A REPORT OF NATURAL REMANENT MAGNETIZATION OF DIRT ICE LAYERS COLLECTED FROM ALLAN HILLS, SOUTHERN VICTORIA LAND, ANTARCTICA

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Abstract: Paleomagnetic studies are performed for the dirt ice specimens collected from the Allan Hills, Southern Victoria Land, Antarctica. These specimens have fairly stable NRM against AF demagnetization up to 500 Oe. Every specimen has normal magnetization with 2.5×10^{-6} emu$\cdot$g^{-1} intensity, $-69°$ inclination and 164° declination. The NRM carriers are estimated to be almost pure magnetite with a pseudosingle domain structure. Although the NRM acquisition mechanism cannot be explained at this time, it may be important to evaluate the possibility of NRM acquisition when the snow containing volcanic ash changes to ice under pressure. Since the nondipole components of the geomagnetic field are large in the southern polar cap area, the NRM cannot estimate the age and the place of NRM aquisition from the VGP position of these specimens.

1. Introduction

Dirt ice layers, usually a few centimeters to less than fifty centimeters in thickness, are recognized in drilled ice cores from Ross Ice Shelf (GOW, 1963), Byrd Station (GOW and WILLIAMSON, 1971; KYLE and JEZEK, 1978; KYLE *et al.*, 1981), South Pole (KING and WAGSTAFF, 1980), Dome C (KYLE *et al.*, 1981) and Vostok Station (KYLE *et al.*, 1982), and bare ice fields, such as the Yamato Mountains (Queen Maud Land) and the Allan Hills (Southern Victoria Land) (NISHIO *et al.*, 1984; KATSUSHIMA *et al.*, 1984). They documented the existence of volcanic ash fragments in these layers.

In the 1980 austral summer season, NISHIO collected blocks of the dirt ice samples with orientations from the bare ice field in the Allan Hills (76.7°S, 158.8°E). One dirt-ice block sample, dark yellow in color, was selected for magnetic investigations. The dirt ice layer in this sample tilts 16° to the southwest and its thickness is about 8 cm.

Using a band saw in our -20°C laboratory, this sample was cut into 14 cubic specimens. A horizontal plane was established and the specimens were therefore oriented before cutting. These cubic specimens, which include the dirt ice layer at least in part, are 18–35 g in weight. Their cut surfaces were rinsed with clean water in order to remove the contamination. The specimens were then stored at -20°C in a refrigerator.

2. Natural Remanent Magnetizations

Natural remanent magnetization (NRM) of representative specimens were demagnetized using alternating fields up to 500 Oe. The NRMs of these specimens, measuring rapidly by the 3 axis superconducting rock magnetometer, are very stable against AF demagnetization. Their original intensities, ranging from 2.5 to 3.4×10^{-6} emu$\cdot$g^{-1}, are demagnetized gradually and the directions remain stable up to the maximum field. Figure 1 illustrates the progressive AF demagnetization of the NRM for a typical specimen by use of the Zijderveld projection. The NRM remains stable to 500 Oe, and the value of the median demagnetization field (MDF) exceeds 500 Oe for this specimen.

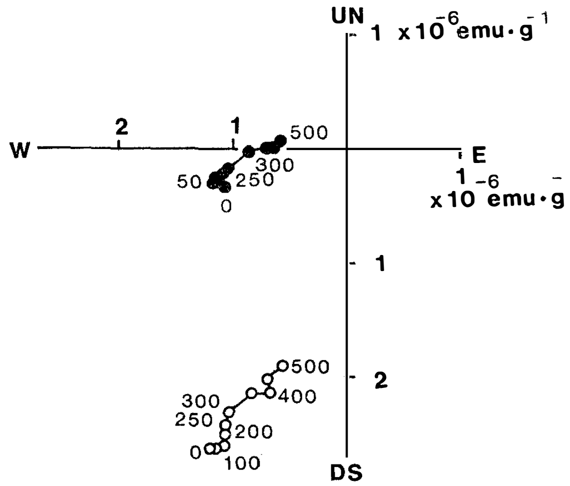

Fig. 1. Typical Zijderveld diagrams for progressive AF demagnetization for a dirt ice specimen. Solid (open) circles are projection on horizontal (E-W vertical) plane. Numerals denote demagnetization levels in Oe.

Total of 14 specimens have almost the same normal directional NRMs. This is indicated in Table 1; large values for the precision parameter (K) and a small radius of 95% confidence (α_{95}) suggest that the specimens have parallel directional NRMs to each other. The mean directions of NRMs for the 14 specimens after 100 Oe demagnetization and after the bedding correction are illustrated in Fig. 2a; their mean direction is $-72°$ inclination and 120° declination. Since the geomagnetic field direction at the sampling site is shown as $-77.2°$ inclination and 159.3° declination, the mean direction of NRM after the bedding correction is almost parallel to the present geo-

Table 1. Paleomagnetic results of dirt ice layers collected from Allan Hills meteorites ice field.

Bedding correction	Demag.	N	In $\times10^{-7}$ emu$\cdot$g^{-1}	Inc.	Dec.	K	α_{95}	pLat. °S	pLong. °E
Before	0	14	22.1	$-69°$	164°	241	2.6°		
After	0	14	22.1	-72	119	241	2.6		
After	100	14	21.8	-72	120	347	2.1	49	113

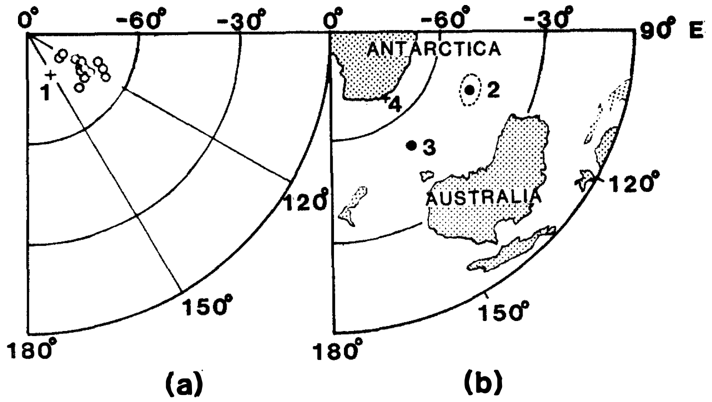

Fig. 2. (a) Directions of NRMs of 14 dirt ice specimens. (b) VGP position obtained from the mean NRM direction. Equal area projection. 1. Present geomagnetic field direction at the Allan Hills. 2. VGP position and 95% confidence level for dirt ice specimens. 3. VGP position obtained from the present geomagnetic field direction at the Allan Hills. 4. Present geomagnetic pole position.

magnetic field. The calculated virtual geomagnetic pole (VGP) position from this mean NRM is 49.1°S latitude and 113.4°E longitude as illustrated in Fig. 2b.

The volcanic ash was collected after evaporation of the melted specimens at 90°C, and the collected ash was used for measurements of the magnetic hysteresis properties at room temperature and for thermomagnetic analyses using the vibrating sample magnetometer. The obtained magnetic hysteresis loop parameters are as follows: the saturation magnetization (I_S)=1.13 emu·g^{-1}, the saturation remanent magnetization (I_R)=0.28 emu·g^{-1}, the coercive force (H_C)=152 Oe and the remanent coercive force (H_{RC})=402 Oe. Thermomagnetic curves were measured for that volcanic ash under 1.1×10^{-2} pa in atmospheric pressure. The reversible thermomagnetic curves show only one clearly defined 570°C Curie point of magnetite.

3. Discussion

The NRM carrier in the dirt ice specimens appears to be pure magnetite grains according to the thermomagnetic curve results. Day *et al.* (1977) examined the relationships between the domain structures and the hysteresis properties. Since the ratios of I_R/I_S and H_{RC}/H_C are 0.25 and 2.65 respectively, the magnetic grains are estimated to have a pseudosingle domain structure based on their results. Therefore, the reliability of NRM is reasonably high supported by not only the magnetic hysteresis results but also the AF demagnetization results.

Although there is no definite idea of the NRM acquisition mechanism for the dirt ice layers, the following discussion should provide some insight.

(1) The possibility of DRM acquisition during sedimentation under the constantly strong wind, called "katabatic wind", would appear to be very small compared with the conditions of ordinary sedimentation. Therefore, if the snow acquires DRM by sedimentation of volcanic ash on the ice sheet surface, the intensity should be extremely weak compared with the tuffaceous sediments deposited in the deep seas and

on land. Since the examined specimen includes the volcanic ash in the amount of 0.194 wt%, and has an NRM intensity of 2.5×10^{-6} emu·g^{-1}, the NRM intensity of the volcanic ash is estimated as 1.3×10^{-3} emu·g^{-1}. This is therefore stronger than that of ordinary sediments or sedimentary rocks. The alignment of NRM directions among the blocks is fairly good as $K=347$ and $\alpha_{95}=2.1°$ (see Table 1). From a viewpoint of the strong intensity and the alignment consistency, the NRM characteristic of the dirt ice layer is similar to thermal remanent magnetization (TRM) rather than to the DRM. If NRM was acquired under the katabatic wind, it seems that the NRM of dirt ice layer may have been acquired after sedimentation of volcanic ash on the surface.

(2) When fine volcanic ash is sedimented on the snow surface under the condition of very weak wind, the snow should acquire DRM.

(3) When snow or ice contacted with volcanic ash is partially molten due to absorption of strong solar radiation, the magnetic grains may be aligned in the geomagnetic field direction at that time. However, it may be difficult to assume the mechanism in the inland of Antarctica without strong solar radiation.

(4) During the formation process from snow to ice at a shallow depth of the ice sheet, the magnetic grains may be aligned in the geomagnetic field without the melting of ice. However, there has been no report about this type of magnetization mechanism up to the present.

Although we cannot definitely decide when and how the NRM was acquired for the dirt ice layers in Antarctica, it is important to study the posibility and main points of the stable NRM. Every sedimentary rock has the possibility of NRM acquisition in the geomagnetic field direction during diagenesis, due to the growth of silicate and calcite crystals around the magnetic grains in the sediments for example.

The VGP displacement angles and the variations of the non-dipole component of the geomagnetic field are systematically great in the high latitude region of the sourthern hemisphere (COX, 1962); it exceeds 18° at 70°S in latitude. The VGP position, the geomagnetic pole position and the VGP position obtained from the present geomagnetic field direction at the Allan Hills are distributed independently as shown in Fig. 2b. Therefore, it is difficult to determine the age and the place of NRM acquisition by the paleomagnetic method. However, the NRM directions of dirt ice would be useful for analysis of glacial movement. It is also useful for identification of individual dirt layers among the different regions. Furthermore, measurements of NRM intensities in drilled ice cores suggest the existence and the relative abundance of the volcanic ash without destroying the ice cores.

4. Conclusions

The NRM of dirt ice specimens is fairly stable as supported by AF demagnetization tests and magnetic hysteresis analyses. The NRM carrier is estimated to be pure magnetite with a pseudosingle domain structure. Although the NRM intensity is 2.5×10^{-6} emu·g^{-1} for dirt ice specimens, if the intensity is converted into specific volcanic ash, it can be as strong as 1.3×10^{-3} emu·g^{-1}. The NRM acquisition mechanism cannot be explained at this time, but one possible mechanism may involve the conversion of dirt snow to ice under some pressure without melting. The NRM direction after the bedding correction is almost parallel to that of the present geomagnetic field. However, the estimation of age and place of the NRM acquisition may be difficult because of the non-dipole components of the geomagnetic field. The direction of NRM is useful for the analysis of glacial movement and for the detection of volcanic ash in drilled core samples without destroying the samples.

Acknowledgments

The authors wish to thank Dr. F. NISHIO (National Institute of Polar Research) for his kind offer of the dirt ice samples for our studies and also for glaciological discussions.

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(Received May 1, 1985; Revised manuscript received September 2, 1985)