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Recent progress in researches on biogenic magnetite and applications to paleoceanography

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Magnetotactic bacteria, which have chains of magnetite crystals, were discovered in 1975 by Blakemore, and magnetites of bacterial origin preserved in marine sediments (magnetofossil) were first reported in 1986. Since then, biogenic magnetites have been recognized as one of sources of magnetic minerals in sediments. Biogenic magnetites can be identified with TEM from their sizes confined within a single-domain range (several tens of nano-meter) and their characteristic morphologies under biological control. Yet, quantitative estimations such as a proportion of biogenic and terrigenous magnetic minerals were difficult because it is required to extract magnetic minerals for TEM observations, which may distort original magnetic mineral assemblages. However, recent progress of rock magnetic techniques has enabled quantitative estimations for amount and morphology of biogenic magnetites (e.g., Egli, 2010), and it is revealed that biogenic magnetites are dominant magnetic minerals in sediments at least in high latitudes and the equatorial zone (Roberts et al., 2012; Yamazaki and Ikehara, 2012). Quantification of biogenic magnetites have opened new applications to researches on paleoceanography and paleoenvironment, as a kind of fossils. In this presentation, I will introduce examples of such applications.

On the other hand, the discovery for the dominance of biogenic magnetites in sediments has strongly impacted paleomagnetism and its applications, because models of remanent magnetization acquisition processes of sediments did not incorporate contribution of biogenic magnetites. Remanent magnetization of sediments has been explained by a zone magnetization model; remanent magnetization is acquired within a zone with some thickness below the seafloor during compaction after deposition of sediment particles. This implies that there is a lag between a horizon of remanent magnetization fixing and seafloor or the bottom of the bioturbation mixing zone (called lock-in depth). Various models for the amount of the lock-in depth have been presented so far, from few centimeters to more than 40 cm, and have debated for more than thirty years. This is a significant problem when correlating magnetostratigraphy with biostratigraphy and oxygen isotope stratigraphy. Recently, Suganuma et al. (2010) apparently settled the problem by concluding a lock-in depth of ~15 cm from the comparison of geomagnetic paleointensity minimum at the Brunhes-Matuyama polarity transition with abundance of a cosmogenic nuclide 10Be, which is an independent method for estimating paleointensity devoid of a depth-lag. However, previous arguments on remanent magnetization acquisition mechanism did not seriously consider contribution of biogenic magnetites. It is thought that magnetotactic bacteria live in a sharp chemical gradient from oxic to anoxic in a sediment column and that near the Fe-redox boundary is the most preferable position for magnetotactic bacteria. If this is true, and if biogenic magnetites are the main carrier of remanent magnetization, the magnetization will be fixed near the Fe-redox boundary and the amount of the depth-lag will vary from millimeters to tens of meters depending on sedimentary environments. At present, importance of biogenic magnetites as a carrier of remanent magnetization is not clear even if they are dominant magnetic minerals. This is a significant issue to be solved.

Keywords: biogenic magnetite, magnetotactic bacteria, rock magnetism, paleoceanography, depositional remanent magnetization, Fe-redox boundary