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GR Focus Review

A review of Precambrian palaeomagnetism of Australia: Palaeogeography, supercontinents, glaciations and true polar wander

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A B S T R A C T

This is the first review of the Australian Precambrian palaeomagnetic database since that undertaken by Idnurm and Giddings (1988) 25 years ago. In this period the data have almost tripled in number from about 60 to more than 170 and while some segments of the pole path are now quite well defined, overall the data are sparse. It is debatable whether the extant rock record amenable to palaeomagnetism is complete enough for full palaeogeographic histories to be reconstructed. The SWEAT connection is apparently ruled out for Rodinia as both the 1200 Ma and 1070 Ma poles from (ancestral) Australia and Laurentia disallow it. However, older palaeopoles do support a SWEAT-like configuration for the pre-Rodinia supercontinent Nuna but the geological reasoning for SWEAT applies to Rodinia so a Nuna SWEAT is less than gratifying. The concept of a "grand-pole" is introduced here, which includes all the "key-pole" features but is predicated on the condition that two or more independent laboratories are in agreement.

Precambrian data from Australia include the oldest palaeopole yet defined, the record of one of the oldest geomagnetic polarity reversals, the most definitive evidence for low-latitude Neoproterozoic glaciation, the first study of BIFs and the timing/nature of iron-ore genesis, the most unusual 'field test' (impact melt rock and ejecta horizon host rocks), some of the best examples of complete contact tests and the timing of craton assembly. Some old caveats that can no longer be ignored, such as corrections for inclination flattening and the permitting of rotations between contiguous intracontinental cratons to bring conflicting palaeopoles into alignment are required. Care should be exercised when inferring palaeolatitudes from sedimentary derived palaeoinclinations. TPW should only be considered if there is evidence from more than one, and preferably more, independent continents. Future work identified includes a complete magnetostratigraphic study of ~300 my Adelaidean succession, better age constraints for the Adelaidean and Officer Basin successions and a better age for the Gawler Craton GB dykes.

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1. Introduction

The first palaeomagnetic study of Australian Precambrian rocks was undertaken during the early years of palaeomagnetism by Irving and Green (1958). They studied oriented samples of the Nullagine Lavas, now called the Fortescue Volcanics (Mount Roe Basalts), from the Pilbara, the Edith River Volcanics (now the Plum Tree Creek Volcanics, part of the Edith River Group) from the McArthur Basin and the Buldiva quartzite (now part of the Tolmer Group) from Arnhem Land. While the palaeomagnetism of the Mount Roe Basalt and the Plum Tree Creek Volcanics has been re-studied since, and their ages better defined stratigraphically and geochronologically, the original observations have stood the test of time in the sense that the early pole positions remain valid. Briden (1967) undertook a palaeomagnetic study of Late Precambrian Adelaidean strata from the southern end of the Adelaide Geosyncline (fold belt) but was frustrated by Mesozoic and Tertiary overprinting evidenced by negative fold tests.

McElhinny and Embleton (1976) reviewed the Proterozoic to Early Palaeozoic (2500 Ma to 400 Ma) palaeomagnetic data from Australia and introduced their somewhat less stringent version of ranking poles than that proposed by Stewart and Irving (1974). The scheme designed by the latter workers ranked poles between 1 and 3 based on the palaeomagnetic and age data, and also the timing of remanence relative to rock age (a perfect score would be 9, although no North American pole made that grade). McElhinny and Embleton (1976) relented on the third criterion, the timing of remanence, in a pragmatic step to retain enough Australian data for postulation and debate. They showed that the polar motion for the Late Proterozoic–Early Palaeozoic period averaged about 1°/My. They also showed that results from other Gondwana continents were consistent with the Australian pole path and therefore argued that the Pan-African (550 ± 100 Ma) orogenic belts were of ensialic origin. It was also argued that the Australian data are consistent with a common apparent polar wander (APW) path back to 2500 Ma, with an average wander rate of 0.3°/Myr, indicating that the mobile belts separating the Precambrian cratons of the Australian shield are ensialic like the Pan-African belts.

The next significant advance in establishing a Precambrian palaeomagnetic framework for Australia focused on the Neoproterozoic (McWilliams and McElhinny, 1980). That study showed that the sigmoidal structural trends of the Adelaide Geosyncline are original and indicated low latitudes for the late Precambrian glacial deposits in South Australia, all findings that remain valid today.

A complete review of extant Australian Precambrian palaeomagnetism was provided by Idnurm and Giddings (1988), after they had undertaken an extensive palaeomagnetic investigation of Mesoproterozoic units in Northern Australia, particularly the McArthur Basin and the Pine Creek Inlier. That study included discussions on the validity of the Geocentric Axial Dipole (GAD) hypothesis for Precambrian time, the structural unity of the Australian Precambrian cratons since their amalgamation, global reconstructions during the Precambrian and finally the authors questioned uniformitarianism with regard to Precambrian palaeoclimates and palaeolatitudes. All these aspects are revisited in this current review.

Since 1988 various groups, namely the Australian Geological Survey Organisation (AGSO), the Tectonics Special Research Centre (TSRC) of the University of Western Australia, and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), have continued to make many contributions to the Precambrian palaeomagnetism of Australia. In addition, several groups from the USA, Canada, the Netherlands and Japan have added to the data base. Idnurm (2004) updated the Precambrian palaeolatitudes of Australia, incorporating pre-2004 AGSO and TSRC data although not the late Neoproterozoic data mainly from CSIRO. It is timely to undertake a new review of Australian Precambrian palaeomagnetic results.

The Australian content of the Global Palaeomagnetic Database (GPMDB; McElhinny and Lock, 1996; Pisarevsky, 2005) has been updated to the end of 2011 (Sergei Pisarevsky, pers. comm., 2012) and can be downloaded from www.magresearch.org. These data and data published later in 2012 form the basis of this review (Supplementary data).

2. Distribution of Precambrian outcrop and sampling localities

Australia is divided into a number of tectonic cratons with the Archaean and Proterozoic in the western two-thirds and Phanerozoic terranes in the east (Fig. 1). The boundary between the Precambrian and the Phanerozoic is referred to as the Tasman Line. This boundary is mostly obscured by younger rocks and is inferred from gravity and magnetic lineations. The exact location and geological nature of the Tasman Line is a source of much debate with some disputing that it is the margin of Precambrian Australia (Direen and Crawford, 2003; Kennett et al., 2004).

The Pilbara and Yilgarn cratons were sutured during a series of orogenies beginning with the ca. 2.2 Ga Ophthalmian Orogeny, followed by the 2.0–1.96 Ga Glenburgh Orogeny and the 1.83–1.78 Ga Capricorn Orogeny to form the Western Australia Craton which exhibits tectonic features as old as 3.65 Ga to less than 2.0 Ga (Betts et al., 2002). The Bangemall Basin formed just after the Capricorn Orogeny during the Meso–Neoproterozoic. Granite–greenstone belts of the Yilgarn, the largest Archaean craton in Australia, attest to continental accretion between 3.73 Ga and 2.55 Ga. The Hamersley Basin of the southern Pilbara contains banded iron-formations (BIF) and shale units from 2.6 to 2.45 Ga deformed during the Ophthalmian Orogeny (Betts et al., 2002).

The McArthur Basin, Kimberley, Arunta and Mt Isa cratons of northern Australia were assembled into the North Australia Craton (Fig. 1) during the 1.82 Ga Halls Creek Orogeny. The Pine Creek Inlier is partly of Archaean age (Betts et al., 2002).