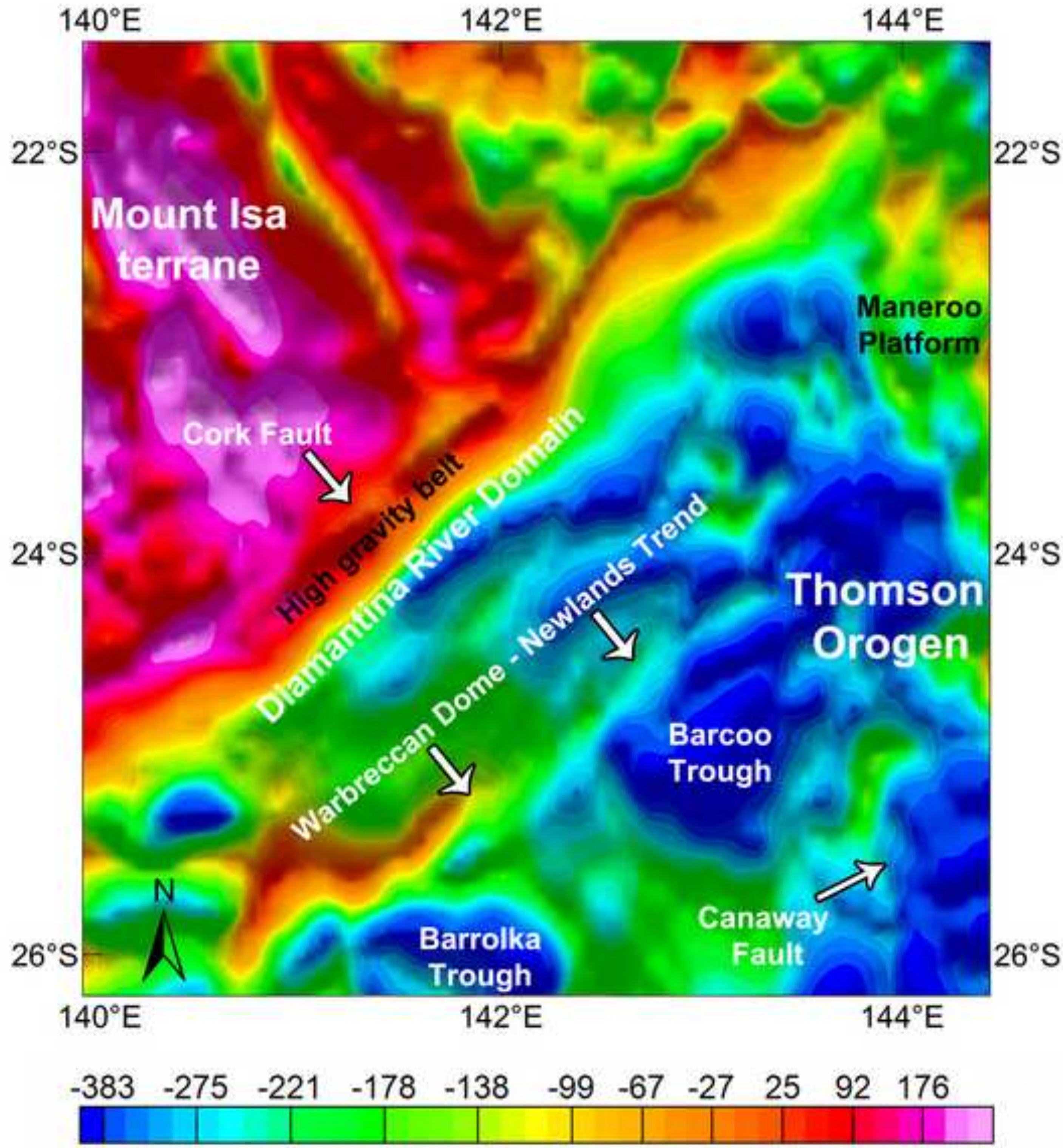
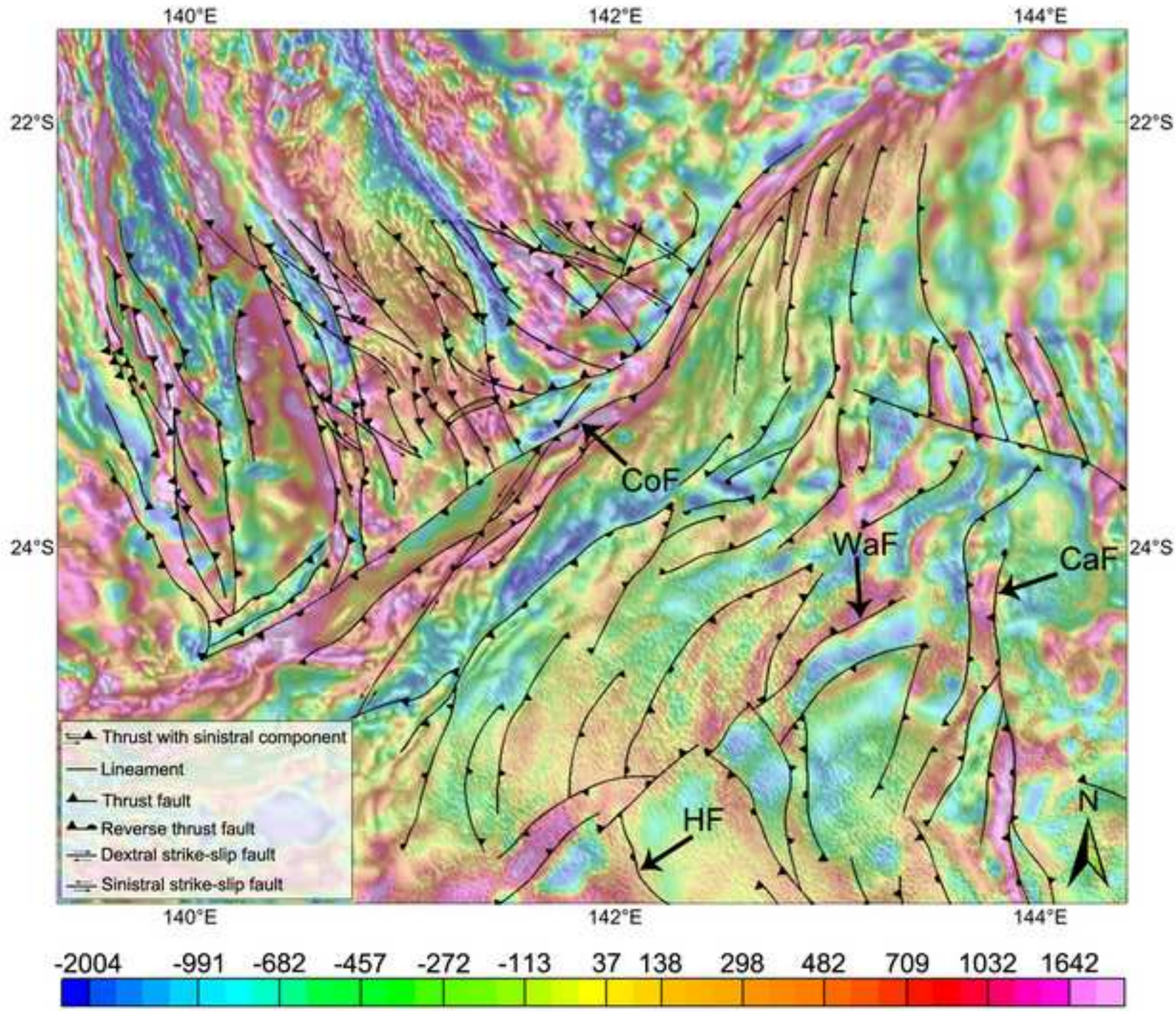

140°E
142°E
144°E
22°S
24°S
26°S
Mount Isa terrane
Cork Fault
High gravity belt
Diamantina River Domain
Warbreccan Dome - Newlands Trend
Maneroo Platform
Thomson Orogen
Barcoo Trough
Canaway Fault
Barrolka Trough
N
-383 -275 -221 -178 -138 -99 -67 -27 25 92 176

Figure11



140°E
142°E
144°E
22°S
24°S
CoF
WaF
CaF
HF
N
Thrust with sinistral component
Lineament
Thrust fault
Reverse thrust fault
Dextral strike-slip fault
Sinistral strike-slip fault
-2004
-991
-682
-457
-272
-113
37
138
298
482
709
1032
1642

Figure12

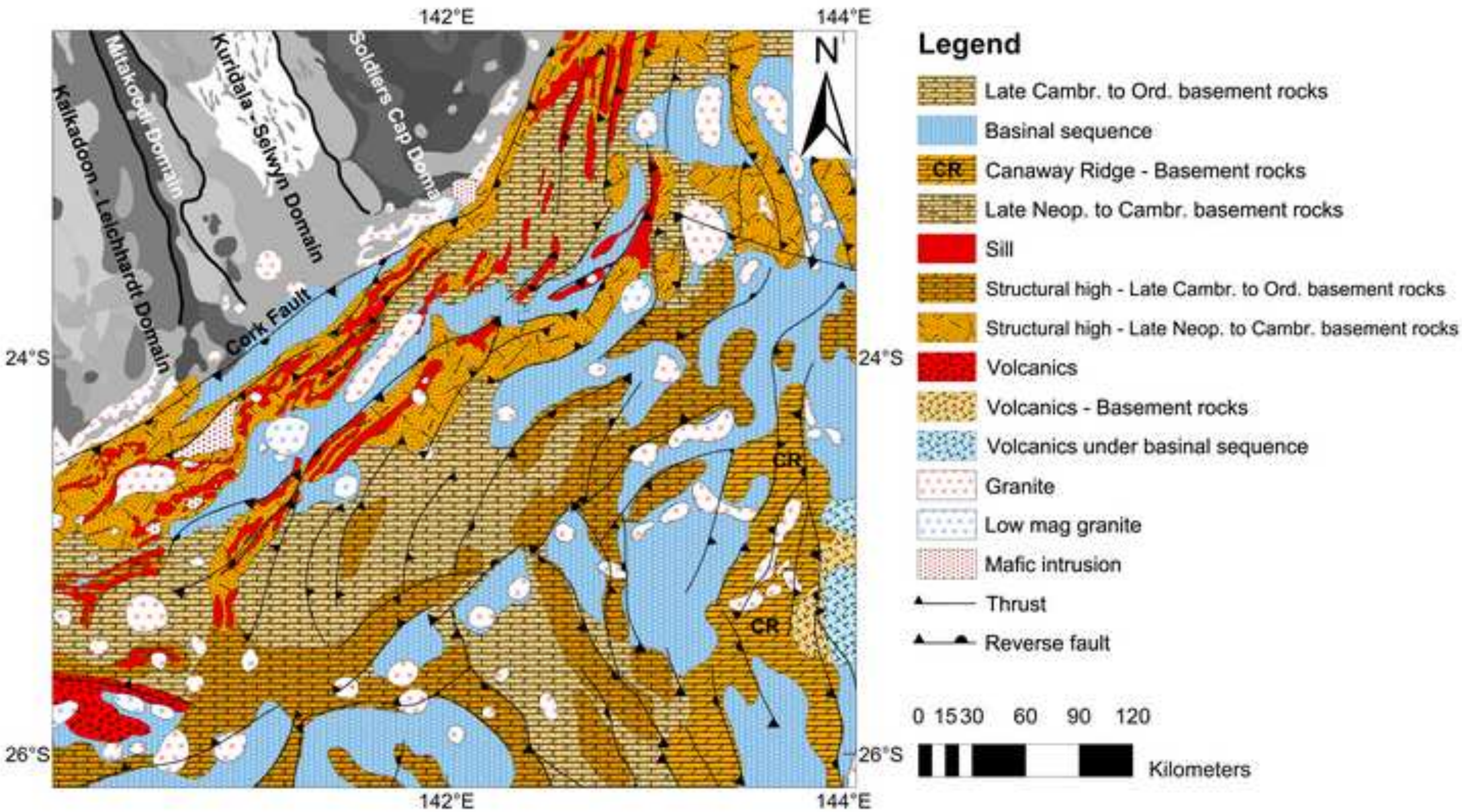
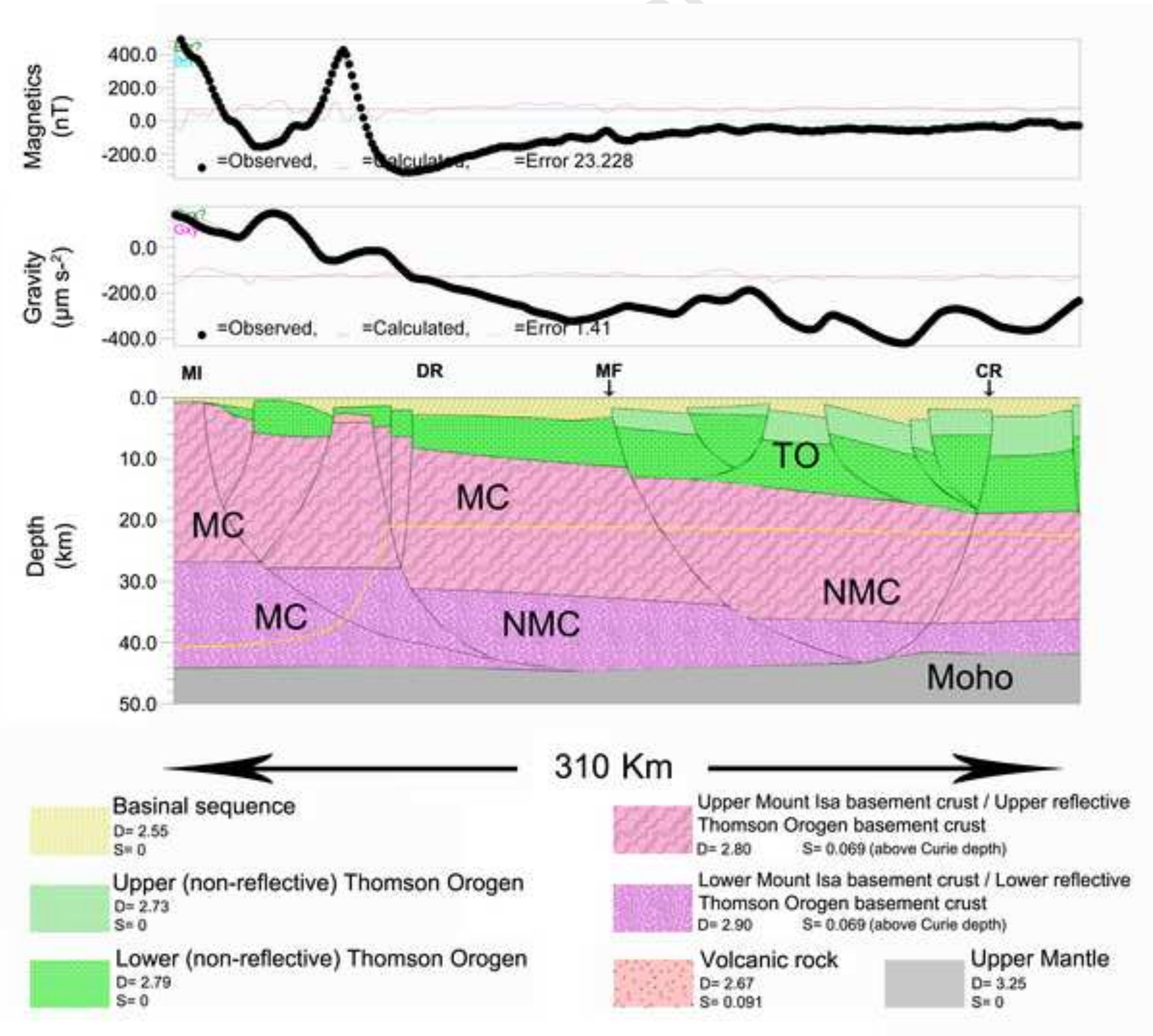

142°E
144°E
N
Kalkadoon - Leichhardt Domain
Mitakoodi Domain
Kuridala - Selwyn Domain
Soldiers Cap Domain
Cork Fault
CR
CR
24°S
24°S
26°S
26°S
142°E
144°E
Legend
Late Cambr. to Ord. basement rocks
Basinal sequence
CR Canaway Ridge - Basement rocks
Late Neop. to Cambr. basement rocks
Sill
Structural high - Late Cambr. to Ord. basement rocks
Structural high - Late Neop. to Cambr. basement rocks
Volcanics
Volcanics - Basement rocks
Volcanics under basinal sequence
Granite
Low mag granite
Mafic intrusion
Thrust
Reverse fault
0 15 30 60 90 120
Kilometers

Figure13



Magnetics (nT)
400.0
200.0
0.0
-200.0
=Observed,
=Calculated,
=Error 23.228
Gravity (µm s-2)
0.0
-200.0
-400.0
=Observed,
=Calculated,
=Error 1.41
MI
DR
MF
CR
Depth (km)
0.0
10.0
20.0
30.0
40.0
50.0
TO
MC
MC
MC
NMC
NMC
Moho
310 Km
Basinal sequence
D= 2.55
S= 0
Upper (non-reflective) Thomson Orogen
D= 2.73
S= 0
Lower (non-reflective) Thomson Orogen
D= 2.79
S= 0
Upper Mount Isa basement crust / Upper reflective Thomson Orogen basement crust
D= 2.80 S= 0.069 (above Curie depth)
Lower Mount Isa basement crust / Lower reflective Thomson Orogen basement crust
D= 2.90 S= 0.069 (above Curie depth)
Volcanic rock
D= 2.67
S= 0.091
Upper Mantle
D= 3.25
S= 0

Figure14

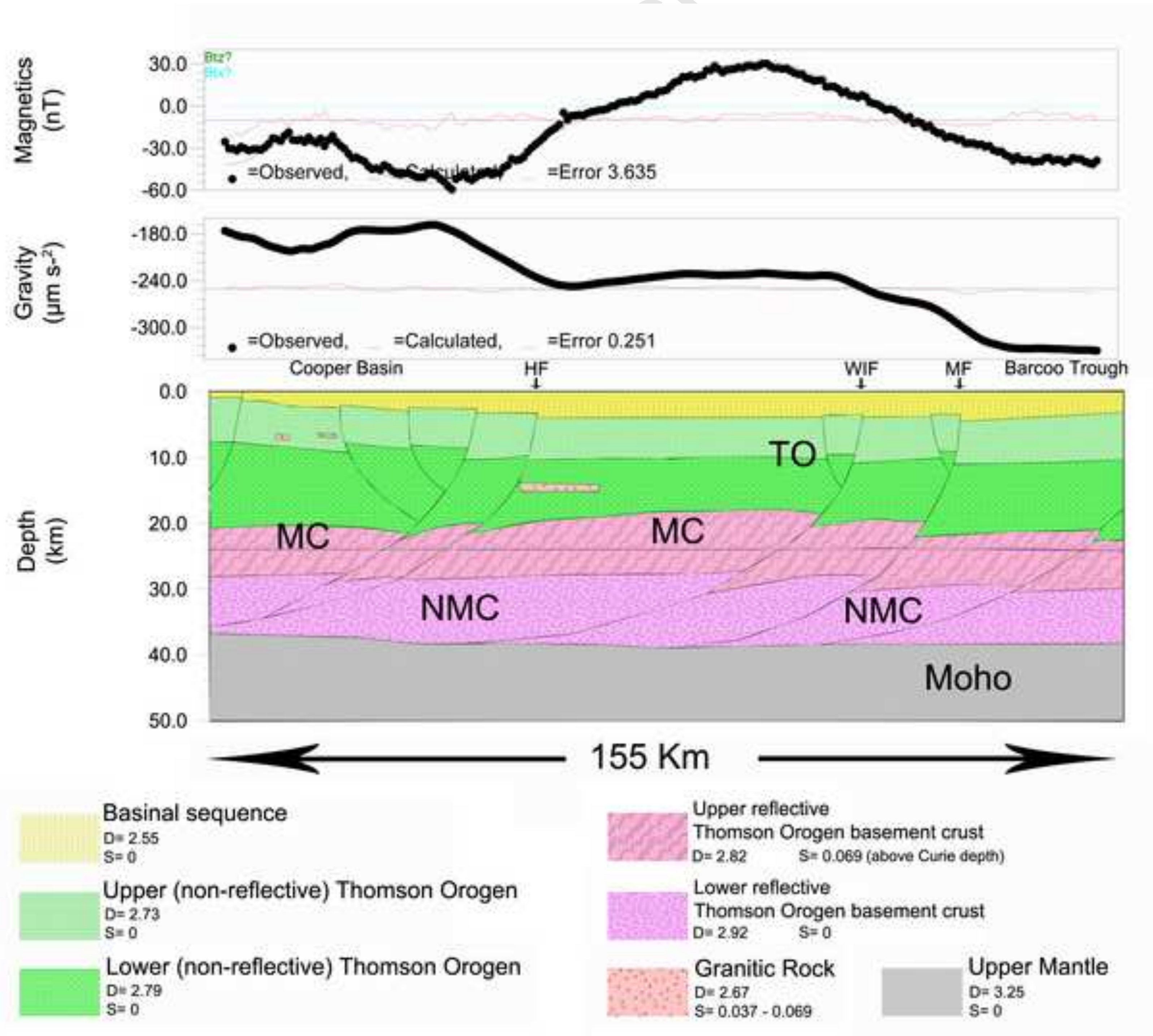

Magnetics (nT)
30.0
0.0
-30.0
-60.0
Btz?
Btx?
=Observed,
=Calculated,
=Error 3.635
Gravity (µm s-2)
-180.0
-240.0
-300.0
=Observed,
=Calculated,
=Error 0.251
Cooper Basin
HF
WIF
MF
Barcoo Trough
Depth (km)
0.0
10.0
20.0
30.0
40.0
50.0
TO
MC
MC
NMC
NMC
Moho
155 Km
Basinal sequence
D= 2.55
S= 0
Upper (non-reflective) Thomson Orogen
D= 2.73
S= 0
Lower (non-reflective) Thomson Orogen
D= 2.79
S= 0
Upper reflective
Thomson Orogen basement crust
D= 2.82
S= 0.069 (above Curie depth)
Lower reflective
Thomson Orogen basement crust
D= 2.92
S= 0
Granitic Rock
D= 2.67
S= 0.037 - 0.069
Upper Mantle
D= 3.25
S= 0

Figure15

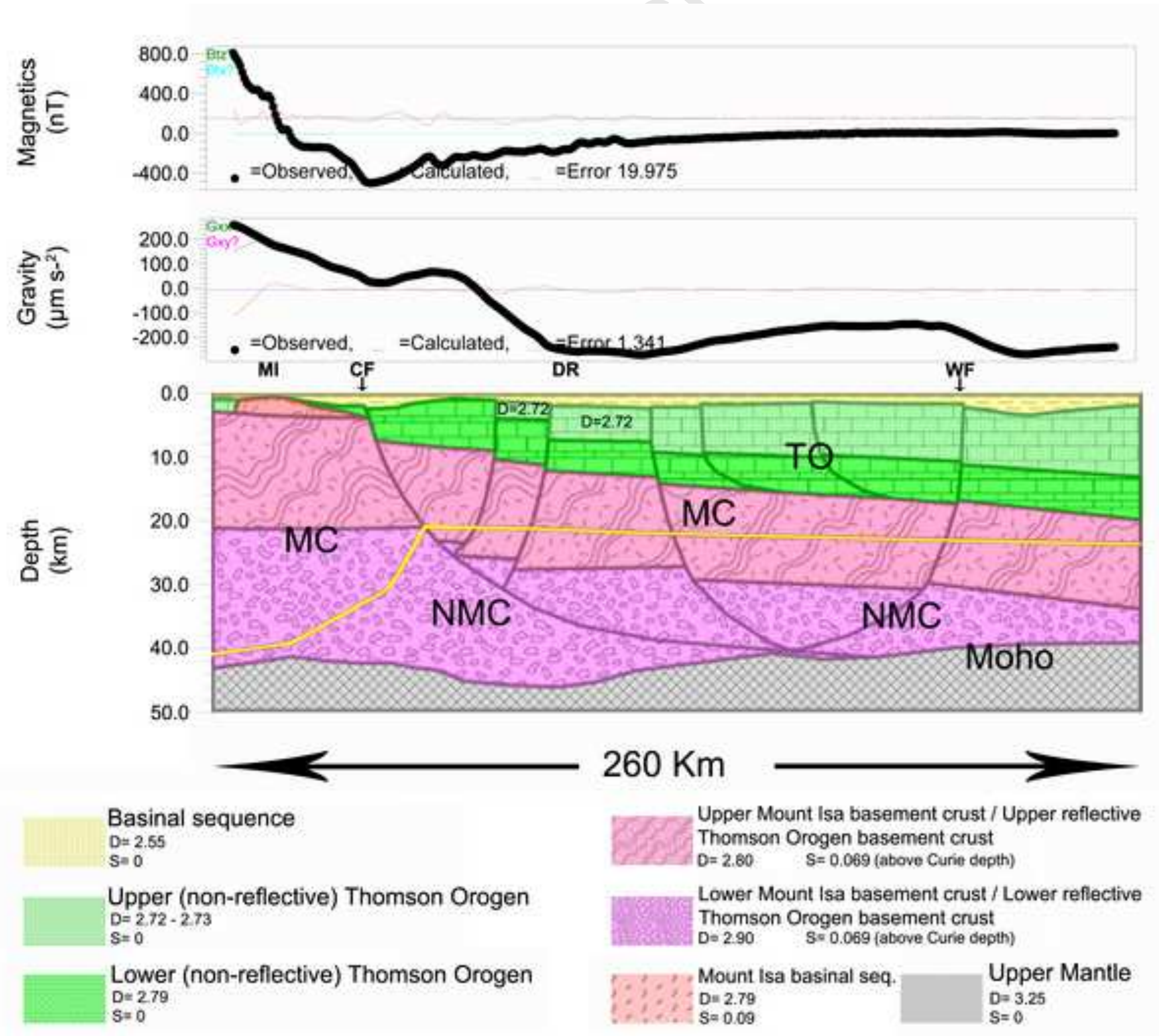

Magnetics (nT)
800.0
400.0
0.0
-400.0
• =Observed, Calculated, =Error 19.975
Gravity (µm s-2)
200.0
100.0
0.0
-100.0
-200.0
• =Observed, =Calculated, =Error 1.341
MI
CF
DR
WF
Depth (km)
0.0
10.0
20.0
30.0
40.0
50.0
D=2.72
D=2.72
TO
MC
MC
NMC
NMC
Moho
260 Km
Basinal sequence
D= 2.55
S= 0
Upper (non-reflective) Thomson Orogen
D= 2.72 - 2.73
S= 0
Lower (non-reflective) Thomson Orogen
D= 2.79
S= 0
Upper Mount Isa basement crust / Upper reflective Thomson Orogen basement crust
D= 2.80 S= 0.069 (above Curie depth)
Lower Mount Isa basement crust / Lower reflective Thomson Orogen basement crust
D= 2.90 S= 0.069 (above Curie depth)
Mount Isa basinal seq.
D= 2.79
S= 0.09
Upper Mantle
D= 3.25
S= 0

Figure16

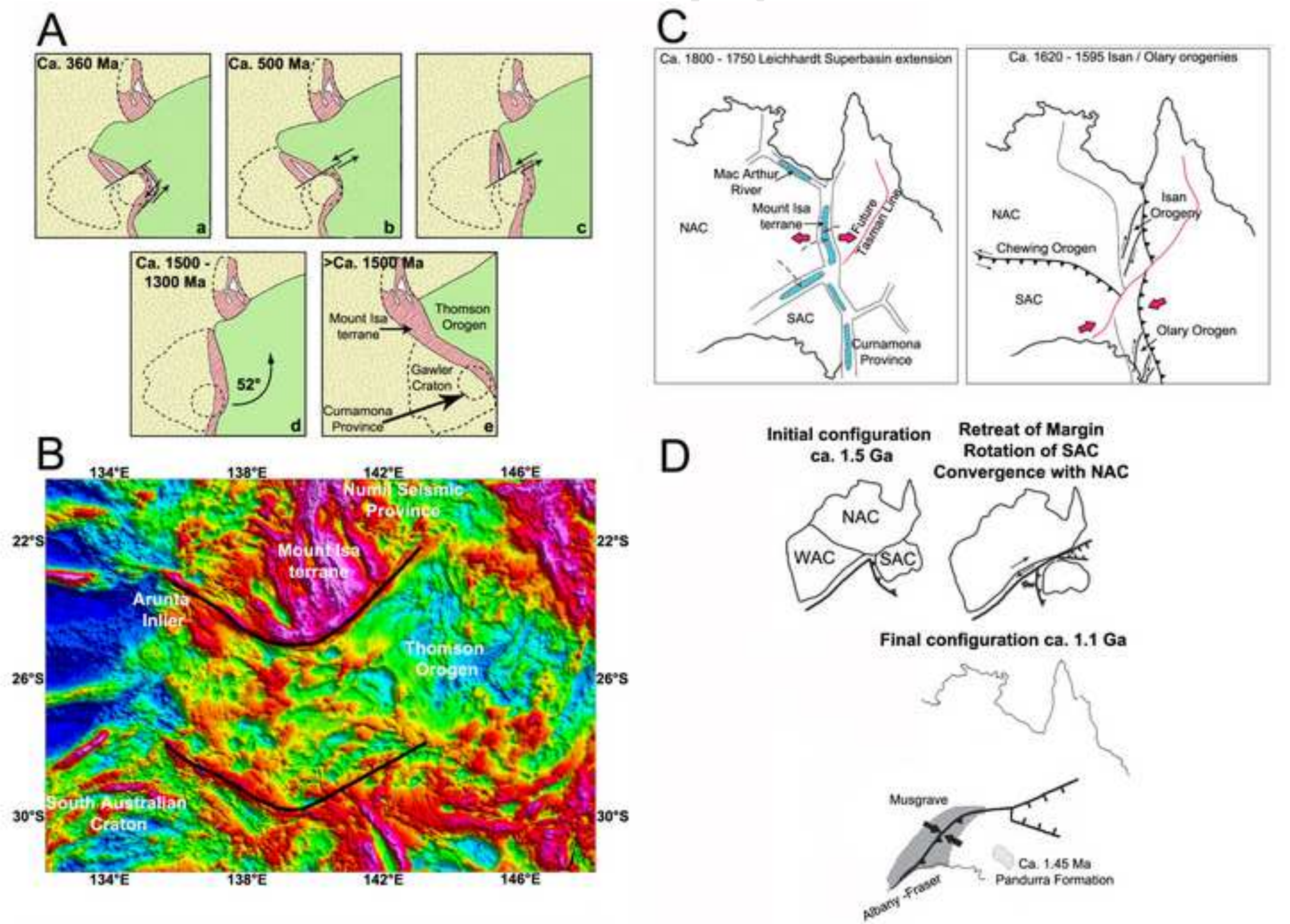
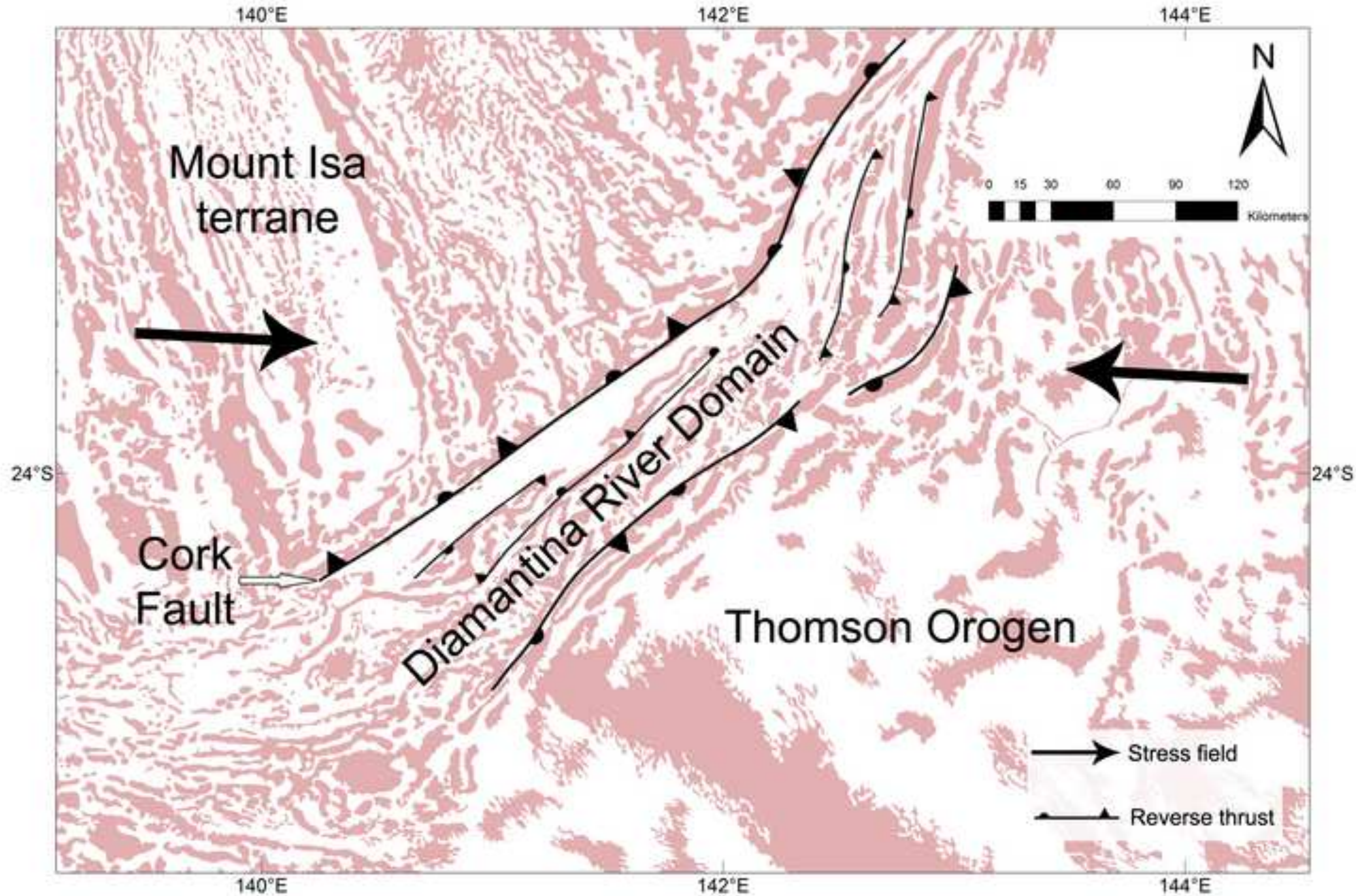

A
Ca. 360 Ma
a
Ca. 500 Ma
b
c
Ca. 1500 - 1300 Ma
52°
d
>Ca. 1500 Ma
Mount Isa terrane
Thomson Orogen
Gawler Craton
Cumamona Province
e
B
134°E
138°E
142°E
146°E
22°S
26°S
30°S
Numil Seismic Province
Mount Isa terrane
Arunta Inlier
Thomson Orogen
South Australian Craton
C
Ca. 1800 - 1750 Leichhardt Superbasin extension
Mac Arthur River
Mount Isa terrane
Future Tasman Line
NAC
SAC
Curnamona Province
Ca. 1620 - 1595 Isan / Olary orogenies
Isan Orogeny
NAC
Chewing Orogen
SAC
Olary Orogen
D
Initial configuration ca. 1.5 Ga
NAC
WAC
SAC
Retreat of Margin Rotation of SAC Convergence with NAC
Final configuration ca. 1.1 Ga
Musgrave
Albany -Fraser
Ca. 1.45 Ma Pandurra Formation

Figure17


140°E
142°E
144°E
24°S
24°S
140°E
142°E
144°E
N
0 15 30 60 90 120
Kilometers
Mount Isa
terrane
Cork
Fault
Diamantina River Domain
Thomson Orogen
Stress field
Reverse thrust