Geomagnetism and Paleomagnetism

GP11A MCC: Level 1 Monday 0830h

Conductivity from Crust to Core I
Posters *(joint with T)*

Presiding: **S Constable,** Scripps Institution of Oceanography**; J A Craven,** Geological Survey of Canada

GP11A-0249 0830h POSTER

Electrical Conductivity Measurement of Granulite Under Mid to Lower Crustal Pressure-Temperature Conditions

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We have developed a technique to measure electrical conductivity of crustal rocks with relatively low conductivity and complicated mineral components in order to compare with results given by Magneto-Telluric (MT) measurements. A granulite from Hidaka Metamorphic Belt (HMB) in Hokkaido, Japan at high temperature and pressure conditions was obtained. The granulite sample was ground and sintered under the conditions similar to those of mid to lower crust. We have observed smooth and reversible change of conductivity with temperature up to about 900 K at 1 GPa. Through the qualitative and quantitative evaluations using Electron Probe Micro Analysis (EPMA), microstructures of the sintered sample were inspected. This inspection is essential to confirm the sample was not affected by chemical interaction of minerals. We also examined the role of accessory minerals in the rock, and the mechanisms of electrical conductivity paths in dry or basic rocks should be reconsidered. Finally, results from electrical conductivity measurements were consistent with the electrical conductivity structures suggested by the former MT data analysis.

URL: http://www.kobe-u.ac.jp/marine/member/fujita

GP11A-0250 0830h POSTER

Modular Approaches to Earth Science Scientific Computing: 3D Electromagnetic Induction Modeling as an Example

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We are developing a modular system for three-dimensional inversion of electromagnetic (EM) induction data, using an object oriented programming approach. This approach allows us to modify the individual components of the inversion scheme proposed, and also reuse the components for variety of problems in earth science computing howsoever diverse they might be. In particular, the modularity allows us to (a) change modeling codes independently of inversion algorithm details; (b) experiment with new inversion algorithms; and (c) modify the way prior information is imposed in the inversion to test competing hypothesis and techniques required to solve an earth science problem. Our initial code development is for EM induction equations on a staggered grid, using iterative solution techniques in 3D. An example illustrated here is an experiment with the sensitivity of 3D magnetotelluric inversion to uncertainties in the boundary conditions required for regional induction problems. These boundary conditions should reflect the large-scale geoelectric structure of the study area, which is usually poorly constrained. In general for inversion of MT data, one fixes boundary conditions at the edge of the model domain, and adjusts the earth?s conductivity structure within the modeling domain. Allowing for errors in specification of the open boundary values is simple in principle, but no existing inversion codes that we are aware of have this feature. Adding a feature such as this is straightforward within the context of the modular approach. More generally, a modular approach provides an efficient methodology for setting up earth science computing problems to test various ideas. As a concrete illustration relevant to EM induction problems, we investigate the sensitivity of MT data near San Andreas Fault at Parkfield (California) to uncertainties in the regional geoelectric structure.

GP11A-0251 0830h POSTER

The electrical image of the Dead Sea Transform on a regional scale

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The trans-continental Dead Sea Transform (DST) forms the boundary between the African and Arabian plates in the Middle East and connects the Red Sea rift in the south with the Alpine orogenic belt in Turkey. The aim of the multi-disciplinary DESERT project is to study this plate tectonic setting on all scales and to better understand its dynamics in the Earth crust and upper mantle. The experiment was conducted in the Arava valley, where strike-slip displacement seems to be concentrated on a distinct and continuous master fault . We present magnetotelluric (MT) data from 82 sites collected in 2002 along a 100 km long east-west striking profile. This profile follows a seismic reflection / refraction line in Jordan, from the border to Israel, crossing the escarpment of the Edom Mountains to Ma'an in the east. 2D conductivity models of MT data collected in 2000 and 2001 along short profiles in the Arava valley revealed a strong lateral conductivity contrast in form of a conductive half layer west of the DST in1.5 km depth with a sharp vertical conductivity boundary directly beneath its surface trace. The short profile lengths, however, restrict the interpretation to a depth of approximately 5km. With this new MT data set we are now able to model the conductivity structure of the entire crust. The regional 2D inversion models indicate that the zone of anomalously high conductivity associated with the DST could extend down to mid-crustal depth. The area east of the fault in the Arava valley shows intermediate resistivities which can possibly be explained by fractured Precambrian rocks overlain by sediments. The escarpment of the Edom Mountains as well as the plateau is dominated by a generally resistive subsurface. At the edge of the plateau we identify the branches of the Al Quwayra fault system as shallow conductive anomalies. In the eastern part of the profile near Ma'an we resolve the Mesozoic and Cenozoic sedimentary cover that increases in thickness further to the north.

GP11A-0252 0830h POSTER

The Electrical Roots of the Slave and Superior Provinces, Canada.

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Evidence from over five years of magnetotelluric data collection across the Slave craton and western Superior Province reveal dramatic spatial variation and upper mantle conductors with resistivities as low as 10 Ohm m embedded within the cratonic lithosphere. The conductivity of these anomalies is approximately two orders of magnitude higher than laboratory studies and petrophysical modelling predict for an olivine or pyroxene mineralogy dominated upper mantle. Given the depth location, age, and tectonic setting as well as the observed conductivity of these electrical conductors, we conclude that they are likely due to carbon in the form of interconnected graphite. The evidence for deep-seated graphitic conductors spatially related to other deep-seated geophysical and geochemical anomalies may be taken together with independent estimates of upper mantle oxygen fugacities within two log units of the iron-wüstite buffer to suggest that partial melting and formation of the cratonic root may be related to redox melting during Meso and NeoaArchean times.

GP11A-0253 0830h POSTER

Study of dielectric dispersion in moist rocks at low frequency as a possible clue for sounding of H_20 in the Earth's crust

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This work is motivated to examine the possibility of remote observation of H_2O and its tectonic roles by studying the nature of dielectric dispersion. Slight wetting of rocks appears to show a drastic increase in dielectric permittivity ε in reciprocal proportion to frequency below several hundreds kilohertz, whereas electric conductivity σ is almost independent of frequency (Lockner & Byerlee 1985, Jonscher 1976, etc.). This peculiar dielectric dispersion may be useful to characterize H_2O within the Earth's crust remotely by low frequency electromagnetic sounding from the surface. Field observation as well as property measurement in laboratory provide complex conductivity $\sigma^* = \sigma + j\omega\varepsilon = \sigma(1 + j\gamma)$ (which is physically equivalent to complex dielectric permittivity, $\varepsilon^* = \varepsilon + \sigma/j\omega$ as a function of frequency. Usually the quantity defined by $\gamma = \omega\varepsilon/\sigma = 1/\tan\delta$) has been supposed to be too small (less than 0.1) in comparison with the observation error both in situ and in laboratory. Further, laboratory studies on the dielectric dispersion have been quite controversial so far. However, there is a hope in future availability of high-precision EM sounding method (Nakajima *et al*, 2000), and (1) we developed a reliable and precise four electrode method of measuring complex dielectric permittivity at low frequencies to a demanded precision of 10^{-3}, and (2) laboratory measurements of dielectric dispersion are made to clarify the basic characteristics in order to correlate with the observation in situ. We noted that the ordinary measurement methods usually show the large (1) measurement error originated from noise, and also (2) significant bias in γ due to the disturbance of electric field in the sample caused by potential electrodes even in 4 electrode method. Therefore, we have used very accurately controlled sinusoidal signals to obtain the high S/N ratio by data stacking, and also a 4 electrode method to enable us to measure the bulk property and interface property simultaneously by using a new type of potential electrodes with least polarization. As a result, we came to determine both real part of complex conductivity to a precision to 10^{-5} and imaginary parts at least to a precision of 10^{-3} at the frequency down to 10 mHz. This means that $\gamma = \omega\varepsilon/\sigma$ can be determine to a precision of 10^{-3}. Our results of measurements are as follows (a) Heterogeneous materials such as mixture of glass beads soaked in water show that γ is nearly constant $0.01 \sim 0.003$. This suggests that ε is in reciprocal proportion to frequency and there should be some electrochemical reactions involved in this dielectric dispersion. The demanded precision in field observation to obtain the meaningful data on dielectric dispersion in situ is $\sim$0.003 or better. (b) uniform materials such as water and glass do not show any increase of ε in reciprocal proportion to frequency, whereas some previous paper reported the frequency dependence of ε very probably due to the bias originated from the distortion of electric field by potential electrodes in the measurement.

GP11A-0254 0830h POSTER

Crustal Structures of Cenozoic Pantanal Wetland (SW Brazil) From MT and Gravity Studies: Geophysical Evidence of a Buried Neoproterozoic-Cambrian Suture Zone

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The Paraguay fold belt and the actual positions of the Amazonian/Parana cratonic borders under the vast Cenozoic sedimentary cover of the Pantanal Wetland are still unresolved and constitute a major problem in understanding the geological and tectonic evolution of the central and southern South American Platform. In order to provide further geophysical constraints to help solving these geological uncertainties, we carried out a high resolution magnetotelluric (MT/AMT) study within the Pantanal basin and over the exposed northern segment of the Paraguay fold belt. MT data in the broadband frequencies of 1000 Hz to 0.006 Hz were collected and analyzed along a 350 km long NE - SW profile between the towns of Corumba and Coxim and along a WNW-ESE profile between the towns of Barra dos Bugres and Poxoreo. The analyses of the broadband MT data, including dimensionality studies and 2D inversion, have indicated the presence of a prominent electrical resistivity anomaly(< 50 Ohm.m) and strong electrical anisotropy in central Pantanal basin at depths beyond 6 km. Variations in the local geomagnetic transfer function, shown as induction vectors, have further strengthened the presence of these mid-crustal conductors. In a joint interpretation with gravity data, these crustal conductors are attributed to a suture zone related to graphitized metasediments and/or circulation of mineralized fluids in mid crustal fractures whereas the gravity anomaly is thought to be caused either by remnants of squeezed magmatic-arc terranes and/or by an overthrusted lower crust, along a collisional boundary between two petrophysically distinct crustal blocks. Within the framework of the regional geology, the western and eastern blocks are attributed to the Rio Apa Craton and the Parana block, respectively. The deeper geophysical signature of this collisional boundary may be the evidence of the previously postulated northward continuation of the Pampean belt (as Paraguay orogenic belt) under the Pantanal sedimentary cover.

GP11A-0255 0830h POSTER

Potetial use of paleomagnetism for the chronology of tectonic related Plio-Quaternary fan-system deposits from the Appenines: preliminary results from the Campoli Appennino locality (Val Roveto, Italy)

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The Roveto Valley area is part of a segment of the Apennine chain, which was intensively deformed by Neogene-Quaternary compressional and extensional tectonics. This sector of the chain mostly formed in Neogene times in the context of the eastwards piggy-back propagation of the thrust system. Geomorfologically, the Roveto Valley is a narrow and elongated -trending morphological depression, bounded by some of the most relevant regional tectonic features of the whole Apennines, such as the Simbruini-Ernici Mts. basal (leading) thrust and the Val Roveto-Atina-Caserta line. Continental Plio-Quaternary deposits (alluvial-fan conglomerated and sands) locally tilted, are clear geomorphic markers and outcrop at different topographic elevations. These sedimentary bodies constitute a morpho-lithostratigraphic succession linked to the local tectosedimentary setting. These sediments do not contain materials suitable for biochronological determinations, as is often the case for most the central Apennines continental deposits. Therefore, to determine the chronology of the Roveto valley deposits and to assert the acquisition time with respect to the tectonic tilting, four different units of the morpholisthostratigraphic succession were sampled for magnetostratigraphic investigations. A better assessment of the tectonic Quaternary evolution of the Campoli Appennino sector has been achieved by the integration of paleomagnetic data with stratigraphic, morphological and tectonic features.

GP11B MCC: Level 1 Monday 0830h

New Approaches in Rock Magnetism and Paleomagnetism: Merging Magnetic Methods With Analytical Techniques Posters *(joint with MR)*

Presiding: **Y Guyodo,** University of Minnesota**; S A McEnroe,** CSIRO Exploration and Mining

GP11B-0256 0830h POSTER

CO_2 Step-heating of Feldspar Crystals: A New Technique to Derive Paleomagnetic Directional and Paleointensity Data

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Feldspar grains can contain minute magnetic inclusions (50-300 nm in size) that have been shown to faithfully record the modern magnetic field. Here we explore the possibility of using step heating techniques with a CO_2 laser to extract direction and paleointensity information from such crystals. Test samples were chosen from lavas recovered at Nintoku Seamount (Ocean Drilling Program Leg 197, Site 1205). Samples from lava units that displayed stable behavior during thermal demagnetization (Tarduno et al., 2003) were chosen for the experiments. Basalt groundmass was carefully etched away from thin sections so that only feldspar grains free of visible inclusions remained. Neither the rock chip used to make the thin section, nor the epoxy needed to hold the chip to the microscope slide required heating during the curing process, reducing the chance of the acquisition of spurious magnetizations. A mark was etched into the glass slide to maintain sample orientation. Slides were trimmed so that a single feldspar grain could be heated with a CO_2 laser inside a field free space (provided by shields). The feldspar grains examined ranged in size from 1 mm to several mm (all were approximately 1 mm thick). All remanence measurements were made with a 2G Enterprises SQUID magnetometer, with high resolution sensing coils. In initial experiments, an oriented feldspar grain was given an isothermal remanent magnetization (IRM). Step heating was carried out with a CO_2 laser with wattage calibrated against a similar sample attached to a thermocouple. The demagnetization of the IRM showed a simple decay to the origin in orthogonal vector plots. Preliminary experiments to investigate natural remanent magnetizations held by the Site 1205 feldspar grains show directions similar to those of the whole rock from which they were extracted.

GP11B-0257 0830h POSTER

Low-Temperature Magnetic Behavior: Diagnostic for the Interpretation of Magnetic Mineralogy of Basalt?

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Basalts are the most important rocks carrying magnetic anomalies on Earth and the understanding of the magnetic properties, which are dominated by titanomagnetites (tmt), is a main target in rock magnetism. Depending on different parameters like temperature and fugacity that are controlled by extrusion conditions and chemical composition of the magma, different paragenesis and textures as well as compositional types of tmt occur, which create a variety of different rock magnetic behaviors. A detailed study on Hawaiian subaerial and submarine lava flows (Kontny et al. 2003) revealed different groups of magnetic behavior related to varying degrees of oxidation and subsolidus reactions (subaerial flows) and quenching histories (submarine flows). But not only homogeneous, unexsolved tmt compared to exsolved and oxidized tmt create different magnetic properties but also some basalts with homogeneous tmt. Some of these basalts show a complex behavior of low-temperature initial susceptibility. This feature seems to correlate with variations in room temperature hysteresis parameters and AF demagnetization behavior and therefore its understanding may be diagnostic for rock magnetic interpretations. The complex behavior indicates a superposition of different Fe-bearing phases like Ti-rich hemo-ilmenite, pyrrhotite and chromian spinel which all show low-temperature transitions and were observed in different amounts and combinations together with tmt in the Hawaiian basalts. A combination of low-temperature (2 to 280 K) initial susceptibility, remanence and hysteresis measurements along with BSE-images and microprobe analyses will be presented for natural basalts. For a better understanding of this low-temperature behavior, data from synthetic equivalents consisting of tmt and ilmenite will be discussed in relation to natural samples. Kontny et al. (2003) G3 Geochemistry Geophysics Geosystems, 4 (1)

GP11B-0258 0830h POSTER

Bridging the Gap between Micromag and Cryogenic Magnetometer Measurements

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The alternating gradient magnetometer (Micromag) and the cryogenic magnetometer are two of the most useful instruments for determining the mineral magnetic properties of rocks, sediments and soils. However, each instrument has its limitations. Measurements on the Micromag are usually done with small quantities of material whose mass is difficult to determine, especially when sediments and soils are being studied. This makes it difficult to quantitatively relate magnetic parameters determined using the Mircomag with those obtained from conventional measurements on standard-sized samples. On the other hand, standard-sized samples often have isothermal remanent magnetizations (IRMs) that exceed the measurement capabilities of a cryogenic magnetometer. We have developed a method that overcomes the limitations of both instruments. The key to the method is the use of the same small "Micromag" samples for hysteresis and FORC studies done with the Micromag and for IRM acquisition and AF demagnetization studies done with the cryogenic magnetometer. The small sample size keeps the intensities of magnetization below the upper limit for the cryogenic magnetometer. In order to relate these measurements to more conventional magnetic measurements, we measure the anhysteretic remanent magnetization of both the Micromag samples and standard-sized samples prior to the IRM studies. We then determine the mass of the Micromag samples from the mass of the standard-sized samples. The overall approach allows us to bridge the gap between Micromag and cryogenic magnetometer measurements and to report all magnetic properties on a per-unit-mass basis. The method is particularly efficient when used with an automated long-core cryogenic magnetometer operated in a discrete mode.

GP11B-0259 0830h POSTER

Magnetic Field Gradient Differentiation of Pedogenic Iron Oxide Minerals From Chinese Loess and Paleosols

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The correlation between paleosols and enhanced magnetic susceptibility on the Chinese Loess Plateau is by now well established. However, scant effort has focussed on the interpretation of paleoclimate via the specific iron oxide mineral assemblages contributing to the enhanced magnetic susceptibility signal.