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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.

This paper focuses on the separation and identification of the pedogenic (< 1 micron) fraction of iron oxide/oxyhydroxide minerals from selected loess and paleosol layers of the Loess Plateau. Heretofore, it has been difficult if not impossible to isolate mixed iron oxide mineral phases due to their very similar physical and magnetic properties. Chinese loess and paleosol samples were chosen to illustrate the utility of the technique to natural soil systems. In the following method, initial size separation of mineral particles at 0.5 micron or less by gravity and centrifugation reduces the problem of overlapping magnetic susceptibilities due to mixed grain sizes. The submicron mineral fraction is then subjected to a series of high field gradient (HFG) magnetic separations utilizing a new design. Although HFG magnetic separation methods have been used before, the new design is able to differentiate submicron iron oxide mineral phases from bulk earth material. The design includes a Franz Isodynamic Separator fitted with a custom-made flow cell. A recirculating liquid is used to suspend the mineral particles between the poles of the electromagnet. By varying the strength of the field gradient, recirculation time, and flow velocity, step-wise separation of ferrimagnetic from antiferromagnetic minerals is possible. Because of the tendency for particles to aggregate during recirculation, some mixing of the oxide mineralogy has been unavoidable. Although theoretical arguments favor a narrow grain size distribution (about 50-100 nm) for stable single domain magnetite, in soil environments, and particularly for nanoscale materials, discrete particles are the exception rather than the rule. Therefore it is likely that nanoscale iron oxide minerals occur as aggregates of oxide and clay mineral particulates. To test this, HFG mineral separates were examined by SEM for morphologic identification. Although synthesized iron oxide minerals show good crystal habit, soil formed minerals do not. Energy dispersive XRF was used in conjunction with SEM for qualitative geochemical identification of oxide and aluminosilicate mineral phases. Further work is necessary to refine the HFG method to reduce aggregation and increase the separation efficiency of minerals with very similar susceptibilities. However, this is a first step toward the goal of comparing pedogenic iron oxide formation to soil paleoenvironmental conditions. With continued progress, it may be possible to correlate specific climatic properties to the resulting (stable) oxide mineral assemblages. The use of pedogenic iron oxides as paleoclimatic proxies will be broadened when the physico-chemical conditions of mineral crystallization, along with magnetic susceptibility, can be brought to bear.

GP11B-0260 0830h POSTER

Electron Paramagnetic Resonance Spectroscopy: Magnetic Method vs Analytical Technique

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Electron paramagnetic resonance (EPR) spectroscopy is a powerful tool to study molecules and materials containing unpaired electrons in magnetic fields at which they come into resonance with monochromatic radiation. Magnetic fields of about 0.3 Tesla (T) correspond to resonance with an electromagnetic field of frequency 10 GHz and wavelength 3 cm (X-band of the microwave (mw) region of electromagnetic spectrum). An EPR spectrum can be described by the g-value, the hyperfine coupling constant A, and the line width as well as line shape. The g-value gives information about the electronic structure and A about the ligand field of a paramagnetic species. Microwave radiation absorption by magnetic minerals is referred to as ferromagnetic resonance (FMR). The EPR absorption peak due to ferromagnetics can be orders of magnitude more intense than peaks due to paramagnetics. In natural samples ferromagnetic impurities such as coatings or inclusions can produce usually broad spectra which superpose paramagnetic signals of interests. As example, an α-FeOOH-γ-Fe_2O_3-α-Fe_2O_3-system is presented to demonstrate the potential EPR spectroscopy to analyze magnetic phases. The results exhibit that EPR is very sensitive to detect magnetic phases, but for the detailed identification and characterization complementary tools such as classical rock magnetic techniques or X-ray diffraction are mandatory.

GP11B-0261 0830h INVITED POSTER

Orientations of Exsolved Magnetite Inclusions in Clinopyroxene and Plagioclase Determined With Electron Backscatter Diffraction (EBSD)

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Crystallographically oriented magnetite inclusions occur as subsolidus exsolution features in slowly cooled mafic rocks and are of interest to paleomagnetism because of their highly stable magnetic remanence. Many inclusions in both clinopyroxene and plagioclase exist as elongate laths with generalized dimensions of 1 μm x 2 μm x 50 μm. Of initial interest is the formation temperature and orientation of these elongate inclusions with respect to their silicate hosts. In this study, the electron backscatter diffraction (EBSD) technique is used to determine orientation relationships across exsolution boundaries for magnetite inclusions > 0.5 μm in diameter in host crystals of both clinopyroxene and plagioclase. Magnetite inclusions in clinopyroxenes from the Early Cretaceous Messum Complex of Namibia occur as two arrays growing within (010) of clinopyroxene and elongated subparallel to either the [100] or [001] axes. Inclusions subparallel to $[100]_{cpx}$ have $[-110]_{mag}$ // $[010]_{cpx}$, $(-1\text{-}11)_{mag}$ // $(-101)_{cpx}$, and $[112]_{mag}$ // $[101]_{cpx}$. Inclusions subparallel to $[001]_{cpx}$ have $[-110]_{mag}$ // $[010]_{cpx}$, $(111)_{mag}$ // $(100)_{cpx}$, and $[-1\text{-}12]_{mag}$ // $[001]_{cpx}$. Both arrays of inclusions are oriented such that planes of roughly close-packed oxygen atoms in both phases, {111} in magnetite and (-101) and (100) in clinopyroxene, are aligned. These EBSD-derived orientation relationships agree well with previous TEM and X-ray diffraction studies on similar materials, and are consistent with a high-temperature exsolution origin for the magnetite and coexistent amphibole. In contrast to clinopyroxene, the orientation relationships between plagioclase and its exsolved magnetite inclusions have so far been unexplored. Such inclusions are responsible for stable magnetic remanence in both layered intrusions and oceanic gabbros. Exsolved magnetite inclusions in plagioclase crystals from anorthosites in the Early Jurassic Freetown Complex of Sierra Leone have been investigated. Preliminary results from EBSD analyses of plagioclase (An_{66}) enable us to discern at least two arrays of magnetite inclusions. In the first array, $(100)_{mag}$ // $(101)_{pl}$ and $(111)_{mag}$ // $(011)_{pl}$. In the second array, $(311)_{mag}$ // $(101)_{pl}$ and $(111)_{mag}$ // $(111)_{pl}$. A unit cell with c = 14.203 Å was used to index the plagioclase diffraction patterns.

GP11B-0262 0830h INVITED POSTER

Observing the Interaction Between Magnetic and Chemical Microstructures at the Nanometer Scale Using Electron Holography

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Off-axis electron holography in the transmission electron microscope has been used to image the spatial distribution of magnetic fields in a natural intergrowth of magnetite and ulvospinel with nanometer resolution. The morphology of these intergrowths consists of cuboidal blocks of magnetite with average size 100 nm within a matrix of ulvospinel. Since ulvospinel is paramagnetic at ambient conditions, the initial MD grain is subdivided by the non-magnetic lamellae to yield an approximately cubic array of interacting SD or PSD magnetite particles. The technique allows both single-domain and vortex states within individual blocks to be imaged, and provides detailed information about the magnetostatic interaction fields between neighbouring blocks. Combined with high-resolution chemical maps obtained using electron spectroscopic imaging, we are able to present a comprehensive analysis of the relationship between the magnetic and chemical microstructures of the intergrowth. The observations provide new insight into the question of whether such intergrowths are a potential source of strong and stable remanent magnetization on the Earth and other planets. The high spatial resolution of the technique makes it ideal for the study of nanoscale particles at the boundary between SD and PSD behaviour, and provides the opportunity to study the crystallographic, chemical, and defect microstructures of the sample simultaneously with the holographic measurements. This is the first study to apply electron holography to one of the central problems of rock magnetism, and paves the way for a new era of magnetic microscopy in this field.

GP11B-0263 0830h INVITED POSTER

Iron at the L-edge: spectromicroscopy of Fe minerals and Fe oxidizing Bacteria

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If a natural geologic or biomineralized sample contained an unknown Fe mineral at the sub-micron level, could we unravel its nature with synchrotron spectromicroscopy? To address this question we analyzed 20 compounds and minerals containing Fe(II) and Fe(III) at the Fe L-edge with x-ray absorption near edge structure (XANES) spectroscopy. In addition, we characterized the differences in Fe L-edge spectra between crystalline and amorphous Fe oxides. This enabled the interpretation of data from the natural red biomineral accumulations in a flooded mine in Tennyson, WI.

GP11B-0264 0830h POSTER

Rock Magnetic and HRTEM Study of Iron Oxyhydroxide Nanoparticles

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Low-crystallinity, nanophase iron oxyhydroxide minerals such as ferrihydrite are common environmentally-relevant magnetic minerals, and have recently been proposed as possible building blocks for larger, more crystalline phases such as goethite or hematite (Schwertmann et al., *J. Coll. Inter. Sci. 209*, 215-223, 1999; Banfield et al., *Science 289*, 751-754, 2000; Guyodo et al., *Geophys. Res. Lett. 30*, 10.1029/2003GL017021, 2003). Despite the ubiquitous presence of iron oxyhydroxides in soils and sediments, their detection and quantification in natural samples is often difficult due to their low-crystallinity and the poor resolution of their x-ray diffraction (XRD) spectra. Highly sensitive, low-temperature rock magnetic techniques may therefore provide a crucial additional tool for the detection and quantification of such minerals in complex mixtures. In this presentation, we address major aspects of the growth and evolution of synthetic ferrihydrite nanoparticles prepared under systematically different synthesis conditions. These nanoparticles have been studied by low-temperature magnetometry and susceptometry, Mössbauer spectroscopy, and high-resolution transmission electron microscopy (HRTEM). We provide examples of relationships between the low-temperature magnetic properties of the samples and (1) nanoparticle crystallinity (e.g., 2-line versus 6-line ferrihydrite), (2) particle aggregation (isolated primary nanoparticles versus oriented aggregates), and (3) phase transformations (e.g., ferrihydrite-to-goethite or to-hematite).