behaviour of the geomagnetic field leading up to, during and after successive field reversals. Here we present results from a microwave palaeointensity study (including rock magnetic analysis) through two sequences, the Puu Heleakala section leading up to and including the Gilbert Gauss reversal and the Puu Paheehee section containing the Lower Mammoth event. The Heleakala section contains 35 lava flows and two samples per flow were studied. Unfortunately many samples were affected by lightning so only 37 samples from 21 flows were suitable for microwave palaeointensity analysis. The mean intensity of is 21 +/- 5 microtesla. The Paheehee section consists of 28 flows, and three samples per flow were studied. The average intensity pre reversal is 5.8 +/- 0.9 microtesla and post reversal is 16.9 +/- 6.1 microtesla.

GP72A-0997 1330h POSTER

Trying to Make Sense of Multidomain Arai Diagrams

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Variable contributions from specimen to specimen of two types of multidomain (MD) tail can explain the concave-up, concave-down, and S-shaped Arai diagrams exhibited by samples of the 1915 Mount Lassen dacite treated by Thellier's method. The slope of the line joining the endpoints of each Arai diagram gives a good estimate of the known geomagnetic field intensity for the Mount Lassen region during the 1915 eruption. In other words, the NRM divided by the total TRM gives the correct slope for the Thellier experiment, a feature long recognized as characteristic of MD remanence that is stable to heating. Fabian (2001) has demonstrated very elegantly that the common concave-up shape of MD Arai diagrams can be well accounted for by the low-T tail of each pTRM segment acquired during cooling from the Curie point in the earth's field. By low-T tail we mean that part of the pTRM with the unblocking temperature less than blocking temperature. However, concave-down and more complex shapes cannot be explained by Fabian's phenomenological theory of TRM. We suggest that the reason is its inability to incorporated the experimentally observed tail of pTRM*, that is, the tail with unblocking temperature greater than the blocking temperature of the pTRM produced during each Thellier step by heating to an intermediate temperature and cooling back down to room temperature in the laboratory field. If the pTRM* tail is systematically greater than the corresponding low-T pTRM tail, the Arai diagram will be concave-down, whereas if it is systematically smaller the shape will be concave up. If the two tails always make equal contributions, the Arai diagram will yield the ideal straight line with slope corresponding to the correct paleointensity. Such could occur if the non-ideal MD remanence were distributed symmetrically about the T-unblocking = T-blocking line of Fabian (2001). Finally, if one tail is greater than the other tail at low temperatures and greater at high temperatures, the Arai diagram will be S-shaped.

Fabian, K., 2001, A theoretical treatment of paleointensity determination experiments on rocks containing pseudo-single or multidomain magnetic particles, Earth Planet. Sci. Lett. 188, 45-55.

GP72A-0998 1330h INVITED POSTER

Effects of Cooling Rate on Blocking Temperature and Paleointensity, Revisited: Old and New Results

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Recent years have witnessed a renaissance in experiments to determine paleointensities. Some of the most notable studies have focused on the rapidly chilled margins of oceanic pillow basalts; other studies have yielded paleointensities from single domain magnetite within parent crystals which cooled slowly within an igneous body. Yet, work by several authors has shown theoretically that cooling rate can affect the blocking temperature and the intensity of weak-field thermoremanent magnetization (TRM) acquired by single domain (SD) grains. If the natural cooling rate was sufficiently slow, a Thellier-Thellier paleointensity experiment can yield an ancient field value that is several tens of percent higher than the true field in which the particles originally cooled. In this talk, the theory of this effect is reviewed for SD magnetite. New calculations are presented, which account for a range of grain volumes and aspect ratios in SD magnetite particles, as well as for different sizes and shapes of the cooling body. These results are discussed in light of time variations in the virtual dipole moment and secular variation in direction of the earths field.

GP72A-0999 1330h POSTER

Absolute Paleointensity of Oligocene Lava Flows From the Kerguelen Archipelago (Southern Indian Ocean)

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In order to define more accurately the geodynamo behavior, numerous paleomagnetic investigations are needed. The aim is to increase both temporal and spatial resolution of paleomagnetic records. For the last 30 Ma, there is a lack of paleointensity results in the southern hemisphere, especially at high latitudes.

Located in the southern hemisphere at 49° latitude (northern part of the Kerguelen-Gaussberg plateau), this study will present new paleointensity results on Oligocene Kerguelen flood basalts (24-30Ma). The 57 lava flows of Monts des Ruches, Temptes and Rabouillre sections are thermally or AF demagnetized. Looking at the viscosity index, NRM scatter and principal component analysis, 32 flows were suitable for a pilot paleointensity experiment and 12 were totally analysed using Thellier-Thellier method.

Application of strict a posteriori criteria make us confident about the quality of the 12 new mean-flow determinations, which are the first reliable data available for the Kerguelen Archipelago. Compilation of these results with a selection of the 2002 updated IAGA palaeointensity database lead to a higher Oligocene mean VDM than previously reported. However, these Kerguelen palaeointensity estimates represent half of the reliable Oligocene determinations and thus a bias toward higher values.

Nonetheless, the new estimates reported here strengthen the conclusion that the recent geomagnetic field strength is anomalously high compared to that older than 0.3 Ma.

GP72A-1000 1330h POSTER

Magnetization of ALH84001: Inferences for the Martian Magnetic Anomalies.

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The magnetization of ALH84001 and the origin of its magnetic carriers have implications for the martian dynamo and the crustal anomalies on Mars. It is now evident that the magnetization of ALH84001 is predominantly carried by single domain magnetite, which formed by thermal decomposition of siderite at elevated temperature in a major impact event at about 4.0 Gyr. Saturation remanent magnetization normalization of the intensity of magnetization of ALH84001 suggests that the ambient field at 4.0 Gyr, in which NRM was acquired, was one order of magnitude weaker than the present geomagnetic field. Since the generating volume for the martian field is smaller than that of the earth, it is unlikely that the field was ever orders of magnitude greater than the geomagnetic field, or even substantially greater than the value interpreted at 4.0 Gyr. Surprisingly, the measured martian anomalies are an order of magnitude larger than anomalies observed on earth at comparable satellite altitudes. This implies that the martian crust contains substantial volumes of source rock more strongly magnetized than found in comparable volumes on earth. The most potent plausible magnetic phase is single domain (SD) magnetite of which about 1 part in 100 in source regions would suffice. We suggest that SD magnetite formed as a result of thermal decomposition of siderite in altered iron rich basaltic rocks. Experiments and theory show that siderite is a major product of percolation and evaporation of brines generated under pressures of more than 0.1bar of carbon dioxide. This is the preferred explanation for the carbonate in nakhlites, as well as in ALH84001. Thermal decomposition of siderite may result from deep burial, magmatic heat sources, or impact heating. The model predicts that conditions in the northern hemisphere of Mars precluded the formation of SD magnetite by the decomposition of siderite, and for this reason the stronger anomalies are confined to the southern highlands.

GP72B MCC: Hall C Sunday 1330h

Paleomagnetic Poles and Tectonic Terrains Posters *(joint with T)*

Presiding: **J C Guerrero-Garcia,** Instituto de Geologia, UNAM**; J W Geissman,** University of New Mexico

GP72B-1001 1330h POSTER

Late Archean Drift of the East Pilbara, Western Australia: a Plate Tectonic Scenario ?

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In the discussion about the nature of tectonic processes in the Archean (e.g. de Wit 1998, Hamilton 1998), no consensus has been reached about whether or not plate tectonics occurred in the Archean. Hence, detailed and robust paleomagnetic studies arre required to obtain an answer. For such a paleomagnetic study to be successful, one must start by investigating the least deformed and least metamorphosed Archean terrains. Indeed, these terrains provide the best chance of the natural remanent magnetization (NRM) to be of primary nature, which is a prerequisite to an accurately dated apparent polar wander path (APWP) and determination of a possible drift rate.

Therefore, the 2.78-2.71 Ga Nullagine and Mount Jope Supersequences of the Pilbara Craton, located in northwestern Australia, have been chosen for this study. These flood basalt dominated successions have not undergone metamorphism above prenite-pumpellyite facies (< 300° C, 200 MPa, Smith et al. 1982) and is generally only gently folded. The Nullagine and Mount Jope Supersequences unconformably overlie the 3.5-2.8 Ga granite-greenstone terrain and are subdivided in 12 unconformity bound packages (Blake 2001). Samples have been taken from various basins in the east Pilbara region, from a total of 134 sites throughout the succession. Most samples were taken from flood basalts, but also mafic tuff, felsic porphyry and mafic dykes were sampled. These samples have mainly been thermally demagnetized; only occasionally alternating field demagnetization was used. The results show two characteristic components of magnetization. One is an overprint, which is dated at ca. 2200 Ma acquired during a thermal event. The other is a primary component of NRM, substantiated by positive results for fold, conglomerate and reversal tests.

Furthermore, we have established at least two geomagnetic reversals that occurred during deposition of the succession, and which we interpret as the oldest unambiguous, accurately dated geomagnetic reversals. The pole positions of the sequence follow a consistent and logical path. Paleolatitude reconstructions show that the Craton has not been stable from 2.78 to 2.71 Ga, but that substantial drift - with a minimum of 2750 km - has taken place within this time interval. This amount of drift would is not easily explained by mantle plume tectonics only, and therefore plate tectonics seems a more feasible way to accommodate this observed drift.

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GP72B-1002 1330h POSTER

An Attempt tp Obtain Reliable Paleomagnetic Poles From Paleozoic Dikes in the Juchatengo Complex of Southern Mexico

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The Juchatengo complex of Southern Mexico, a green rock tholeiitic sequence emplaced between the Oaxaquia and Xolapa Terranes is made up from bottom to top, of gabbroic and plagiogranitic dikes and stocks (ca 289+/-6 Ma, K-Ar hornblende); basalts and pyroclastic rocks and a series of deep water marine sediments. The deposition and deformation of the complex occurred in Early Permian followed by the emplacement of Permian-Triassic calc-alkaline plutons (K-Ar hornblende ages from 286+/-6 Ma to 238+/-5 Ma).

In an attempt to test the possibility of obtaining reliable paleomagnetic poles of that age from the sequence, we sampled nine different sites. A minimum of eigth cores were drilled and sun- oriented at each site. At the laboratory the specimens were subjected to a.f. demagnetization cleaning procedures in sixteen progressive steps from NRM to 100mT. Next, the samples were thermally demagnetized in fifteen increasing temperature steps from NRM to 675^{o}C. Principal component analysis was applied to each of the samples in order to obtain their respective mean directions. In addtion, rock magnetic experiments such as k-T (Curie point determinations) and SIRM were carried out on the samples drilled in order to identify the magnetic carriers of the NRM and to determine their characteristic properties as a check on the reliability of the the dikes under study.

Thus far, we consider that reliable paleomagnetic poles were obtained from three sites. The laboratory experiments indicate that the samples have not been remagnetized and that the ChRM has been succesfully isolated. The calculated VGPs are: I. Plong:319.0E; Plat:85.7N; alfa 95:8.0 II. Plong:214.5E; Plat:79.8N; alfa 95:5.0 III. Plong:298.7E; Plat:09.5S; alfa 95:7.0 None of them fall within the APWP for cratonic North America for Permian times.

GP72B-1003 1330h POSTER

Palaeomagnetism of Some Neoproterozoic and Early Paleozoic Igneous Rocks from Sinai Peninsula and South Eastern Desert, Egypt

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A palaeomagnetic study has been carried out in the Neoproterozoic (older Granitoids) and Early Paleozoic (younger Granitoids) rocks from Sinai Peninsula and Hafafit area in the southeastern desert of Egypt. Nineteen sites comprising 158 samples of granite were collected from Saint Katherina area in south Sinai and Wadi Hafafit area, southeastern desert of Egypt. Rock magnetic properties such as Curie temperature and microscopic observations were carried out for these samples to identify the magnetic carrier; it is found to be magnetite. The samples collected were subjected to stepwise thermal and alternating field treatment. Nine sites of Neoproterozoic granite (590 my) yielded reliable magnetic directions, with analysis of the results using standard principal component and great circle analysis. The mean direction for these sites is D=4.5^o, I=53.3^o, K=57.7,α95=12.2.The Neoproterozoic granite yield a mean pole at 79.7^o N, 55.9^o E.The results are compatible with data reported from other Gondwana cratonic areas for this time period.

GP72B-1004 1330h POSTER

Paleomagnetism of Lower Permian Abo and Yeso Formation, Carizzo Arroyo, Lucero Uplift, New Mexico

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We report paleomagnetic data from Lower Permian hematite-cemented sandstones and siltstones from Carrizo Arroyo, on the eastern edge of the Lucero uplift along the west-side of the middle Rio Grande rift, to test the hypothesis that the rift margins have accommodated extensional strain via vertical axis rotation. In addition, we present a revised interpretation of the structural setting and deformation history of the area, were late-Tertiary transtensional stresses have produced the majority of the structures in the area. The paleomagnetic data are discussed in the context of this hypothesis. In the Rio Grande rift area, a mid-Cenozoic and younger extensional feature defining the eastern margin of the Colorado Plateau, relatively little work has been done to assess the magnitude and sense of vertical axis rotations of fault-bounded crustal blocks within and at the margins of the plateau. A growing body of evidence shows that the Colorado Plateau has experienced some degree of vertical axis rotation and some magnitude of northward translation, although the magnitudes of the rotation and translation have been subject to considerable debate. Eight to ten oriented samples from 50 sites have been fully demagnetized with all sites yielding interpretable results: 41 sites from three sections in the Lower Permian Abo Formation, and 9 sites in the Meseta Blanca Member of the overlying Yeso Formation. In most cases, progressive thermal demagnetization resulted in a nearly univectorial decay of the magnetization to the origin that is well grouped at the site level. After correcting for modest dip of strata, the 50 sites in Carrizo Arroyo yield an estimate group mean (D = 162.1°, I = -4.1°, α_{95} = 6.8°, k = 10.18). Overall, the data from this part of the west side of the rift are discordant, in a clockwise since, with Early Permian (about D = 140°, I = -2.0°) and mid-Permian (about D = 145°, I = -4.0°) expected directions. We interpret the paleomagnetic data from Carrizo Arroyo to be consistent with modest clockwise vertical axis rotation of these sections since the latest Paleozoic, arguably during Laramide deformation and subsequent Rio Grande extension. We hypothesize that a component of tectonic rotation has accommodated extensional strain along the margins of the Rio Grande rift since inception. The observed rotation could be the result of oblique-slip displacement of the hanging wall block; in this case, the observed rotation is apparent. Alternatively, the rotation is a true block rotation where the block is decoupled from the underlying strata along a detachment surface. Additional field mapping will help to distinguish between these two possible models.

GP72B-1005 1330h POSTER

Paleomagnetic Results From the Natal Belt, South Africa

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The position of the Kalahari block within the Rodinia supercontinent is only poorly constrained by existing paleomagnetic data. Specifically, there are no pole positions for the critical time span from 1.0 to 1.1 Ga. The Equeefa dikes and the Port Edward charnockite intrude the the Mesoproterozoic Namaqua-Natal belt which rims the Archaic Kaapvaal craton to the south. They yielded zircon SHRIMP ages of 1083$\pm$2 and 1028$\pm$8 Ma, respectively. The directions of magnetization of 4 Equeefa dikes and 4 sites in the enclosing Mzumbe gneiss are statistically indistinguishable and yield a pole position at 25°N, 17°E. Thermochronological studies demonstrate that the sampling area, the Mzumbe terrane, cooled below 500°C only at 1005 Ma. Because the remanence is carried by titanomaghemite with a Curiepoint of about 320 to 340°C, the age of magnetization must be younger. Titanite fission track analyses indicate a reheating of the Mzumbe terrane to about 300°C near 530 Ma which is the best estimate for the age of magnetization of the Equeefa dikes. The remanence of the Port Edward charnockite is carried by magnetite and hematite and thus its magnetization was locked in near 1005 Ma. The pole lies at 7°S, 328°E. This pole is agrees with poles from the western part of the Namaqua-Natal belt where a similar thermal history has been proposed. This makes it difficult to find rocks of the desired magnetization age.

GP72B-1006 1330h POSTER

Paleomagnetism and Paleosecular Variation Study of the Mt. Cameroon Volcanics (0.0 to 0.25 Ma), West Africa

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We have conducted a paleomagnetic study of 94 samples drilled from 13 lava flows in Mount Cameroon (0.0. to 0.25 Ma). Mt Cameroon (4075m) is a large volcanic horst which belongs to the Cameroon Volcanic Line (CVL) and is one of Africa's largest volcanoes. Many recent volcanic cones found on the mountain are aligned SW-NE, as is the general morphology of the massif. This mountain is presently the only active volcano on the CVL, with eight eruptions this century, the most recent being in 2000. At least 8 samples from each site were demagnetized by means of a.f. and thermal methods. The characteristic remanent magnetism (ChRM) was calculated using principal component analysis for the demagnetization diagrams with a well-defined component trending towards the origin. No bias or systematic departure from the origin was accepted, and in all cases the ChRM relies on a minimum of seven successive directions isolated during stepwise demagnetization. In parallel, at least three samples per site were used for absolute paleointensity studies with the hope of documenting the full vector and not restraining the data to directions only. In addition, low-field susceptibility versus temperature (k-T) and SIRM experiments were performed on at least one sample per site. As a result of such tests, we were able to identify magnetite (575^{o}C) but also sites characterized by low-temperature mineral phases (e.g. 100-200 and 300-400^{o}C), reflecting the presence of titanomagnetite with low Ti content as suggested by the large susceptibility. Successful mean paleomagnetic directions were obtained for all the 13 sites. The final site mean directions were calculated from at least 7 samples per site. Three sites with inclinations significantly away from the axial dipole were discarded. Thus a total of 10 sites have been retained with a mean declination of 354.2^o and mean inclination of 4.8^o (k=13, alpha 95=12.1) this direction belongs to rocks which have been dated by K-Ar and range in age from 0.0 to 0.25 Ma. The angular standard deviation of the VGPs was found to be 13.91^o around the mean pole. This last value is slightly higher than the PSV model G" values.

GP72B-1007 1330h POSTER

Deformation Along the Southeast Extension of the Lake Mead Fault System Evaluated with Paleomagnetic Data From Miocene Igneous Rocks, Hoover Dam area, Nevada and Arizona

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At and near Hoover Dam, southeast of Las Vegas, Cenozoic left-slip offset along the NE-SW trending Lake Mead fault system (LMFS) has resulted in the apparent rotation of structures and total displacement of up to 65 km. Defining any rotation of blocks within and near the LMFS is critical to assessing the kinematics of strike-slip faulting and attending extension. Paleomagnetic data from Miocene volcanic and some sedimentary rocks and intrusions (over 160 sites) deposited on Precambrian basement show that part of the Hoover Dam locality has experienced counterclockwise rotation . The middle Miocene (ca. 14.2 Ma)Tuff of Hoover Dam (THD)(sampled at over 90 sites) yields a well-grouped characteristic magnetization (ChRM); about 5 km south and east of the dam, gently east-dipping, north-striking rocks of the THD yield a corrected ChRM of moderate positive inclination and northwest declination (D=324.8°, I=27.4°, a95=10.7°, k=24, N=9 sites). Structural corrections, based on compaction fabrics in the THD are consistent with stratigraphic contacts. The anomalous shallow inclination for the THD ChRM implies that it was emplaced over a short period of time during a field instability. contact and conglomerate test results are interpreted to show that the THD ChRM is primary. Corrected data from north and west of the dam (D=289.7°, I=30.2°,a95=8.6°,k=32, N=10) are interpreted to indicate about 35° of counterclockwise rotation (R= -35.1°, delR= 12.4, F= -2.8°, delF = 10.8, relative to

data from south of the dam) of crust across the dam site, consistent with progressive changes in strike of tilted fault blocks. The transition from apparently unrotated crust to rotated crust occurs over a zone about 1 km wide, where blocks of THD and older strata have been tilted up to 50°, probably concurrent with rotation. Rotation of crust northwest of Hoover Dam may reflect differential extension northwest of the LMFS (e.g.,River Mountains area) as strain is partitioned into west to southwest-dipping normal faults on either side of the LMFS.

GP72B-1008 1330h POSTER

Paleomagnetism and $^{40}Ar/^{39}Ar$ Dating of Folded Sills in the Lombard Thrust Sheet, South Central Montana: Implications for the Timing of Fold and Thrust Deformation and Vertical Axis Rotations Along the Southern Margin of the Helena Salient

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We report new paleomagnetic and $^{40}Ar/^{39}Ar$ data from sills exposed in folds of the Lombard Thrust Sheet along the southern margin of the Helena Salient in Southwest Montana. The folds in the Doherty Mountain fold complex represent the southern extension of the Devils Fence anticline structural culmination along the Southwest Montana Transverse Zone east of Whitehall, Montana. Numerous intermediate composition sills probably temporally related to the Late Cretaceous Boulder Batholith are well exposed in complexly deformed Cambrian through Mississippian strata in the hanging wall of the Jefferson Canyon–Cave fault system. We report well-defined paleomagnetic results from 14 sites in sills exposed in four different folds. After correction for fold plunge and then bedding tilt, all four folds yield positive fold tests at 100% unfolding indicating that their remanence was acquired prior to folding. We suggest that these magnetizations are primary thermoremanent magnetizations acquired during sill emplacement prior to fold and thrust deformation. $^{40}Ar/^{39}Ar$ dates on biotites from two sills in two different folds yield identical plateau dates of 77.26 ± 0.36 Ma and 77.00 ± 0.31 Ma (2σ), consistent with a Late Cretaceous age for deformation. Although the group mean directions from sills in each of the folds probably represent spot readings of the geomagnetic field, their structurally corrected grand-mean direction (*Dec.* = 344°, *Inc.* = 65°, k = 82, α_{95} = 10°) is statistically indistinguishable from the expected Late Cretaceous cratonic reference direction from the Adel Mountains Volcanics. Consequently, this result suggests that hangingwall strata in the Lombard Thrust Sheet of the Helena Salient in this vicinity have probably not experienced significant vertical axis rotation (R = -8.5° ± 20.5°) due to thrust movement along the Southwest Montana Transverse Zone.

GP72B-1009 1330h POSTER

Paleomagnetism of Upper Jurassic to Lower Cretaceous Volcanic and Sedimentary Rocks From the Western Tarim Basin: Implications for Inclination Shallowing and the ISEA? chron

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Stepwise demagnetization isolates a stable magnetic component in 13 sites of basalt flows and baked sediments dated at 113+-1.6 Ma from the Tuoyun section, western Xinjiang Province, China. Except for one flow from the base of the 300 m-thick section, the rest have exclusively reversed polarity. Five of 11 sites of Early Cretaceous red beds that underlie the basalts possess coherent directions that pass both fold and reversals tests. Six sites of Upper Jurassic red beds have a magnetic component that was likely acquired after folding in the Tertiary. The mean paleolatitude of the Lower Cretaceous red beds is 11° lower than that of the Lower Cretaceous basalts suggesting the red beds underestimate the true field inclination. We further test this result by calculating the paleolatitudes to a common point of the available Early Cretaceous to Present paleomagnetic poles from red beds and volcanic rocks from central Asian localities north of the Tibetan plateau. We find that paleolatitudes of volcanic rocks roughly equal the paleolatitudes calculated from the reference Eurasian apparent polar wander path (APWP) and that paleolatitudes of red beds are generally 10° to 20° lower than the paleolatitudes of volcanic rocks and those predicted from the reference curve. Our study suggests that central Asian red beds poorly record the Earth's field inclination, which leads to lower than expected paleolatitudes. Good agreement in paleolatitudes from volcanic rocks and the Eurasian APWP argues against proposed canted and non-dipole field models.

GP72B-1010 1330h POSTER

Paleomagnetic Constraints on Central Asian Kinematics: Displacement Along the Altyn Tagh Fault and Rotation of the Qaidam Basin

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We carried out a paleomagnetic study of 1500 cores from 106 sites along the Altyn Tagh fault, in the Qaidam and Tarim basins, and on the Tibetan plateau. High temperature components from 10 of 13 age/locality groups pass fold and/or reversal tests and likely represent primary remanent magnetizations. The ten overall mean directions display a complex pattern of vertical-axis block rotations that are compatible with a tectonic model of clockwise rotation of the Qaidam Basin and concomitant left-lateral slip on the Altyn Tagh fault. Two of the ten localities are rotated significantly counterclockwise; they lie adjacent to the Altyn Tagh fault zone, consistent with the idea that left-lateral strike-slip motion occurred along it. The age of counterclockwise rotation near the eastern extremity of the fault was dated as younger than 19 Ma. Three widely spread areas within the Qaidam Basin exhibit similar and significant clockwise rotations, on the order of 20°, with respect to the North China Block, Tarim and Eurasia. The mean of the three values is thought to represent the total rotation of Qaidam. Because the youngest rocks displaying clockwise rotations are Oligocene, the main phase of Qaidam Basin rotation, and hence shear on the Altyn Tagh fault, took place after or near the end of the Oligocene (ca. 24 Ma). Upper Neogene strata located on the Qaidam Basin are not significantly rotated, thus tectonic deformation acting since the Upper Neogene (ca. 5 Ma) is not resolvable by paleomagnetic methods. Given a 20°+-5° clockwise rotation of the Qaidam Basin with respect to the Tarim Basin, the maximum left lateral displacement on the Altyn Tagh fault since 24 Ma is 500± 130 km.

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Paleomagnetism and multi-model stereo photogrammetry of the West Greenland flood volcanic province

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We present new paleomagnetic and multi-model photogrammetry data from the West Greenland part of the North Atlantic igneous province (NAIP). During fieldwork the paleomagnetic sampling sites were photographed from helicopter with stereoscopic overlap and in colour. The photographs have been set up for multi-model photogrammetry allowing three-dimensional lithological mapping, giving us important information for interpreting the paleomagnetic data in their stratigraphic context. Another advantage of the multi-model photogrammetry coverage is that individual lavas can be traced in three-dimensional space allowing very precise measurements of the attitude of strata (+/-0.5°) to be made for tectonic correction of the paleomagnetic data.

The paleomagnetic study is based on a large collection of 586 oriented paleomagnetic drill cores collected from 81 lava flows. All sampled flows carry stable thermoremanent magnetization of reversed polarity. The earliest part of the volcanic sequence (i.e. Vaigat Fm.) is characterized by several consecutive flows recording statistically indistinguishable paleomagnetic field directions. The thickest Vaigat Fm. directional group consists of 37 lava flows (combined thickness 104 meter), which based on photogrammetry and XRF observations we interpret to represent a single flow field (i.e. one eruption consisting of several lavas erupted in a short period of time). If Paleocene paleosecular variation was similar to Holocene variations, the thick directional groups would form within 100 years implying an extreme volcanic activity at the onset of NAIP volcanism on West Greenland.

Based on directional groups we obtain a new well-defined paleomagnetic pole for Greenland, which is statistically similar to a recently published NAIP pole from Faroe Islands (Riisager et al., 2002) rotated to Greenland. The corresponding paleolatitude of the central NAIP in Paleocene is ∼20° south of the present latitude of the Iceland hotspot, indicating that the Iceland hotspot has moved north since Paleocene.

References: Riisager et al., 2002. Earth Planet. Sci. Lett., 201, 261-276.

GP72B-1012 1330h POSTER

Magnetic Constraints on the Thermal Evolution of a Collapsing Orogen: Betic Cordillera, Southern Spain.

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In this study the thermal evolution of an orogen undergoing late-stage extension was investigated using rock magnetic properties of a suite of mafic dyke rocks affected by greenschist grade metamorphism. The dykes are intruded into two superposed, lithologically distinct, geological units.

The natural remanent magnetization in the dykes intruded into the lowest geologic unit is made up of up to three components. The lowest temperature component is in the direction of the present day magnetic field and is believed to be a chemical or viscous remanent magnetization. The intermediate temperature (IT) component unblocks between 200 and 450° C is thought to be largely a thermoviscous overprint acquired during metamorphism. This component is carried by pyrrhotite and low-unblocking temperature magnetite. The component of magnetization with the highest blocking temperature is isolated above 450° C. It is most likely that this component is carried by magnetite that resides in the plagioclase and has been shielded from the chemical effects of metamorphism. Thermal demagnetization of these dykes separates the IT overprint from the primary remanence at a sharp junction at 450° C. For single domain grains this translates to a peak palaeo-temperature in the natural sample of approximately 370° C, which is close to the estimated temperature experienced by the country rocks (400° C).

Results obtained from a dyke that is intruded into an overlying weakly metamorphosed geologic unit, indicate that temperatures only reached about 175° C in this unit. This is consistent with temperatures deduced from geologic constraints and they imply that between 4 and 6 km of section has been removed between the two units during late orogenic extension. These data can then be combined with previously published Ar-Ar wholerock geochronology and information on vertical axis rotations to constrain the thermotectonic evolution of this collapsing orogen.

GP72B-1013 1330h POSTER

A Negative Fold Test on the Lorrain Formation of the Huronian Supergroup: Uncertainty on the Paleolatitude of the Paleoproterozoic Gowganda Glaciation

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One of the major contributions of paleomagnetic studies to the field of paleoclimatology has been to provide constraints on the latitude of Proterozoic glacial intervals. As reviewed recently by Evans[1], several tightly-constrained results for the Neoproterozoic indicate the presence of tropical glaciers near the Equator which have led to the much-debated Snowball Earth hypothesis. In contrast, of the several results from the Paleoproterozoic glaciogenic units, only one[2] from the Transvaal Supergroup of South Africa is constrained directly by a paleomagnetic field test of stability. Although two recent studies of the youngest glacial interval in the Huronian supergroup of Canada [3,4] isolated high-temperature, low-latitude components, the authors did not conduct either conglomerate or soft-sediment fold tests to constrain more precisely the time that the magnetizations were acquired.

Upon examination of a large road-cut exposure of the purple siltstone member of the Lorrain formation along highway 17 near the town of Desbarats (one of the sites reported in [3]), we discovered a ductile chevron fold covering a $\sim$100-m^2 area, with an axis plunging 19° to the WSW, roughly perpendicular to the high-temperature characteristic direction reported for this unit [3]. The angular discordance between the two limbs was measured at $\sim$ 55°. Using a portable concrete saw, we sliced out and oriented a boomerang-shaped wedge $\sim$ 45 cm long, $\sim$ 10 cm wide, and $\sim$ 3 cm thick, which was cut perpendicular to the fold axis. From this we obtained 74 standard specimens for paleomagnetic analysis, distributed symmetrically on the two limbs. All of these were progressively demagnetized using similar techniques to the earlier studies [3,4]. Demagnetization behavior reveals the prevalence of a low-inclination northerly component isolated by high-temperature thermal demagnetization and resolved by PCA, which resembles the Lorrain D component reported previously [3], but lays within the scatter cone of the Lorrain A direction. Prior to the corrections for fold and tilt, average directions from both limbs share a common mean North and shallow direction ($p < 0.4$), whereas after correction the two means diverge by nearly 50° ($p << 0.001$), which indicates a very highly significant but negative fold test, supporting the conclusion in [3] that the Lorrain D was secondary.

However, directions similar to Lorrain D and A persist at temperatures above 580°C, the maximum temperature reported for Lorrain D in [3]. Further, we find it difficult to distinguish the high-T Lorrain components (C, B, and A) reported in [3]. Small-scale microconglomerates and other deformational features which are present in the exposure may provide additional constraints for testing the origin of these high-T components using scanning SQUID microscopy.

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GP72B-1014 1330h POSTER

A kinematic model for Afar Depression lithospheric thinning and its implications for hominid evolution: an exercise in plate-tectonic paleoanthropology

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We present a detailed Nubia-Arabia-Somalia (NUAR-SOM) kinematic reconstruction based on magnetic sea floor isochrons in the Gulf of Aden and Red Sea and piercing points along the Red Sea margins. The reconstruction is combined with digital topographic and depth-to-Moho data to constrain in 4D the Late Oligocene to present-day evolution of the Afar supra-Moho crust. Opposite end-member models for crustal evolution are described. We conclude that less than 20% of the present-day Afar supra-Moho crust was constructed by magmatic processes such as diking and underplating. The reconstructions indicate that the greater percentage of crustal thinning (extension) occurred before 6.2 Ma. We model the thinning of the effective elastic lithosphere that accompanied extension, and show that the regional-scale topographic development of the Afar depression was virtually complete by Mid Pliocene time.

The plate-tectonic model has paleoanthropological implications. Prior to 6.2 Ma the proximal positions of NU-SOM, AR, and the Danakil block suggest subaerial conditions prevailed between Yemen and Ethiopia. Uninhibited Africa-Eurasia faunal exchange through Afar and Arabia (corroborated by isotopic and paleontologic data) was tectonically permissible until the time of the earliest hominids. Continued stretching caused the Afar land bridge(s) to disappear during Early to Mid Pliocene time. Primitive hominid populations living within the Afar Depression became isolated from AR sometime before 3.2 Ma. With the plateau becoming less habitable due to long-term Late Neogene cooling, hominids that remained in the Afar Depression were required to adapt to a smaller range that was effectively bounded by the already well-developed NU-SOM escarpments and the newly opened Straits of Bab el Mandeb. The combination of high quality habitat,topographic confinement, and a gradual (tectonic) reduction in range, exacerbated by potentially severe fluctuations in local climate (well documented by land and marine paleoclimate proxies) appears to have been unique to Afar in Mid Pliocene Africa, and may have caused hominids living in the Depression to undergo physical and cultural evolution more rapidly and successfully than hominids inhabiting equally productive but less confined ranges elsewhere. We suggest that plate-tectonic induced isolation caused the Afar Depression to become the cauldron within which genus Homo arose to prominence. If our interpretation is correct, continental drift played a major role in hominid-to-human evolution.

GP72B-1015 1330h POSTER

Application of Magnetic Mapping to Proterozoic Continental Reconstruction

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Models of the Neoproterozoic (1.0-0.8 Ga) assembly of the supercontinent Rodinia include the SWEAT hypothesis, which places Proterozoic eastern Australia adjacent to the Proterozoic western margin of Canada, and the AUSWUS hypothesis, which juxtaposes the Proterozoic southwestern U.S. and Proterozoic eastern Australia. The disparity between the two models is largely due to an inability to correlate different basement mapping techniques used for the two continents. A thick weathering regolith in Australia has required the use of magnetic signature maps to define the Precambrian basement. Because of abundant basement exposure in the western U.S., isotopic methods have been used to define Precambrian terrane boundaries and little magnetic mapping has been done.

The eastern margin of Proterozoic Australia is defined by magnetic mapping as the Tasman line. SWEAT places the eastern Proterozoic margin of Australia, west of the Tasman line against the northwestern margin of Proterozoic Canada. This model is mainly based on geologic piercing points and stratigraphic/isotopic correlations. The AUSWUS model connects the Tasman line to the western margin of the Proterozoic U.S., adjacent to the $^{87}Sr/^{86}Sr$ line. The $^{87}Sr/^{86}Sr$ line has been suggested to divide Proterozoic basement to the east and younger accreted terranes to the west.

Magnetic mapping of the Proterozoic margin of the southwestern U.S. through the reduction of aeromagnetic data allows comparison with the magnetically defined margin of Proterozoic Australia. Preliminary evaluation of magnetic styles (amplitude and wavelength) and linear trends of the southwestern U.S. suggest that both Proterozoic and Phanerozoic igneous rocks greatly influence the total magnetic signature. Isolation of the Proterozoic component from the total aeromagnetic signal requires understanding the character, distribution, and magnitude of the magnetism in the Proterozoic rocks.

The magnetic signatures of two suites of granites in the southwestern U.S. could provide substantial support for the AUSWUS reconstruction. First, numerous Proterozoic granites crop out in western Arizona in the boundary between the Mojave and Yavapai provinces. The AUSWUS reconstruction suggests that the boundary zone is correlative with the Broken Hill block in Australia and that Proterozoic rocks in the boundary may correlate with the Arunta arc assemblage in Australia. Understanding the magnetic signature of the Mojave/Yavapai boundary will aid in resolving possible magnetic lineaments across the AUSWUS reconstruction. Second, a band of $\sim$1.4 Ga, possibly anorogenic granites transects the continental U.S. If continued along strike in the AUSWUS reconstruction, this band may be cogenetic with rocks in the Gawler craton of Australia. Magnetic susceptibilities of both suites of Proterozoic granites will be presented and contrasted with magnetic trends from the Australian craton.

GP11A MCC: Hall C Monday 0830h

The Use of Magnetic Properties as a Petrologic Tool I Posters *(joint with OS)*

Presiding: **J Rosenbaum,** U.S. Geological Survey**; K L Verosub,** University of California, Davis

GP11A-1061 0830h POSTER

Borehole Magnetometer Data as Information Source for Internal Structure and Stratigraphic Evolution of Mauna Kea Volcano

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A quasi-continuous magnetic log has been obtained in the Hawaii Scientific Drilling Project 2 (HSDP-2), providing information down to 1800 mbsl of Mauna Kea volcano flank deposits. The HSDP borehole penetrates in this depth section series of Aa- and Pahoehoe subaerial lava flows in the upper part followed by heterogeneous submarine series of hyaloclastites with changing amount of intercalated massive flows. The borehole magnetometer was employed to measure the horizontal and vertical magnetic fields. Measurements were taken in downhole and uphole runs, with a good correlation between both runs. The logs were processed to calculate rock magnetizations from magnetic components, using a multi-disk cylindrical model for the penetrated rocks. The disk thickness corresponds to the logging sampling rate of 0.1 m. Magnetic borehole logging in the HSDP-2 hole reveals strong magnetic anomalies in the subaerial as well in the submarine part with deviations from the normal field of up to 15000 nT. Since the magnetic behavior in the subaerial basalts is mainly related to early processes of high temperature alteration of the lava flows during extrusion, the continuous borehole magnetic data provide information to the amount of high temperature affected material within single lava flows. The magnetic data of the submarine part show a heterogeneous picture with longer sections of an undisturbed magnetic field and intercalated zones with strong anomalies. These anomalies are not restricted only to massive basalt flows as it might be expected, but also appear in series described as hyaloclastic units. A detailed comparison between core information, borehole magnetic data and other downhole logs (spectral gamma-ray and electrical resistivity) allowed us to distinguish between at least two types of hyaloclastites with different genetic origin. Hyaloclastites with strong magnetization are generated from former massive lava flows, exhibiting low matrix contents, a low natural gamma ray and a fragmented, auto-brecciated appearance, while hyaloclastites with low magnetization show a more typical sedimentary character and are characterized by high matrix contents which correspond to high gamma-ray values. Taking this information into account the continuous borehole data allow to subdivide the encountered submarine deposits into several volcanostratigraphic units, as well as to detect unconformities in the volcanic deposits which are most probably produced by landslides or debris avalanches. The most prominent boundary is encountered at about 1670 mbsl. There, the log and core data strongly point to a basis of the large landslide. This hypothesis is further supported by a strong change of the magnetic inclination towards low values.