[3]Geology, University of Toronto, Mississauga Rd. N, Mississauga, ON L5L 1C6, Canada

Simulated Thellier experiments using total TRM as NRM were performed on dark minerals (biotite, amphiboles) from a diabase and on 1, 6, 20 and 135 um fractions of crushed magnetite crystals, all annealed and sealed under vacuum. The 135 um magnetite had strong downward curvature of the Arai plot, as predicted by theory. The 20 um and dark minerals samples, which behaved identically, and the 6 um magnetite had progressively less curvature, and the 1 um magnetite behaved almost ideally. Detailed pTRM checks and pTRM tail checks were performed for the 135 um and dark minerals samples. When the laboratory field H was parallel to the NRM, all pTRM tail checks were zero, as reported by Yu and Dunlop (JGR, Nov. 2003), but when H was perpendicular to NRM, pTRM tails were detected after 3rd heatings in zero field. Undemagnetized pTRM residuals were likely present in both cases, but were hidden when pTRM is parallel to NRM. For the 135 um magnetite, pTRM checks for all temperatures were positive. For the dark minerals, pTRM checks grew larger than the original pTRMs as heating temperatures rose. The most deviant of these was rechecked by giving a new total TRM ("NRM") to the sample and replicating this single pTRM. The second pTRM check was closer to, but still larger than, the original pTRM. Two further experiments were undertaken as closer replications of the complete Thellier experiment. The only differences were that the NRM was pre-treated by either 15 mT AF or LTD. In both experiments, seven new pTRMs closely matched original pTRMs. Neither AF nor LTD made the Thellier results much closer to ideal; the treated NRM and pTRMs still gave convex-down Arai plots with initial slopes of 2-2.5 instead of 1. However, our experiments do verify that these strongly curved Arai plots are reproducible and have a purely physical cause. They do not result from irreversible physiochemical alteration. Conventional pTRM checks depend on magnetic history in multidomain samples and do not always reproduce the original pTRMs. Nevertheless the Arai plots are reproducible if the entire Thellier experiment is repeated ab initio.

GP44A-04 1615h INVITED

The Early Brunhes Chron and Matuyama-Brunhes Boundary Interval (500-900 ka) in North Atlantic Drift Sediments

James E.T. Channell[1] (352 3923658; jetc@nersp.nerdc.ufl.edu)

Jason H. Curtis[1] (curtisj@ufl.edu)

Benjamin P. Flower[2] (bflower@seas.marine.usf.edu)

[1]University of Florida, Department of Geological Sciences, PO Box 112120, Gainesville FL 32611, United States

[2]University of South Florida, College of Marine Science, St. Petersburg FL 33701, United States

We compare magnetic and oxygen isotope data for the 500-900 ka interval from Ocean Drilling Program (ODP) Site 984 with those from ODP Sites 980 and 983. These sites from North Atlantic sediment drifts provide high-resolution records for the early Brunhes Chron and for the Matuyama-Brunhes boundary. At ODP Site 984 (Bjorn Drift, Iceland Basin), the mean sedimentation rate in the 500-900 ka interval is 12 cm/kyr based on an age model derived by matching the planktic and benthic oxygen isotope records to an Ice Volume Model. The Matuyama-Brunhes polarity transition at Site 984, as defined by virtual geomagnetic polar (VGP) latitudes less than 40°, has an apparent duration of 7 kyr with a mid-point at 773.5 ka, compared to 772.5 ka at neighboring Site 983. Outside the polarity transition at both Sites 984 and 983, excursions in VGP latitude, to values less than 40°, at 540 ka, 590 ka, 670 ka, 860 ka and 880 ka correspond to troughs in the paleointensity record. The u-channel paleomagnetic data across the Matuyama-Brunhes boundary at Sites 984 and 983 are compared for the different holes from each site, and with back-to-back 1-cm cubic discrete samples. Clusters of VGPs in the South Atlantic and NE Asia in both u-channel and discrete sample records imply that polarity transition fields have characteristics reminiscent the modern field stripped of its axial dipole.

GP44A-05 1635h

Secular Variation and Paleointensity Records From the Eirik and Gardar Drifts (North Atlantic Ocean)

Helen F Evans[1] (352 392 3298; geohelen@ufl.edu)

James E. T Channell[1] (jetc@ufl.edu)

Joseph S Stoner[2] (stonerjs@buffmail.colorado.edu)

Claude Hillaire-Marcel[3] (chm@uqam.ca)

[1]Department of Geological Sciences, University of Florida, PO Box 112120, Gainesville, FL 32611, United States

[2]Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Campus Box 450, Boulder, CO 80309, United States

[3]Centre de Recherche et Geodynamique (GEOTOP-UQAM-McGILL), University of Quebec a Montreal, Case Postale 8888, Succursale Centre-Ville, Montreal, QC H3C 3P8, Canada

Jumbo piston cores and gravity cores collected by the RV Knorr from the Eirik and southern Gardar drifts (North Atlantic) in 2002 have yielded records of secular variation and paleointensity for the last few hundred thousand years. The magnetic data from the Eirik Drift are augmented by results from a 43 m long core (MD99-2227) collected during the 1999 cruise of the Marion Dufresne II, that has a detailed oxygen isotope record. Both the Laschamp (40 ka) and Iceland Basin (190 ka) excursions are recorded in u-channel samples from the higher-sedimentation-rate cores. Paleointensity and magnetic susceptibility records can be correlated to published results from older piston cores (HU90-013-012 and HU90-013-013) from the Eirik Drift collected by the R/V Hudson. On the Eirik Drift, the contrasting glacial/interglacial sedimentation rates between shallower (2500 m) and deeper-water (3500 m) sites are sensitive to changes in the outflow of the WBUC (therefore in the production of NADW) and allow us to develop a composite record with a higher resolution than at any single site. The new magnetic data from southern Gardar Drift sites at 3000 m water depth can be correlated to published results from ODP Sites 983/984 from shallower (<2000 m) sites on the northern Gardar/Bjorn drifts, and to the NAPIS-75 (North Atlantic) paleointensity stack.

GP53A CC: 519 B Friday 1330h

Rock Magnetism and the 40th Anniversary of the Vine-Matthews-Morley Hypothesis I

(joint with G, T, V)

Presiding: **D J Dunlop,** University of Toronto**; J Gee,** Scripps Institution of Oceanography

GP53A-01 1335h

The Origin of the Geomagnetic Polarity Time Scale: an Historical Footnote

Ted Evans (evans@phys.ualberta.ca)

University of Alberta, Institute for Geophysical Research, Physics Department, Edmonton, AB T6G 2J1, Canada

Coincidence sometimes plays an important role in scientific discovery, as, for example, when two individuals happen to come together in a particular institution. Sometimes, however, the coincidence takes place but the discovery doesn't. The geomagnetic polarity time scale - a central ingredient in setting up the Vine-Matthews-Morley hypothesis - grew from the seminal work of Cox, Doell and Dalrymple published in June 1963. This did not result from coincidence, but rather from a program with the clear objective of determining the magnetic polarity and the radiometric age of suitable geological targets. In his excellent book describing these historical developments, William Glen ponders why this major advance was not made in the University of Alberta. After all, Jan Hospers was there, doing palaeomagnetism, and Joseph Lipson was there, building mass spectrometers - in the same department. Everything was in place for a breakthrough. Or was it?

GP53A-02 1355h INVITED

Magnetic Anomalies over the Osbourn Trough in the Southwest Pacific Cretaceous Quiet Zone

Steven C Cande[1] (858-534-1552; scande@ucsd.edu)

Joann Stock[2] (jstock@gps.caltech.edu)

Rob Clayton[2]

Michael Gurnis[2]

[1]Scripps Institution of Oceanography, Mail Code 0220, La Jolla, CA 92093

[2]Caltech, Mail Stop 2521, Pasadena, CA 91125

Detailed surveys of magnetic anomalies over ocean crust that formed during long intervals of predominantly one polarity and that formed at moderate to fast spreading rates, such as anomaly 5 in the Northeast Pacific, often display a pattern of small scale, linear anomalies that reflect a mixture of short polarity events and/or intensity fluctuations of the paleomagnetic field. These tiny wiggles have been mapped in many regions of the ocean representing large portions of the last 180 Ma including the Jurassic Quiet Zones. However, they have not been reported in the Cretaceous Quiet Zones. Although the lack of tiny wiggles in the Cretaceous Quiet Zones might reflect a difference in field behavior during the Cretaceous Long Normal Polarity Interval, it more likely reflects the lack of good surveys in areas where tiny wiggles are most likely to be preserved. The Southwest Pacific Cretaceous Quiet Zone, with its fast spreading rates and high paleo-latitude, is ideally located for preserving small scale anomalies. Recent data collected on transits of the R/VIB Nathaniel B. Palmer reveal a linear pattern of moderate amplitude (+ - 100 nT), short wavelength (10-30 km) magnetic anomalies straddling the Osbourn Trough, an east-west striking fossil spreading center east of the Tonga-Kermadec Trench. Although the age of the Osbourn Trough is uncertain, it is likely to have formed around 95 or 100 MA, in the middle of the Cretaceous Long Normal Period. The magnetic profiles straddling the Osbourn Trough document a magnetic anomaly pattern that is very similar in appearance to classic tiny wiggles; that is, they are not as strongly linear as would be expected for anomalies generated by true reversals, but they are definitely linear and have a unique pattern. They most likely represent a record of paleointensity fluctuations at this time and will help in unraveling the tectonics of this enigmatic region.

GP53A-03 1410h

Magnetic Gradiometer and Vector Magnetometer Survey of the Galapagos Triple Junction

Jeff Gee[1] (1-858-534-4707; jsgee@ucsd.edu); Steven C. Cande[1] (scande@ucsd.edu); Robert L. Parker[1] (rlparker@ucsd.edu); Peter F. Lonsdale[1] (plonsdale@ucsd.edu); Julie Bowles[1] (jbowles@ucsd.edu); Chris Symons (csymons@cox.net)

[1]Scripps Institution of Oceanography, UCSD, La Jolla, CA 92093, United States

Several fundamental tectonic problems of the equatorial Pacific remain unsolved due to the lack of magnetic anomaly data. A basic limitation encountered with the use of the standard proton precession magnetometer (or any total field instrument) is that total field anomalies over approximately N/S striking bodies are very small at low magnetic latitudes. Another problem encountered with magnetic surveys near the magnetic equator are the diurnal variations associated with the external field. Measurements of the vector anomalous field and total field gradient offer ways to overcome these limitations. Total field gradiometer data allow recognition and removal of time dependent external field variations. Vector magnetic anomalies provide two distinct advantages over total field measurements. Although the total field anomalies are small (typically 50 nT) over most of the equatorial Pacific, the vertical and horizontal components of the anomalous field are 2-5 times larger. In addition, vector anomaly data can be used to evaluate the two dimensionality of the magnetic source since the along track and vertical anomalies are related by a 90° phase shift for a perfectly two dimensional source. To evaluate the advantages of these systems, we conducted a survey of the trails of the Galapagos triple junction using both a high resolution total field gradiometer and a vector magnetometer. The longitudinal gradiometer system consists of two Overhauser sensors (0.01 nT sensitivity) towed 350 and 450m behind the survey vessel. The towed vector magnetometer utilizes a commercial motion reference sensor (0.02° orientation accuracy with three fluxgate sensors) suitable for measuring horizontal and vertical anomalies as small as 30-50 nT. Vector anomalies across Cocos-Nazca crust corroborate the high degree of linearity of these E/W lineations; horizontal and vertical anomalies exhibit high coherence (>0.9) and the expected 90° phase relationship at wavelengths longer than 8km. Vector data from lower amplitude Pacific-Cocos and Pacific-Nazca lineations are more difficult to interpret, with lower coherence at somewhat longer wavelengths (>11km). The lower apparent degree of linearity over these N/S lineations in part reflects the much higher amplitude of any three dimensional sources. The combined use of vector and gradiometer measurements shows considerable promise for mapping magnetic lineations in low latitude regions.

GP

GP53A-04 1425h INVITED

Magnetization of lower oceanic crust and upper mantle

Eiichi Kikawa (81-46-867-9293; kikawa@jamstec.go.jp)

JAMSTEC, 2-15 Natsushima-cho, Yokosuka 237-0061, Japan

The location of the magnetized rocks of the oceanic crust that are responsible for sea-floor spreading magnetic anomalies has been a long-standing problem in geophysics. The recognition of these anomalies was a key stone in the development of the theory of plate tectonics. Our present concept of oceanic crustal magnetization is much more complex than the original, uniformly magnetized model of Vine-Matthews-Morley Hypothesis. Magnetic inversion studies indicated that the upper oceanic extrusive layer (Layer 2A of 0.5km thick) was the only magnetic layer and that it was not necessary to postulate any contribution from deeper parts of oceanic crust. Direct measurements of the magnetic properties of the rocks recovered from the sea floor, however, have shown that the magnetization of Layer 2A, together with the observations that this layer could record geomagnetic field reversals within a vertical section, is insufficient to give the required size of observed magnetic anomalies and that some contribution from lower intrusive rocks is necessary. Magnetization of oceanic intrusive rocks were observed to be reasonably high enough to contribute to sea-floor spreading magnetic anomalies, but were considered somewhat equivocal until late 1980Os, in part because studies had been conducted on unoriented dredged and ophiolite samples and on intermittent DSDP/ODP cores. Since ODP Leg 118 that cored and recovered continuous 500m of oceanic intrusive layer at Site 735B, Southwest Indian Ridge with an extremely high recovery of 87 percent, there have been several ODP Legs (legs 147, 153, 176, 179 and 209) that were devoted to drilling gabbroic rocks and peridotites. In terms of the magnetization intensities, all of the results obtained from these ODP Legs were supportive of the model that a significant contribution must come from gabbros and peridotites and the source of the lineated magnetic anomalies must reside in most of the oceanic crust as well as crust-mantle boundary. However, it would be wise to note that similar to upper extrusive layer, geomagnetic field reversals were observed for Leg 153 gabbros and that process of magnetization acquisition of mantle peridotites still remains unclear, though we believe mantle peridotites acquire CRM with the formation of magnetite during the process of serpentinization near the ridge axis.

GP53A-05 1445h INVITED

Determination of Titanium Content and Degree of Oxidation (Maghemitization) of Magnetite in MORB by Electron Microscopy

Rob Van der Voo[1] (734-764-8322; voo@umich.edu)

Daming Wang[1] (wangdm@umich.edu)

Donald R Peacor[1] (drpeacor@umich.edu)

[1]University of Michigan, Dept. Geological Sciences, Ann Arbor, MI 48109-1063, United States

Variations in Ti-content of titanomagnetites (x) and variable degrees of oxidation of titanomagnetite to titanomaghemite (z) cause changes in the Curie temperature of MORB samples. Traditionally, however, Curie temperatures have been used as a proxy for one or the other of these parameters. Clearly, without knowing one of these parameters, the other can only be estimated by making assumptions, and this hampers study of the magnetization carriers in fresh and altered MORB. Furthermore, rock magnetic properties of titanomaghemite strongly depend on both x and z. For MORB samples, z values represent a later chemical modification of original titanomagnetite, whereas x values reflect variations in initial Ti content as well as low-temperature alteration in which the Fe/Ti ratio changes. We have developed a method for independently determining x and z by electron microscopy. The data reveal that variations in x and z can occur on temporal and spatial scales that are not always predictable; thus, conclusions drawn from Curie temperatures about correlations between rock magnetic parameters and the composition of the magnetic carriers can be erroneous. In this review, we examine some case histories that illustrate variations in x and z in MORB with ages within the Brunhes Chron as well as back to Mesozoic times.

GP53A-06 1500h

Insights into the magnetic structure of oceanic crust from near-bottom magnetic field observations.

Maurice Tivey (mtivey@whoi.edu)

Woods Hole Oceanographic Institution, Woods Hole, MA 02543

The Vine-Matthews-Morley (VMM) hypothesis elegantly explains the basic concept of how Earth's magnetic field is recorded by the seafloor spreading process, but how does it fare at the seafloor? Are reversal boundaries sharply defined on the seafloor or are they simply a gradational zone? How far can we push the resolution of the magnetic signal to estimate timescales? Near-bottom magnetic observations remove the filtering effect of the water depth and allow us to constrain the resolution of the marine magnetic anomaly record, in essence, determine how wide the recording head is in the tape recorder analogy. Since the early 1970's deep-towed magnetic sensors have been used to look at the relationship between magnetic anomalies and the formation of oceanic crust; Project FAMOUS in the Atlantic being a classic early example. A seminal near-bottom magnetic measurement in confirmation of the VMM hypothesis was undertaken at the Brunhes reversal on the East Pacific Rise. In this survey, a deeptow profile located the "average" position of the reversal boundary, while a submersible-mounted magnetic gradiometer determined the polarity of seafloor outcrops and thus the seafloor polarity boundary. The seafloor boundary was displaced more than a km from the "average boundary" indicating a dipping polarity boundary within the extrusive layer. A similar submersible experiment looked at the vertical cross-section of the Brunhes and Jaramillo chrons exposed at Blanco Fracture Zone. Dipping polarity horizons were mapped in cross section within the extrusive layer showing a dip towards the axis over a lateral distance of more than a kilometer. This implies accretion takes place over a zone several kilometers wide. Detailed studies of how this accretion is achieved are now ongoing and maps of unprecedented resolution show the magnetic character of the seafloor can be resolved on the scale of individual flow units. These studies show that lava can be transported several kilometers from the eruptive trough and deposited off-axis. The width of this accretionary or neovolcanic zone modulates the geomagnetic signal recorded by the lavas and limits the lateral resolution to ∼2 km half-width. The amount of time this represents will be dependent on spreading rate. The present day central anomaly magnetic high (CAMH) is a first order estimate of the resolution capability of the spreading center in that it represents a recording of recent intensity of Earth's magnetic field filtered through the crustal accretion process. Even with this resolution limit, it is remarkable how well the VMM hypothesis remains valid even at the seafloor.

GP54A CC: 519 B Friday 1530h

Rock Magnetism and the 40th Anniversary of the Vine-Matthews-Morley Hypothesis II

(joint with G, T, V)

Presiding: **D J Dunlop,** University of Toronto**; J Gee,** Scripps Institution of Oceanography

GP54A-01 1530h

Near-bottom seafloor spreading anomalies around Hole 801C in Pacific Jurassic crust

Maurice Tivey[1] (mtivey@whoi.edu); Roger Larson[2] (rlar@gso.uri.edu); William Sager[3] (wsager@ocean.tamu.edu); Sang-Mook Lee[4]; Robert Pockalny[2] (lrobp@gso.uri.edu); Hans Schouten[1] (hschouten@whoi.edu)

[1]Woods Hole Oceanographic Institution, Woods Hole, MA 02563

[2]GSO University of Rhoad Island, Narragansett, RI 02882

[3]Texas A&M University, College Station, TX 77843

[4]Seoul National University, Korea

A deeptowed magnetic survey of Jurassic ocean crust was completed in the Pigafetta Basin of the western Pacific in the vicinity of ODP Hole 801C. The objectives of the survey were to extend the marine magnetic anomaly timescale as far back as possible within the remaining marine Jurassic crust extant in the Pacific basin and to tie the Hole 801C results into the lateral magnetic anomaly pattern. Hole 801C reaches 444 meters into Jurassic basement beneath 493 m of sediment cover for a total depth penetration of 937 meters below seafloor (mbsf). Downhole magnetic logging was completed to a depth of 850 mbsf. The magnetic logging data show multiple magnetic anomalies downhole, which implies a high reversal rate if these are all magnetic reversals. The in-phase relationship of the horizontal and vertical magnetic fields imply formation in the southern hemisphere. Apparent inclination calculated from the component data suggest an inclination of ∼40 degrees which implies a latitude of formation ∼22S. Monotonic change in inclination downhole is attributed to rotation of the lava sequence during crustal accretion. The computed rotations are approximately equivalent to the dips calculated from the Formation Micro Scanner data, which suggest lava dips up to 40 degrees at depth. The deeptow survey completed 7 lines, each 35 km long and spaced 1-10 km apart around the Hole. The lines show strong anomalies (200 nT) and good lateral correlation with a strike azimuth of 25 degrees suggesting seafloor spreading magnetic lineations are present at this location. There are ∼5 major anomalies over this area implying a reversal rate of ∼8 rev/My given a spreading rate of 55 km/My. The hole resides on a small positive anomaly on the southern flank of a larger double-peaked positive magnetic anomaly, which in this hemisphere indicates a reversely magnetized block. This is consistent with the downhole results, which show that the majority of the hole appears to be reverse polarity. Hole 801C thus appears to faithfully record seafloor spreading lineations.

GP54A-02 1545h

Titanium content and degree of oxidation of titanomaghemite in Mesozoic MORB: implications for magnetization intensity

Daming Wang[1] (734-763-2149; wangdm@umich.edu)

Rob Van der Voo[1] (734-764-8322; voo@umich.edu)

Donald R. Peacor R. Peacor[1] (734-764-1452; drpeacor@umich.edu)

[1]University of Michigan, Department of Geological Sciences, 425 E. Univ. Ave., Ann Arbor, MI 48109-1063, United States

The magnetization intensity of oceanic crust shows systematic variations with a comparatively lower intensity for ages ranging from 10 to 40 Ma, which can be attributed to low-temperature alteration of the natural remanent magnetization carrier titanomagnetite to titanomaghemite. Prior to this low magnetization intensity period, the amplitudes of magnetization are surprisingly higher and stay at a high level between 80 and 160 Ma. Numerous mechanisms have been proposed previously to explain the higher magnetization of older oceanic crust. We present electron microscopy results on Mesozoic mid-ocean ridge basalt (MORB) recovered from 4 ODP/DSDP sites in the southern Indian Ocean, western Pacific Ocean and western Atlantic Ocean. In general, the x values (reflecting titanium content) of titanomagnetite for these 4 sites are less than 0.65 and degrees of oxidation (z) of titanomaghemite are usually less than 0.7. In contrast, x and z of titanomaghemites in MORB with ages between 10 to 40 Ma often reach higher values. Because x and z are two important control factors on rock magnetic properties, the relatively low x and z values for the Mesozoic MORB seem to be, at least in part, responsible for high NRM and saturation magnetization. We will compare and contrast effects of x and z on NRM and rock magnetic properties in Tertiary and Mesozoic MORB samples.

GP54A-03 1600h INVITED

Self-reversed magnetizations in oceanic basalts

John A Tarduno[1] (john@earth.rochester.edu)

Pavel Doubrovine[1] (pavel@earth.rochester.edu)

[1]Department of Earth and Environmental Sciences University of Rochester, 227 Hutchison Hall, Rochester, NY 14627, United States

Verhoogen (1956) proposed that ionic reordering in titanomaghemite could result in self-reversal of magnetization. This concept was subsequently refined, restricting the composition of titanomaghemite which can undergo self-reversal to higher oxidation states (O'Reilly and Banerjee, 1966) than those originally proposed by Verhoogen (1956). Furthermore, it was thought unlikely that these high oxidation states would be reached under low temperature conditions. For this reason (and others), self-reversal has not been considered in depth, even though many oxidized oceanic basalts contain near antipodal directions. Recently we have reported such directional behavior from oceanic basalts of ODP Site 883 from the northwestern Pacific Ocean (Detroit Seamount). X-ray diffraction and rock magnetic data demonstrate that the high oxidation states that were once thought to be unachievable in low temperature conditions have in fact been reached, probably due to seawater flux. Results from a host of rock magnetic experiments (including pTRM studies, magnetic hysteresis, and high and low thermomagnetic measurements) indicate that self-reversal of remanence has taken place. One of the most important observations is the presence of N-type magnetic behavior, with compensation points distributed above room temperature, for samples showing antipodal natural remanent magnetization (NRM) components. The NRM intensities of such samples are on average 4 times less than