The Precambrian Geomagnetic Field: Testing The Dipole Hypothesis

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The role of the Precambrian geomagnetic field is important in many aspects of the geodynamo evolution, for understanding the core-mantle interactions and the convection processes taking place in the core and the mantle as well as in formation of supercontinents. One of the most important aspects is to define the nature of the field, i.e. whether it was dipolar or non-dipolar and whether it had long term trends during the Precambrian. Here we present a serie of analyses to test the GAD-hypothesis using (i) inclination and intensity frequences, (ii) reversal asymmetry and rate and (iii) paleosecular variation (PSV) data. We subdivided the Precambrian into three periods: 3455-1900 Ma; Early, 1900-1170 Ma; Middle and 1171-542 Ma; Late, with a notion that these are centered at three supercontinents, Kenorland, Nuna and Rodinia, respectively. We updated the Preacambrian directional and intensity databases in order to select only the most reliable data for analysis. We used the global online PALEOMAGIA database in the analysis of the three topics. For paleointensity we used the PINT database to include Q_{PI}-values as applied to Precambrian. The inclination frequency and the asymmetry data suggest that the field was close to the geocentric axial dipole (GAD) with a ca. 11 % octupole and a zero quadrupole component. The PSV analysis is not sensitive enough to isolate individual non-dipole field contributions, yet raises a possibility that the field in general was less dipolar during the late Paleo-Mesoproterozoic era, when the Nuna supercontinent prevailed, than during the Archean - Early Proterozoic and Late Proterozoic eras, when the Kenorland and Rodinia supercontinents existed. It is noteworthy that the most reliable paleointensity data suggest a weak but significant latitudinal dependence of the field somewhat similar to that expected from GAD field, although non-dipole features cannot be ruled out. The reversal rate seem to be smallest during the Mesoproterozoic when the field was weaker and more non-dipolar and when the cratons seemed to move more slowly.

Precambrian paleointensity and early Earth evolution – The knowns and unknowns

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Data on the strength of the Precambrian magnetic field are important for understanding the behavior of Earth’s geodynamo in the deep past. Furthermore, Precambrian paleointensity has been used to explore a multitude of important interconnected Earth’s evolution processes including the Earth’s thermal evolution, age of the inner core, core thermal conductivity, mantle convection, plate tectonics, magnetospheric shielding, atmospheric chemistry, and even the emergence of life. However, obtaining reliable Precambrian paleointensity data still remains one of the most challenging tasks of paleomagnetic research. Consequently, although the Precambrian spans more than 85 % of the entire geological record, the Precambrian paleointensities only comprise about 9 % of the available data and are characterized by an uneven geographical and temporal distribution. In this talk I will provide a review of the Precambrian paleointensity records is provided together with the related perspectives and challenges. A special emphasis will be given to a discussion of what questions we can or cannot address based on the available paleointensities: What are the knowns and unknowns related to the existing Precambrian paleointensity record?

Testing the core of the Supercontinent Nuna with Mesoproterozoic paleomagnetic data from Finland

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To understand processes occurring from the planetary interior to the surface environment, a robust paleogeography of tectonic plates is important. Paleomagnetism coupled with geochronology is powerful quantitative method for providing ancient latitudes and azimuthal orientations of continents. The Earth’s continental crust is considered to have been assembled to form several supercontinents at different times. The three youngest supercontinents Pangea; late Neoproterozoic to Cambrian Gondwana, and Neoproterozoic Rodinia are widely accepted. The concept of older supercontinents becomes more controversial as the age of the geological formations increases, due to paucity of paleomagnetic data and inherent dating problems. The development of models of pre-Rodinian Paleo-Mesoproterozoic Nuna (a.k.a. Columbia, Hudsonland) supercontinent has been slow. Recently new high quality paleomagnetic and geochronological data from mafic dykes, that are amenable for precise U-Pb dating and often preserve a stable record of ancient magnetic fields, have been produced allowing new Nuna reconstructions.

To reconstruct Nuna and to study its life cycle it is vital to reconstruct its core. There is a general agreement that a tectonic "core" of the Mesoproterozoic Nuna supercontinent incorporates Baltica and Laurentia in a geologically and paleomagnetically viable connection between Northern Europe and North America (NENA), where Baltica is in “upside-down” position relative to Laurentia. However, contradicting reconstructions have been proposed. We show that new high quality Mesoproterozoic paleomagnetic data with new geochronology results for Baltica support NENA connection. Those include Mesoproterozoic data from 1.64 Ga Häme, 1.58 Ga Åland, and 1.58 Ga Satakunta diabase dyke swarms in Finland.

Advances in Nuna reconstructions will also require more high quality paleomagnetic data for other cratons. It was recently proposed that Siberia forms the Nuna core together with Baltica and Laurentia. Adding cratons around the core of Nuna has been a major initiative among paleogeographers in recent years that has lead to the paleogeographical model of Nuna to take shape.