Rotation and environment reconstructed for a manganese nodule from Penrhyn Basin, South Pacific using paleomagnetism and rock magnetism

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Marine manganese nodule (nodule, hereafter) is a future mineral resource with elements such as Cu, Ni, Co, and rare earth elements (REE) in addition to the major elements, Mn, and Fe. At the same time, they are invaluable long-term archives of marine environments since they grow very slowly at a speed of a few millimeters per million years.Occasionally, nodules are found to be exposed on sediment surface without being buried by the sediments. The mechanisms for the occurrence and growth have not yet been fully resolved. Here, we report a possibility of rotation of a nodule during the growth process utilizing paleomagnetic record. In addition, we conducted rock magnetic analyses to understand the environment and secure the reliability of paleomagnetic records. We used a spheroidal nodule collected by a box corer from Penrhyn Basin (Lon.: 158.5˚W, Lat.: 12˚S, Water depth: 5248 m), South Pacific during GH83-3 cruise.

Vertical upward direction was marked on the top of the nodule. Two planar blocks A and B were taken from the nodule perpendicular to each other passing trhough the marker. Each block was cut into five lengthy blocks vertically, then further cut horizontally to make 5 or 10 specimens serially from the surface to the core of the nodule. Paleomagnetic analyses were made using a superconducting rock magnetometer on the specimens with stepwise alternating field (AF) demagnetization up to 80 mT. Rock magnetic analyses were made on a selected series of specimens (5 or 10) along a line from the surface to the core, including low-T magnetometry, isothermal remanent magnetization (IRM) acquisition, First Order Reversal Curve (FORC) analyses, etc.

Low temperature magnetometry suggests that the nodule contains magnetite. Specimens from surface to 16 mm depth (Group 1) is magnetite with low-temperature oxidation, whereas specimens from 16 mm to 20 mm depth (Group 2) is maghemite resulting from complete oxidation. Further, analyses on IRM acquisition and FORC enables to classify magnetic minerals based on mean coercivity (Bh) and magnetic domain state. Group 1 is composed of single domain (SD; Bh ~ 35 mT), vortex (Bh ~ 20 mT), and MD (Bh ~ 5 mT) magnetite, and a higher coercivity (Bh ~ 500 mT) magnetic mineral presumed to be hematite. Magnetite with low-temperature oxidation was recognized as a mineral with Bh ~ 100 mT. Group 2 is considered to contain vortex and SD magnetite, whereas MD magnetite and higher coercivity mineral were not identified.

Paleomagnetic directions suggest that high coercivity component (17.5~40 mT) has positive polarity (specimens from blocks A & B). Higher coercivity component with normal polarity could be considered be acquired in the Brunhes normal polarity chron between 0.77 Ma and present. On the other hand, the age of the oldest specimens of about 8 Ma based on 10Be isotopes and absence of reversed polarity directions may suggest that this is not primary magnetization. The surface specimen for block B adjacent to block A shows paleomagnetic inclination close to -23˚, which is expected for magnetic field direction at the site produced by a geocentric dipole. Correction of -45˚ for paleomagnetic declination of the specimen gives declination value of zero. The same corrections were made on the declinations for a series of specimens to the core, which give paleomagnetic directions on a great circle. The pole for the great circle is along the northeast direction with 45˚ downward dip. The paleomagnetic direction for the oldest specimen could be restored to the geocentric dipole field direction by 100˚ anticlockwise rotation along

this pole. This suggests that the nodule acquired secondary magnetization during the last normal polarity period successively while rotating clockwise along the rotation axis. In the presentation ,we discuss possible causes of the rotation for the nodule.

Keywords: manganese nodule, natural remanent magnetization, magnetic mineral

