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Paleomagnetic record of Africa and South America for the 1200–500 Ma interval, and evaluation of Rodinia and Gondwana assemblies

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Abstract

At least two supercontinents – Rodinia and Gondwana – have been proposed for the 1200–500 Ma time interval on the basis of stratigraphic, geochronological and paleomagnetic grounds. Although the exact configuration of Rodinia is still a matter of debate, both supercontinents are linked insofar as the demise of the older Rodinia begat the younger Gondwana. In order to constrain the paleogeographic transition between these two supercontinents, we evaluate an updated paleomagnetic database (148 poles) for Africa together with unpublished data from South America, using the *Q*-factor criteria of Van der Voo [Van der Voo, R., 1990. The reliability of paleomagnetic data. Tectonophysics 184, 1–9]. A postulated Grenvillian suture between Laurentia and the united Amazonia–West Africa craton is supported by comparing the Meso-Neoproterozoic drift history of these two cratons. Comparing this drift history with that of the remaining West Gondwanan cratonic elements: São Francisco–Congo, Kalahari, Rio de Plata, and Arabian–Nubian shield, reveals that these cratons were not part of Rodinia. The contrasting drift history of Laurentia cum Amazonia–West Africa with "central" West Gondwanan cratons São Francisco–Congo, Kalahari suggests the continued existence of at least two separate tectonic plates separated by an ocean basin. The assembly of central Gondwana, i.e. Kalahari, São Francisco–Congo, and the Arabia–Nubian shield was completed during latest Neoproterozoic times, as indicated by the approximation of ca. 550 Ma paleomagnetic poles. The collision of these central Gondwanan blocks with the Amazonia–West Africa craton appears to have occurred by mid-Cambrian times, after the opening of the Iapetus ocean basin between Laurentia and Amazonia–West Africa. We propose a scenario in which West Gondwana was formed through at least two distinct orogenic episodes: terranes and cratons accreting to the São Francisco–Congo craton in a series of collisions from 940 to 550 Ma, followed by the collision with Amazonia–West Africa and minor contiguous blocks (Rio Apa and Pampia) at ca. 520 Ma. West Gondwana was not a coherent tectonic unit before the end of Precambrian times, with a major mobile belt separating at least two separate continental masses.

Keywords: Proterozoic; Paleomagnetism; Rodinia; West Gondwana; Amazon; West Africa; Kalahari; São Francisco; Congo; Arabia–Nubia

1. Introduction

Paleomagnetic investigations of the Precambrian era have been at the heart of many long-standing arguments regarding how much of early Earth history can be reliably described by uniformitarian principles. Inferences about deep Earth processes during the Precambrian

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are drawn from paleomagnetic data; examples include absolute time constraints on the initiation of the geodynamo (Layer et al., 1996) and the long term geometric attributes of the terrestrial field (Kent and Smethurst, 1998) imparted by a differentiated core with stable convection patterns established in the outer core (Merrill and McFadden, 1995). The absolute, global reference frame implicit to paleomagnetic data is ideal for documenting the history and dynamics of the plate tectonic regime (Van der Voo and Meert, 1991; Meert et al., 1993). Non-uniformitarian alternatives to the plate tectonic regime, such as the subduction-free, ensialic orogeny (Piper, 1976, 1983; Kröner, 1977), or the possibility of pan-lithospheric drift (i.e. true polar wander) occurring outside of a plate tectonic framework (Goldreich and Toomre, 1969), commonly rely on paleomagnetic data for support (Kirschvink et al., 1997; Evans, 1998) or repudiation (Meert, 1999; Torsvik et al., 2001). The more conventional debate over paleogeography for the Proterozoic relies heavily on the paleomagnetic record, especially given the breakdown in the traditional link between paleoclimatic indicators and paleolatitude engendered by the Snowball Earth hypothesis (Hoffman et al., 1998; Williams and Schmidt, 2000).

The review of paleomagnetic data for West Gondwana presented here is part of an ongoing reassessment of Proterozoic paleogeography being undertaken by many workers (e.g. Weil et al., 1998; D'Agrella-Filho et al., 1998; Pesonen et al., 2003; Meert, 2003; Meert and Torsvik, 2003; Pisarevsky et al., 2003). The renewal of interest in the paleomagnetic record from the Precambrian focuses chiefly on two controversial hypotheses that have come to dominate discussion of the late Mesoproterozoic to Cambrian interval of Earth history: the Rodinia supercontinent (cf. Paleopangea of Piper, 1980, 2000) and the snowball Earth hypothesis invoked to explain Neoproterozoic glacial deposits at low latitudes (Kirchvink, 1992; Meert and Van der Voo, 1994), as reviewed recently by Evans (2000) and Meert and Torsvik (2004). On the paleographic front, a recent review of the geochronological and paleomagnetic data from India, Australia, Antarctica, and eastern Africa challenges the classical view of a long-standing, united East Gondwana (Meert, 2003). In contrast, the tectonic models for West Gondwana, especially the South American units – Amazon, Rio de la Plata, Luis Alves, and São Francisco cratons and their intervening mobile belts – have not benefited from uniform scrutiny of the paleomagnetic database. In this contribution, we present new, previously unpublished data from South America, as well as a comprehensive review of the existing South American and African databases. In the time elapsed since the last review of the African database (Van der Voo and Meert, 1991), new paleomagnetic and geochronological data have been reported, allowing for an updated reassessment of the paleogeography of the constituents of West Gondwana (Fig. 1). We have chosen the time interval 1200–500 Ma as appropriate for our review, as this interval covers the proposed assembly and break-up of the Rodinia supercontinent, as well as the subsequent assembly of Gondwana, thus providing the reference frame of a unifying paleogeographic model.

2. Paleomagnetic database and selection criteria

In conducting this review, we have gathered together data from articles published in standard journals with an international audience, in addition to "grey" literature sources such as regional journals, PhD theses, and meeting abstracts. Some of the data assembled from this process were deemed fit for inclusion in the subsequent discussion of paleogeography, while others have been excluded from construction of the individual apparent polar wander paths (APWP) for each craton. The philosophy underlying our selection process and the (admittedly) skeletal APWPs that emerge differs from other recent reviews of the Precambrian database (e.g. Buchan et al., 1994, 2001), where more stringent criteria are used to exclude all but a few paleomagnetic "key poles." The "key pole" approach emphasizes the reliability of those paleopoles that are privileged by more precise geochronological data and/or field tests suggestive of a primary remanence. One would expect that paleogeographic reconstructions based exclusively on "key poles" would be somehow more reliable. Alas, a consequence of the more conservative approach to paleomagnetic data is that paleogeographic reconstructions themselves are much more loosely constrained. A number of factors contribute: the lack of "reliable" data and the consequently long and frequent hiatuses in the drift record, the uncertain polarity of pre-Jurassic paleomagnetic data, and the mismatch in ages in comparing acceptable paleopoles from different cratons. It is our contention that paleogeographic reconstructions based on the APWP approach present a more realistic approximation of a continuous geological drift history, even where certain portions of the path are based on individual poles that cannot be verified by field tests or precise geochronology. In short, data that are not demonstrably good are not necessarily bad data. Excluding such data a priori runs the risk of eliminating accurate recorders of the geomagnetic field and, incidentally, discourages present and future workers from further refining or revisiting these results.