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Chronological constraints on the Permian geodynamic evolution of eastern Australia

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ABSTRACT

The New England Orogen in eastern Australia developed as a subduction-related orogen in the Late Devonian to Carboniferous, and was modified in the Permian by deformation, magmatism and oroclinal bending. The geodynamics associated with the development of the New England oroclines and the exact timing of major tectonic events is still enigmatic. Here we present new $^{40}Ar/^{39}Ar$ results from metasedimentary and volcanic rocks from the southern New England Orogen. Eight grains from four metasedimentary samples (Texas beds) that originated in the Late Devonian to Carboniferous accretionary wedge yielded reproducible plateau ages of ~293, ~280, ~270 and ~260 Ma. These results suggest a complex thermal history associated with multiple thermal events, possibly due to the proximity to Permian intrusions. Two samples from mafic volcanic rocks in the southernmost New England Orogen (Alum Mountain Volcanics and Werrie Basalt) yielded eruption ages of 271.8 ± 1.8 and 266.4 ± 3.0 Ma. The origin of these rocks was previously attributed to slab breakoff, following a period of widespread extension in the early Permian. We suggest that this phase of volcanism marked the transition from backarc extension assisted by trench retreat to overriding-plate contraction. The main phase of oroclinal bending has likely occurred during backarc extension in the early Permian, and terminated at 271–266 Ma with the processes of slab segmentation and breakoff.

1. Introduction

The New England Orogen (NEO), the easternmost and youngest component of the Tasmanides in eastern Australia (Fig. 1a), is characterized by a series of orogenic curvatures (oroclines). The oroclinal structure, which is recognized by the map-view pattern of Late Devonian to early Permian tectonic units, defines an ear-shaped geometry comprising four bends (Fig. 1a) (Glen and Roberts, 2012; Rosenbaum, 2012; Rosenbaum et al., 2012). However, the origin of this orogenic-scale structure and its tectonic evolution remain poorly understood. Previous models have considered the possibility that the New England oroclines formed in the proximity of a transform plate boundary (Cawood et al., 2011b; Offler and Foster, 2008) or in a backarc extensional setting associated with a retreating subduction zone (Rosenbaum et al., 2012). These models are preliminary and suffer from the scarcity of data on the magnitude of block rotations and the timing of deformation, metamorphism and magmatism.

The aim of this paper is to establish constraints on the timing of tectonic processes associated with oroclinal bending in the NEO. We present new $^{40}Ar/^{39}Ar$ data from metasedimentary and volcanic rocks, which are spatially and temporally linked to the oroclines. We target two different tectonic units. The first set of samples is from deformed metasedimentary rocks (Texas beds), which are characterized by a structural fabric parallel to the oroclinal structure (Texas Orocline, Fig. 1) (Lennox and Flood, 1997; Li et al., 2012a). $^{40}Ar/^{39}Ar$ ages from these rocks could provide a maximum age constraint on the timing of oroclinal deformation, although subsequent heating could potentially reset these ages. The second set of samples includes mafic volcanic rocks from the southernmost NEO (Alum Mountain Volcanics and Werrie Basalt, Figs. 1a and 2). These rocks were supposedly derived from an asthenospheric source, and their origin was attributed to slab breakoff (Caprarelli and Leitch, 2001). The eruption ages, therefore, may provide information on the timing of lithospheric-scale processes associated with oroclinal bending (e.g. slab tearing and segmentation).

The results of this paper do not allow us to directly constrain the timing of deformation. However, they provide new information on the thermal and magmatic history of the NEO during the early Permian. We argue that it was during this period (290–270 Ma) that the New England oroclines formed (Rosenbaum et al., 2012), in a convergent environment that was dominated by backarc extension (Holcombe et al., 1997a; Korsch et al., 2009b). As such, our results shed new light on the geodynamic processes responsible for oroclinal bending.

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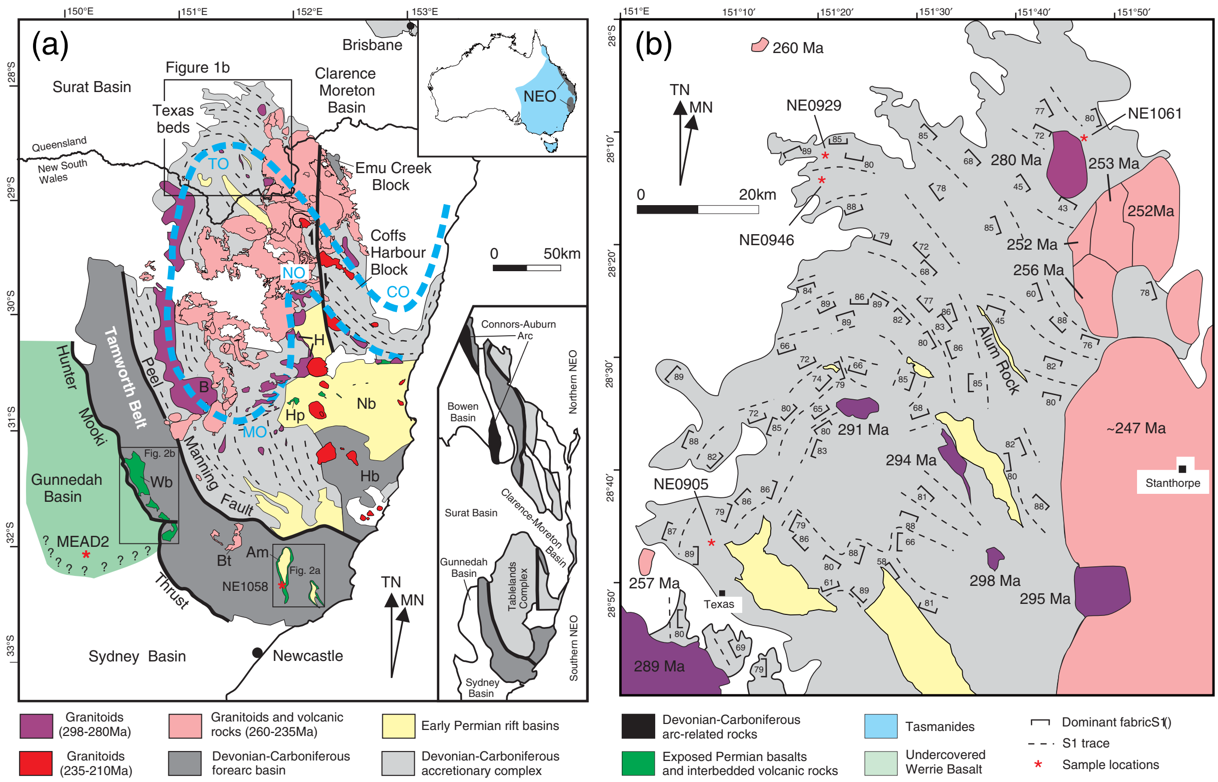

Fig. 1. (a) Geological map of the southern NEO. The blue dashed line traces the oroclinal structure (TO: Texas Orocline; CO; Coffs Harbour Orocline; MO: Manning Orocline; NO: Nambucca Orocline). The thin black dashed lines show the general orientation of the dominant S_1 fabric. Inset map in the upper right corner shows the location of the Tasmanides and NEO in eastern Australia. Inset map in the lower right corner shows major tectonic elements within the NEO. B: Bundarra granite; H: Hillgrove Suite; Hp: Halls Peak Volcanics; Am: Alum Mountain Volcanics; Wb: Werrie Basalt; Bt: Barrington Tops Granodiorite; Nb: Nambucca Block; Hb: Hastings Block. (b) Geological map of the Texas Orocline (after Li et al., 2012a) and sample locations. The oroclinal structure is traced by the S_1 structural fabric.
The ages of intrusive rocks are from the age database summarized in Li et al. (2012b) and Rosenbaum et al. (2012).

2. Geological setting

2.1. Regional tectonic framework

The NEO developed as an ocean–continent convergent system along the eastern Gondwanan margin from the Late Devonian to the Triassic (Glen, 2005). The orogen is subdivided into northern and southern segments, which are separated from each other by the Mesozoic Clarence–Moreton Basin (Fig. 1a). The oldest tectonic units of the NEO comprise, from west to east, Devonian–Carboniferous arc, forearc basin and accretionary complex (Leitch, 1975; Murray et al., 1987), indicating a west-dipping subduction system. In the southern NEO, the volcanic arc is rarely exposed and is interpreted to be underthrust below the forearc basin or covered by younger sedimentary rocks (e.g., Glen and Roberts, 2012). The forearc basin (Tamworth belt) and accretionary complex (Tablelands Complex) are well exposed and are overlain by early Permian rift-related clastic successions (Fig. 1a). Rocks in the Tablelands Complex are dominantly low grade metamorphic rocks with a penetrative slaty cleavage (Binns et al., 1967; Fergusson, 1982; Korsch, 1978, 1981), which is absent in the overlying early Permian sedimentary rocks (Li et al., 2012a). This indicates that the accretionary complex underwent regional deformation and metamorphism (D1, M1) prior to the deposition of the early Permian rocks. Metamorphic conditions during M1 in the northern part of the Tablelands Complex (Coffs-Harbour Block, Fig. 1a) were inferred to be in the field of prehnite–pumpellyite to lower-greenschist facies (Korsch, 1978). Syn-M1 mineral assemblages in the Tablelands Complex are aligned parallel to the structural fabrics (S1 and L1), indicating that regional deformation occurred simultaneously with metamorphism (Korsch, 1978; Li et al., 2012a). Subsequently, some of the rocks in the Tablelands Complex were subjected to an overprinting metamorphic event (M2) associated with the intrusion of Permian to Triassic granitoids (Korsch, 1978).

The Devonian to Carboniferous rocks were subjected to oroclinal bending in the Permian, which gave rise to a series of tight oroclines (Korsch and Harrington, 1987; Rosenbaum, 2012; Rosenbaum et al., 2012). Oroclinal bending took place during the early Permian, contemporaneously with the emplacement of S-type granitoids and the development of rift basins, possibly in an extensional backarc setting (Rosenbaum et al., 2012). The timing of early Permian S-type magmatism has been constrained to ~295–285 Ma, with minor occurrences at ~280 Ma (Cawood et al., 2011a; Donchak et al., 2007; Rosenbaum et al., 2012). Early Permian sedimentary rocks occur in the Sydney–Gunnedah–Bowen basins and in several units within the southern NEO (e.g., Nambucca Block, Fig. 1a). Leitch (1988) has suggested that all early Permian sedimentary rocks in the southern NEO were deposited in a larger rift basin, referred to as the Barnard Basin. Volcanic rocks from the base of these basins yielded U–Pb SHRIMP zircon ages of 293–291 Ma (Roberts et al., 1996) and 292.6 ± 2.0 Ma (Cawood et al., 2011a). These ages overlap with the intrusion of the S-type granitoids, supporting the suggestion that the emplacement of S-type magmas occurred in a hot backarc extensional setting, possibly in response to eastward trench retreat (Rosenbaum et al., 2012).

After a period with very little occurrence of magmatism at ~280–260 Ma (Rosenbaum et al., 2012), the southern NEO was subjected to regional ~E–W shortening (Hunter–Bowen phase) (Holcombe et al., 1997b; Korsch et al., 2009c) and arc-related magmatism (Wandsworth Volcanic Group and I-type granitoids) (Bryant et al., 1997; Stewart, 2001). These observations are consistent with the existence of an advancing west-dipping subduction zone during the late Permian and early Triassic (Jenkins et al., 2002; Li et al., 2012b).