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Paleomagnetic study of ferromanganese crusts recovered from the northwest Pacific — Testing the applicability of the magnetostratigraphic method to estimate growth rate

Atsushi Noguchi [a,b], Yuhji Yamamoto [a,*], Keisuke Nishi [a], Akira Usui [a], Hirokuni Oda [b]

[a] Kochi University, B200 Monobe, Nankoku, Kochi 783-8502, Japan
[b] Research Institute of Geology and Geoinformation, Geological Survey of Japan, AIST, Central 7, 1-1-1 Higashi, Tsukuba 305-8567, Japan

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ABSTRACT

Previous studies have shown that ferromanganese crusts in the Pacific Ocean commonly record paleomagnetic reversals and that the reversal patterns can be used to estimate growth rates. In order to investigate the applicability of the magnetostratigraphic method, we conducted paleomagnetic measurements of crust samples recovered from five locations in the northwest Pacific. A series of thin slices, with thicknesses of 0.5–1.0 mm, was prepared for each sample, and a paleomagnetic polarity was determined for each slice. In all five samples, we found a consistent reversal pattern of N1–R1–N2–R2–N3 from the surface to the inner part of the crust. In three samples, another polarity interval (R3) was recognized below the N3 section of the crust. These data suggest that ferromanganese crusts in the northwest Pacific recorded paleomagnetic reversals and that reversal patterns can be used for ocean-scale correlations. The magnetostratigraphic method suggests constant growth rates of 1.49, 2.54, 3.56 and 3.67 mm/Ma for four samples, three of which are consistent with those estimated using $^{10}Be/^{9}Be$ dating at the 2σ (standard deviation) level.

1. Introduction

Ferromanganese crusts, one of the important marine mineral resources, typically grow on seamounts and their abundance could be estimated by geophysical investigation by multi-channel seismic survey in combination with rock sampling (e.g. Lee et al., 2009). Construction of their reliable age models and hence growth rate estimates are important in understanding the abundance of the crusts. Ferromanganese crusts have been demonstrated to record paleomagnetic reversals. Chan et al. (1985) found six reversals in 13 thin (~1 mm), sequential slices cut from a dredged sample taken from the north Pacific (30°N, 140°W) from the water depth of 3840 m. Linkova and Ivanov (1993) observed six reversals in a series of 10 thin slices (~2–4 mm) cut from a sample taken from the Yuryaku seamount in the central Pacific (32°N, 172°E). Unfortunately, as the most surficial layers of the samples were not characterized by normal polarity (which should be expected for the last 0.78 million years), these studies were not successful in correlating the reversals with the geomagnetic polarity time scale (GPTS). Joshima and Usui (1998) studied three dredged samples recovered from the Nishi–Shichito Ridge (31–32°N, 138–139°E), estimating their growth rates as 14–17 mm/Ma based on 7–10 reversals found in 19–29 thin sequential slices. However, the thickness of the slices (2 mm) seemed to be too large to resolve multiple paleomagnetic polarity records into individual slices, and as a result gave an inaccurate magnetostratigraphy. Oda et al. (2011) successfully constructed a submillimeter scale magnetostratigraphy for one of the Nishi–Shichito Ridge samples using a scanning superconducting quantum interference device (SQUID) microscope. They provided a high-fidelity age model giving an updated growth rate of 5.1 ± 0.2 mm/Ma, which is consistent with the rate of 6.0 ± 0.2 mm/Ma obtained with the $^{10}Be/^{9}Be$ dating method.

The above-mentioned studies have shown that ferromanganese crusts in the Pacific commonly record paleomagnetic reversals and that reversal patterns recorded in the crusts can be used to estimate growth rates. To date, scanning SQUID microscopy on the crust sample from the Nishi–Shichito Ridge by Oda et al. (2011) has been the only successful case for estimating the growth rate based on its magnetostratigraphy. Scanning SQUID microscopy for geological samples is in an early stage of development and not a common method in paleomagnetism and rock magnetism. In this study, we used an ordinary SQUID magnetometer to investigate the applicability of the 'magnetostratigraphic' method. Thin slices were carefully prepared from crust samples recovered from five locations in the northwest Pacific (Ryukyu trench, Ryusei seamount, Hanzawa seamount, Takuyo-Daigo seamount and Nosappu fracture zone), and they were subjected to

* Corresponding author.
E-mail address: y.yamamoto@kochi-u.ac.jp (Y. Yamamoto).

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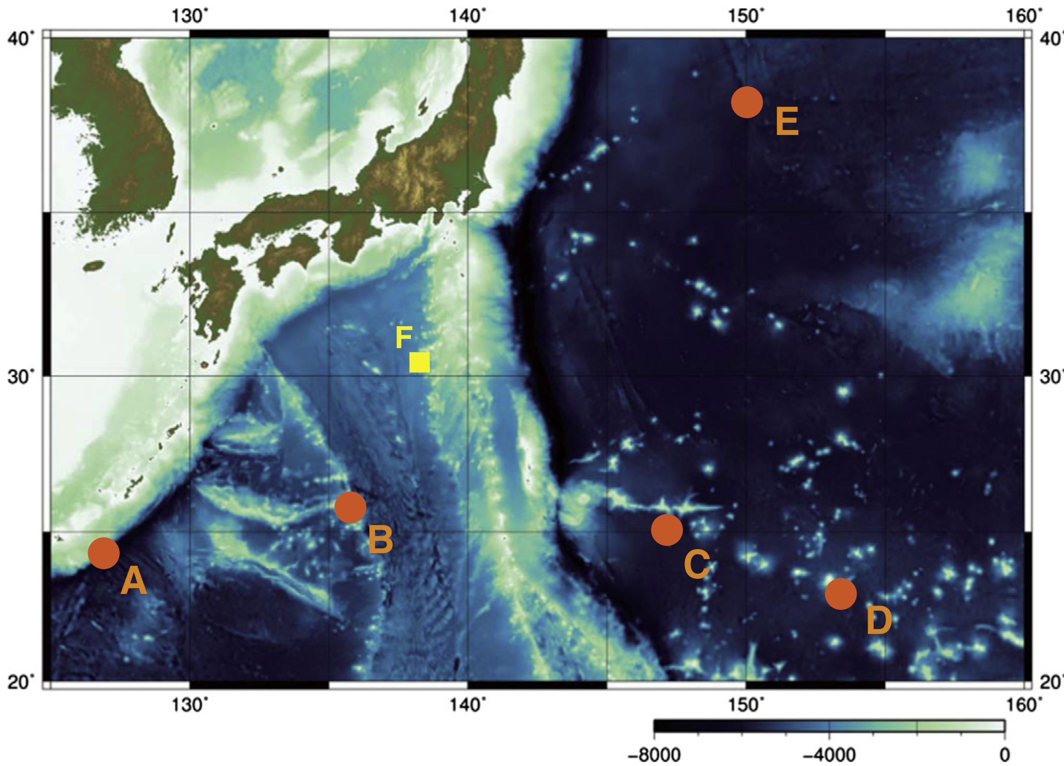

Fig. 1. Location of the sampling sites. (A) Ryukyu trench, (B) Ryusei seamount, (C) Hanzawa seamount, (D) Takuyo-Daigo seamount, and (E) Nosappu fracture zone. (F) Location where sample D96-m4 was taken for the study of Oda et al. (2011).

paleomagnetic measurements. We report and discuss the paleomagnetic measurement results, and estimate a growth rate for each sample based on a magnetic reversal pattern deduced from the results.

2. Material and methods

2.1. Samples

Samples of ferromanganese crusts used in this study were recovered from five locations in the northwest Pacific: Ryukyu trench (24°18.50′N, 127°36.20′E, water depth 6462 m); Ryusei (25°32.37′N, 135°34.33′E, 1529 m), Hanzawa (25°42.58′N, 146°44.90′E, 4362 m) and Takuyo-Daigo (22°41.04′N, 153°14.63′E, 2239 m) seamounts; and Nosappu fracture zone (38°14.27′N, 150°8.27′E, 5961 m) (Fig. 1). The samples were taken with a remotely operated vehicle (ROV) (except for a dredged sample at Nosappu fracture zone) during the cruise KR06-03 for characterization of ferromanganese deposits organized by the Japan Agency for Marine–Earth Science and Technology (JAMSTEC) onboard of R/V Kairei. The advantage of bottom sampling with a ROV is that oceanographic and geochemical parameters are measured on site just above the ferromanganese crusts, and that configurations and occurrences of ferromanganese deposits are observed in detail. A piece of crust can be usually removed from an outcrop with a rotary blade. This method allows selecting only the hydrogenetic crusts firmly attached to rock outcrops, which are also directly overlain by bottom waters without any sediment cover. The approximate gradient of a crust's surface was measured during the operation of the ROV, and was up to 20°. The declinations were not measured during these ROV dives.

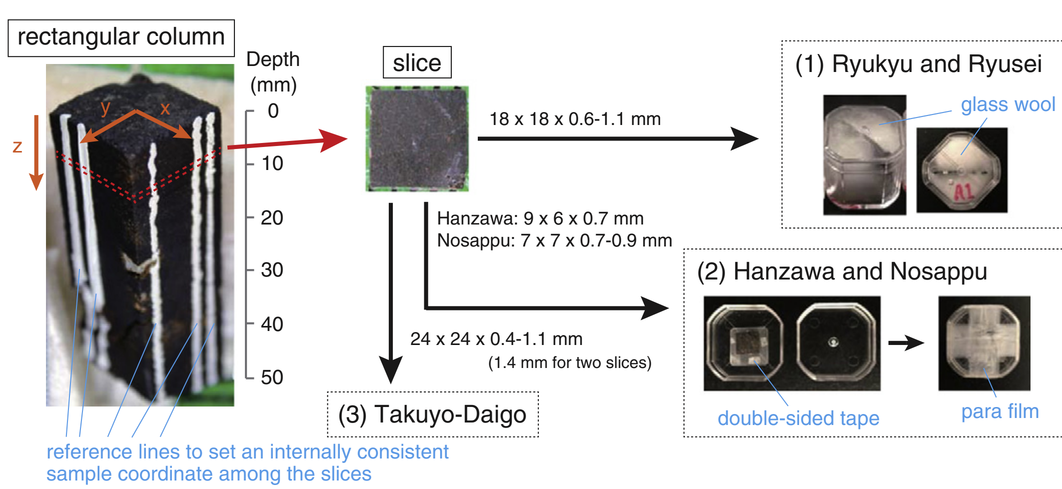

Fig. 2. Sample preparation procedure.