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Preface

Endings and beginnings: Paleogeography of the Neoproterozoic–Cambrian transition

1. Paleogeography at the "cutting edge"

The Neoproterozoic to Cambrian interval is of singular significance in Earth history, hosting a fundamental diversification of life and perhaps the most severe extremes in climate (Grotzinger et al., 1995; Kaufman et al., 1997). This transition featured widespread rifting and orogenic activity that accompanied the opening of new oceans and the closing of others during the Late Neoproterozoic–Early Paleozoic assembly of the supercontinent Gondwana (Trompette, 1997). The Neoproterozoic–Cambrian transition may also have had unusual geodynamic events such as rapid plate motions (Meert et al., 1993; McCausland and Hodych, 1998) and/or substantial "true polar wander," i.e. the bulk tumbling of the Earth's mantle and lithosphere with respect to its spin axis (Kirschvink et al., 1997; Evans, 2003). A newly introduced period in the global time scale, the Ediacaran, is delimited by the occurrence of the cap carbonate at its base which overlies the Marinoan global-scale glaciation (~630 Ma) and by the first occurrence of shelly fauna at the base of the Cambrian at 543 Ma, thus highlighting the transition from the Precambrian Earth to the more familiar Phanerozoic Earth (Knoll et al., 2004).

Knowledge of the paleogeography of the Neoproterozoic–Cambrian transition is fundamental to understanding the Late Neoproterozoic climate extremes, the rapidly evolving Ediacaran and Cambrian fauna, and global geodynamics. Paleogeography prior to the Middle Cambrian is poorly known, however, with few high quality (Van der Voo, 1993) paleomagnetic constraints and poor biogeographic control. A large part of the difficulty lies in the absence, prior to the Cambrian radiation, of useful index fossils for constraining depositional age and the possible spatial relationships and correlations between strata. Another, less-realized problem is the proliferation of peri-Laurentian and peri-Gondwanan terranes during Late Neoproterozoic to Cambrian time, obscuring the timing and nature of the geological linkages between continents (Cawood et al., 2001).

Most importantly, the formation of the supercontinent Gondwana by the end of the Neoproterozoic, and its persistence throughout Paleozoic time, has been a lynchpin for Pre-Pangea paleogeographic reconstructions. Gondwana contained much of the Earth's landmass during its existence, such that it has been possible with minimal information to estimate the global Paleozoic paleogeography and even plate boundary relationships with respect to the Gondwanan supercontinent (e.g., McElhinny et al., 2003; Stampfli and Borel, 2002). There is, however, great uncertainty as to the relative positions of the component cratons of Gondwana prior to its Cambrian final amalgamation. Furthermore, for the Neoproterozoic time prior to Gondwana's assembly there does not seem to have been a single, long-lived supercontinent with a defined paleogeography (Cordani et al., 2003; Murphy et al., 2004), despite concerted efforts to recognize and test proposed supercontinents such as Palaeopangea (Piper, 1976, 2000) and versions of Rodinia (Hoffman, 1991; Dalziel, 1997; Weil et al., 1998; Torsvik, 2003; Meert and Torsvik, 2003). Although the extent and configuration of Rodinia remains unresolved, the record of widespread "Grenville" age collisional 1.1–1.0 Ga orogenesis and circum-Laurentian Neoproterozoic rifting (cf. Hoffman, 1991) still suggests that a major, Laurentia-cored landmass existed during the Early Neoproterozoic (Meert and Torsvik, 2003).

As a result of the lack of supercontinental constraints, much more paleomagnetic and geological information will be required from each continent and continental fragment to develop robust global paleogeographies for Neoproterozoic through Cambrian time. The Neoproterozoic–Cambrian transition is, then, the "cutting edge" for resolving global paleogeography, where

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issues of regional tectonics, geodynamics, paleomagnetism, global change and biodiversity converge. Before this seminal interval, the Precambrian – nearly 88% of geologic time – is still poorly understood, and perhaps intractably so, without first solving the paleogeography of the Neoproterozoic–Cambrian transition.

2. Neoproterozoic–Cambrian global paleogeography

The papers of this special issue, "Endings and beginnings: Paleogeography of the Neoproterozoic–Cambrian transition," arise from a special session held at the Spring 2004 meeting of the American Geophysical Union in Montreal. These 12 contributions focus on several outstanding paleomagnetic and geological issues of the Precambrian–Cambrian transition paleogeography.

Paleomagnetic studies offer a unique, quantitative estimate of the paleolocations and motions of continents with respect to one another, provided that there are a sufficient number of successive, well determined paleomagnetic results for each continent. Tohver et al. (2006) provide a rigorous assessment of the currently known 1200–500 Ma paleomagnetic record for the tectonic elements of Africa and South America, drawn from published (and hitherto poorly accessible) paleomagnetic results. They find that, despite the sparseness of the paleomagnetic record, it is nevertheless possible to establish from latitudinal drift histories that: (1) West Gondwana cannot have been a complete entity until the Late Neoproterozoic–Cambrian collision of Amazonia-West Africa-Rio de la Plata with Congo-Sao Francisco-Kalahari; and (2) the latter, predominantly African core elements of Gondwana likely did not travel with Laurentia in Early Neoproterozoic time and therefore were not part of a Rodinia supercontinent. The paleomagnetic compilations of West Gondwana (Tohver et al., 2006), and for elements of East Gondwana (Powell and Pisarevsky, 2002; Meert, 2003), imply that Rodinia may at best have been an assemblage of continents, rather than a Pangea-like supercontinent occupying a single plate.

Rapalini (2006) further substantiates the Late Neoproterozoic–Cambrian timing of Gondwana assembly, reporting a new paleomagnetic result derived from sedimentary compaction-corrected red claystones of Ediacaran age in the Rio de la Plata craton. Comparison of this result with the handful of other coeval Gondwanan paleomagnetic results from Uruguay, eastern Africa, Arabia and Australia indicates that by Late Ediacaran time (ca. 550 Ma), Gondwana was already assembled or nearly so.

Laurentia is postulated to have been the core of the Rodinia supercontinent, largely based on lithostratigraphic evidence for the presence of mid-to-Late Neoproterozoic rift-drift successions along each of its margins (Hoffman, 1991). For each margin, the identity of the conjugate margin to Laurentia is controversial (Dalziel, 1997; Weil et al., 1998; Sears and Price, 2000; Wingate and Giddings, 2000; Cawood et al., 2001; Meert and Torsvik, 2003; Murphy et al., 2004). As a result, there is broad agreement on the existence of a Rodinia of some extent based on the widespread ca. 1.1 to 1.0 Ga collisional orogens, but there is no emerging consensus on its configuration.

Weil et al. (2006) refine the mid-Neoproterozoic paleomagnetic record for Laurentia, reporting an extensive study of the well-preserved ca. 800–750 Ma Uinta Mountains Group of northern Utah and Colorado. They confirm that Laurentia occupied a low-latitude position at ∼800 to 750 Ma, perhaps coinciding with the occurrence of worldwide glaciation, and that possible Rodinia cratonic relations along Laurentia's Cordilleran margin are no longer viable by the mid-Neoproterozoic, consistent with the widespread record of rift-to-drift activity along the margin during that time.

Gladkochub et al. (2006) update previous suggestions for a ca. 1 Ga Siberia-Arctic Canada connection with geochemical data and Ar-Ar, U-Pb geochronological results from three generations of mafic dykes and sills emplaced in the Neoproterozoic passive margin of southwestern Siberia. They note similarities in age and geochemistry of the older generation of sills with the plume-related ca. 723 Ma Franklin intrusions of northern Laurentia, and extend the ca. 1 Ga paleomagnetic-based fit of Siberia to Arctic Laurentia (Pisarevsky and Natapov, 2003) to the mid-Neoproterozoic. An implication of this mid-Neoproterozoic Siberia-Laurentia connection is that the Late Neoproterozoic passive margin along the Arctic flank of Laurentia may have bordered the Paleo-Asian Ocean, which probably contained an as yet unfathomed collage of Central Asian terranes, many of which accreted to Siberia and Baltica during its Paleozoic closure (e.g., Khain et al., 2003).

Rifting along Laurentia's eastern, Iapetan margin may have been complicated in latest Neoproterozoic–Cambrian time by the separation of terranes (Cawood et al., 2001). The rift-drift transition is recorded along the incipient Iapetan margin of Laurentia at the Precambrian–Cambrian boundary (Bond et al., 1984; Williams and Hiscott, 1987), but paleomagnetic evidence indicates that the oft-proposed conjugate margin Amazonia could not have been adjacent to eastern