Paleomagnetic age dating of the Caravia-Berbes fluorite deposits of Asturias, Spain.

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Paleomagnetic results are reported for the Caravia-Berbes fluorite deposits of Asturias, Spain. The Caravia-Berbes district is a major fluorite producing area in Europe where the fluorite occurs as either mantos or veins. Paleomagnetic analyses of 191 specimens collected from the Emilio manto and the Caliza de Montaña Formation near the Mina Ana vein lode were done using alternating field and thermal step demagnetization methods. A stable characteristic remanent magnetization (ChRM) isolated in the specimens from Emilio manto yields a paleoinclination that gives an age of ~206 Ma after correction for Neogene Pyrenean tilt. This age indicates a major hydrothermal and ore emplacement event that is coeval with the onset of Pangea's breakup. Another stable ChRM in a silicified dolomitic alteration zone of the Caliza de Montaña Formation yields a paleopole positon at ~115 Ma after Neogene tilt correction, indicating that the western Cantabrian basin was also impacted by a major hydrothermal alteration and remagnetization event during the Aptian-Albian ~35° counterclockwise rotation of Iberia away from the Eurasian plate. Our results show that the Mesozoic strata has experienced at least two major hydrothermal events.

Keywords: Paleomagnetism, Remagnetization, Fluorite mineralization

Remagnetization during vertical axis rotation. A Carboniferous tale from the Iberian peninsula.

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The Variscan mountain belt in Iberia defines a large “S” shape with the Cantabrian Orocline in the north and the Central Iberian curve, an alleged orocline belt of opposite curvature, to the south. The Cantabrian Orocline is kinematically well constrained, but the geometry and kinematics of the Central Iberian curve are still controversial. I have performed extensive paleomagnetic studies to investigate the kinematics of the Central Iberian curve, which plays an important role in the amalgamation of Pangea since it may have accommodated much of the post-collisional deformation.

We have performed a paleomagnetic study on Carboniferous granitoids and Cambrian and carboniferous limestones within the hinge of the curve. Paleomagnetic and rock magnetic results show a primary magnetization in Carboniferous granitoids and a widespread Carboniferous remagnetization in the sedimentary rocks studied.

Granitoids show ca. 70˚ counter-clockwise rotations consistent with the southern limb of the Cantabrian Orocline (the one to the north). Post-kinematic granitoids and Cambrian limestones show consistent inclinations but very scattered declinations suggesting that they were magnetized coevally to and after the ~ 70˚ rotation. Our results show no differential rotations between northern, southern limb and the hinge zone. Therefore, I discard a late Carboniferous oroclinal origin for the Central Iberian curve.

Rock magnetic signature of gas hydrate-bearing sediments: insights from the Kumano Basin, Nankai Trough, offshore Japan

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Interest in gas hydrate occurrences have been increasing in the last decades because of their potential value as an energy resource. Signatures in the rock magnetic record has successfully been used to identify present gas hydrate-bearing horizons in marine sediments, and can potentially indicate former gas hydrate accumulation zones. Recent studies carried out at Integrated Ocean Drilling Program (IODP) Site C0008, in the frontal thrust of the Nankai Trough, have shown that authigenic ferrimagnetic iron sulfide-rich layers characterize present day gas hydrate horizons. Here we present a detailed rock magnetic study of gas hydrate-bearing sediments from the Kumano forearc basin in the Nankai Trough drilled during IODP Expedition 338. We aim to characterize the present distribution of gas hydrate-bearing horizons in the basin. Our data are from Site C0002 from 200 to 500 meters below sea floor (mbsf), which is cut by prominent, regional bottom simulating reflector (BSR) observed at ~400 mbsf in seismic data. Downhole evolutions of concentration, grain size and composition of the magnetic minerals are investigated by a series of rock magnetic measurements. The preliminary results support a characteristic rock magnetic signature related to gas hydrate and suggests the presence of gas hydrate beneath the BSR, i.e. below the base of gas hydrate stability. This deeper signature of hydrate occurrence correlates with the depth of a discontinuous, but widespread double-BSR in 3D seismic data.

Keywords: Nankai Trough, Gas hydrate, Rock magnetism

Monitoring of the 2011 Tohoku tsunami deposits by geochemical and rock magnetic analyses in Sendai bay sediments.

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Near-shore marine sediments deposited along island arcs preserve evidence of past disaster events such as tsunamis. A tsunami occurred on 11 March 2011 off the Pacific coast of Tohoku, Japan, associated with the 2011 off the Pacific coast of Tohoku Earthquake. The event is likely preserved in marine sediments. This study aims to constrain the distribution of tsunami deposits and its preservation states in Sendai Bay, located west of the earthquake, by geochemical and rock magnetic analyses. Surface sediments on the seafloor were collected at four stations, the entrance (S-2) and outer sites (S-3, S-4, and S-5) in the Bay, between 2011 and 2014. Stations S-4 and S-5 are located under the axis of the storm wave base, which erode modern sediments (e.g., Saito, 1989). Results of low-temperature magnetometry indicate that transported magnetite by the tsunami is oxidized within a year at stations S-4 and S-5. Magnetic grain size parameters, Mr/Ms and Hcr/Hc, show that coarse grains are supplied at stations S-4 and S-5 in 2013-2014. Magnetic extracts observation with a scanning electron microscopy (SEM) and element identification by energy dispersive X-ray spectrometry (EDX) indicates that Ti-poor magnetite particles with less lamellae increase in the samples that collected after the 2011 Tohoku tsunami. Fe_2O_3 and Cr contents are high in the samples. While Cr content decreases from 2013 at all stations. Fe_2O_3 content also declines at station S-5 in 2014. It is implied that the 2011 Tohoku tsunami deposits are not preserved after 2013 at least.

Keywords: Tsunami deposit, Rock magnetism, Sendai Bay

Reconstruction of paleosecular variation from Lake Biwa sediments: Pass-through measurements and SQUID microscopy

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We have conducted measurements on one of the three piston cores taken from Lake Biwa off Takashima (BWK12-2; length 1633 cm). Sediment comprises of clay intercalated with at least 13 ash layers. Thirteen horizons were dated with ^{14}C using plant pieces giving a maximum age estimate of more than 40 ka. Paleomagnetic cube specimens, u-channel samples and LL-channel samples were taken from the core. Paleomagnetic cube specimens were measured with a SQUID Rock Magnetometer at AF demagnetization steps of 0-80 mT. Results of inclination from the cube samples show an agreement with the paleosecular variation reported by Ali et al. (1999). For example, Inclination show a minimum of ~40˚ at 2600 year BP and a maximum of ~58˚ at 3400 year BP, both of which can be correlated with a minimum 'h' at 2400 year BP and a maximum 'i' at 2900 year BP presented by Ali et al. (1999), respectively. Pass-through measuremens on u-channel and LL-channel samples were conducted both at Geological Survey of Japan and Kochi Core Center. Paleomagnetic results after deconvolution for u-channel and LL-channel at two different laboratories with different sensor response functions will be compared together with the results of cube samples. Further, a preliminary results measured with a scanning SQUID microscope on some block samples taken from LL-channel samples are going to be presented.

Keywords: Scanning SQUID microscope, paleosecular variation, Lake Biwa

Magnetic instability and slow-wave propagation in a rotating fluid sphere

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We investigate instability of a toroidal basic field cofined in a rotating, finitely conducting and inviscid fluid sphere. In order to represent a system where the Lorentz-force term dominates in the vorticity equation like in the Earth's core, we use the magnetostrophic approximation by which the inertial term is exactly zero. The equation is linearized and represented in the azimuthal wavenumber (m) space. The remaining meridional space is discretized using the finite difference method. In this method, the grid points do not necessarily fall on the spherical surface (the core-mantle boundary), but the second-order accuracy can be kept by carefully implementing the boundary condition. The numerical method is verified by comparing the exact solution of the magnetic decay mode and our previous numerical code. The Arnoldi method and the inverse power method are used to solve the eigenvalue problem about the growth rate of the perturbed magnetic and velocity fields.

We generally assumed a basic toroidal field that is proportional to $(1 - s^2 - z^2)\, s^k$ (k=1, 3, 5, ...) or $(1 - s^2 - z^2)\, z\, s^{k-1}$ (k = 2, 4, 6, ...) where (s, z) are the cylindrical coordinates. This basic field is exactly zero at the spherical surface and the position of the intensity maximum tends to approach the equator on the spherical surface as k increases. When the Elsasser number, the only dimensionless parameter representing the square of the basic field intensity, increases and exceeds a certain value, the system turns to be unstable and a slow magnetostrophic wave propagates eastward (prograde) or westward (retrograde). The critical Elsasser number is not significantly dependent on k; the critical value is basically O(1) and is not greater than 10 when k is varied up to 10. The magnetic instability tends to occur at a higher wavenumber when k increases. For example, when k = 8, the critical azimuthal wavenumber is around m = 6. The growth rate tends to be higher at a higher wavenumber mode. The wave propagation is largely eastward and the phase velocity is not significantly different from the characteristic slow-wave speed. This study suggests that the geomagnetic westward drift seen at the low latitudes of the Earth's core surface is basically explained by a westward mean flow that is probably created by the thermal convection inside the core, but is partially modulated (slowed down) by the eastward wave propagation, if the instability of a strong toroidal field hidden below the core-mantle boundary is a significant process in the core dynamics.

Keywords: geomagnetic secular variation, magnetohydrodynamics, Earth's core

Decadal-centennial scale features of the Matuyama-Brunhes magnetic reversal

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The Matuyama-Brunhes magnetic reversal is the youngest and most investigated reversal on record, and this has greatly furthered our understanding of the geodynamo by providing detailed records of a highly dynamic change of the earth's magnetic field. Recent paleomagnetic observations in various localities reveal many centennial-scale changes during the reversal. However, we have never observed sub-centennial scale features. Here, we report a 10-yr resolution record of the Matuyama-Brunhes transition (MBT) from a marine sequence from the Chiba Section, central Japan. The record is based on paleomagnetism mainly carried by greigite and an astronomical age model. The transition spans about 9000 yr in total, consisting of two precursory events, the main transition, and rebound. There are two precursory events characterized by multiple polarity swings. The first event occurred in the earliest marine isotope stage (MIS) 19 and spans ca. 1100 yr; the second occurred just after highstand MIS 19.3 and spans ca. 100 yr. The main MBT spanning ca. 2000 yr has nine large directional swings in both inclination (> 50 deg.) and declination (> 100 deg.). The main MBT is postdated by three steep inclination events persisting for 40—70 yr within about 300 yr, regarded as rebounds. Besides these features, there is an interval characterized by large declination fluctuations persisting for about 1200 yr around highstand MIS 19.3. Some of these centennial scale features can be seen in previous high-resolution MBT records from other locations around the world.

Keywords: Matuyama-Brunhes polarity transition, Geomagnetic reversal, Chiba Section, depositional detrital remanent magnetization, depositonal chamical remanent magnetization

A high resolution relative paleointensity record across the Matuyama-Brunhes polarity transition from the Chiba composite section, a candidate for the L-M Pleistocene boundary GSSP

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We report a high-resolution paleomagnetic direction and relative paleointensity records from a continuous marine succession exposed on the Chiba composite section of the Kokumoto Formation, Kazusa Group, Japan. The Chiba composite section is a candidate for the Lower-Middle Pleistocene boundary GSSP. Our records provide detailed behaviors of the virtual geomagnetic poles (VGPs) and relative paleointensity changes during the Matuyama-Brunhes (M-B) polarity transition. The resultant relative paleointensity and VGP records show a significant paleointensity minimum near the M-B boundary, which is accompanied by a clear “polarity switch” like change in terms of the paleomagnetic direction. The relative paleointensity seems to keep in a low level for more than 10 thousand years associated with an unstable normal polarity. A high-resolution oxygen isotope chronology for the Chiba composite section indicates that the M-B boundary is located in the middle of Marine Isotope Stage (MIS) 19 and yields an age of 771.7 ka for the boundary. This age is consistent with those based on the latest astronomically tuned marine and ice core records and with the recalculated age of 770.9 ±7.3 ka deduced from the U-Pb zircon age of the Byk-E tephra. Moreover, our relative paleointensity record exhibits a consistent variation with other paleointensity records including Be10 derived intensity proxy from deep sea and ice cores. Our paleomagnetic data especially for the relative paleointensity represent one of the most detailed records on this geomagnetic field reversal so far obtained from marine sediments and will therefore be key for understanding the dynamics of the geomagnetic dynamo and for calibrating the geological time scale.

Keywords: relative paleointensity, geomagnetic reversal, Matuyama-Brunhes boundary, Chiba composite section

Investigation of a marine magnetic polarity reversal boundary in cross-section at the northern boundary of the Kane Megamullion, Mid-Atlantic Ridge 23°40’ N

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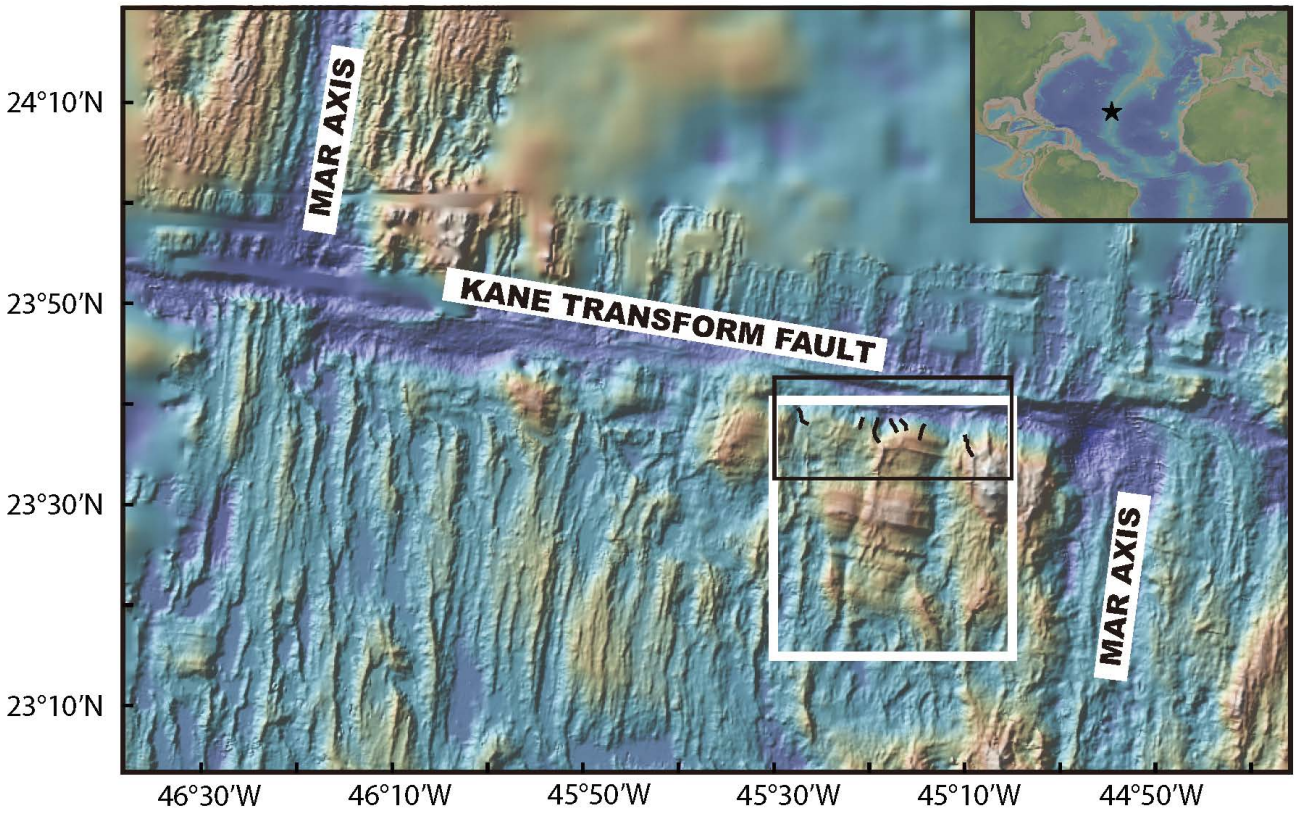
Near-bottom magnetic field measurements made by the submersible *Nautile* during the 1992 *Kanaut Expedition* define the cross-sectional geometry of magnetic polarity reversal boundaries and the vertical variation of crustal magnetization in lower oceanic crust exposed along the Kane Transform Fault (TF) at the northern boundary of the Kane Megamullion (KMM). The KMM exposes lower crust and upper mantle rocks on a low-angle normal fault that was active between 3.3 Ma and 2.1 Ma. The geometry of the polarity boundaries is estimated from an inversion of the submarine magnetic data for crustal magnetization. In general, the polarity boundaries dip away from the ridge axis along the Kane TF scarp, with a west-dipping angle of ~45° in the shallow (<1 km) crust and <20° in the deeper crust. The existence of the magnetic polarity boundaries (e.g. C2r.2r/C2An.1n, ~2.581 Ma) indicates that the lower crustal gabbros and upper mantle serpentinized peridotites are able to record a coherent magnetic signal. Our results support the conclusion of *Williams* [2007] that the lower crust cools through the Curie temperature of magnetite to become magnetic, with the polarity boundaries representing both frozen isotherms and isochrons. We also test the effects of the rotation of this isotherm structure and/or footwall rotation, and find that the magnetic polarity boundary geometry is not sensitive to these directional changes.

Keywords: Near-bottom magnetic, Kane Megamullion, Magnetic Reversal Boundary, isotherm and isochron



Paleomagnetic secular variation of 3–4 ka from lava flows around the post-caldera cones of Aso Volcano and its contribution to the volcanic stratigraphy

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We have conducted a paleomagnetic study on Holocene lava flows around the post-caldera cones of Aso Volcano, central Kyusyu, Japan. On the basis of the paleomagnetic directions, combined with geological evidences, we have refined the stratigraphic relationship of the lava flows and the distribution of them. In the previous studies, lava flows distributed around a cone (volcanic center) were described as a single geological unit corresponding to each cone. Paleomagnetic directions obtained in this study are useful to recognize temporal correlation or distinction between the studied sites. It is also noted that the paleomagnetic directions obtained from 22 sites around three cones and a scoria cone are distributed on a simple curve, which is considered to record paleomagnetic secular variation (PSV) during the period between 4 and 3 ka. This PSV curve contributes to an improved volcanic stratigraphy including temporal gaps of the order of 10–100 years.

Keywords: paleomagnetic secular variation, volcanic stratigraphy, Aso Volcano

Archeomagnetic database of Japan: direction and intensity

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In Japan, there have been many paleomagnetic measurements on archaeological relics and ruins. The total number of the site of archeodirection in Japan seems several thousands, but the accurate number is not well known because of dissipation of the reports.
We have been gathered the archeomagnetic data and constructed a new database including well-dated datasets. Now archeodirection data obtained from about 700 sites are reported on our website. Moreover there are more than one thousand data remaining in the stock which have unclear age and quality and we have a plan to review the data in detail and will be published.
Here we introduce the classification, searching, reposition and publication of the data measured.

Keywords: paleomagnetism, archeomagnetism

The time-averaged palaeomagnetic field during 3-7 Ma at high northern latitudes

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The geocentric axial dipole (GAD) hypothesis states that when we average the geomagnetic field over sufficient time intervals, the time-averaged field (TAF) behaves like a dipole aligned along the Earth's spin axis and positioned at the Earth's centre. This hypothesis is crucial in palaeomagnetic research such as palaeosecular variation, palaeoclimate and plate tectonic reconstruction. However, the time interval to average the field to achieve a GAD is still debated. For example, there is some evidence for the persistence of long-term hemispheric asymmetry on time scales of 10^5-10^6 yr, particularly at high-latitudes. As most palaeomagnetic research is conducted under the GAD hypothesis, the hypothesis needs to be rigorously tested. In this research we aim to investigate the symmetry of the palaeomagnetic field and to test the GAD hypothesis during 3-7 Ma using full-vector palaeomagnetic data - including palaeodirection and palaeointensity - from dated lava piles in northern Iceland.

The demagnetisation measurements including alternating field (AF) and thermal were made to determine palaeomagnetic directions. In order to improve quality of high-latitude data, approximately 6-10 directional data per site were used to calculate mean directions. We found mean declination and inclination of 355.0˚ and 72.0˚ with 95% confidential limit of 2.2˚. The modelling of the field was performed by adding 4% of quadrupole and 11% of octupole to the model; the model returns the inclination of 72.1˚ at 65˚N. Our dataset passed the reversal test with Class A which is indicative of high accuracy. The directional data were converted to virtual geomagnetic pole (VGP) which is located at 81.3˚ N and 180.2˚E.

The Curie temperature determination was performed using strong field thermomagnetic analysis prior to palaeointensity experiment. Evidence from strong field thermomagnetic curves indicates the presence of Ti-rich titanomagnetite, Fe-rich titanomagnetite and titanomaghemite in samples across the lava flows. Palaeointensity experiment was conducted in a helium atmosphere in order to prevent oxidation on the samples. We used the infield/zero-field and zero-field/infield protocol with partial thermoremanent magnetisation (pTRM) checks. Samples from 20 lava flows yield successful results. We found the mean intensity of 22.0±2.7 μT, which is lower than the intensity of the GAD field (55.9 μT) at 65˚N, and the virtual dipole moment (VDM) of 32 ZAm^2. The investigation of palaeomagnetic data from Icelandic basalts reveals that the non-dipole field persists during 3-7 Ma at high-northern latitudes. However, the results of this study should be compared with the time-averaged field data at high-southern latitudes especially at 65˚S to see the symmetry of the field during 3-7 Ma.

Keywords: Iceland, Geocentric Axial Dipole (GAD) hypothesis, Palaeomagnetism

Composition law of oblique anhysteretic remanent magnetization and its relation to the magnetostatic interaction

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The basic properties of oblique anhysteretic remanent magnetization (OARM) acquired in a weak and steady magnetic field with an arbitrary angle to the alternating field direction were studied. OARM and rock-magnetic experiments were conducted on samples of basalt, granite, and sediment containing non-interacting single-domain (SD), interacting SD, pseudo-single-domain, and multidomain low-Ti titanomagnetites. The intensity of OARM (M_{OARM}) systematically increased or decreased with increasing angle between alternating and steady field directions (θ_{SF}), while the angle between alternating field and OARM directions (θ_{OARM}) increased with increasing θ_{SF} for all samples. During stepwise alternating field demagnetization, the OARM vector shows a single component parallel to the steady field direction for θ_{SF} = 0˚ ($ARM_{\parallel}$) and 90˚ ($ARM_{\perp}$). The median destructive field of $ARM_{\perp}$ is larger than that of $ARM_{\parallel}$. For intermediate angles (θ_{SF} = 30˚, 45˚, and 60˚), the OARM vector was not parallel to the applied steady field; instead, it gradually increased with coercivity. These experiments indicate that the OARM vector is approximately given by the sum of two orthogonal magnetizations coinciding with $ARM_{\parallel}$ and $ARM_{\perp}$, respectively. Thus, the OARM vector can be determined by acquisition efficiencies of $ARM_{\parallel}$ and $ARM_{\perp}$ in an individual sample. Based on these experiments and associated rock-magnetic measurements, non-interacting SD samples show lower $ARM_{\perp}/ARM_{\parallel}$ ratios, compared to other samples. This result suggests that OARM can be used as a conventional tool to detect non-interacting SD particles in the paleomagnetic samples.

Keywords: Anhysteretic Remanent Magnetization, Magnetostatic Interaction, Rock Magnetism

Ocean waves-induced magnetic effects in Taiwan

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12 magnetic stations routinely monitor changes in the geomagnetic total intensity field are utilized in this study to examine magnetic ocean wave effects in Taiwan. The time-varied magnetic data are transferred into the frequency domain via the Fourier transform to investigate the frequency characteristics associated with ocean waves. Significant enhancements can be found from spectrums in the frequency band of about 0.05–0.3 Hz at stations located very close to the seashore. Frequency characteristics of magnetic data were compared with them of significant wave heights monitored using nearby meteorological observation buoys. The agreement in the frequency characteristics suggests that the magnetic field is affected by ocean waves directly hitting the seashore in open oceans. In contrast, ocean waves with the double-frequency recorded by the marine metrological buoys reveal the locally dominate wave-wave interaction around bays.

Keywords: Ocean waves, Magnetic disturbance, Microseisms

