The Earth's magnetic field during the Archean

Arata Yoshihara[1]; Ikuro Sumita[2]; Tadahiro Hatakeyama[3]; Yozo Hamano[4]

[1] Dept. of Earth Sciences, Toyama Univ.; [2] Earth Sci., Kanazawa Univ.; [3] IPC, Okayama University of Science; [4] Dept. Earth & Planetary Physics, Univ. of Tokyo

Knowledge of the Earth's magnetic field during Archean and Proterozoic times can provide important sources of information for understanding the internal and environmental evolution of the Earth. The long-term variation in field intensity and reversal rate is considered to reflect mode changes in powering the geodynamo. Stevenson et al. (1983) revealed that the release of gravitational energy and latent heat that accompanied the inner core formation drastically increased the field intensity. Breuer and Spohn (1995) presented simulations of mantle convection at the end of the late Archean and showed that a breakdown of two-layer convection at the Archean-Proterozoic boundary also brought about a significant increase in field strength due to enhancement of core cooling. The onset of the intense field probably played a key role also in emergence of photosynthesis bacteria, since it enabled them to develop under the protection of the magnetosphere from cosmic rays.

Although there have been several recent efforts to reconstruct the Precambrian geomagnetic field, the volume of reliable paleomagnetic data is still insufficient to characterize it. Aiming at global accumulation of paleomagnetic data during the Archean, we conducted paleointensity and paleodirectional measurements with volcanic and sedimentary rocks from four of the best-preserved Archean cratons: the Slave Province, Canada, the Kaapvaal craton, South Africa, the Zimbabwe craton, Zimbabwe, and the Pilbara craton, Australia.

Paleointensity results from diabase dikes of the Slave Province suggest that, in the Earth's core, the dynamo process of comparable activity to that of the present day has already existed at ca. 2.6 Ga. Results from komatiites of the Belingwe greenstone belt in Zimbabwe imply that the field strength at ca. 2.7 Ga seems to be within the range of the dipole fluctuation of Phanerozoic times. While, weak virtual dipole moment values obtained from the Mount Roe basalts of the Pilbara craton and another datum at ca. 2.8 Ga from Greenland by Morimoto et al. (1997) are close to the lower limit of the dipole fluctuation of Phanerozoic times. Therefore, the variation of the virtual dipole moment values from 2.8 Ga to 2.6 Ga appears to be consistent with the picture by Hale (1987) that there is a sharp increase in field intensity between 2.7 Ga and 2.1 Ga by the inner core nucleation. For the early Archean, paleointensity values from komatiites of the Barberton greenstone belt in the Kaapvaal craton and the Salgash pillow basalts from Pilbara suggest a possibility that the geomagnetic field at ca. 3.5 Ga has either comparable or even larger intensity compared to that of the present field.

In the banded iron formation from the Pilbara craton with an age of 3.2-3.3 Ga, we found also magnetic reversals. More than 20 polarity changes were observed in the section with a thickness of about 1.7 m, and their two characteristic remanence directions are nearly antipodal to each other. The most natural explanation for these flips is that they are records of the Archean geomagnetic field reversals. However, the origin of the remanences has not been well proved, allowing an alternative interpretation that they are reprintings by weathering during the Tertiary.