Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SEM001-P01 Room:Convention Hall Time:May 26 10:30-13:00

Strained magnetite and its remanence properties of Vredefort crater granite

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Vredefort crater granite shows anomalous remanence properties with strong intensity and random orientations of the remanence. These properties were enigmatic but recent drilling study (Carporzen et al. 2010 AGU abstract) reveals the origin of these properties is of lightning strike for some underground samples which can easily be alternating-field (AF) demagnetized in less than 20mT. Still some rock samples show the presence of strong intensity and high coercive coarse magnetite grains which are resistive against stepwise alternating-field demagnetization up to 50mT in scanning MI magnetic microscopy analysis. Here we show a collaborative study of micro-Raman spectroscopy, magnetic Kerr microscopy and a magnetic force microscopy (MFM) for the highly resistive coarse magnetite grains in Vredefort granite. The micro-Raman spectroscopy study reveals the presence of magnetite with a A_{1g} mode (680 cm^{-1}) and hematite as a lamellae in the high coercive coarse-grained magnetite along $\{111\}$ plane which is same plane as twinning of magnetite. The magnetite A_{1g} mode shows an obvious blue-shift from normal magnetite of 667cm^{-1}. The magnetic Kerr microscopy and MFM studies of the same grain showed striped magnetic domain walls along $\{111\}$ plane. The same blue-shifted Raman mode of magnetite and the presence of striped domain wall have been observed in strained magnetite artificially deposited on $SrTiO_3$ film by Chen et al. (2008). Also their hysteresis study showed the strained magnetite has a larger coercivity, and they concluded that these observations result from the formation of more pinning centers induced by high density of defects grown along specific direction like $\{111\}$. Therefore, we can conclude analogically that our Vredefort magnetite is affected by strains due to impact and their strain-induced domain wall pinning causes high coercive strong intensity of the remanence of coarse-grained magnetite in Vredefort crater granite.

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SEM001-P02 Room:Convention Hall Time:May 26 10:30-13:00

Ultrafine-scale magnetostratigraphy with SQUID microscope: Application to ferromangenese crust and other materials

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Scanning SQUID microscopy enables us to do mapping of magnetic field over thin sections of geological samples at submillimeter scale. With this new technique, ultrafine magnetostratigraphy can be achieved on geological sample which we could not observe the polarity pattern due to the limitation of the spacial resolution. In the presentation, we show a successful example on marine ferromanganese crust and extend the possibility in the future. Hydrogenetic ferromanganese crusts are iron-manganese oxide chemical precipitates on the seafloor that grow over periods of tens of millions of years. Their secular records of chemical, mineralogical, and textural variations are archives of deep-sea environmental changes. However, environmental reconstruction requires reliable high-resolution age dating. Earlier chronological methods using radiochemical and stable isotopes provided age models for ferromanganese crusts, but have limitations on the millimeter scale. For example, the reliability of 10Be/9Be chronometry, commonly considered the most reliable technique, depends on the assumption that the production and preservation of 10Be are constant, and requires accurate knowledge of the 10Be half-life. To overcome these limitations, we applied an alternative chronometric technique, magnetostratigraphy, to a 50-mm-thick hydrogenetic ferromanganese crust (D96-m4) from the northwest Pacifi c. Submillimeter-scale magnetic stripes originating from approximately oppositely magnetized regions oriented parallel to bedding were clearly recognized on thin sections of the crust using a high-resolution magnetometry technique called scanning SQUID (superconducting quantum interference device) microscopy. By correlating the boundaries of the magnetic stripes with known geomagnetic reversals, we determined an average growth rate of 5.1 +- 0.2 mm/m.y., which is within 16% of that deduced from the 10Be/9Be method (6.0 +- 0.2 mm/m.y.). This is the finest-scale magnetostratigraphic study of a geologic sample to date. Ultrafine-scale magnetostratigraphy using SQUID microscopy is a powerful new chronological tool for estimating ages and growth rates for hydrogenetic ferromanganese crusts. It provides chronological constraints with the accuracy promised by the astronomically calibrated magnetostratigraphic time scale (1-40 k.y.). The technique can be extended to other geological objects such as stalagmite, hydrothermal deposites, desert varnish, etc. An analogue of dersert varnish would be found on Mars, which might have recorded ancient Martian magnetic field.

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SEM001-P03 Room:Convention Hall Time:May 26 10:30-13:00

Magnetic anomaly lineations in the Gulf of Aden

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The Gulf of Aden is located in the Indian Ocean between Yemen on the south coast of the Arabian Peninsula and Somalia in Africa. The Gulf of Aden is a young ocean basin formed by the rifting of Arabia away from Somalia. The Arabian plate moves away from Africa in a NE direction, at a rate of about 2 cm/yr. The rifting started from Oligocene.

Seafloor spreading started at 17.6 Ma in the eastern part of the Gulf of Aden (Fournier et al., 2010) and propagated westward into the Arabia-Africa continent (Manighetti et al., 1997). It reached the Afar hotspot area about 10 Ma (Audin et al., 2001). The spreading system continues to interact with the hotspot up to the present. Tamsett and Searle (1988) exposed that strike of segmentations of the spreading centers in the Gulf of Aden is NW-SE, although the trend of the spreading system is ENE.

To expose the seafloor spreading history of the Gulf of Aden west of the Alula-Fartak Fracture Zone, we examined magnetic anomaly lineations. Most of the geomagnetic data used in our study were collected by the cruises by R/V L'Atalante in 1995 and R/V Hakuho-maru in 2000. Geomagnetic data collected by other ships were also examined.

Elongated negative magnetic anomalies are observed over the spreading centers. The elongated anomalies are parallel with the spreading centers. The elongated magnetic anomalies west of 46 30'E have an E-W trend around the spreading centers. Our identification of magnetic anomaly lineations indicates a symmetric seafloor spreading, although Leroy et al. (2004) showed an asymmetric seafloor spreading of the Sheba Ridge, east of our study area. It also indicates a westward decrease in spreading rates in our study area. The kinematics of the Arabia plate changed about 5 Ma, but our results did not show any coeval change in spreading rates of the spreading system in the Gulf of Aden.

Keywords: Gulf of Aden, magnetic anomaly lineations, slow-spreading system

Japan Geoscience Union Meeting 2011
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SEM001-P04 Room:Convention Hall Time:May 26 10:30-13:00

Submersible magnetic observations at a back-arc spreading center of the Mariana Trough at 17N

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We surveyed the Mariana Trough in the western Pacific to understand detailed volcanic and crustal formation processes of the back-arc basin. Three dives of the Japanese submersible Shinkai 6500 were made in the axial valley situated in the spreading center of the 17N segment [Fujiwara et al., InterRidge News, 2008]. The 17N segment is suggested to have ever been in vigorous magmatic stage, because sheet lava flows, suggesting a high rate of eruption, occupy the seafloor even the slow spreading with a full-rate of ~3 cm/yr [Deschamps et al., G3, 2005; Asada et al., G3, 2007]. The sheet lavas and pillow lava mounds suggesting a low effusion rate coexist in the axial valley. Near-seafloor magnetic observations provide high-resolution magnetic anomaly that is valuable for studies of detailed magnetization structure. The magnetization intensities relate to relative age differences of the lavas, therefore the magnetic data provide a geophysical evidence for discussion whether the segment is in the magmatic waxing or waning stage at present. The deep-sea magnetometer installed on the submersible was designed to measure three components of the geomagnetic field. Because the trough is situated at low magnetic latitudes, vector components have advantages over using only total field anomaly. The measured magnetic field was affected by motion and magnetization of the submersible. The effects were determined and necessary corrections were applied by using the formulation of Isezaki [Geophys, 1986]. After the calibration, the ~4000 nT effect of the submersible was reduced to a residual less than 500 nT. Two dives traversed the western and eastern flanks of the valley in the segment center, and the other dive was on the western flank slightly in the segment end. Magnetic anomalies with large-amplitude and short-wavelength (several tens of meters) were observed near-seafloor. Particularly high amplitude anomalies (up to 5000 nT) were observed in the western flank near the middle portion of the axial valley in the segment center where sheet lavas were dominant. High magnetization intensity (up to 50 A/m) was estimated over the flank, therefore the sheet lava flows are likely young in age and recently emplaced. It suggests the segment is still magmatically vigorous at present. On the other hand, low amplitude anomalies suggesting old lava flows were observed in the eastern flank of the valley. The amplitudes in the western flank to the segment end are moderate and fall somewhere in between. The sheet lavas there seem to be slightly old. It may suggest infrequent magma effusion compared to the segment center. These magnetic age estimations are consistent with observations of sediment deposition from visual inspections and measurements of a sub-bottom profiler attached on the submersible, and also sampled rock magnetization and geochemical measurements. The across-axis magnetic structure along the dive path (a distance of ~2 km) shows the magnetization intensity decreased toward the off-axis, suggesting the seafloor age increases toward the off-axis. However the detailed variation of the magnetization distribution does not show simple seafloor age increment in proportion to distance from the spreading center because there is no clear correlation between the across-axis distribution of magnetization intensity and a compiled dataset of paleointensity variation [e.g. Sint-800: Guyodo and Valet, Nature, 1999]. It implies the complexity of the crustal formation process. A possible explanation is that lava eruption at the segment was not focused on the fixed and stationary volcanic axis, but was dispersed rather broad volcanic zone because of the enhanced magmatic activity. Otherwise ridge jumps at small distances occurred. And/or new sheet lava flows traveled a long distance and overlapped old lava flows, and the lavas overprinted the seafloor magnetization. As the result, the sequential paleointensity variation was not recorded.

Keywords: Mariana Trough, back-arc basin, submersible, magnetic anomalies, magnetization of ocean crust, volcanic processes

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SEM001-P05 Room:Convention Hall Time:May 26 10:30-13:00

Near-bottom magnetic surveys around hydrothermal sites in the southern Mariana Trough using AUV

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Near-bottom magnetic survey by using an AUV is an effective method to reveal the detailed magnetic anomaly signatures of ocean floor such as those around hydrothermal vent sites. In order to detect signals of hydrothermally altered rocks in the southern Mariana Trough, the measurements of total intensity and three-components of the geomagnetic field are conducted by using AUV URASHIMA during the YK-09-08 cruise. Four three-axis fluxgate type magnetometers and overhauser type magnetometer are attached on AUV URASHIMA.

During the cruise, three components of geomagnetic field by the four fluxgate type magnetometers are successfully obtained along the all dive tracks of AUV URASHIMA. Total intensities of geomagnetic field by the overhauser magnetometer are only collected along almost E-W oriented observation lines due to the sensitivity of the sensor.

We will present vector magnetic anomaly field around hydrothermal sites in the southern Mariana Trough and distribution of crustal magnetization derived from the inversion method.

Keywords: magnetic anomaly, Mariana Trough, AUV, hydrothermal vent

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SEM001-P06 Room:Convention Hall Time:May 26 10:30-13:00

Some tips on data reduction for practical magnetic survey

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One of the most popular instruments for magnetic survey on land is proton magnetometers for its stability of the obtained data and convenience of use at the field. Recent years, the type of the proton magnetometer utilized the Overhauser effect has been often used above all. The Overhauser proton magnetometer has the ability of much more stability of measurement which can acquire data even in the high gradient magnetic field. The component of the data obtained by proton magnetometer is usually only the total intensity of the geomagnetic field.

Magnetic survey within a limited area usually requires simultaneous magnetic observation at a fixed point for a reference in order to remove time-varying component of the geomagnetic field. The fixed point observation, however, is sometimes failed to be obtain due to non-availability or breakdown of instruments. On the time of no reference data, here an example of making synthetic reference data is introduced.

On times we are sometimes suffered from the intense magnetic field from artificial obstacles such as guard rail along the road, ditches made by iron and concrete, or metal net or wires around there. An example of reduction such noises is also introduced here. The method of reduction is fitting noise data to theoretical magnetic dipoles using a kind of inversion.

These examples of reduction of magnetic data are applied practical data at a field of a pottery site where the magnetic anomalies due to thermal remanent magnetization are expected.

The magnetic survey was carried out around the Shiraiwa pottery site Senboku city, Akita prefecture. The production of potteries, however, had ceased more than one hundred years ago.

Since the Shiraiwa pottery site is the oldest one in Akita prefecture, the value as a historical heritage is very high. Consequently the exact knowledge of the positions and their scales of the kiln vestiges with buildings in surrounding area are also required.

Keywords: magnetic survey, proton magnetometer, data reduction, inversion

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SEM001-P07 Room:Convention Hall Time:May 26 10:30-13:00

Magnetic imaging as an inverse boundary value problem: Application to mapping of the lunar magnetic anomalies

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Magnetic imaging of the static magnetic field at the surface is mathematically regarded as solving an inverse boundary value problem. It is known that there are three types of the boundary value problem: Dirichlet (the first kind), Neumann (the second kind) and Cauchy (the third kind) problems. For example, the magnetic field at any point over the surface is given by the surface integration of potential values (Dirichlet type), radial components (Neumann type) or magnetic charges (Cauchy type). The kernel of the surface integral is determined from a kind of the boundary value and morphology of the boundary surface. Inversely the boundary value is obtained from observations over (or inside) the boundary surface by solving an inverse boundary value problem such as the deconvolution or the downward continuation.

There have been several equivalent source models of the magnetic imaging at the boundary surface. The equivalent vertical magnetization at the surface is considered to be an inversion of the Dirichlet problem, so that the obtained vertical magnetizations express the surface potential. The equivalent source model of horizontal currents or horizontal magnetizations at the surface is an inversion of the Neumann problem. Although the boundary surface should be closed or infinite in these problems, the methods are approximately applicable to an unclosed region if effects of boundary values in other part of the surface are negligible. In this case, the observation is assumed to be filtered with a rectangular window of a closed or infinite surface. If the observation is distributed along a track, constraints from the discrete sampling should be considered in the analysis, especially in the downward continuation. Therefore, it is needed for improvement on the magnetic imaging method to carefully consider a kind of the boundary value, mathematical properties of the kernel function, observational conditions, noise sources and assumptions of modeling.

Providing the lunar magnetic anomaly map is regarded as the magnetic imaging by a satellite magnetometer. Previous maps of vector fields of the lunar magnetic anomaly have been provided at a certain altitude such as 30 km and 100km. However, those maps show insufficient spatial resolutions when compared with geological and topographical data on the surface. We have developed a new method for the surface vector mapping of the lunar magnetic anomalies observed by a satellite magnetometer. We will discuss the method of surface mapping of the lunar magnetic anomalies and show several examples of mapping results based on the Kaguya and Lunar Prospector datasets.

Keywords: magnetic imaging, inversion, boundary value problem, Moon, magnetic anomaly

SEM001-P08 Room:Convention Hall Time:May 26 10:30-13:00

Equivalent Pole Reduction: concept and advantages

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We developed Equivalent Pole Reduction (EPR) method for restoring the 3-d distributions of the lunar magnetic field from the satellite data (Lunar Prospector and Kaguya). It is essentially a variant of equivalent source method. It uses magnetic monopoles instead of widely used magnetic dipoles.

The EPR has several advantages to the Equivalent Source Dipole (ESD) method. Ease of calculation, stability of inversion and small edge effects are some of the advantages. It has large advantage with the satellite or airborne data in which the altitude is not always pre-determined, but will work with other data like shipborne or microscale measurements since it uses advantages of the nature of potential field.

Keywords: Magnetic mapping, Equivalent source method, Planetary magnetism