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ANALYSIS OF FINE STRUCTURE OF CHERT AND BIF BY MEASUREMENT OF HIGH RESOLUTION MAGNETIC FIELD AND SCANNING X-RAY ANALYZED MICROSCOPE

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Abstract: The fine structure of chert and BIF was analyzed by magnetic measurement and Scanning X-ray Analyzed Microscope. The magnetic study was done by the HFD system of magnetic field analysis with high Tc (superconducting critical temperature) SQUID. We examined that the HFD system measures the vertical magnetic field around the magnetized sample at high space resolution.

The HFD system was applied to Inuyama chert which has a pinkbed layer at the Triassic/Jurassic boundary. The magnetic field at the upper part of the pinkbed layer showed the upward direction and that of the lower chert layer showed the downward direction. Taking the results of rock magnetic study and Scanning X-ray Analyzed Microscope (SXAM) into consideration, the upward magnetic field corresponds to reversed magnetization at the pinkbed layer, which suggests the short reversed polarity in the Nuanetsi normal geomagnetic polarity zone (E. MCELHINNY and J. BUREK, Nature, **232**, 98, 1971; D.V. KENT *et al.*, J. Geophys. Res., **100**, 14965, 1995). The HFD measurement on BIF of Antarctica showed the clear striped structure of BIF.

The results in this study indicate that HFD measurement with the analysis by SXAM becomes an useful method to investigate the fine structure of geological samples.

key words: distribution of magnetic field, chert, BIF, Scanning X-ray Analyzed Microscope

1. Introduction

The paleomagnetic method has contributed to the study of tectonics and age dating. Recently, several types of paleomagnetic apparatus have been developed, and accordingly studies of new paleomagnetic subjects have been attempted. In this study, as one such apparatus, we will introduce the measurement system called HFD to investigate the finite magnetic structure of a plate sample.

After testing the system by applying it to an artificially magnetized sample, the chert of Inuyama and BIF (banded iron formation) of Antarctica are studied. The Scanning X-ray Analyzed Microscope is used to investigate the distribution of chemical elements on the same sample. The results by the two methods will be combined to discuss the fine structure of the chert and BIF.

2. Apparatus

2.1. HFD system

The HFD system was developed by FIT (Forshungesellschaft für Informationstechnik mbH) of Germany. The system comprises high Tc SQUID (superconductor: yttrium alloy of Y-Ba-Cu-O), universal stage moving two dimensionally, and the analyzing part (Fig. 1). The noise level of the system is less than 4.6 pT √‾ Hz. It measures the distribution of magnetic flux of the plate sample on the universal stage. The stage can move to X and Y axis in 0.1 mm precision. The sample size up to 150×50 mm with thickness 20 mm is applicable.

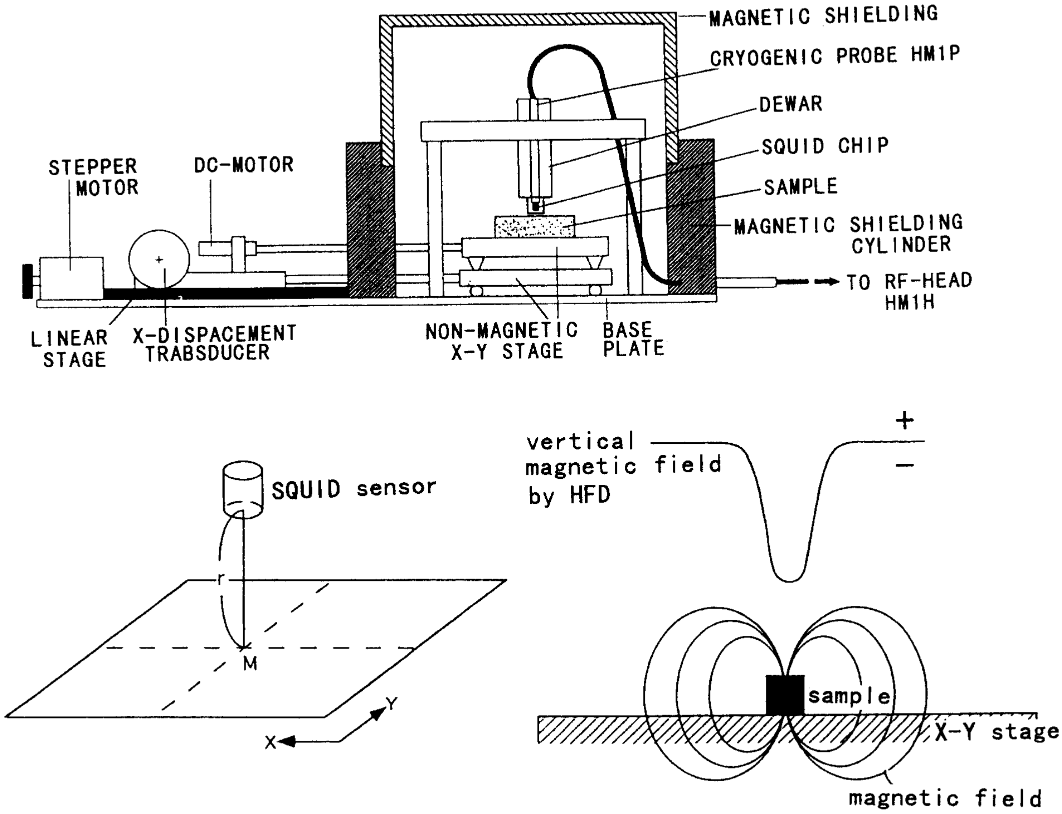

Fig. 1. Block diagram of the HFD system and illustration of the measurement.

2.2. Scanning X-ray Analyzed Microscope

The Scanning X-ray Analyzed Microscope (SXAM) was developed to study the chemical elements of a plate sample (NAKAZAWA *et al.*, 1990; TAKANO *et al.*, 1997). The system can measure the two dimensional distribution of chemical elements with the space resolution of 10 μm to 0.8 mm. Plate samples of sizes from 2.56×2.56 mm to 200×400 mm can be analyzed.

3. Experiments by HFD System on the Artificially Magnetized Samples

3.1. Needle type magnet sample

The HFD system was applied to the needle type magnet cemented near the surface

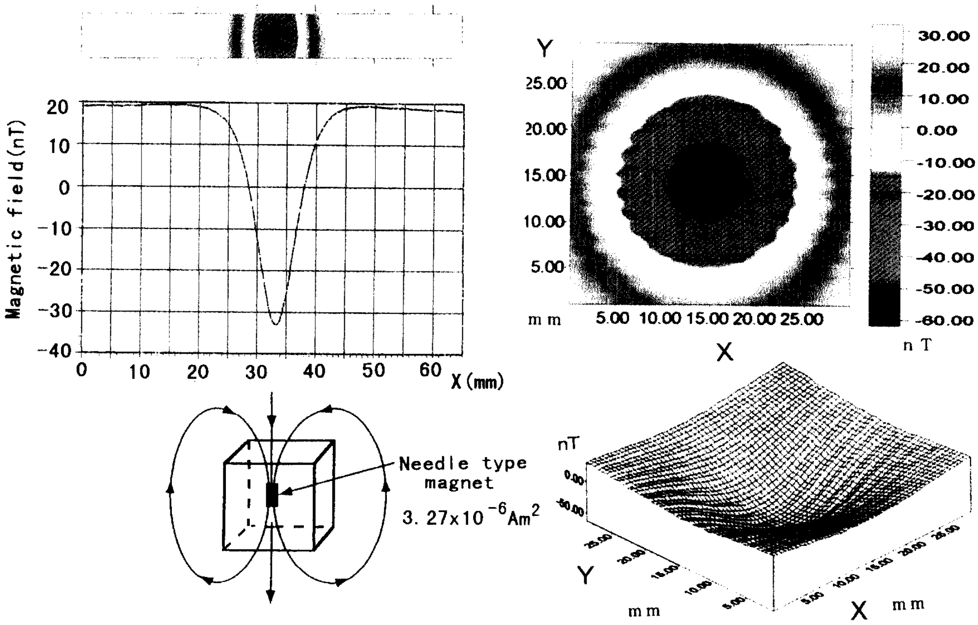

Fig. 2. Left: Variation of magnetic field along the line running through the center of needle magnet set about 1 mm under the SQUID. Right: Distribution of magnetic field around the needle magnet.

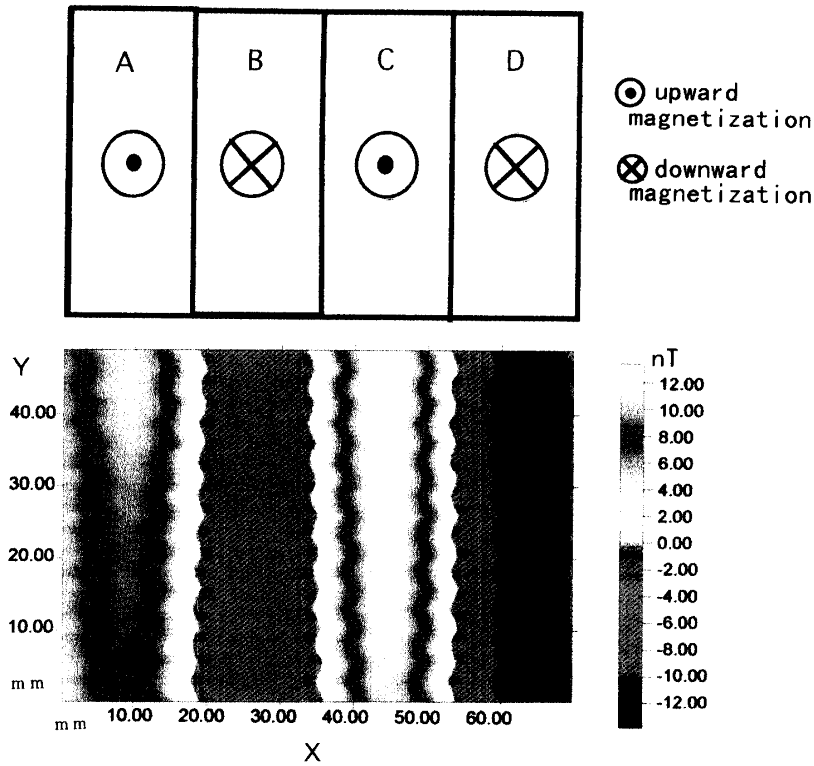

Fig. 3. Distribution of magnetic field around the sample with the layered magnetizations of antipodal direction.

of a cubic case by gypsum. The left figure in Fig. 2 shows the variation of magnetic field along the line running through the center of the needle. The distance between the sample and HFD sensor is about 1 mm. The magnetic field measured by HFD indicates a space resolution of about 1 mm.

The right figure shows the two dimensional distribution of magnetic field around the needle magnet. We can see the clear radiating magnetic field around the sample.

These results suggest that the HFD system measures the finite structure of the magnetic field around the magnetized sample.

3.2. Sample with layered magnetizations of antipodal direction

The HFD system was applied to the sample which has the layered magnetic components of antipodal direction. Four specimens of stripe shape (40×10×5 mm) were prepared and were magnetized by electromagnet. The four specimens (A, B, C, D) were then arranged on the universal stage as Fig. 3, where mark X shows the downward magnetization and dotted mark shows the upward magnetization. The magnetic intensities of specimens A to D are 3.5, –3.6, 3.7, –3.5 ($\times 10^{-6}$ Am^2), respectively (downward magnetization is taken as plus). The sample is regarded as a particular case of a geological formation having striped layered structure with different magnetization.

The lower figure in Fig. 3 shows the distribution of magnetic field around the composed four specimens. We can identify the antipodal magnetic field corresponding to each magnetization of specimen.

4. Geological Samples for HFD and X-ray Analysis

The study with HFD and SXAM was conducted on the following chert and BIF.

The chert sample was collected in the Sakahogi area of Inuyama city in Aichi Prefecture (Fig. 4). The chert covers the age from Triassic to Jurassic which was studied by HORI (1988) from the analysis of radiolaria. At the portion around the Triassic and Ju-

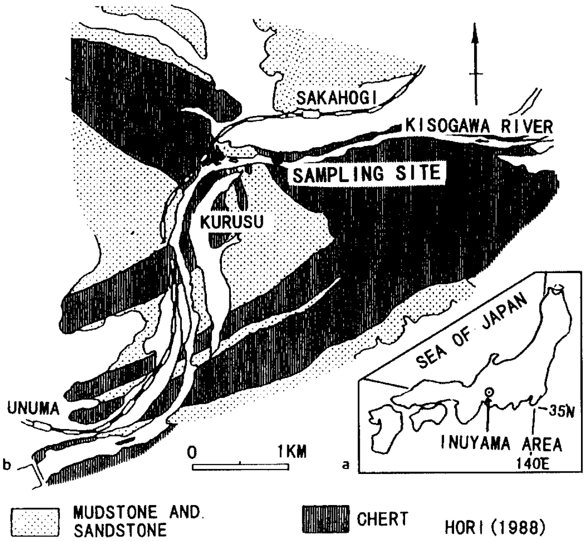

Fig. 4. The location where the chert in this study was collected (HORI, 1988).

rassic boundary (T/J boundary), the chert changes color and is called the pinkbed layer. The experiment was performed on the polished plate sample from the chert block including the pinkbed layer. Sedimentation rate of the chert is estimated to few mm per thousand year.

The BIF sample was collected at Dumont d'Urville Station of Antarctica by FUNAKI in 1994. The age is estimated to be Palaeozoic. The polished plate sample of 100×150×20 mm was used in the experiment.

5. Results and Discussion for Inuyama Chert

5.1. X-ray fluorescent analysis by SXAM

The chert sample was marked the orientation (magnetic north direction and horizontal plane) at the outcrop. The plate sample was cut with due regard to this orientation as shown in the upper figure of Fig. 5. The lower figure shows the distribution of silica and iron elements on the plate sample analyzed by SXAM. Concentration of silica is expressed as red and that of iron is shown as green. The distribution of these elements is not different between the pinkbed layer and the lower chert layer.

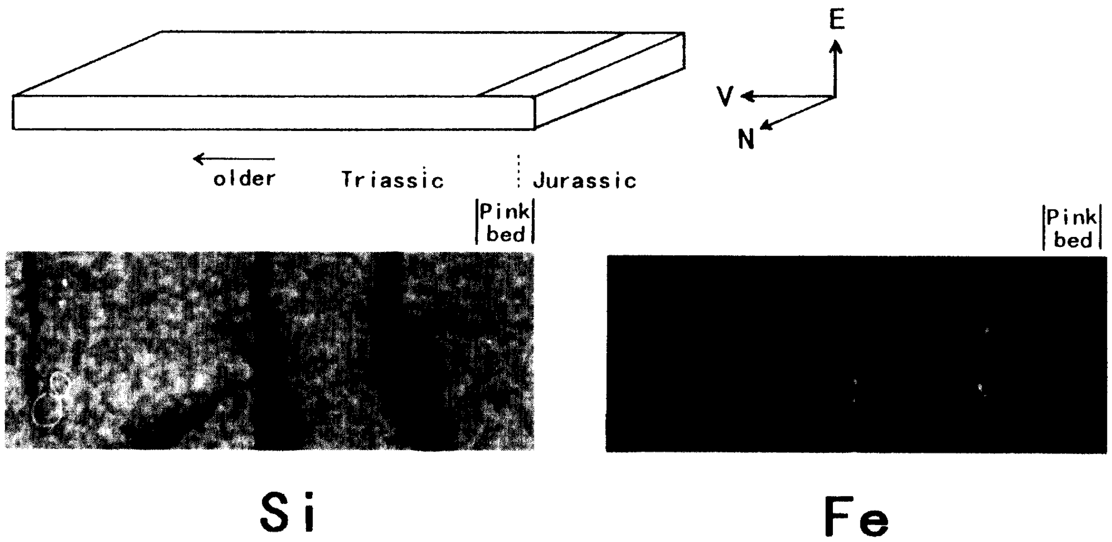

Fig. 5. Distribution of silica and iron elements on the plate sample of Inuyama chert, measured by Scanning X-ray Analyzed Microscope. The Triassic/Jurassic boundary exists in the pinkbed layer of the sample.

5.2. Measurement by HFD system and remanent magnetization

The HFD system was applied on the same plate sample. Figure 6 shows the magnetic field distribution. We can identify the upward magnetic field at the pinkbed layer.

To know the further magnetic property of pinkbed layer, the upper portion of the plate sample was cut into five small specimens (SP.1 to SP.5) as shown in Fig. 7. The remanent magnetization with stepwise alternating field demagnetization experiment was made on these specimens using a SQUID rock magnetometer (2G SRM-760R). Figure 7 shows that the direction of remanent magnetization is different between the specimen

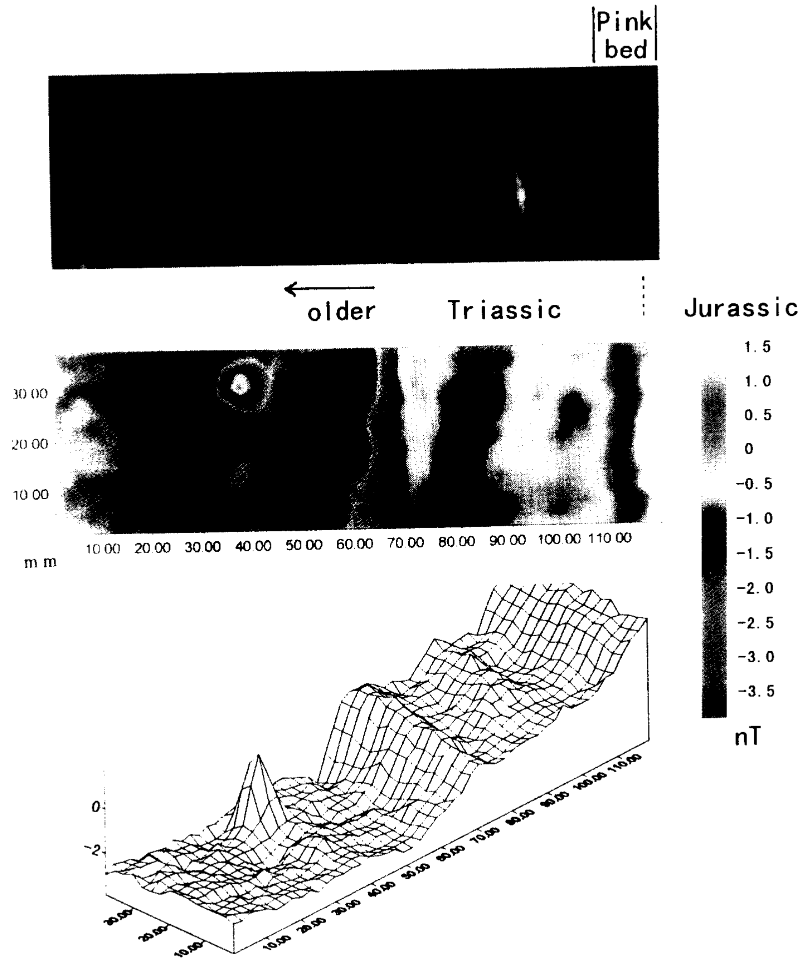

Fig. 6. Distribution of magnetic field on the plate sample of Inuyama chert measured by HFD system.

SP.1 and the lower specimens. The specimen SP.1 shows the upward inclination with westward declination and strongest intensity among the specimens. The intensity of the pinkbed layer (SP.1, SP.2, SP.3) is stronger than that for the lower specimens.

The remanent magnetization of five specimens is consistent with the data studied by the HFD system. That is, the pinkbed layer has strong magnetization compared with the lower chert layer and the upper layer of pinkbed has magnetization antipodal to that of the lower layers.

McELHINNY and BUREK (1971) showed the geomagnetic normal polarity zone around the T/J boundary, called the Nuanetsi Zone. Recently, KENT *et al.* (1995) studied the magnetostratigraphy of the late Triassic-earliest Jurassic from the basalt in drill cores. They showed that a normal polarity zone (E23) succeeded the few million years around T/J (202 Ma). Taking that the sedimentation rate of chert is few mm per thousand years into consideration, the chert layer (12 cm thickness) studied here is considered to be in this polarity zone. In the case, the antipodal magnetization found in pinkbed layer suggests the short reversed geomagnetic polarity in Nuanetsi normal polarity zone. KENT *et al.* (1995) also reported the possibility of short reversal at the T/J boundary.

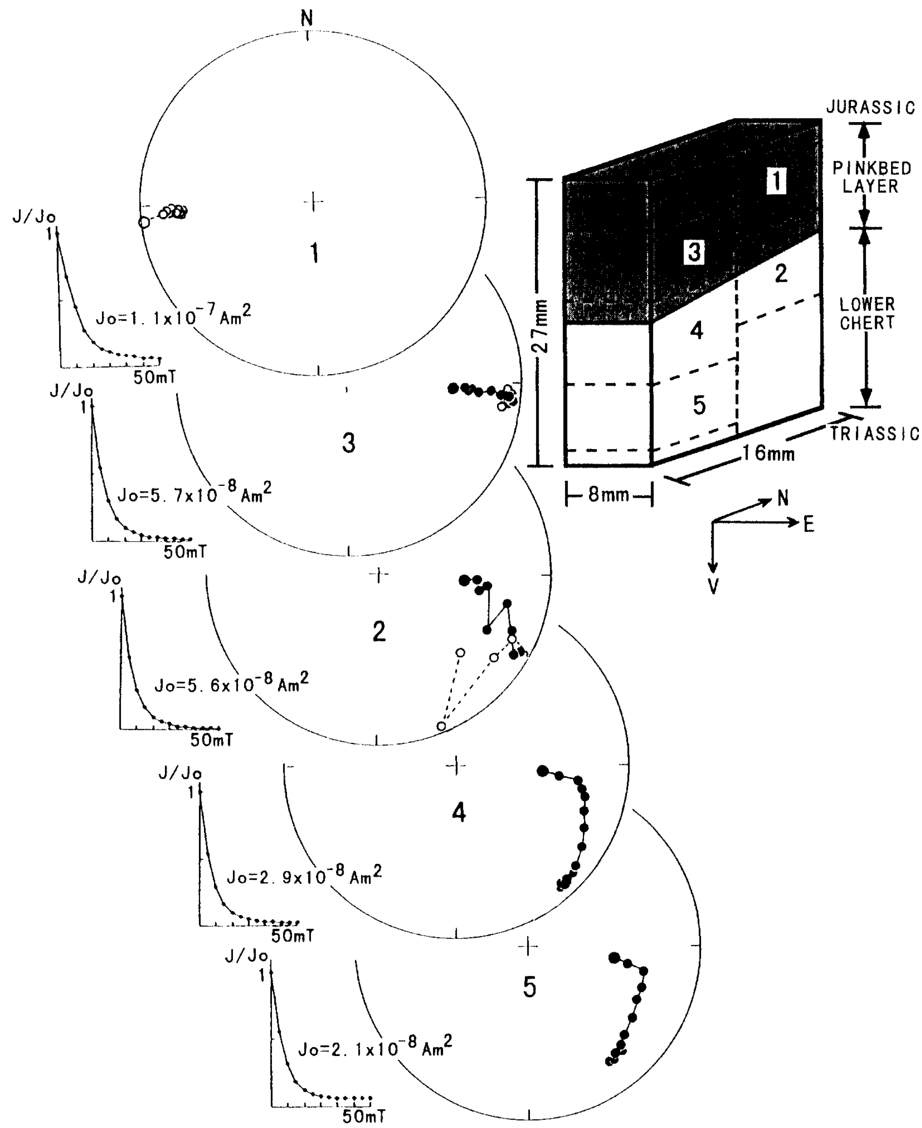

Fig. 7. Alternating field demagnetization of five specimens around T/J boundary from Inuyama chert. For each specimen, the directional change of magnetization is shown in the equal area net projection of the right figure and the intensity change is in the left figure. The magnetization in situ is plotted.

As the X-ray analysis by SXAM shows that the iron content does not differ between the pinkbed layer and lower chert, the strong magnetization of pinkbed is not caused by the concentration of iron. For the strong magnetization at the pinkbed layer, the contribution of magnetic spherule (Nickel oxidate) was examined, however, no such mineral was found (Kawakami, private communication). Further investigation of magnetic minerals is necessary for the study of the pinkbed layer in relation to the environmental change at the T/J boundary.

6. Results and Discussion for BIF Sample of Antarctica

The left figure of Fig. 8 shows the distribution of iron and silica components on a

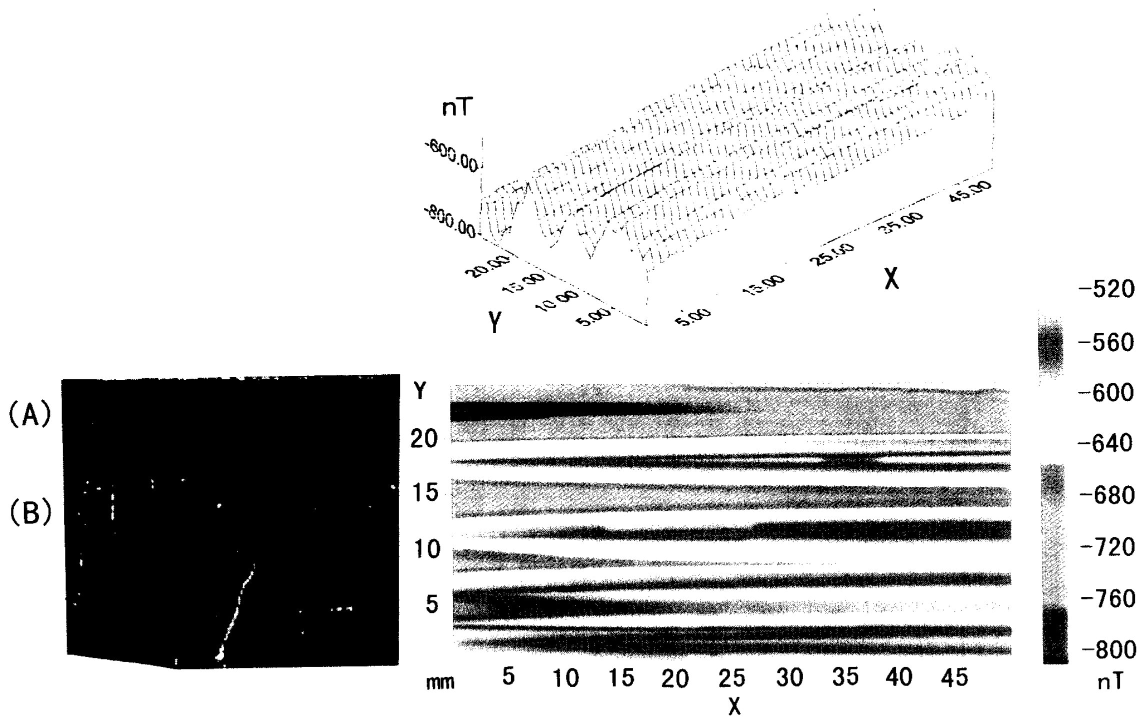

Fig. 8. Right: Distribution of magnetic field measured by HFD system on the plate sample of BIF of Dumont d'Urville Station. Left: Distribution of iron and silica components on the same sample. The content of iron is shown by red and the content of silica by green. Clear boundary of contents of iron and silica exists between region (A) and region (B).

BIF plate sample from Dumont d'Urville Station measured by SXAM. In the figure, the concentration of iron is shown as red and that of silica is expressed as green. The reddish region indicates the iron-rich layer. Between region (A) and region (B), the content of iron and silica is clearly different.

The right figure shows the distribution of magnetic field measured by the HFD system. The distinct boundary between regions (A) and (B) was identified. Region (B) shows a stronger magnetic field than that of region (A), which may be caused by the difference in content of iron oxide suggested by X-ray analysis.

In region (B), the striped structure of BIF was clearly identified consisting of areas of strong and weak magnetic field.

7. Summary

High resolution measurement of magnetic field becomes possible by HFD system possessing the sensitive high Tc SQUID. We applied a HFD system to the artificial magnetized samples and found that the system can measure the distribution of magnetic field to a resolution of 1 mm in space.

The chert in Inuyama having pinkbed layer at Triassic/Jurassic boundary was studied. The HFD system shows the different directions of magnetic field between the pinkbed layer and the lower cherts. Analysis by SXAM indicates that the iron content does not differ between these chert layers. These results, combined with the rockmagnetic data, suggest that the difference in features of the magnetic field of the pinkbed layer is due to antipodal magnetization between the pinkbed layer and the lower chert layer.

HFD measurement and SXAM analysis conducted on BIF of Antarctica showed the clear striped structure of BIF. HATAKEYAMA *et al.* (1995) studied the BIF of Pirbara in Australia whose age is 33 billion years, and found the antipodal magnetizations in the section of few cm, which suggests that the fine structure of BIF corresponds to geomagnetic polarity reversal event. The HFD may examine the antipodal magnetizations and the geomagnetic polarity reversal from BIF, chert etc.

The results of this study indicate that the HFD system, combined with Scanning X-ray Analyzed Microscope, becomes an useful method to investigate the fine structure of geological samples without distorting the samples.

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