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Intraplate termination of transform faulting within the Antarctic continent

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Abstract

The sector of Antarctica facing Australia east of 139 °E is characterized by the abundance of exceptionally long oceanic fracture zones that are collinear to post-rift right-lateral strike–slip fault systems developed at the northeastern edge of the Antarctic continent. High-resolution reflection seismic profiles indicate recent strike–slip activity at the southeastern edge of the Balleny Fracture Zone, similar to what is observed onshore in North Victoria Land. The architecture, kinematics, and timing of this intraplate deformation at the northeastern edge of Antarctica cannot be reconciled with typical plate tectonic kinematics, in particular, with a classical divergent plate boundary environment. Here we show that combined geological and geophysical data in northeastern Antarctica support the post-rift southeastward reactivation of the passive margin east of 139 °E along intraplate right-lateral strike–slip deformation belts. These deformation belts include oceanic transform faults and their collinear oceanic fracture zone and continental shear zone extensions. A striking consequence is that there is intraplate accommodation of transform fault slip in this region of Earth's surface along fracture zones and a long-active region of intracontinental deformation that is 'reusing' prior plate boundary fault zones. As the intraplate termination of plate boundary transform faulting is not predicted by classical plate tectonic theory; this region is one of the most clear examples of the transition from rigid to semi-rigid plate tectonic deformation during the formation and long-lived incubation of a potential new plate boundary.
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Keywords: Antarctica; transform fault; fracture zone; plate tectonics; intraplate deformation

1. Introduction

An outstanding feature of the Antarctica–Australia plate boundary east of 139 °E is the abundance of extraordinarily well-developed fracture zones that segment the mid oceanic ridge in this part of the Southern Ocean (Fig. 1). These fracture zones are remarkably well aligned with major morphotectonic lineaments on the Antarctic continent in the Ross Sea region (namely Victoria Land and Ross Sea; Fig. 1) and in southwestern Australia, supporting the correlation between continental and oceanic structural fabrics (Foster and Gleadow, 1992). Wilson's plate-tectonic definition of a transform fault (Wilson, 1965) predicts that only the intra-ridge segments of fracture zones, i.e. the transform faults, should be tectonically active, while the older, generally longer intraplate segments in this region should not deform by strike–slip (Antolik et al., 2000). Several lines of

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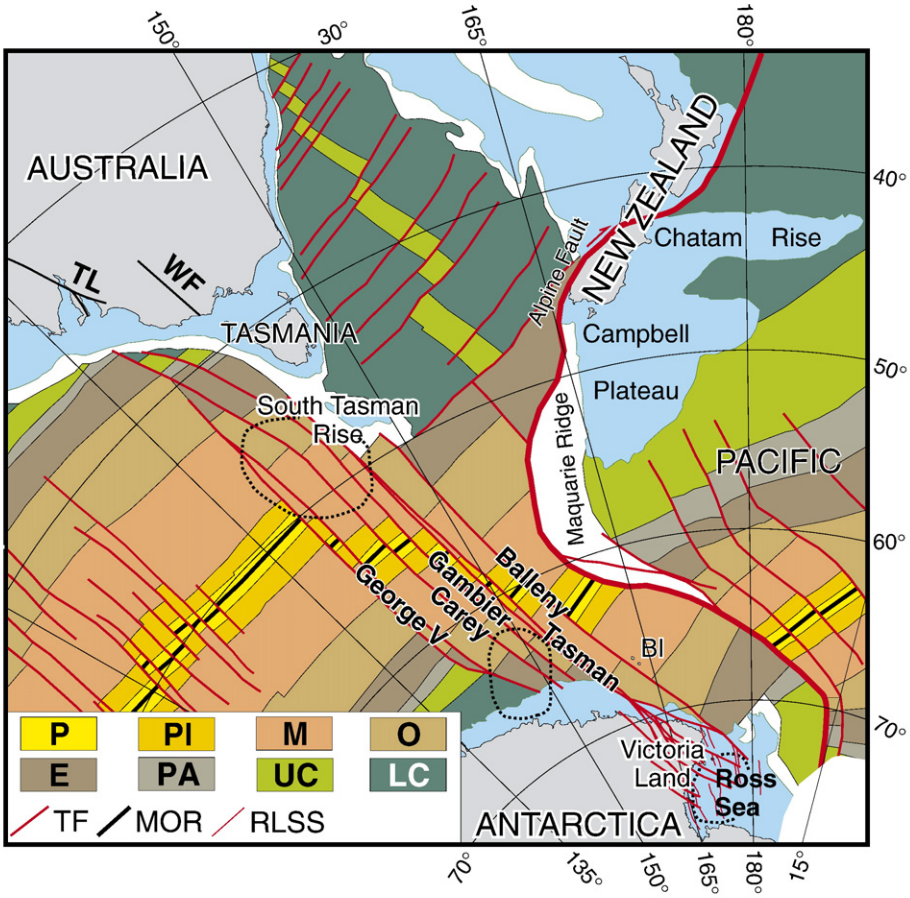

Fig. 1. Australia–Antarctica–Pacific plate boundaries and seafloor-spreading history showing magnetic anomaly ages of the Southern Ocean (after Hayes, 1991; Salvini et al., 1997). Main fracture zones between Tasmania and Victoria Land are shown. The thick red line marks the western boundary of the Pacific Plate. The location of low velocity regions in the upper mantle is marked by dotted lines (after Danesi and Morelli, 2000). Sea floor ages: P, Pleistocene (0.01–1.8 Ma); Pl, Pliocene (1.8–5.3 Ma); M, Miocene (5.3–23.8 Ma); O, Oligocene (23.8–33.7 Ma); E, Eocene (33.7b–54.8 Ma); Pa, Paleocene (54.8–65.0 Ma); UC, Upper Cretaceous (65.0–112.0 Ma); LC, Lower Cretaceous (112.0–144.0 Ma). Emerged continental areas are in grey. Submerged continental areas are in cyan. Symbols: TF, transform fault; MOR, mid oceanic ridge, RLSS, right-lateral strike–slip fault systems in north Victoria Land; TL, Torrens Lineament; WF, Woorndoo Fault.

evidence, however, indicate that fracture zones east of 139 °E have been slowly deforming along their entire length in the Antarctic Plate during the Cenozoic, with tectonic activity persisting into the present. It follows that at the northeastern edge of the Antarctic Plate, the plate tectonic principle that transform faults must initiate and terminate at convergent or divergent plate boundaries has been violated during a long period of slow internal plate deformation. To demonstrate this, we first introduce some of the major features of the region and also introduce a few central concepts that will be used in the following sections.

1.1. Plate tectonic setting and uncertainties

The sector of Antarctica facing Australia west of 139 °E (Fig. 1) is a typical passive margin developed in a divergent plate boundary environment (e.g. Colwell et al., 2006). On the other hand, the oceanic region to the east of 139 °E is strongly compartmentalized by fracture zones developed by the synrift reactivation of paleostructures active during the Early Palaeozoic Delamerian–Ross Orogeny (Foster and Gleadow, 1992; Miller et al., 2002). The Balleny Fracture Zone is the easternmost of these fracture zones (Fig. 1). The plate boundary region is characterized by a complex kinematic and tectonic pattern in the Macquarie Ridge, which includes strike–slip, transpressional and transtensional deformations (Lodolo and Coren, 1997; Massell et al., 2000), and inferred rigid rotations of the Macquarie Plate in the last 6 Ma (Cande and Stock, 2004).

Antarctica–Australia rifting started in Albian–Cenomanian times (110–95 Ma) (Mutter et al., 1985; Veevers, 1986; Lawver and Gahagan, 1994; Royer and Rollett, 1997) and was probably diacronous along strike (Tikku and Cande, 1999). A major global re-organization of plate motions occurred in Eocene times (Müller et al., 2000), with an eventual increase of the spreading rate in the Southern Ocean at about 43 Ma, from 6.5 mm/yr to 22.0 mm/yr (Veevers, 2000). In particular, oceanic spreading was inferred to be consistently faster east of 139 °E (Tikku and Cande, 1999; Cande et al., 1996).

Intra-Antarctica deformation continues to be the largest current source of uncertainty in the reconstructions of the history of relative motion between the Antarctic, Australian, and Pacific plates. The geometry of oceanic fracture zones offshore East Antarctica derived from satellite altimetry is consistent with both the hypothesis of long-lived intraplate deformation and the hypothesis that in the Late Cretaceous Antarctica behaved as two distinct plates (McAdoo and Laxon, 1997). Despite gross agreement between various reconstructions (Lawver et al., 1991), the kinematics since the early Mesozoic (180 Ma) of these three tectonic plates has yet to be completely resolved. Reconstructions of Southwestern Pacific produce mistfits between Pacific and Australia plates south of New Zealand in the Early Tertiary (e.g. Stock and Molnar, 1982; Cande et al., 2000). Gaps have been addressed using the assumption of a rigid plate rotation between East and West Antarctica in Cenozoic time (Cande et al., 2000; Stock and Cande, 2002). Overlap problems between north Victoria Land and the South Tasman Rise characterize most plate tectonic reconstructions of Antarctica with respect to Australia; these have been provisionally resolved by hypothesising paleodeformation in the Antarctic Plate prior to 65 Ma (e.g. Schmidt and Rowley, 1986; Sutherland, 1999; Steinberger et al., 2004. However, evidence that right-lateral transtension in the region started in Eocene times (Salvini et al., 1997; Rossetti et al., 2006), questions pre-Eocene significant intraplate deformations in the Ross Sea region. Similarly, proposed reconstructions of Cenozoic rifting and drifting in northeastern Antarctica, involving rigid rotations of West Antarctica (Cande et al., 2000), intraplate deformations in the Australian Plate and a rigid behaviour of Antarctica (Cande and Stock, 2004) linked to extension in the Adare Basin and Northern Basin (Cande and Stock, 2006; Davey et al., 2006), fail to explain post-Eocene intraplate right-lateral strike–slip tectonics in Victoria Land and western Ross Sea (Wilson, 1995; Salvini et al., 1997; Hamilton et al., 2001; Rossetti et al., 2003; Rossetti et al., 2006).

Such uncertainties highlight the need of a multidisciplinary approach to address complex geodynamic scenarios like the Tertiary interaction between the Antarctic, Australian, and Pacific plates. The integration of onshore and offshore structural and geophysical data provides the basis for our alternative interpretation of the tectonic history of this region.

1.2. Intraplate seismicity

The northeastern edge of Antarctica is characterized by intraplate seismicity (Reading, 2002), mainly localized in the oceanic domain to the northwest of the Balleny Islands and in the continental crust of North Victoria Land (Fig. 2). In particular, the 1998 8.2 Mw Balleny event is one of the largest intraplate earthquakes ever recorded (Wiens et al., 1998). Triggering mechanisms of this earthquake are still under debate and include either tectonics (Conder and Forsyth, 1998; Choy and McGarr, 2002) or deglaciation (Kreemer and Holt, 2000; Tsuboi et al., 2000; Ivins et al., 2003; Gangopadhyay, 2006). Despite significant potential bias arising from the sparse and uneven distribution of Antarctic seismic recorders (Reading, 2006), clustering of earthquakes in this region of the Antarctic plate suggests ongoing tectonic activity far from the plate boundary.

1.3. Plate non-rigidity and diffuse plate boundaries

Plate rigidity and narrow plate boundaries are central assumptions of the original formulations of plate tectonics (Wilson, 1965; McKenzie and Parker, 1967; Morgan, 1968). More recent views, however, indicate that in many cases plates can be, in part, non-rigid and that plate boundaries are very wide, both in continental and oceanic lithosphere (Gordon, 1998). Plate non-rigidity implies the possibility for slow internal deformation of plate interiors, while they can still possibly retain narrow plate boundaries. On the other hand, diffuse plate boundaries relax the assumption of narrow boundary regions, while possibly retaining internal plate rigidity. Both mechanisms are not necessarily in opposition (Gordon, 1998). This suggests that the plate mosaic covering the Earth surface consists of few large composite plates, with a large composite plate possibly including smaller component subplates, i.e. more rigid portions in relative motion to each other that are separated by diffuse plate boundaries (Royer and Gordon, 1997). Within these frameworks, the southeasternmost edge of the Australian Plate can be interpreted as either a diffuse plate boundary region (Gordon, 1998), or as forming the Macquarie component plate (Cande and Stock, 2004) of Australia. In this paper we discuss

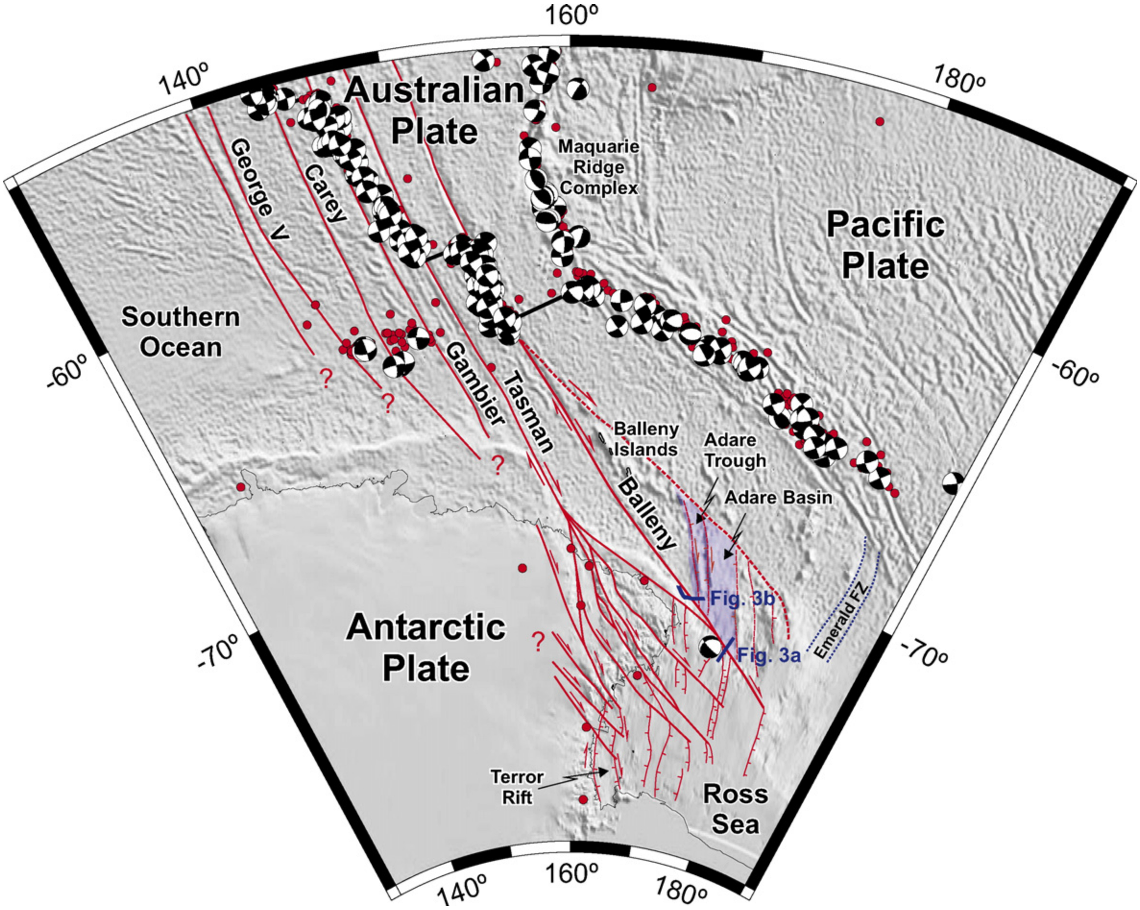

Fig. 2. Satellite-derived free-air gravity map of the study region (gravity grid from McAdoo and Laxon (1997), Sandwell and Smith (1997)) showing earthquake location (1976–2004; red dots; Mw >5) and available CMT focal mechanisms. Offshore data are from the Harvard catalogue (www.seismology.harvard.edu). Onshore data are from Cattaneo et al. (2001), Reading (2002). The trace of major fracture zones (after Hayes, 1991) and their onshore extensions (modified from Salvini et al. (1997)) are shown in red. Locations of geoseismic cross sections in Fig. 3 are shown in blue. The approximate location of the Adare Basis (Davey et al., 2006) is also shown in light blue.

application of the diffuse plate boundary and plate non-rigidity concepts to the northeasternmost portion of Antarctica.

2. Active fracture zones in Antarctica east of 139 °E

Primary indirect evidence of fracture zone activity east of 139 °E is the small-circle inconsistency of their strike with the Antarctica–Australia plate boundary further west. This implies the occurrence of intraplate deformations either to the northwest (De Mets et al., 1988) or to the southeast (Conder and Forsyth, 2000) of the mid oceanic ridge (or both sides).

The presumed tectonic inactivity of fracture zones would necessarily imply that sediments overlying them must be undeformed. However, high-resolution reflection seismic data acquired across the southeasternmost segment of the Balleny Fracture Zone and in the southern Adare Basin (Spezie et al., 1993) shows the actual geometry of modern fault splays arranged in flower-like structures (Fig. 3) which is distinctive of strike–slip faulting (Harding, 1985). This provides clear evidence of recent strike–slip faulting along the Balleny Fracture Zone. Furthermore, reflection seismic data indicate the occurrence of strike–slip to transtensional faulting along the Balleny Fracture Zone from 32 to 15 Ma (Whittaker and Müller, 2006), and post-26 Ma faulting in the Adare basin (Müller et al., 2005). Finally, the occurrence of a historic earthquake along the southeasternmost segment of the Balleny Fracture Zone (Behrendt et al., 1996) (Fig. 2) confirms that it is tectonically active.

An outstanding feature of the Antarctic continent east of 160 °E is the abrupt transition between the smooth topography of the East Antarctic Craton and the rough

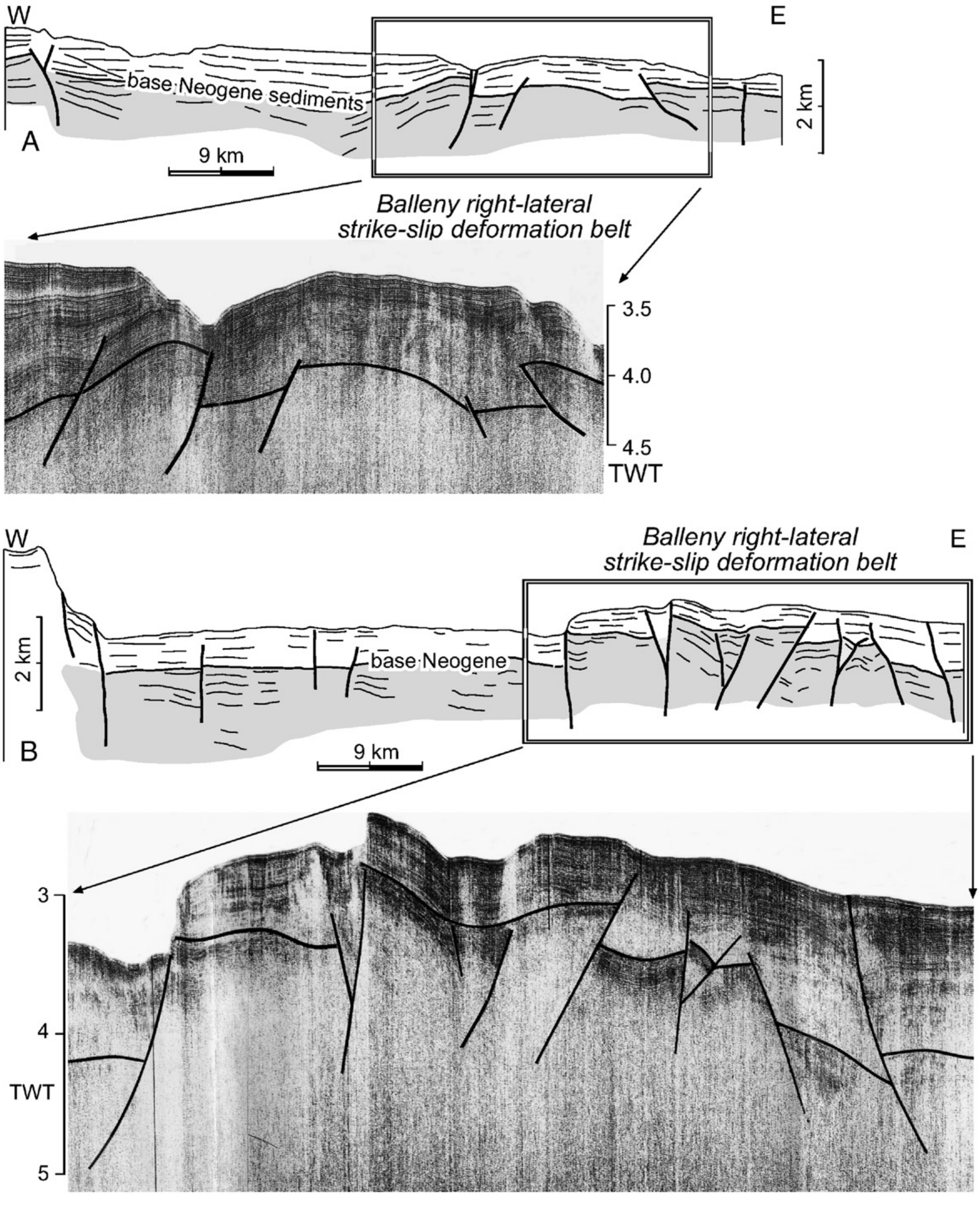

Fig. 3. Line drawings of depth-converted and re-interpreted high-resolution (sparker 8 kj) seismic profiles across the Balleny Fracture Zone (from TWT profiles in Spezie et al. (1993)). Segments of the original TWT profiles illustrating the most effective deformational features are also shown. Recent strike–slip deformations across the Balleny Fracture Zone (A, B) and the southern termination of the Adare Trough (B) are unequivocally imaged in both profiles. See Fig. 2 for location.

morphological grain of north Victoria Land, which occurs across the southeastward continuation of the Tasman Fracture Zone into the continent (Fig. 4). Furthermore, the continental shelf of East Antarctica is offset southeastward by about 280 km across the southernmost segment of the Tasman Fracture Zone

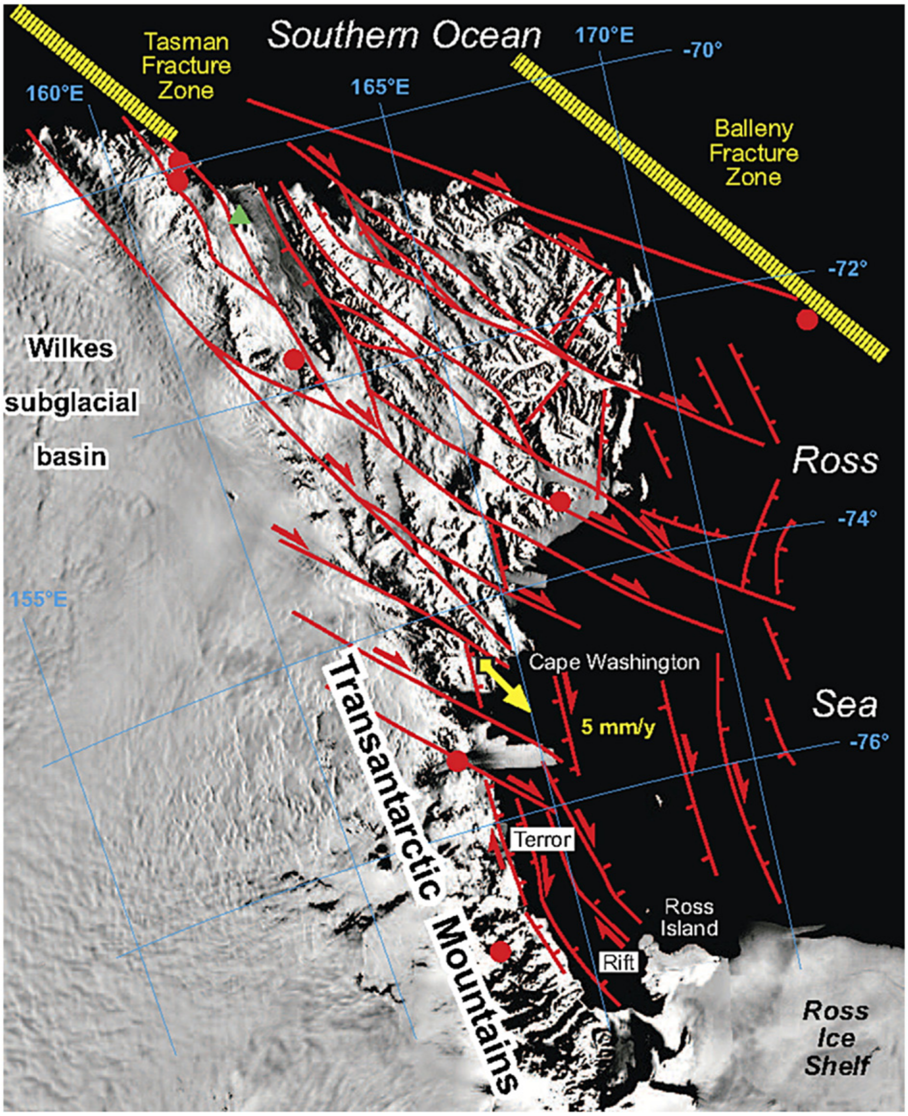

Fig. 4. Cenozoic fault network (after Salvini et al., 1997; Rosetti et al., 2003, 2006) and earthquake occurrences (Cattaneo et al., 2001; Reading, 2002) in the Ross Sea Region, and absolute motion (~ 5 mm/yr) of the permanent GPS station at the Mario Zucchelli Italian Antarctic Station (yellow arrow; after Negusini et al., 2005). The green triangle indicates location of Fig. 5.

(Fig. 2). The morphological evidence of the continental continuation of this fracture zone is strongly supported by a large amount of structural data showing that in north Victoria Land there is a network of major NW–SE striking Cenozoic right-lateral strike–slip fault systems that post-date rifting in the Southern Ocean and in the Ross Sea (Storti et al., 2001; Rossetti et al., 2002; Rossetti et al., 2003). Many of these fault systems can be traced from the onshore area facing the Tasman Fracture Zone in the Southern Ocean (Fig. 5), across north Victoria Land, and up to the western and central Ross Sea (Fig. 4), where in reflection seismic profiles they show flower-like fault arrays that crosscut Late Cenozoic sediments (Salvini et al., 1997). In many cases, faults affect the whole sedimentary succession and reach the sea bottom — another indication of recent activity (Rossetti et al., 2006). Coupled magnetic and gravity data support intimate relationships between Neogene–Quaternary magmatic activity in the Cape Washington area and right-lateral strike–slip faulting in coastal north Victoria Land (Ferraccioli et al., 2000). The physical continuity between the Tasman Fracture Zone and the collinear right-lateral strike–slip fault systems in north Victoria Land suggests that a slowly deforming strike–

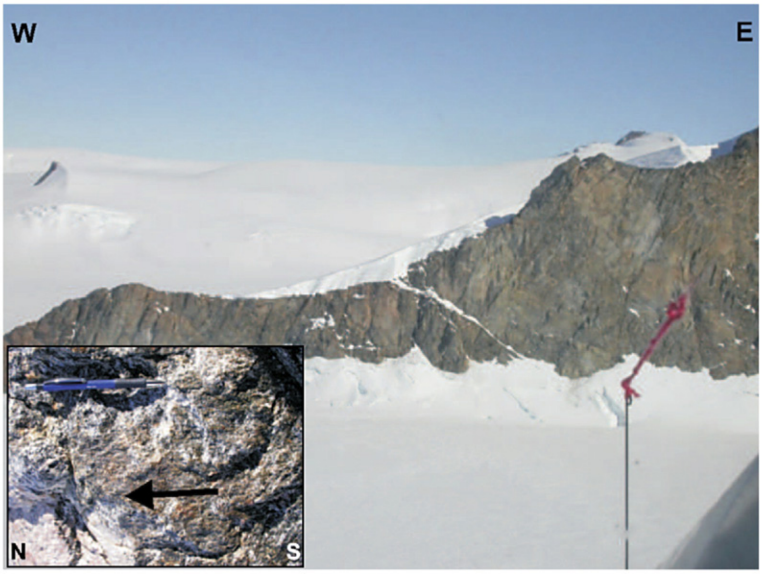

Fig. 5. Helicopter view of high-angle NNW–SSE striking right-lateral transtensional fault zones bounding the western shoulder of the Rennick Graben along the Southern Ocean coast (Wilson Hills area). These fault zones cut the Southern Ocean shoulder at a high angle and affect the previously structured Paleozoic basement rocks of the Ross Orogen. See Fig. 4 for location. The insert shows a detail of a fault surface in this outcrop, indicating a right-lateral sense of shear (the arrow indicates the motion of the missing block).

slip deformation belt stretches all the way from a mid-ocean transform fault segment in the Southern Ocean to the central Ross Sea. Earthquakes recorded along the continental strands of Tasman Fracture Zone (Fig. 4) also support its ongoing tectonic activity.

3. The new geodynamic scenario

The above observations indicate that the fracture zones developed in the Antarctic plate east of 139 °E belong to a network of intraplate strike–slip deformation belts tectonically active along their entire length. This implies that the 'quasi-passive' interior of tectonic plates can be dissected by strike–slip deformation belts that start from mid-ocean ridge segments and that separate adjacent, partially coupled lithospheric slivers experiencing differential translations within the zone of deformation. These 'non-ideal' internal differential displacements are then accommodated by distributed deformation within the plate interior (Fig. 6), so that localized strike–slip deformation is ultimately dissipated into a non-rigid plate.

Five major intraplate strike–slip deformation belts can be traced from the mid-oceanic ridge in the Southern Ocean into the interior of the Antarctic Plate (Fig. 2). Their sense of shear is left-lateral in the transform segments, switching to right-lateral in the fracture zone continuations because of the eastward increase of the

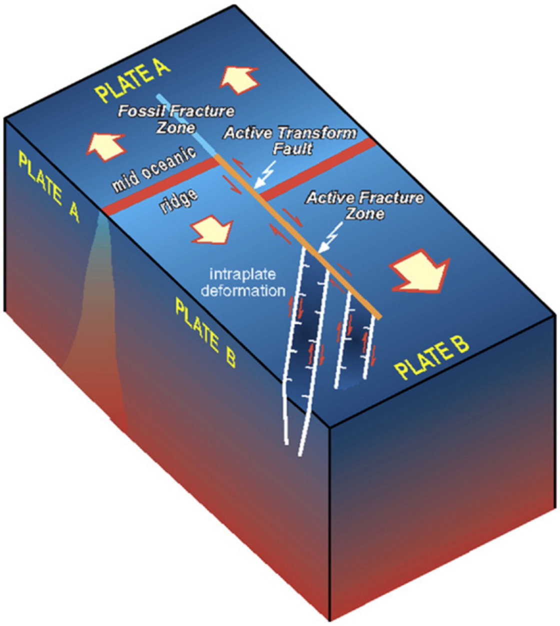

Fig. 6. Cartoon schematically illustrating the proposed extension of the 'ideal' rigid Plate Tectonics idealization that strike–slip deformation is limited to a transform fault (active) with the fracture zone continuation being tectonically inactive (Plate A) by adding the possibility of intraplate accommodation of persistent slow shear along a tectonically active fracture zone (Plate B). The size of the large yellow arrows relates to the spreading rate and indicates that the plate sector on the right side of Plate B is moving faster than the sector to the left. This implies a right-lateral sense of shear along the active fracture zone that compartmentalizes Plate B.

spreading rate ((Figs. 1, 2, 6)). Net right-lateral shear is dissipated in the interior of the Antarctic plate by concurrent transtensional basin opening in north Victoria Land and in the western and central Ross Sea (Salvini et al., 1997; Rossetti et al., 2003), and by fault splaying (Storti et al., 2001). The efficiency of these mechanisms is maximised in the continental crust because of favourably oriented, inherited deformational structures that were previously active during the Cambrian–Ordovician Ross Orogeny (Gunn and Warren, 1962) and during the Mesozoic orthogonal rifting of the Ross Sea (Cooper et al., 1987; Luyendyk et al., 2001). These pre-existing zones of weakness are apparently prone to be re-activated as either strike–slip or transtensional fault systems, respectively (Salvini et al., 1997). The mid Eocene age for the onset of intraplate strike–slip faulting can be inferred from several lines of geological evidence (Rossetti et al., 2006): (1) Apatite thermochronology indicates that a major uplift event occurred in the onshore inception area of the Tasman intraplate strike–slip deformation belt between 50 and 40 Ma (Rossetti et al., 2003; Lisker et al., 2006); (2) To the south, along the western shoulder of the Ross Sea, apatite thermochronology indicates that significant uplift started at about 50 Ma (e.g. Fitzgerald and Gleadow, 1988; Fitzgerald, 1992; Lisker, 2002); (3) Isotopic dating of fault-related pseudotachylyte veins hosted within NW–SE striking right-lateral strike–slip fault strands documents fossil seismicity at about 34 Ma (Di Vincenzo et al., 2004); (4) Cenozoic subcrustal magmatism started at about 48 Ma (Tonarini et al., 1997) and was associated with right-lateral transtensional faulting along the western shoulder of the Ross Sea (Wilson, 1995; Salvini et al., 1997; Hamilton et al., 2001; Rocchi et al., 2003).

These events in the Antarctic continent occurred concurrent with a major global re-organization of plate motions (Müller et al., 2000), with particularly strong reorganization within the Pacific Basin (Sharp and Clague, 2006). This logic implies that intraplate strike–slip faulting began at this time to cause/accommodate the southeastward extrusion of the plate fragment east of 139 °E. A rough calculation provides an average slip rate of 6.3 mm/y for the extruded block, assuming that the offset of the continental shelf at the inception point of the Tasman right-lateral strike–slip deformation belt was entirely produced by fault activity during the past 43 Ma. Preliminary data from the GPS permanent station at the Mario Zucchelli Italian Antarctic Base (Fig. 4) indicate a southeastward movement of about 5.0 mm/yr (Negusini et al., 2005), confirming that large-scale extrusion continues at a slow but significant (200 km/40 Ma) rate, comparable to our previous estimates.

4. Discussion

4.1. Implications for the Cenozoic Geodynamics of Antarctica

The proposed geodynamic scenario suggests an alternative explanation for Eocene–Oligocene opening and seafloor spreading in the Adare Basin (Cande et al., 2000) and subsequent rifting in the Adare Trough (Müller et al., 2005) by relating them to the possible activity of a northern strand of the Balleny strike–slip belt, tentatively mapped in Fig. 2. This tectonic setting in oceanic crust is the oceanic analogue to the opening of the Terror Rift along the western Ross Sea shoulder (Fig. 4) as an accommodation basin at the tip of major NW–SE right-lateral strike–slip fault systems in the Cape Washington area (Storti et al., 2001). Transfer of right-lateral shear into the Adare Trough is supported by the prominent flower structures imaged at the southern termination of this basin (Fig. 3). Slight counterclockwise rotations in the oceanic sector that is bounded to the south by the Balleny strike–slip deformation belt (Cande et al., 2000) may have facilitated the intraplate accommodation of the south-eastward extrusion of the lithospheric sector to the SW. Compensation within the Ross Sea of the residual right-lateral shear along the Balleny and Tasman strike–slip deformation belts (Salvini et al., 1997) permits: (a) continuous post-Oligocene occurrence of strike–slip tectonics despite the lack of a thoroughgoing plate boundary between East and West Antarctica younger than chron 8 (26 Ma) (Cande et al., 2000); (b) the lack of significant extensional deformation in the eastern Ross Sea younger than the middle-late Cenozoic (Luyendyk et al., 2001).

The latter evidence implies that the possible Eocene–Oligocene rigid rotation of West Antarctica must have been confined to a crustal sector to the north of the eastern Ross Sea. Accordingly, the oceanic domain to the east of the Ross Sea should have been fragmented into at least two blocks separated by a lithospheric discontinuity that we tentatively locate along the Emerald Fracture Zone. Such a possible fragmentation adds to the significant width of the boundary region between the Antarctica and Pacific Plates around the Macquarie Ridge (Lodolo and Coren, 1997) (Fig. 2), and further suggests that, at the northeastern edge of Antarctica, plate non-rigidity and diffuse plate boundaries may coexist.

4.2. Implications for Antarctica–Australia drifting

Low shear-wavespeed regions characterize the mantle underlying the Ross Sea and the Southern Ocean shoulder on the Antarctic plate, and the area immediately to the west of the South Tasman Rise below the Australian Plate (Danesi and Morelli, 2000). These slow wavespeed mantle anomalies are located beneath areas strongly compartmentalized by major intraplate strike–slip faulting in Antarctica and their conjugate fracture zones in Australia (Fig. 1). It is intriguing to speculate that the low wavespeeds are related to ridgeward flow of plume material from Antarctic (e.g. Balleny?) and Australian (Bass Strait?) plumes, a relationship that may help to keep the lithosphere in these deformation belts persistently hot and weak, thus facilitating their post-rift activity.

The alignment between the George V Fracture Zone and the onshore trace of the Torrens Lineament (Fig. 1), suggests that the latter might be a preferred mechanical discontinuity suitable to have been reactivated by Cenozoic intraplate strike–slip faulting. The onshore continental extension of the Tasman Fracture Zone, i.e. the Woorndoo Fault (Fig. 1), constitutes a first-order discontinuity on the structural and sedimentary architectures of the Australian continental margin (Cooper et al., 1987; Foster and Gleadow, 1992) that may have acted as an intraplate strike–slip fault system in Cenozoic times.

Incorporation of Eocene to Present post-rift tectonic activity along the major Antarctic (and possibly Australian) intraplate strike–slip deformation belts east of 139 °E, and their fading into a Ross Sea transtensional province leads to a more harmonious reconstruction of the Antarctica–Australia drifting history (Fig. 7).

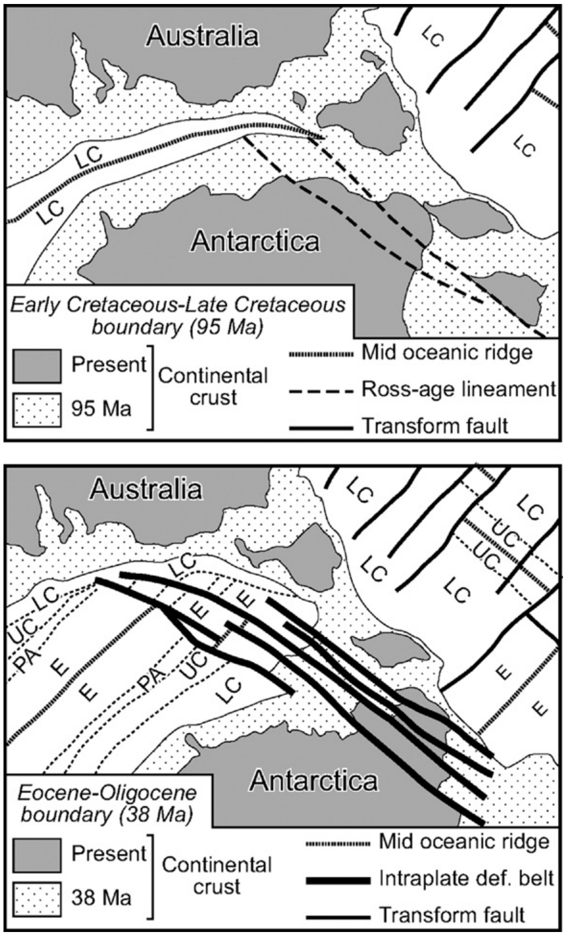

Fig. 7. Schematic paleogeographic reconstruction of the Australia–Antarctica region at 95 Ma and 38 Ma, respectively, obtained by including intraplate strike–slip faulting east of 139 °E in the progressive restoration of the Southern Ocean seafloor age pattern in Fig. 1. The purpose of this first-order attempt is simply to show that specific further work using the same boundary conditions is expected to be very promising for eventually producing a more accurate reconstruction of the Australia–Antarctica drifting history.

4.3. Global implications

The concept of potential intraplate termination of oceanic transform + fracture zone shear is not yet fully implemented into the kinematics of plate tectonics. This possibility significantly broadens the range of possible geodynamic settings for intraplate seismicity and magmatism in regions of slow intracontinental and intraplate deformation. Persistent slow slip on the fracture zone extension to a major oceanic transform fault provides an effective solution for (i) the occurrence of unexpected, strike–slip-related deformations along "typical" passive margins, such as the Southern Atlantic, and their continental shoulders, where regions of enhanced seismicity and volcanism occur; and (ii) the persistent activity within fossil strike–slip deformation belts in the continents that are the onshore continuations of oceanic fracture zones (Sykes, 1978).

Relative plate motions are commonly reconstructed by treating tectonic plates as ideal rigid shells obeying the simple rules of relative motion on a sphere (McKenzie and Parker, 1967; Morgan, 1968). Here we have shown evidence for a distinct mode of 'soft-plate' deformation in which plate-tectonics-created zones of weakness (the fracture zone extensions to transform faults, possibly weakened by deep serpentinization during transform slip and thermal stress concentrations induced by the plate age discontinuity) are used to transfer deformation at a mid-ocean ridge plate boundary into its neighboring plate interior. The occurrence of this non-ideal soft-plate, "subtle" deformation will affect spreading at neighboring plate boundaries. When not properly recognized and constrained, it can contribute to increased uncertainty and error in the reconstructions of global plate circuits.

4.4. Alternative interpretations?

To further validate the unusual geodynamic scenario proposed for this region of Antarctica, we next briefly discuss the drawbacks of possible alternative interpretations that appear able to explain in a "more conventional" way the geological and geophysical evidence described above. One idea would be to interpret the onshore strike–slip fault systems as an array of crustal-scale transfer shear zones linking different extensional gradients within the Southern Ocean, the Victoria Land and the Ross Sea. Four lines of evidence, however, appear to argue against this interpretation: (1) The development of transfer strike–slip faulting in Victoria Land would imply coeval extensional deformation to the west and to the east. This is not observed; instead the major rifting episodes in both the Southern Ocean (Mutter et al., 1985; Veevers, 1986; Tikku and Cande, 1999) and in the Ross Sea (Lawver and Gahagan, 1994; Salvini et al., 1997) predate the Eocene onset of strike–slip faulting in Victoria Land (Rossetti et al., 2006). (2) The NW–SE trend of the strike–slip fault systems in Victoria Land would imply a roughly perpendicular orientation, i.e. NE–SW, of coeval basin boundary fault systems in the extensional domains to the west and to the east. No evidence of such extensional fault systems has been found in either the Southern Ocean, where master faults along the rift shoulder strike almost E–W (Colwell et al., 2006), or in the Ross Sea, which is characterized by N–S oriented basins (Cooper et al., 1987; Salvini et al., 1997; Hamilton et al., 2001; Davey et al., 2006). (3) The interpretation of a transfer region would imply the lack of strike–slip deformation along the basin boundary fault systems in the adjacent extensional domains. In contrast, the Cenozoic brittle deformation pattern in the Ross Sea is characterized by dominant right-lateral transtensional to strike–slip faulting (Wilson, 1995; Salvini et al., 1997; Rossetti et al., 2006). (4) If the strike–slip fault systems in Victoria Land and western Ross Sea were to belong to a continent-scale transfer region, then the coexistence of both dextral and sinistral kinematics would be anticipated. Onshore data collected both in Northern and Southern Victoria Land, however, indicate systematic dextral shear (Wilson, 1995; Storti et al., 2001; Rossetti et al., 2002; Rossetti et al., 2003; Lisker et al., 2006).

Another possible explanation for intraplate strike–slip deformation in NE Antarctica within the framework of "classical" plate tectonics is for it to be related to the formation of the Maquarie plate (Cande et al., 2004) and the onset of right-lateral transpressional to strike–slip faulting in the Maquarie Ridge–Alpine Fault Pacific–Australian plate boundary (Massell et al., 2000). However, the development and rigid rotation of the Maquarie plate occurred in the last 6 Ma and its related intraplate deformation is confined into the Australian plate (Cande et al., 2004). Both of these observations rule out a genetic relationship with intraplate strike–slip deformations in NE Antarctica that began in the Eocene (~50 Ma) (Rossetti et al., 2006). A comparable age discrepancy exists with the onset of dextral shear along the Maquarie Ridge, — this deformation started at about 10 Ma (Cande and Stock, 2004) (in addition this deformation is confined to the Australian–Pacific plate boundary).

5. Conclusions

The drifting history between Antarctica, Australia and Pacific is not yet fully constrained and provides a continued source of uncertainty in the reconstructions of the global plate tectonic circuit. Several lines of evidence indicate the occurrence of post-rift intraplate deformation in northeastern Antarctica. In this paper we provided a synthesis of most available geological and geophysical data to demonstrate that they support the transfer and accommodation of transform shear from the Southern Ocean into the interior of the Antarctic continent for much, in not all of the past 50 Ma. The deformation transfer is observed to take place along intraplate right-lateral strike–slip belts composed of oceanic transform faults and their collinear oceanic fracture zone and continental shear zone extensions.

The potential compartmentalization of passive continental margins by strike–slip belts between a mid-ocean ridge and a deformable plate interior is more consistent with diffuse plate boundary and soft plate idealizations than with perfectly rigid plates and narrow plate boundaries. Integration of the possibility of real intraplate strike–slip faulting into global plate reconstructions may provide a better way to characterize and quantify the non-rigid internal plate deformation that is needed to reconstruct the kinematic evolution of imperfectly rigid plates.

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