

## Testing paleointensity determination using Wilson method

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The classical Thellier method still remains most reliable for paleointensity determination, but requires a quite demanding and rarely satisfied condition; a natural remanent magnetization (NRM) must be completely replaced by a laboratory thermoremanence (TRM) at every temperature interval. If a significant amount of multidomain grains is present, this condition is not satisfied and resulting in erroneous paleointensities as obtained from curvatures seen on the Arai diagrams.

A single-step heating method, which sounds quite primitive as adopted in early times (e.g., Folgheraiter [1899]) but is essentially still alive as in the Shaw method, escapes from the strict condition posed on the Thellier method. The Wilson method, being a sort of single-step heating methods, was developed a half century ago (Wilson, 1961 & 1962); comparison of high-temperature continuous thermal demagnetization curves, measured for a natural remanent magnetization (NRM) and then a thermal remanent magnetization (TRM) acquired in a known laboratory field, yield a paleointensity. The reason why the Wilson method was rarely used for paleointensity studies is that magnetization needs to be measured at elevated temperature. Yet this method has a great advantage of being extremely quicker than the other paleointensity methods. If using a modern automated high-temperature magnetometer, we can complete a Wilson measurement within one hour for a 1-cc cube.

We performed testing paleointensity measurements based on the Wilson method for 27 1-cc cubes of basalts and scorias of the 1983 eruption in Miyakejima (the expected field of 45.1 microT). A 1-cc cube was heated in air at the rate of ~40 deg.C per minute along with measuring three-component NRM at elevated temperature using a Orion three-component vibrating sample magnetometer at the Borok Geophysical Observatory. When the magnetization is decreased less than 1 percent of the initial value, heating was stopped and then total TRM was imparted during cooling down in the magnetic field of 45 microT. The total TRM was also continuously demagnetized in the same way as NRM.

We did find nicely straight lines on the NRM-TRM diagrams for 85% of measured samples, indicating that the shapes of unblocking temperature spectrum are essentially unchanged for NRM and TRM. We obtained the expected field intensity of 45.1 microT for the about half of the samples. The Thellier method for the sister samples also gave the expected field, but some of the samples did not. For the another half, the gradients of NRM-TRM lines significantly deviated from unity to higher or lower values. This means that thermal alteration (NOT including domain alteration) increased or decreased TRM capacity but did not appreciably changed unblocking temperature spectrum. Such a kind of alteration is not detected on NRM-TRM diagrams, therefore it is possible to give erroneous paleointensities.

Although the Wilson method is quick and robust even for samples containing multidomain grains, we need to take caution that thermal alteration is not necessarily detected from the linearity on NRM-TRM diagrams. This caution should be exercised for other kinds of single-step heating methods.

Keywords: paleointensity, Wilson method, Thellier method, high-temperature magnetometer

## Microscopic observation of titanomagnetite grains during paleointensity experiments of volcanic rocks

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Titanomagnetite (Tmt) grains, some partially maghemitized, of various oxidation levels were microscopically observed under reflected light as a function of temperature step in a Königsberger Thellier Thellier experiment in air. The reflected light microscopy indicated that the brownish colour of homogeneous Tmt turned blue at  $\sim 300$  °C. This false blue colour was caused by submicron scale rugged stripes on the surface, according to scanning electron microscope observations, which was made after the final heating step. The typical grey-to-bluish colour of maghemitized parts of Tmt grains turned to a brownish colour at  $\sim 300$  °C, indicating inversion of titanomaghemite to a mixture of magnetite and ilmenite (Ilm) or haematite (Hem). Although these observations were from Tmt grains on the sample surface, oxidation must have proceeded similarly within samples because the surface changes in the Tmt grains were highly correlated with behaviour of data points on Arai plots. Alterations in Tmt after heating at 610 °C in air for increasing times from 10 to 500 min were evaluated by reflected light microscopy and scanning electron microscopy at the end of the experiment. Mottled patches gradually emerged in the Tmt grains during subsequent heatings. However, the formation of new Ilm lamellae was not observed, even after the final 500 min heating. In conclusion, the alteration of Tmt during laboratory heating in air at  $\sim 600$  °C is likely not due to the typical high-temperature oxidation that forms trellis-type Ilm lamellae. Below  $\sim 400$  °C, the process should be closer to low-temperature oxidation. On the other hand, maghemitized parts of Tmt grains invert instantaneously at 300 °C, and a trellis-type structure with Hem lamellae soon emerges when heated at 610 °C.

## Archeointensity trend between 8th and 11th century in Okayama

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This study presents three new archeointensity estimated from Sayama-area (Bizen city, Okayama prefecture), for the period of 8th to 11th century. The baked-earth samples (archaeological artifacts) we used in this study were collected from old kilns (part of floor and wall) of Sue wares. These kilns were found during the course of five excavations which were conducted under an archaeological project (see Archaeological lab, Okayama University of Science, 2012; 2013) aiming to trace development-history of ceramics production activity in Sayama-area between Nara and Heian-era. If we adopt the archeological chronology based on the Sue-mura type (e.g. Nakamura, 2006), the Sayama-Shin-ike kiln and the Sayama-Higashiyama kiln were estimated to be under operation during last half of 8th century (? 775±25 year), and the Sayama-Higashiyama-Oku kiln to be at around 10 century (? 900±50 year) (See Archaeological lab, Okayama University of Science, 2012; 2013).

Various rock magnetic and stepwise thermal demagnetization experiments revealed that (1) the samples are generally resistant to laboratory heating, (2) shape anisotropy is small, and (3) main magnetic carriers are Ti-poor titanomagnetite with high blocking temperature. Archeointensity measurements were done by using the IZZI Thellier method (double heating method; Yu & Tauxe, 2005). We applied this method to 19 specimens from 15 samples of the Shin-ike kiln, 10 specimens from 10 samples of the Higashiyama kiln, and 19 specimens from 9 samples of the Higashiyama-Oku kiln. After applying a set of very strict criteria, averaged archeointensity (with one standard deviation) is obtained as follows: 61.6±4.4 μT for the Shin-ike kiln (N=4), 51.8±6.5 μT for the Higashiyama kiln (N=8), and 49.8±9.8 μT for the Higashiyama-Oku kiln (N=9). These values are not contradicted from the ones obtained by the Tsunakawa-Shaw method (Tsunakawa and Shaw, 1994; Yamamoto et al., 2003) though they are preliminary. Our new data show general agreement with the most recent archeointensity compilation in Japan (Yoshihara et al., 2003) and confirm the rapid intensity decrease at ~600 AD on average.

Keywords: Archeointensity, IZZI-Thellier method, Tsunakawa-Shaw method, Old kilns of Sue wares

## Absolute paleointensity determinations of welded tuffs: Correlations between relative and absolute paleointensity data

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Absolute geomagnetic paleointensities (APIs) have been estimated from igneous rocks, while relative paleomagnetic intensities (RPIs) have been reported from sediment cores. These two datasets have been treated separately, as correlations between APIs and RPIs are difficult on account of age uncertainties. We present a procedure for directly correlating APIs with RPIs of a RPI stack. Correlations between APIs and RPIs were conducted with virtually no associated age errors using both tephrochronologic correlations and RPI minima. Using the stratigraphic positions of tephra layers in oxygen isotope stratigraphic records, we directly compared the RPIs and APIs reported from welded tuffs contemporaneously extruded with the tephra layers. In addition, RPI minima during geomagnetic reversals and excursions were compared with APIs corresponding to the reversals and excursions. The comparison of APIs and RPIs at these exact points allowed a reliable calibration of the RPI values. In this study, we applied the Tsunakawa-Shaw method to 21 welded tuffs to increase API dataset. We obtained mean paleointensities for 16 of the 21 welded tuffs. Since eight of the 16 welded tuff units were correlated with the oxygen isotope stratigraphy, they can be added to the API data used in the correlation procedure. Combining these API data with the reported data, we correlated API data with RPIs from the PISO-1500 stack and SINT-800 stack. For 13 correlation points, RPIs of the PISO-1500 stack showed a linear relationship with virtual axial dipole moments (VADM) calculated from the APIs, indicating that the PISO-1500 stack has a linear relation to the axial dipole moment. On the other hand, RPIs from the SINT-800 stack has a trend with VADM and the correlation coefficient is lower than that of the PISO-1500 stack. The correlation procedure with increased API data can contribute to constraining the relation between RPI of a RPI stack and API and calibrating a RPI stack to absolute values.

Keywords: absolute paleointensity, relative paleointensity, tephra, oxygen isotope stratigraphy, welded tuff

## Rock magnetic study of the North Atlantic sediment during late Pliocene and early Pleistocene

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As the ocean is a major component in the climatic system, it is crucial for palaeoclimatic study to understand the past evolution of the thermohaline circulation. The North Atlantic Ocean is one of the most important sea areas because newly formed deep water mass is redistributed to the global ocean from there (Broecker et al., 1991). In order to recover the past change in deep ocean circulation at the North Atlantic Ocean, a variety of proxies have been studied. However, the change during Pleistocene and Pliocene is still poorly understood.

In this study we conducted rock magnetic measurement of deep-sea sediments recovered from IODP Site U1314 on the Gardar Drift, to investigate the past change in bottom current flows at the North Atlantic Ocean. Since a coercivity of magnetic mineral varies sensitively with its state such as chemical composition, grain size, grain shape, stress, and so on, coercivity spectra can be used as a proxy for the constituent spectra of the sediment.

The samples were collected at 16 - 50 cm resolution from 199.3 to 262.5 mcd of the core, which corresponds to the age between 2.22 and 2.75 Ma according to the age model by Hayashi et al. (2010). Rock magnetic properties were measured for these samples using a MicroMag 2900 Alternating Gradient Magnetometer. The isothermal remanent magnetization (IRM) acquisition curve was obtained by the application of stepwise-increasing uniaxial fields to the sample at 30 steps from 1 mT to 1 T. The ratio of IRM acquired in a back-field of 0.1 T to that in a forward-field of 1 T (S-ratio) was also measured for all samples.

In order to reveal constituents of the sediment, decomposition of coercivity spectra were conducted. The IRM acquisition curve was normalized by the IRM intensity at 1 T and then the first derivative of the curve was calculated with respect to log<sub>10</sub> field (hereafter referred to as IRM gradient curve). The least square fit was performed so as to decompose the IRM gradient curve into linear combination of two end-members. Two end-member components were calculated by averaging the IRM gradient curves of selected samples. Samples with low S-ratio (<0.57) and younger than 2.4 Ma were chosen for component 1. Samples with high S-ratio (>0.88) and during MIS100, which were associated with the ice rafted debris, were chosen for component 2. These components were distinctly different from each other; coercivity distribution of component 1 was magnetically harder than that of component 2.

In consequence of the decomposition, the fitting error was significantly small for all samples, indicating that North Atlantic sediments in the Garder Drift during late Pliocene and early Pleistocene are explained by mixing of two end-member components. The fraction of two components periodically changes with time and agrees well with the LR04  $\delta^{18}\text{O}_{\text{benthic}}$  stack (Lisiecki and Raymo, 2005): the high-coercivity component dominated during interglacial periods, and the low-coercivity component dominated during glacial periods.

On the basis of the elemental ratio of potassium to titanium (K/Ti), Grutzner and Higgins (2010) reported change in proportion of sources of sediment at Site U1314 during the last 1.1 Ma. They demonstrated that Ti-rich basaltic material transported by the Iceland-Scotland Overflow Water and K-rich particle (continental rock like) derived from the other source dominated during interglacial periods and glacial periods, respectively. Our result is consistent with their result because high-coercivity and low-coercivity components are interpreted as the fine-grain titanomagnetite of Icelandic sources and the coarse-grain magnetic mineral of continental sources, respectively. Therefore the change in fraction of two end-member components represents change in fraction of bottom currents, and the bottom current flow patterns similar to those during the last 1.1 Ma might prevail at the North Atlantic Ocean during late Pliocene and early Pleistocene.

Keywords: North Atlantic Ocean, Deep-sea Sediment, IRM acquisition curve, Bottom current flow

## Magnetic properties of REY rich red clay near Minami-Torishima in the Pacific Ocean

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Red clay accumulates slowly on the seafloor deeper than CCD in mid-latitudes. Paleooceanographic and paleomagnetic studies were limited so far because red clay does not yield microfossils that can be used for precise age estimation and sedimentation rates were extremely low, less than a few meters per million years. However, red clay has attracted interest since Kato et al. (2011) reported that red clay rich in REY (rare-earth elements and yttrium) distributes widely in the Pacific Ocean. In this paper, we present magnetic properties of red clay cores obtained from the seafloor near Minami-Torishima during the R/V Kairei KR13-02 cruise. From these cores, extremely high REY contents were reported (Fujimoto et al., 2013, JpGU; Suzuki et al., 2013, JpGU). We will discuss a possible relationship between REY content and magnetic properties.

It is known in red clay that magnetostratigraphy can be established back to only ~3 Ma, and this also holds for the KR13-02 cores. However, noisy but rather coherent inclinations were obtained throughout the cores even where polarity reversal patterns were obscure. Although a possibility that these directions are of magnetic overprint cannot be excluded, the observed inclinations are not much lower than that expected from the GAD model at the present latitude. This may suggest that the sediments including the intervals of high REY content are not very old, possibly Eocene to Oligocene or younger in age, and that they deposited in the northern latitudes not very far from the present sites. This result is not consistent with the idea that the high REY content is influence of hydrothermal activity along the East Pacific Rise. The cores showed a common magnetic susceptibility variation pattern, and a peak of REY content occurs just below an interval of high magnetic susceptibility. The REY peak coincides with a sharp upward decrease in the ratio of ARM to SIRM, which indicates an increase of the mean magnetic grain size and/or an increase in the proportion of detrital to biogenic magnetic mineral component. These results suggest that the increased REY concentration may have occurred in association with a paleooceanographic event.

Keywords: red clay, REY, rock magnetism, environmental magnetism, Pacific, Minami-Torishima

## A method for measuring rapid magnetization change in high field using a pulse magnetizer: A new rock magnetic approach

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Pulse magnetizers have frequently been used in rock magnetic studies for the convenience of the production of high magnetic field without the need for a large electromagnet, enabling the rapid acquisition of isothermal remanent magnetization (IRM) for short (*c.*  $10^{-2}$  sec) period of time. Because the demand for high field is limited as much as 10 T for rock magnetism, the pulse magnetizer can be compact and low-cost, and several commercial systems are available for the purpose of imparting IRM. We propose in this study a new method for measuring the dynamical behavior of magnetization in pulsed high-field, a new cost-effective system comprised of a fast broad-bandwidth digital oscilloscope and a newly designed coil system. We show examples of such dynamical behaviors from a set of natural samples, and discuss these results in comparison with conventional rock magnetic analyses.

Keywords: rock magnetism, pulse magnetic field, magnetic hysteresis

## Paleomagnetic study of the Holocene volcanic rocks and tephra from post-caldera central cones of Aso Volcano

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We have conducted a paleomagnetic study on Holocene volcanic rocks and tephra from post-caldera central cones of Aso Volcano. Paleomagnetic sampling was made at 25 sites of seven units. Nineteen out of 25 sites gave reliable mean paleomagnetic directions that had a 95% confidence circle of lower than 5 degree. Different sites from a few lavas, which had been treated as a single unit in the geological map of Aso Volcano (Ono and Watanabe, 1985), gave distinct mean directions at 95% confidence level. For Kishimadake lava, Ojodake lava, Nakadake young volcanic edifice, two different mean directions were obtained from multiple sites. These differences in mean directions indicate that multiple flows were extruded with a temporal gap of more than 10 or 100 years. We also found that Kamikomezuka scoria, two sites of Kishimadake lava, two sites of Ojodake lava gave identical mean directions at 95% confidence level. The concordance of the mean directions suggests that the multiple vents erupted simultaneously, in a time interval of the order of 10 years, and these lavas were extruded over a wide area of the post-caldera central cones. In this study, we also made paleomagnetic measurements on tephra layers in a section. Oriented samples were collected from 22 layers of a tephra section, 4km NNE of Nakadake volcano (Miyabuchi and Watanabe, 1997). Seventeen of the 22 layers gave mean paleomagnetic directions that had a 95% confidence circle of lower than 5 degree. Most of the N6 layer, and N5 and N4 layers give an identical direction, which suggests these layers were formed in a short period of several tens of years. A tephra layer record a same direction of a lava flow, which suggests a simultaneous formation of the tephra layer and lava flow.

Keywords: Aso Volcano, paleomagnetic direction, volcanic rock, tephra



## Paleomagnetic secular variation record for the last 7000 years observed in piston cores from the Ichinomegata Maar

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The Ichinomegata is a maar lake located in Oga peninsula, Akita Prefecture. Thin-wall core samples (IMG06) obtained in 2006 provided a Holocene paleomagnetic secular variation (PSV) record through measurements of natural remanent magnetization (NRM) of u-channel samples. In this study, we collected the piston-core samples (IMG13P-1 and IMG13P-2) from the center of the lake, and measured magnetic susceptibility, anisotropy of magnetic susceptibility (AMS) and natural remanent magnetization (NRM) of 7cc cubic samples. According to correlation between IMG06 and the piston cores based on lithological and magnetic susceptibility data, both IMG13P-1 and IMG13P-2 cover the last 7000 years. Stepwise AF demagnetization of the NRM showed that high intensity NRM decayed toward the origin linearly in most samples, so we determined the directions by applying the principal component analysis. We excluded some by evaluating inclinations of minimum axis and shape parameters  $q$  of AMS ellipsoids. Excepting some intervals that probably disturbed in coring, inclination and relative declination are showed consistent variations between IMG13P-1, IMG13P-2 and IMG06 cores. Therefore, we argue that the sediments of the Ichinomegata Maar are suitable for PSV studies. The paleomagnetic record from the Ichinomegata Maar shows a good similarity with the archeomagnetic secular variation from southwest Japan (Shibuya, 1980) and the PSV record from Lake Biwa (Ali et al., 1999), implying a great importance in regional reconstruction of the PSV record in Japan.

Keywords: Paleomagnetic secular variation, remanent magnetization, magnetic susceptibility, Ichinomegata Maar

## Thermomagnetic characteristics in the Hikageyama lava: searching a paleomagnetic record of the Laschamp excursion

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In the JpGU 2013 Meeting, we reported a paleomagnetic record from the Hikageyama lava. Among the 9 sites, 4 sites in the eastern part of the Hikageyama yielded consistent site mean directions characterized by shallow inclinations and easterly deflection. These site mean directions provide virtual geomagnetic poles (VGP) at around 50 N and 100 W. It can be assumed therefore that the Hikageyama dacite recorded anomalous geomagnetic field at the time of the Laschamp excursion. In addition to the above record, stepwise thermal (TH) demagnetization revealed that the above 4 sites yielded consistent site mean directions.

Thermomagnetic analysis revealed that most samples are composed of a single phase Curie temperature, suggesting magnetite as a remanence carrying mineral. And, the above 4 sites are classified into two groups. One (HKG-9, 10) shows a single phase, similar to the above. The other (HKG-11, 12) shows two phases, suggesting titanohematite and hematite. According to TH demagnetization results, one has two or three NRM components remanence. The other has a single component, which showed highly stable remanence which cannot be demagnetized at peak alternating field of 100 mT as previously reported. We will report these components discussion together with the thermomagnetic results.

Keywords: Rock magnetism, Hikageyama lava, Geomagnetic excursion, Laschamp excursion

## Electromagnetic core-mantle coupling and length-of-day variation in numerical dynamo models

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Exchange of angular momentum between the core and the mantle is likely to be responsible for the decadal variations in the length-of-day (LOD). If the changes in the angular momentum of the mantle are balanced by the opposite changes of the core, some coupling mechanisms between the core and the mantle should be invoked. Here we examine the electromagnetic (EM) coupling as a possible mechanism of angular momentum exchange. We use numerical dynamo simulations to investigate the mechanism to explain the LOD variations with respect to time including the decadal time scale. In numerical dynamo models, we impose a uniformly electrically conducting layer of about 200 km-thick on the mantle side of the core-mantle boundary corresponding to the D'' layer. The electric current associated with the dynamo-generated magnetic field can flow in the conducting layer and the Lorentz force can yield a net EM torque with respect to the rotation axis. The electrical conductivity of the layer is varied from 200 - 500 S/m in dynamo models. The LOD variations can put some feedback effects on flows in the core through the changes in the angular velocity, which emerge as a change in the effective Ekman number and the Poincare force. Influences of such a feedback are also included in numerical models. The Ekman number adopted as a nominal value is  $10^{-4}$ . We have obtained the EM torque resulting in typical angular velocity variation of the order of  $10^{-6}$  relative to the nominal angular velocity in a time scale of the magnetic diffusion time. Much smaller changes in shorter time scale are also observed. Based on the findings in the present study, it is suggested that the EM core-mantle coupling in a likely range of the conductance within the D'' layer is a promising mechanism to yield LOD variations in decadal to longer time scale.

Keywords: dynamo, electromagnetic core-mantle coupling, LOD variation, D'' layer

## Influence of surface displacement on fluid motions induced by Joule heating in the inner core of the Earth

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The elastic anisotropy of the earth's inner core as revealed by recent seismic observations is considered to originate from the alignment of texture formed along the solidification of the core or alignment of the preferred orientation of crystals by plastic deformation of fluid motions. The depth dependency of the anisotropy is difficult to explain by the solidification mechanism, whereas the various factors driving fluid flows in the inner core considered thus far do not appear to yield sufficiently strong stresses for generation of the elastic anisotropy. Takehiro (2011) proposed Joule heating of the magnetic field penetrating diffusively from the inner core boundary (ICB) as a possible source of inner core flows. His specific calculation in the case of toroidal magnetic field with the horizontal structure of spherical harmonics  $Y_2^0$  showed that downward flow in the equatorial region and upward flows in the polar region are induced by the Joule heating. This flow field has non-zero radial velocity component at the ICB, causing mass exchange between the inner and the outer core. This feature is a result of the constant normal stress boundary condition at the ICB, and it is implicitly assumed that the phase change occurs instantaneously at the ICB. However, the actual speed of the phase change is finite. If the speed of the phase change is slow enough, the ICB would be deformed and the surface displacement is induced by the non-zero radial velocity at the ICB. This surface displacement may prevent inner core flows due to the buoyancy force originated from the density contrast between the inner and the outer cores. Therefore, in this study, we investigate influence of surface displacement on fluid motions induced by horizontally heterogeneous Joule heating in the inner core. We examine the extent of development of the surface displacement and modification of flow field of the inner core.

The difference of the governing equations from those of Takehiro (2011) is the boundary conditions at the ICB. Temperature disturbance at the ICB coincides with the melting temperature which varies depending on the surface displacement. The normal component of stress equates with buoyancy induced by the surface displacement. The toroidal magnetic field and surface displacement with the horizontal structure of  $Y_2^0$  is given. The flow fields are calculated numerically for various amplitudes of the surface displacement with the expected values of the parameters of the cores.

The results show that, when the surface displacement is the order of 0.01–0.001m or less, the flow and stress fields are similar to those of Takehiro (2011), where the surface displacement vanishes. As the amplitude of the surface displacement is increased, counter flows from the polar to the equatorial regions come to emerge around the ICB, while the flow in the inner regions is directed from the equatorial to the polar regions in the inner region and non-zero radial component of velocity at the ICB still exists. When the surface displacement is about 0.14–14m, radial component of velocity at the ICB vanishes, the surface counter flows becomes stronger than the flow in the inner region, and the amplitude of the stress field near the ICB dominates that of the inner region, which might be inconsistent for the elastic anisotropy in the inner core.

Reference: Takehiro, S., 2011: Phys. Earth Planet. Inter., 184, 134–142.

Keywords: anisotropy of the Earth's inner core, magnetic fields in the Earth's outer core, flows in the Earth's outer core, inner core boundary of the Earth, dynamo action in the Earth's outer core

## Paleomagnetism of the Znp-Ohta tephra in eastern Honshu: relative tectonic rotations at local and regional scales?

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We present paleomagnetic data suggesting relative tectonic rotations in eastern Honshu since 3.9 Ma. Samples were collected from a widespread ash bed, called the Znp-Ohta tephra, at three localities. One is the Tomioka locality located to the east of the Abukuma Mountains, where the ash bed (local name = SF4.5 tephra) was sampled at three sites. The other two are the Miyobara and Kohnsaka localities on the Boso Peninsula, where the ash bed (local name = An85 tephra) was sampled at three sites at each locality. Stepwise demagnetization was performed on all specimens, and the principal component analysis was applied to the demagnetization data to extract characteristic remanent magnetization (ChRM) components. At Tomioka, site-mean ChRM directions were determined at all sites. They are tightly clustered after tilt correction and have a southerly direction of reverse polarity. Interestingly, the direction is deflected significantly counterclockwise with respect to the direction of the correlative tephra at Chita in central Honshu (Hoshi & Deguchi, 2013). At Miyobara and Kohnsaka, the locality-mean ChRM directions are significantly different to each other. The paleodeclination of Miyobara is similar to that of Tomioka, and the paleodeclination of Kohnsaka is almost identical to that of Chita. The difference in paleodeclination between Miyobara and Kohnsaka seems to be related to the difference in the general geological trend of Neogene strata on the Boso Peninsula, suggesting relative rotation on the peninsula. Our results imply that in eastern Honshu, relative rotations have taken place at local and regional scales since the Pliocene.

Keywords: eastern Honshu, paleomagnetism, Pliocene, relative rotation, tectonics, Znp-Ohta tephra

## Past continental shape inferred from GPS data

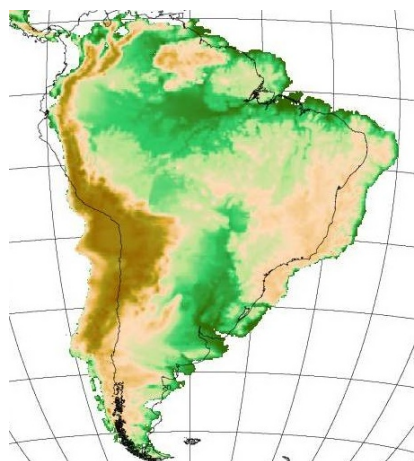
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Kono et al.,1985 analyzed paleomagnetic data around Andes and showed past shape of the south American continent about 50Ma and figured the Andes mountain range were more linear shape than at present. We tried to reconstruct the 50Ma shape of the south American continent from the current crustal motion of GPS data. Plate motion vectors observed from space geodesy including GPS, can comparable with plate motions of geological time scale. Gordon, 1993 showed VLBI plate motion (time scale of years) and NUVEL-1 plate motion (3 million years mean motion) are in great harmony with each other.

We applied a method of Harada and Kato(AGU Fall Meeting 2012), and calculated about 50Ma shape of the south American continent (figure below). The shape of the Andes mountain range were linear and in good harmony with the result of Kono et al.,1985. We conclude, thus, decades scale GPS data can compare with plate deformation of ten thousands years.

Keywords: GPS, Past continental shape, Deformation of plates



## Problems related to the past motion of the Philippine Sea Plate

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Plate motion through geological time is reconstructed based on the correlation of marine magnetic anomaly patterns and/or hot-spot track analysis. But the past motion of the Philippine Sea Plate cannot be clarified because the plate is surrounded by convergent plate boundary (trench) and it has no hot-spot track. Therefore the paleomagnetic approach is the only method to reconstruct the past location and motion of the plate. However this method contains unacceptable problems that the paleomagnetic declination does not indicate the total rotation of the plate around its Euler pole in most cases. The paleomagnetism has been thought as an effective tool to reconstruct the Philippine Sea Plate motion, but actually it is impossible to clarify the past motion of the plate by paleomagnetic method.

Keywords: tectonics, paleomagnetism, Philippine Sea Plate

## Environmental rock-magnetism of red clay in the South Pacific Gyre during the Cenozoic: relation with rare-earth content

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Red clay occupies ~40% of the global ocean floor. Paleooceanographic and paleomagnetic studies of red clay were limited so far because red clay does not yield microfossils that can be used for precise age estimation and sedimentation rates were extremely low, less than a few meters per million years. However, red clay has attracted interest since Kato et al. (2011) reported that red clay rich in REY (rare-earth elements and yttrium) distributes widely in the Pacific Ocean. Among the cores studied by Kato et al. (2011), especially REY-rich mud (2110 ppm at the maximum) of ~40 m thick occurs below 13.5 m below seafloor (mbsf) at the Deep Sea Drilling Project (DSDP) Site 596 at the western edge of the South Pacific Gyre. However, the core sections have large gaps, and rock- and paleomagnetic studies were not conducted. In 2010, Integrated Ocean Drilling Program (IODP) Expedition 329 Site U1365 occupied at almost the same position as Site 596. Continuous pelagic red clay cores of ~76 m thick was recovered above the basaltic basement of ~100 Ma in age.

We conducted an environmental magnetic study using the Site U1365 cores to investigate long-range climatic and paleooceanographic changes during the Cenozoic. We also investigate a relation between magnetic properties and REY of the red clay. On the basis of rock magnetic analyses and transmission electron microscopy, magnetic mineral assemblages are dominated by bacterial magnetites (magnetofossils) throughout the cores (Yamazaki and Shimono, 2013). In the uppermost several meters, terrigenous maghemite probably transported as eolian dust increases. High REY mud (2470 ppm at the maximum) of ~40 m thick occurs below 8 mbsf. The variation pattern of REY content is similar to that at Site 596. The ages of the Site U1365 cores were transferred from those of Site 596, which is based mainly on a constant Co-flux model at Site 596 (Zhou et al., 1992), by inter-core correlation using magnetic susceptibility and REY variation patterns. Paleomagnetic stratigraphy is available for the uppermost several meters at Site U1365.

We discuss a possible relationship between REY content and magnetic properties. The REY peak coincides with a sharp upward decrease in the ratio of  $\kappa_{ARM}$  to SIRM, which indicates an increase of the mean magnetic grain size and/or an increase in the proportion of detrital to biogenic magnetic mineral component. A peak of REY content occurs just below an interval of high magnetic susceptibility. These characteristics are similar to those of red clay cores near Minami-Torishima (Yamazaki et al., 2014, JpGU). This suggests that the increased REY concentration may have occurred in association with a common paleooceanographic event. Eolian dust supply may have increased since ~30 Ma. The Eocene/Oligocene (E/O) transition (~34 Ma) is known as the time when major ocean gateways (the Drake passage and Tasmanian gateway) opened and the Antarctic Circumpolar Current was formed (Scher and Marting, 2004, 2006; Stickley et al., 2004). The onset and increase of dust supply in the South Pacific may have occurred after this time. Northward movement of Australia continent to an arid region (middle-latitude) may have also contributed an increase of dust supply. Hyeong et al. (2013) suggested that phosphatization on the Mid-Pacific mountains took place between 36 and 12 Ma, and it peaked at the E/O transition. They connected the results to paleo-deepwater circulation. A REY peak occur near the E/O transition at Site U1365, which may be related with the phosphorus budget.

Keywords: Red clay, REY, South Pacific Gyre, Cenozoic, Environmental Magnetism



## Regional differences in magnetic properties of topmost sediments of the Northern Lake Biwa

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Rock-magnetic investigations have been performed on topmost sediments above about 30 cm below sediment surface (bss) cored in summer (June to July) and winter (November to December) at eight sites with different water depth, where dissolved oxygen (DO) content in bottom water and its seasonal variation are different, in the first depression at the North Basin of Lake Biwa in order to reveal early diagenetic effect on magnetic properties of the sediments.

Low-temperature magnetometric results indicate that a partially-maghemitized magnetite is a principal magnetic mineral in the sediments. Warming curves from 6 to 300K of isothermal remanence (IRM) imparted at 6K in 1T after zero-field cooling show a remarkable decrease of IRM between 90 and 120K, which is regarded as a suppressed Verwey transition of magnetite. The amount of IRM decrease between 90 and 120K increase downcore at all site, implying the dissolution of maghemite skin covering magnetite. The IRM decrease is more slightly remarkable in the sites with shallower water depth. The degree of maghemitization may be lower in the site. Samples from sites with deeper water depth below about 70m show another IRM decrease between 20 and 30K with the inflection point at about 29K. The IRM drop disappears in samples with hydrochloric acid treatments. These low-temperature IRM behaviors may imply the presence of ferro-rhodochrosite. The IRM drop is detected in samples above about 18 cmbss, and the samples in two zones of 0-3 cm-bss and 6-15 cm-bss show the IRM drop more clearly. The IRM drop is more remarkable in samples with deeper water depth. The occurrence of the magnetic mineral with the characteristic low-temperature magnetic behavior seems to be influenced by the DO values and its seasonal change.

As common characteristics in downcore changes of magnetic properties, the downcore decrease of magnetic coercivity is observed in the uppermost sediments above about 10 cm-bss, and the amount and grain size of magnetic minerals subsequently decreases and increases downcore below 10cm-bss, respectively. These changes are considered to be associated with the dissolution of maghemitized magnetite by the early diagenetic effect. The presence of magnetic minerals with finer grain size and higher magnetic coercivity in the sediments above 10 cm-bss is more remarkable in sites with deeper water depth.

Keywords: rock magnetic property, Lake Biwa, topmost sediment, early diagenesis

## Magnetic properties of the sediments and suspended solids in the sea surface water at the Hiroshima bay station.

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Suspended solids (SS) in sea water are consisted of planktons and insoluble particles, and are an indicator of transparency. SS particles adsorb and incorporate metallic ions. Iron is a metallic ion, and an essential element for phytoplankton. It is supplied from river to sea as bivalent or trivalent ions, and exists as iron compounds as organic complexes in sea water. Aeolian dusts are consisted of SS, and also consists of iron compounds. They will deposit on seafloor, and be sediments as the climatic record. It is important to investigate the distribution and mode of iron compound in SS for the present and past environmental studies. This study aims to diagnose magnetic minerals in SS. Enough amount of SS sample for magnetic measurements are collected by magnetic separation from seawater at the Hiroshima bay station. 4 L of seawater is filtrated, and the particles above 0.45  $\mu\text{m}$  in diameter are recovered for XRF analysis. The amount of magnetic particles in sea surface water shows relatively high values from April to July in the bay. The maximum value is found at the station, which is located near an iron works (the supply source). The particle is opaque minerals and looks like needle. The values of IRM imparted at 0.3 T and 2.5 T are not stable. It suggests that SS has strong anisotropy. Results of thermo-magnetometry indicate that magnetic carriers of SS samples are mainly magnetite, and goethite and hematite is also recognized. Magnetic minerals in the sediments at the station are magnetite, hematite, and greigite. It is implied that goethite present in the sea surface water and it may be dissolved on sea floor.

Keywords: Suspended solids, Iron compounds, Goethite

## Paleomagnetic study of the turbidite sediments around the Daini Atsumi Knoll

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This study is a part of the program of the Research Consortium for Methane Hydrate Resource in Japan (MH21 Research Consortium)

Keywords: Paleomagnetic study, Paleomagnetostratigraphy, Anisotropy of magnetic susceptibility, Paleocurrent analysis, turbidite sediments, Dainii Atsumi Knoll

## Emplacement mechanism of marine volcanoclastic sediments (IODP Site U1397, 1398) based on rock magnetic properties

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Large numbers of marine volcanoclastic sediments with various origins were recovered from the sites U1397 and U1398 during IODP Expedition 340. They were most likely derived from volcanoes on Martinique and possibly from Dominica, Lesser Antilles volcanic arc. Some volcanoclastic units were transported and deposited as turbidites, some were as thin tephra fall deposits and others show both characteristics. They contain various amounts of bioclastic component, pumice and lithic fragments and hemipelagic mud clasts. Therefore, these volcanoclastic sediments are suitable for investigating transport and emplacement mechanisms of volcanic materials and the resultant sedimentary and petro-facies in marine settings. This study focuses on magnetic minerals in the marine volcanoclastic sediments and carried out rock magnetic measurements.

Thermomagnetic measurements showed almost reversible curves and induced magnetization decayed to almost zero below 580 °C, suggesting little contribution of maghemite or hematite. Two Curie temperatures ( $T_c$ ) with 350-400 °C and 500-550 °C indicate that the main magnetic carriers are Ti-rich titanomagnetite and Ti-poor titanomagnetite. The proportion of low- $T_c$  titanomagnetite in central and bottom part of thick turbidite units was larger than that in hemipelagic sediments and in the topmost part of turbidite units, suggesting Ti-rich titanomagnetite is derived from volcanic events. Tephra fall deposits also showed large contributions of Ti-poor titanomagnetite, resulted from large amount of volcanic materials. On the other hand, thin turbidite units showed small contributions of Ti-poor titanomagnetite. This suggests that thin turbidite units are derived from diluted flows which contain few heavy Fe-bearing magnetic minerals.

Magnetic susceptibility and hysteresis measurements showed that heavy and large magnetic minerals in most thick turbidite units were concentrated at the lower part of the unit. Samples from the topmost and bottom part of turbidites showed higher degrees of anisotropy than those from the central part, indicating strong influence of suspension settling at the topmost part and shearing at the bottom part. Bottom parts of fall units contain heavy and large magnetic minerals, whereas upper parts of fall units contain fine magnetic minerals. On the other hand, in thin turbidite units such features cannot be observed and hysteresis parameters and susceptibility values were almost concentrated. Probably thin turbidite units did not experience segregation of specific particles during transportation and settling under the relatively calm condition.

These preliminary results suggest that magnetic minerals are useful indicators of volcanic events and rock magnetic approaches can identify various types of depositional processes about marine volcanoclastic sediments.

Keywords: turbidite, fall deposit, marine sediment, titanomagnetite, magnetic mineral

## Paleomagnetic direction of the Tomikusa Group in southern Nagano Prefecture and its tectonic significance

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<sup>1</sup>Aichi University of Education

We report here a new paleomagnetic direction from Early Miocene (18-17 Ma) sediments of the Tomikusa Group in southern Nagano Prefecture, and discuss the formation of curvature of the Median Tectonic Line (MTL) in central Honshu. Sedimentary rock samples collected from 24 sites were demagnetized stepwise, and site-mean directions were determined for 23. Rock magnetic experiments suggest that the main magnetic minerals are magnetite and maghemite. The site-mean directions pass a reversal test, indicating primary remanent magnetization. The overall mean direction with a northerly declination is indistinguishable from the Early Miocene reference direction derived from the Asian continent. This comparison suggests no significant rotation in the study area with respect to the continent since 17 Ma. The mean declination is deflected about 15 deg counter-clockwise with respect to the strike of the nearby MTL. The same angular relationship is also found in other sedimentary basins in central Honshu (Ichishi in Mie Pref., Chita Peninsula in Aichi Pref., Shitara in Aichi Pref., and Chichibu in Saitama Pref.). Thus we conclude that the MTL was straight in the late Early Miocene (18-17 Ma).

Keywords: paleomagnetism, Tomikusa Group, Median Tectonic Line, Miocene, rock magnetism, tectonics

## Rock magnetism and its petrological characterization of fossil *Porites* coral frameworks in Ishigaki island, Japan

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Radiocarbon (<sup>14</sup>C) is produced by the cosmic rays in the atmosphere and is utilized for analysis of the past sun activity. But the Earth's geomagnetic field also controls radiocarbon variability, suggesting that a strong field would shield the planet from high energy charged particles. This mimics lower sun activity. Also, the short-term (in decadal or centennial scale) movement of the geomagnetic pole to the low latitude, such as geomagnetic jerk, could lead to an increased cosmic ray flux impinging on the terrestrial atmosphere and thus to a higher <sup>14</sup>C production rate. Therefore, in order to study the past sun activity from the <sup>14</sup>C production rate, we need to know the movement of geomagnetic pole position, its field strength and the variability of radiocarbon production during decadal to centennial periods. Many researches, which aim to reveal the paleomagnetic secular variation (PSV), have been performed using datasets obtained from volcanic rocks, sediment, and fired kilns. The some reconstruction models of geomagnetic dipole moment are also established from these data sets. But there are few recorders that can be used for the reconstruction of PSV in a decadal or centennial scale. Here we propose an alternative candidate of fossil coral frameworks as a possible paleomagnetic recorder for PSV research. The coral framework has an advantage in reconstructing both the radiocarbon variability and the geomagnetic field, although usual corals show extremely weak intensity of remanence and its low stability. However, it is shown that our recently-ceased coral framework samples from Ishigaki island possess a remanence intensity of 10<sup>-5</sup> -10<sup>-4</sup> A/m and a single-domain like stability from Lowrie-Fuller test. We prepared the standard 1-inch core samples cut parallel to the growth direction of coral *Porites*, including coral's growth bands for a ten to several tens of years. Our thermal and AF demagnetization experiments of oriented coral samples show that a characteristic remanence direction is parallel to the present Earth's magnetic field with some fluctuations. On the other hand, some samples exhibit different remanence directions from the present geomagnetic field with a calcite peak of X-ray diffraction analysis. The presence of calcite indicates that the meteoric diagenesis which changes aragonite coral frameworks into calcite affect the direction of initial magnetization. To constrain the remanence carriers, we are conducting a first order reversal curves (FORC) measurement and petrologic observations by a Schottky field-emission scanning electron microscope (FE-SEM) of acid-treated residuals of our corals. Our results suggest that *Porites* coral framework samples provide a role as a potential use for paleomagnetic recorder for annual to decadal scales with careful examination of calcite content.

Keywords: fossil *Porites* coral frameworks, paleomagnetism

## Effect of thermal expansion on Neel's relaxation nomograph of magnetite and its agreement with the radiocarbon age

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Age gap between the paleomagnetic viscous dating and the radiocarbon age of tsunamigenic boulders in Ishigaki Island is focused. Recent researchers have conducted radiocarbon dating to label tsunami age, being able to calibrate the paleomagnetic viscous dating. These ages should be the same for the initial tsunami event. In the paleomagnetic viscous dating, time-temperature relation assuming Neel's single domain (SD) theory of magnetite is used. This monograph shows the older remagnetized component in nature can be erased by the higher temperature in the laboratory, and younger is its reverse. Thus, we can predict the age acquired the secondary magnetization by calculating demagnetization temperature and heating time. Our viscous dating results sometimes represented that the unblocking temperature of viscous components for tsunamigenic boulders is higher than the temperature predicted from Neel's relaxation theory of single domain magnetite, suggesting the older age than the one determined from the calibrated radiocarbon age. Previous numerous studies confirmed that the departure from Neel's theory is attributed to the presence of multi-domain magnetite. However, Lowrie-Fuller test, FORC (first order reversal curves) experiments and Low-temperature demagnetization of tsunamigenic boulders confirmed the presence of single domain magnetite. To solve this problem, we consider the thermal expansion of magnetite during stepwise thermal demagnetization process and propose a modified time-temperature relation to be able to fill the age gap. Currently, thermal expansion coefficient of magnetite is reported by some researchers (e.g. Nikolaev and Shipilin, 2000; Levy et al, 2004). If magnetite volume is bigger than initial volume during thermal demagnetization, unblocking temperature should indicate higher value under the assumption of constant coercive force. To confirm this hypothesis, we conducted stepwise thermal demagnetization to a boulder emplaced by 1771 Meiwa tsunami (242 years ago) and compare them to our new modified time-temperature relation.

Keywords: thermal expansion, Neel's theory, single domain, viscous remanence, blocking temperature

## Rock magnetic study of single zircon crystals sampled from river sands

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Geomagnetic field paleointensity data provide critical information such as thermal evolution of the Earth (Stevenson et al., 1983). Also a state of geomagnetic field closely relates to a surface environment (Kulikov et al., 2007). It is pivotal to know the variation of geomagnetic field intensity throughout the history of the Earth. Until now we have not yet obtained, however, enough data to resolve billion-year-scale geomagnetic field variation (Tauxe and Yamazaki, 2007) and need to obtain more paleointensity data.

In this study we focus on a paleointensity experiment using single zircon crystal. Since river sand originates in rocks widely distributed in river basin, detrital zircons in the sand have various ages (Rino et al., 2004). Therefore if the geomagnetic paleointensity can be measured using the single zircon crystal, we will probably obtain paleomagnetic data enough to resolve the long-term geomagnetic field variation.

Zircon crystals used in the present study were sampled from sands of the Nakagawa River, Tanzawa Mountain. The Nakagawa River flows along bodies of tonalite, which is a representative rock of the continental crust. Using coarse-grain single zircon crystals with weight of about 0.1 mg, a suite of rock magnetic measurements were conducted: low-temperature demagnetization (LTD) and stepwise alternating field demagnetization (AFD) of saturation isothermal remanent magnetization (SIRM), and low-temperature cycle using an Magnetic Property Measurement System (MPMS).

SIRM intensities of the single zircon crystals vary four orders of magnitude ranging from  $1 \times 10^{-12}$  -  $2 \times 10^{-9}$  Am<sup>2</sup>, and especially a few percent of the grains have strong SIRM larger than  $1 \times 10^{-10}$  Am<sup>2</sup>. The zircon crystals contain nearly pure magnetite (Fe<sub>3</sub>O<sub>4</sub>), and they are in both single-domain (SD) and multidomain (MD) states. The SD magnetite contained in the zircon crystals has the potential to record the paleomagnetic information. The existence of MD magnetite suggests that stepwise-demagnetization after LTD treatment is an efficient approach for paleomagnetic measurement. Taking into account the relation between SIRM intensity and thermoremanent magnetization (TRM) intensity for magnetite (e.g., Yu, 2010), TRM of single zircon crystal may be measured with a high-sensitivity magnetometer such as a SQUID magnetometer.

Now we plan to sample river sand at the Mississippi River and to conduct rock magnetic measurements of the zircon crystal collected from the sand. On the basis of the rock magnetic studies for the zircon crystals from the Nakagawa River and the Mississippi River, we will discuss the feasibility of the paleointensity experiment using single zircon crystal.

Keywords: Zircon, Rock magnetic study, Paleointensity



## Development of the Japan Archeomagnetism Database

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Here we will report the online service of Japan Archeomagnetism Database which is developed since 2012. Now the database includes about 700 site archeodirection dataset, and we are working to add new data from the backyard stocks which has uncertainty about the independent archeological chronology. Therefore we have to confirm that with searching the dating in the original excavation reports.

Moreover we have added new archeomagnetic data from the archeological archives. More than 100 archeomagnetic data have been manually discovered in the reports.

Now we are also providing a paleomagnetic direction at the Far-East region calculated from the Japanese geomagnetic secular variation models.

Keywords: Archeomagnetism, Database, Geomagnetic secular variations

## Medium scale crustal structure based on magnetic and gravity anomalies in the eastern part of Hokkaido, Japan. -part 2

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<sup>1</sup>Geological Survey of Japan, AIST

The Pacific coast of the eastern Hokkaido (from Kushiro to Nemuro Peninsula) is characterized by high gravity and high magnetic anomalies. However, it was difficult to get a suitable model due to gravity anomalies on land and aeromagnetic anomalies. We sampled basalts in this area and measured densities, natural remanent magnetization, susceptibilities and other magnetic properties. These results were presented in Japan Geoscience Union Meeting 2007. Moreover, new gravity and magnetic anomaly maps of offshore of cape Ochiishi were published by GSJ, AIST (2012). We picked up profiles and modified previous models. Data including new profiles suggested similar models to previous studies.

Keywords: magnetic property, magnetic anomaly, gravity anomaly, Nemuro, Hokkaido

## Seismogenic shear-induced thermal turbulence in Nojima fault gouges: micro-textural and rock magnetic considerations

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Nojima fault gouges exhibit a characteristic flow microtexture of laminated slip zones, billow-like wavy folds and turbulent disordered structures. Power spectral analysis of the wavy folds indicates that the geometry roughly obeys a power-law of -1.9, agreeing well with the previously measured value of Kelvin-Helmholtz (KH) turbulence in natural environments. The well-known example of KH instability is a cloud that the cloud-atmosphere interface becomes an unstable vortex sheet that rolls up into a spiral. The instability occurs at the interface between two fluids of different densities shearing at different velocities (Thorpe 2005). The KH wave in Nojima fault gouges was found along a slip plane in a blackish cohesive gouge (pseudotachylyte-like gouge), resulting in the presence of instability at the slip interface during ancient earthquake or creep. Thin section observations showed the blackish cohesive gouge consisted of granular materials for both sides of the interface and the KH wave occurs in a denser granular material along an earthquake-originated sharp slip plane. Our scanning Magneto-Impedance magnetic microscope observation shows the KH wave dense layer is only magnetized in isothermally-magnetized thin section, revealing the production of magnetic mineral in KH wave. Because the Nojima fault gouge contains iron-carbonate (siderite), the thermal decomposition of siderite produces magnetite more than 400 °C. Therefore, we suggest that the KH wave is generated through KH instability in a high-temperature (>400 °C) granular dense layer with different densities and different slip velocities. This result suggests that shear-induced thermal turbulence in the fault gouge plays an important role to weaken a frictional strength during earthquake slip dynamics.

## Analyzing the early 19 century's geomagnetic declination in Japan from Tadataka Inoh's Santou-Houi-Ki.

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<sup>1</sup>Japan Cartographers Association, <sup>2</sup>San-in System Consultant, <sup>3</sup>Matsue Municipal comitee of property, <sup>4</sup>Studyies of Inoh's map and writing Assoc

Santou-Houi-Ki national treasure of Japan recorded by cartographer Tadataka Inoh in 1800-1816, is 67 volumes ledger consist of approximately 200,000 magnetic compass land survey azimuth data accuracy of 0 degree 05 min, from eastern coast of Hokkaido to Yakushima Isl in western Japan. We continue the work of analysis that stopped after only analysis in 1917, which done about the survey data at known position of the retirement home of Inoh at Fukagawa in Edo (Tokyo) in 1802-1803.

(1)It is able to change Japan as one of the most concentrated area of accurate geomagnetic declination data in the world, in early 19th century, from insufficient area of data, and supply new data to northeast Asia by analysis of Santou-Houi-Ki.

The total number of analyzed points exceeded 178, and the outline isogonic line in Japan archipelago and the distribution of the declination in every15 minutes in western Japan coast in those days, begun to appear.

(2)Compare the isogonic Atlas by Gauss and Weber (hereinafter Gauss Atlas) consisted of observed data in 1828-1830, with the analysis from Santou-Houi-Ki, the foundational structure of isogonic lines in Japan archipelago is roughly similar. But we recognize the contradiction to reverse with secular variation in Northern Kyushuu area and Tsushima Island. There are no observed data in Japan in the table supplemented with Gauss isogonic Atlas. The recorded observational data in Gauss Atlas in East Asia were inland area from Pekin to Eastern Siberia, Ohotsk, Kamchatka etc. From the analysis of Santou-Houi-Ki, we recognize the magnetic declination supposed as the local geomagnetic anomaly in southern coast of eastern Hokkaido. The isogonic line of declination in surrounding area of Japan in Gauss Weber's Atlas had drawn by calculated estimates, on a matrix of 5 degree in latitude and 10 degree in longitude, one cell of this matrix is 500km long. Therefore the analysis of Santou-Houi-Ki becomes very important. Today it is very important to verify with the isogonic map of Andrew Jackson et al Gufm1 by NOAA (1800-1815).

(3)Procedure and advantage of interdisciplinary and simultaneous analysis of Santou-Houi-Ki across geomagnetism, cartography, and local history. 1.It increase precise evidence to verify the azimuth and the name or short description of the reference point or the target points recorded in Santou-Houi-Ki, with not only the survey diary by Inoh or Inoh map or the survey map of today, add historical local map, historical local source material, the old survey map by former Japan imperial army. 2. Use the recreation software of scenery or digital map of GSI Japan to grasp the outline of particular latitude and longitude of the reference point and target points and real azimuth. 3. Calculate the average of remainder as the declination, to deduct the magnetic azimuth recorded in Santou-houi-Ki from the real azimuth. 4. The important point is to calculate backward the precise position of the reference point should be adjusted to the position, where all of the declination values from the magnetic survey azimuth to different targets at the reference point are approximately equal to each other, to use the consecutive formula of Excel for speed up and keep accuracy. 5. Use GPS transmitter at the reference point to investigate longitude and latitude, and recalculate the position under 0 second in latitude and longitude, minute accuracy declination, more detail and accurate than traditional study. 6.It is able to find areas or points of local geomagnetic anomaly, or to restore the precise position of survey reference point by Tadataka Ino, accuracy of less than second in latitude and longitude, or the objective point of survey in accuracy second where the valuable in local history, including disappeared constructions or big tree etc.

Keywords: declination, Inoh, SantouHouiKI, Reference point, interdisciplinary