Reconstruction of Nuna: A working hypothesis

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Plate-tectonic assembly of Laurentia, during the surprisingly brief interval of 1.9-1.8 Ga, has been appreciated by the geological community for more than two decades (Hoffman, 1988). Nonetheless, the only rigorously quantitative method for reconstructing Precambrian cratons and supercontinents, paleomagnetism, has yet to fulfill its potential in describing the histories of Laurentia's and neighboring continents' amalgamation into the late Paleoproterozoic supercontinent Nuna. Here we describe a working model for the assembly of North American cratons, in the context of once-contiguous landmasses, that is based on the current global paleomagnetic database and our own studies in progress.

Prior to Laurentia's amalgamation, its constituent cratons (Slave, Rae, Hearne, Sask, Wyoming, Superior, Nain) might have been located within various continent-sized assemblages of supercratons (Bleeker, 2003), or perhaps a full-fledged Kenorland supercontinent (Williams et al., 1990). The Kenorland postulate is paleomagnetically testable by comparing the lengths and shapes of apparent polar wander paths between precisely coeval data from the allegedly connected cratons. If the paths are of significantly different lengths or shapes, then the proposed connection is refuted. At present the published global database from 2.7-2.2 Ga (the proposed interval in which Kenorland may have existed according to various suggestions, as reviewed by Reddy and Evans, 2009) slightly favors the supercraton option rather than the Kenorland option--but this conclusion hinges on data of less than the highest quality (as reviewed by Evans and Pisarevsky, 2008).

The 2.8-2.7 Ga paleogeography of one supercraton, Vaalbara, is becoming better constrained by recent data from Western Australia and South Africa (Strik et al., 2003; De Kock et al., 2009). Another proposed supercraton, Superia, is taking shape from the geometries of numerous large igneous provinces, in particular mafic dyke swarms (Bleeker and Ernst, 2006). That craton might have included Superior as a central block, flanked by Hearne, Wyoming, Karelia, and undetermined other cratons. Superior has the highest-quality Paleoproterozoic apparent polar wander path of any craton, to the degree that subtle relative motion across the Kapuskasing zone can be discerned and quantified (Buchan et al., 2007; Evans and Halls, in press). Paleomagnetic testing of the LIP-based reconstruction of the Superia supercraton is preliminary, but supportive in a limited number of tests using data (again, unfortunately) that are not yet substantiated by precise ages or guarantees of original, primary magnetic remanences such as the baked-contact test (Harlan et al., 2003; Mertanen et al., 2006). Our current paleomagnetic and geochronologic work on mafic dyke swarms in Wyoming aims to test, definitively, the Roscoe and Card (1993) hypothesis of Wyoming adjacent to southern Superior for 2.7-2.1 Ga.

Slave craton's Paleoproterozoic apparent polar wander path is beginning to take form (Buchan et al., 2009). Much paleomagnetic and geochronologic work in progress (presented by K. Buchan in this session) is calibrating Slave's motions between ca. 2.2 and ca. 1.9 Ga, and already indicates relative motion between Slave and Superior through parts of that time interval. A detailed evaluation of published Slave paleomagnetic data from 1.9 to 1.8 Ga (Mitchell et al., reviewed) indicates numerous rapid oscillations of motion, likely indicative of true polar wander and thus challenging our abilities to make precise pole comparisons through that interval (similar to the Ediacaran-Cambrian paleomagnetic database with large discrepancies that are also contested as putative true polar wander oscillations; Evans, 2003). However, the advantage of the 1.9-1.8 Ga interval is that geological preservation has solved much of the problem for us, as revealed by geological mapping and geochronology of the still-intact assemblage of Laurentian cratons inherited from Nuna's reign. The Nuna supercontinent contained at least Laurentia and originally conjoined cratons to the north (adjacent to Slave and Rae) and northeast (adjacent to Rae and Nain). The strongest craton juxtaposition in Nuna, from a combined geological and paleomagnetic perspective, is the NENA reconstruction of Gower et al. (1990), quantified by numerous high-quality paleomagnetic pole comparisions (Evans and Pisarevsky, 2008). The connection is compelling enough to allow geometric tests of the Earth's Proterozoic magnetic field, specifically whether it was a pure dipole or whether it had non-negligible quadrupolar or octupolar components as measured at the planet's surface (Kent and Smethurst, 1998; Evans, 2006; Swanson-Hysell et al., 2009; Panzik and Evans, in prep.).

The Siberian craton is nearly surrounded by Mesoproterozoic rifted passive margins (Pisarevsky and Natapov, 2003) and therefore likely lay near the center of Nuna. Recently published paleomagnetic and geochronologic data from Siberia (Wingate et al., 2009; Didenko et al., 2009) fill an earlier void in that craton's 1.9-1.5 Ga apparent polar wander path and permit a long-lived direct juxtaposition between Siberia and northern Laurentia through that interval of time (Figure 1). We propose that during the geon prior to final assembly of Nuna at 1.81 Ga (St-Onge et al., 2006), collisional orogens between the Slave, Rae, and Hearne cratons in Laurentia would have extended directly into contemporaneous orogens that welded Siberia and Fennoscandia (northern Baltica). Nuna had thus attained continent-sized, if not supercontinent-sized, proportions by ca. 1.9 Ga, and that Superior had a relatively late arrival in joining the landmass. It is possible to hypothesize Nuna's inclusion of other cratons, such as North China on the far side of Siberia (Wu et al., 2005), Northern Australia and the Mawson Continent to the west of present North America (Betts et al., 2008; Goodge et al., 2008; Payne et al., 2009), and Amazon and West Africa on the far side of Baltica (Bispo-Santos et al., 2008; Johannsen, 2009), but those connections are more speculative at this stage.

If the paleogeographic reconstruction described above is correct, then mafic magmatic events at 1.38-1.27 Ga, as found in North China (Zhang et al., 2009), northern Siberia (Ernst et al., 2000), Baltica (see Ernst et al., 2008), and northern Laurentia (Ernst and Bleeker, in press), might represent breakup of Nuna in mid-Mesoproterozoic time. By the time of ca. 1.0 Ga Rodinia assembly (Li et al., 2008; but note an alternative model presented by Evans, 2009), Siberia had separated by about a craton's distance from Laurentia (Pisarevsky et al., 2008), and Baltica had pivoted around Greenland to arrive at its Neoproterozoic "right-way-up" orientation adjacent to northeastern Laurentia (Cawood and Pisarevsky, 2006). The most obvious difficulty with this Nuna breakup model is the current lack of any known examples of 1.27-Ga Mackenzie-correlative mafic rocks in southern Siberia. To resolve this issue, the search for such rocks in the remote Aldan cratonic region should proceed with utmost urgency.

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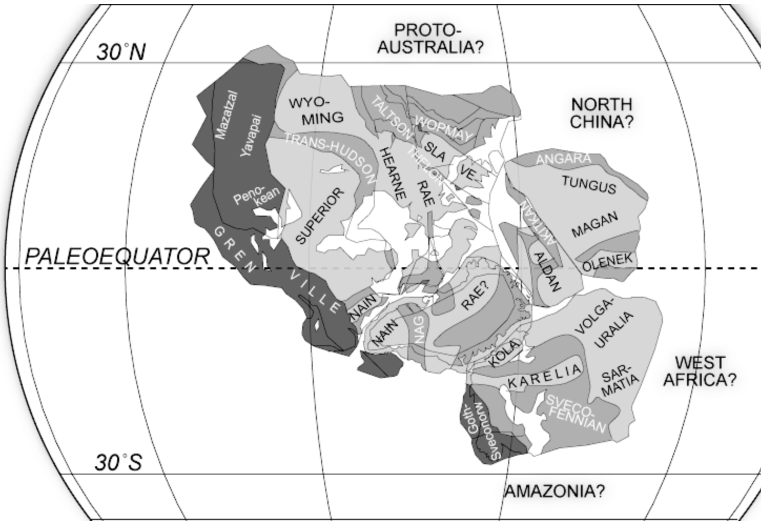

Figure 1. Proposed craton assemblage map of Nuna, reconstructed to paleolatitudes and orientation at the onset of hypothesized breakup at 1270 Ma. Light gray: Archean cratons. Medium gray: Paleoproterozoic orogens. Dark gray: Paleo-Mesoproterozoic accretionary orogens at a long-lived, circum-Pacific-type margin of the supercontinent (Karlstrom et al., 2001). The positions of queried cratons are referenced in the text. From Evans and Mitchell (in preparation).