RAPA-01

MESOZOIC TRUE POLAR WANDER : PALEOMAGNETIC EVIDENCE AND PHYSICAL CONSTRAINTS

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A recent compilation (Prévot *et al.*, 2000) of severely selected paleomagnetic data obtained from continental magmatic rocks collected from the six main lithospheric plates showed the absence of significant relative movement between the Earth's rotation axis and the Atlantic and Indian Oceans hotspot reference frame over the last 80 Ma, while a deviation amounting to 35° in total is observed between 80 and about 140 Ma. If this hotspot frame is fixed with respect to the lithosphere, the angular deviation observed corresponds to True Polar Wander (TPW, defined in the paleomagnetic literature as a displacement of the rotation axis with respect to the lithosphere as a whole). Alternatively, it is possible to deny the occurrence of TPW by assuming that this is the hotspot frame rather than the rotation axis which moves with respect to the whole lithosphere. These two opposite interpretations can not be tested from the paleomagnetic data set used to compute the change with time in the position of the global paleomagnetic pole because only the relative deviation between the hotspot frame and the rotation axis can be determined this way. Therefore, it is important to consider the physical constraints applying to both models. The physical explanation of TPW rely on the fact that, in the long term, the direction of the rotation axis of a rotating body has to be aligned along the major axis of its inertia tensor. It is expected that large-scale mantle convection can modify the mass distribution within the mantle, which modifies in turn the Earth's non-hydrostatic inertia tensor and, consequently, the orientation of the rotation axis. Under the assumption that the lithosphere and the mantle are tightly coupled, this displacement of the rotation axis is identical to the TPW referred to by paleomagnetists. An alternative hypothesis, known as "mantle roll", pretends to offer an alternative to the TPW interpretation. In this model, the deviation between the rotation axis and the hotspot reference frame is supposed to be due to a rotation of the hotspot frame with respect to the lithosphere. This movement is explained by an Eulerian rotation of the entire Earth's mantle (assumed to be decoupled from the lithosphere). However, this interpretation is physically incoherent : the orientation of the Earth's rotation axis being in fine imposed by the distribution of matter within the mantle, rotating the mantle as a whole rotates similarly the Earth's non-hydrostatic inertia tensor. Consequently, mantle roll, which is supposed to provide an alternative to TPW, is in fact a (hypothetical) geophysical process which would produce TPW. Another model, also presented as an alternative to TPW, assumes a large scale differential movement between the mantle underlying the Pacific plate and the mantle below the Atlantic Ocean. This model suffers from the same drawbacks as the mantle roll model. In particular, large scale differential motions of large parts of the mantle would evidently alter the non-hydrostatic inertia tensor of the Earth and thus produce some True Polar Wander. These differential mantle movements can be expected to result in having both the hotspot reference frame and the rotation axis moving (independently from each other) with respect to the lithosphere. Thus TPW occurs, but it is incorrectly measured by the deviation between the hotspot frame and the rotation axis. The only hypothesis which does not imply some built-in TPW is that the large-scale pattern of mantle flow can move some groups of hotspots with respect to each others without changing the large-scale density distribution within the mantle. In the present case, this model requires that the two Atlantic hotspots have moved in unison with respect to the lithosphere between 80 and 140 Ma. This hypothesis can be checked by direct paleomagnetic measurements on hotspot magmatic products, however no decisive data have been obtained so far.

RAPA-02

PALEODIRECTIONAL AND PALEOINTENSITY RESULTS FROM SAN CRISTOBAL AND GARCIA DE LA CADENA VOLCANIC SUCSESSIONS, (JALISCO AND ZACATECAS STATES, CENTRAL MEXICO)

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We sampled a sequence of 56 volcanic units (mostly basaltic lava flows) in the central part of Trans Mexican Volcanic belt (TMVB), in two separate stretches. A detailed rock-magnetic, paleomagnetic and paleointensity study was carried out in order to obtain some decisive constraints for the tectonic evolution of TMVB and for the geomagnetic field strength during Miocene time. Age of the volcanic units lies between 8 and 11 Ma according to available radiometric data. Most of the rocks exhibited well-defined one component remanent magnetization with high unblocking temperatures (mostly above 525°C) and high median destructive fields (30-50 mT). Very small secondary components, probably of viscous origin, were easily removed applying 250-300 °C or 10-15 mT. Two different types of behavior were observed during low-T susceptibility experiments: In first cases, the curves show a rather monotonic decrease from about -185°C to room temperature yielding very poorly defined inflection point at about -150°C. In other cases a well defined pick was observed around the same temperature, which probably indicate to Verwey transition, characteristic of almost pure magnetite. All units (lava flows, dikes and backed sediments) sampled at San Cristobal locality yield normal polarity magnetization and those belonging to Garcia de la Cadena are reverse. With these results, when combined with K-Ar ages, a direct correlation with the reference geomagnetic polarity time scale can be made. The mean paleodirection calculated after discarding intermediate polarity sites is I=32.7°, D=349.4°, k=136, a95=4.2°. The mean inclination is in reasonably good agreement with the expected inclination for the middle Miocene time, as derived from reference poles given by Besse and Courtillot (1991) for North America. The declination, however, is different from that expected (D=1.2°). This may suggests a mean tectonic counterclockwise rotation of about 10°. Seventy-two samples with high Curie point (about 580°C) were chosen for Thellier paleintensity experiments. We accepted only determinations: (1) obtained from at least 6 NRM-TRM points corresponding to a NRM fraction larger than 1/3, (2) yielding quality factor (Coe, et al., 1978) of about 5 or more, and (3) with positive 'pTRM' checks. In

addition, we rejected two flows (5 samples) which yielded within-flow standard deviation higher than 30%. The site mean paleointensities are ranging from 21.2 ± 3.1 to 44.8 ± 4.3 mT, which are in reasonably good agreement with the previously reported Miocene values from Central Mexico.

RAPA-03

SOME NOVELTIES IN PALEOINTENSITY DETERMINATION: DEALING WITH NONLINEAR THELLIER AND PSEUDO-THELLIER DATA AND MULTIVECTORIAL PALEOINTENSITIES

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Curvature of paleointensity data on an Arai plot is usually a sign of chemical alteration during heating. However, multidomain (MD) and larger pseudo-single-domain (PSD) grains give persistent curved characteristics even when no alteration is occurring. In pseudo-Thellier determinations of relative paleointensity, which uses AF demagnetization of NRM and acquisition of partial ARM in place of thermal demagnetization of NRM and acquisition of partial TRM, the analog to the Arai plot (NRM remaining vs. pARM acquired) is also convex downward, although not as strongly as in the case of pTRM. Microscopic models for this behavior and possible remedies will be presented. Another novelty in paleointensity determination is the possibility of extracting two paleofield estimates, for the primary NRM and for asecondary pTRM overprint. Multivectorial NRMs of this type are frequent inorogenic belts and in metamorphic rocks generally. Because thermal overprinting often occurs long after primary magnetization, the difference in directions can be considerable and conventional scalar Arai plots are not suitable. We will present two case-histories for rocks from the Precambrian Grenville Province of Ontario in which the primary and overprint vectors are at large angles (about 60 degrees and 90 degrees, respectively) and also model studies of paleointensity determination for multivectors at these and other angles (including 180 degrees, overprinting following field reversal).

RAPA-04

AN ATTEMPT TO DETERMINE THE MICROWAVE PALEOINTENSITY ON PARICUTIN VOLCANO LAVA FLOWS

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We report a detailed rock-magnetic and microwave paleointensity investigation of historic lava flows of the Paricutin volcano, which span the period between 1943 and 1948. These lava flows seem ideal for absolute intensity study, with well preserved well-exposed, fresh and extensive outcrops. Most of samples are characterized by simple univectorial plots. The IRM curves show saturation at low/moderate fields, indicating to the titanomagnetites series. Hysteresis experiments also indicate that magnetic carriers are likely iron-rich titanomagnetites that present single-domain or pseudo-single-domain behavior. Microwave paleointensity technique was applied on three selected samples using Kono and Ueno's (1979) method; i.e. the direction of applied laboratory field was perpendicular to the direction of remanent magnetization. All three samples yielded different paleointensity values: 11.39, 25.65 and 58.09 microTesla. This difference may be owned from the fact that only a small fraction of natural remanent magnetization was used for paleointensity determination.

RAPA-05

A BRIEF REVIEW OF MICROWAVE MAGNETIZATION

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It is best to start by disposing of 2 common misconceptions among palaeomagneists with regard to microwave effects, probably best illustrated by referee reports I have received:

1) A proposal for support to the NSERC of Canada was dismissed with the remark that that palaeomagnetists had tried it and it hadn't worked. What the referee didn't understand was that putting bricks in microwave ovens was not the same thing. The first proposal to do the job properly was an earlier one to the SERC in the UK by myself and Don Tarling. It failed but for a different reason, the referee said it wouldn't work because

2) "You don't know the temperature of the magnetic grains". He is right but it doesn't matter because the power and exposure time are reproducible with the result that it is possible to perform a "microwave Thellier" experiment. John Shaw and Mimi Hill have recently shown that the thermal and microwave methods yield identical results. On the other hand there is distribution of temperatures among the grains which complicates the removal of undesirable components.

The frequency is important because the microwaves heat the magnetic grains by generating spin waves in the magnetic system. The matrix is not magnetic, and it is only heated by conduction from the magnetic grains. Therefore it's temperature remains relatively low, and that accounts for the success of the microwave method.

In order to generate spin waves the microwave frequency must be higher than twice the lowest spin wave frequency. This creates a problem for very small grains: quantum confinement limits the spin wave wave-length to a scale on the order of the grain size, and since the spin wave frequency increases with decreasing wave-length this frequency can be very high. For grains at the superparamagnetic boundary at room temperature this frequency is too high for practical purposes. This means that demagnetization starts with grains whose blocking temperature is above room temperature. The higher the frequency, the closer to room temperature will be the starting point. The remaining grains, which are not on speaking terms with the microwaves, can be demagnetized, but only by raising their temperature with the attendant risk of alteration. This is why it is important to use the highest practical frequency, and also why it is so easy to get poor results at low frequencies.

RAPA-06

APORTACIONES A LA INTENSIDAD DEL CAMPO GEOMAGNÉTICO DEL PLIO-PLEISTOCENO: CAMPO VOLCÁNICO LOS TUXTLAS, VERACRUZ, MÉXICO

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Estudios de paleointensidad, paleomagnético y de magnetismo de rocas se efectuaron en trece flujos volcánicos del campo volcánico Los Tuxtlas (Faja Volcánica Mexicana), para definir condiciones que ayuden a definir la intensidad del campo geomagnético durante el Plio-Pleistoceno.La edad de las unidades volcánicas, que da estimaciones confiables de paleointensidad, esta entre 2.2 y 0.8 Ma de acuerdo a edades radiométricas disponibles. Los resultados termomagnéticos revelan que la remanencia la portan en muchos casos titanomagnetitas pobres en Ti. Los espectros de temperaturas de desbloqueo y la relativamente alta coercitividad, sugieren pequeños granos magnéticos de dominio pseudo-sencillo para esas titano(magnetitas). Se observaron componentes uni-vectoriales durante el proceso de desmagnetización en la mayoria de casos. Seis flujos muestran magnetización con polaridad inversa, cinco estan magnetizados normalmente y uno muestra polaridad intermedia. Se detectó el efecto de relampágos en un flujo. La posición polar media obtenida es Plat=83.7°, Plong=178.1°, K=36, A95=8.1°, N=10 y la paleodirección correspondiente es I=31.3°, D=352°, k=37, a95=8.2°, que no es significantemente distinta de la dirección esperada de la dirección estimada de la curva de desplazamiento polar aparente para Norteamérica. Se seleccionaron 39 muestras para hacer experimentos de paleointensidad (Thellier) en base a su estabilidad de magnetización remanente y relativamente baja dispersión dentro de cada sitio. Solo 21 muestras, provenientes de cuatro flujos de lava, dieron estimaciones de paleointensidad confiables con un momento dipolar virtual (VDM) de flujo medio que varía desde 6.4 hasta 9.1 x1022 Am2. La combinación de datos contemporáneos mexicanos con resultados de paleointensidad de calidad similar para el Plioceno da un VDM medio de 6.4 x 1022 Am2, que es casi el 80% del campo dipolar geomagnético axial actual. Resultados de paleoitensidad confiables para los últimos 5 Ma son aún escasos y de calidad variable. Se necesitan determinaciones de alta calidad de intensidad absoluta para definir mejor la intensidad del campo geomagnético durante el período Plio-Pleistoceno.

RAPA-07

AN INTEGRATED PALEOMAGNETIC STUDY ALONG THE TRANS-MEXICAN VOLCANIC BELT: PRELIMINARY RESULTS

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About 550 standard paleomagnetic cores belonging to 67 volcanic units were sampled to test the hypothesis of large-scale left-lateral displacement along the TMVB and to conduct experiments on some selected basalt flows to determine absolute paleointensity of the geomagnetic field, a fundamental constraint that is needed for recent supercomputer models of the geodynamo. Age of the volcanic units lies between 13.5 and 4.2 Ma according to available radiometric data. Isothermal remanent magnetization curves show that saturation is reached in moderate fields of the order of 100-200 mT, which indicates to a spinel phase. Judging from the ratios of hysteresis parameters, it seems that the samples fall in the pseudo-single-domain grain size. This probably indicates a mixture of mutidomain and a significant amount of single-domain grains.

In most samples a single and stable component of magnetization was observed upon both alternating field and thermal treatment. A generally minor secondary component, probably a viscous overprint from the recent field, was present but was easily removed. Three sites are characterized by unusually high intensity and scattered NRM directions. Both factors may point to strong lightning-produced magnetization overprint. These samples will be rejected for further paleomagnetic analysis. The median destructive fields (MDF) range mostly in the 30-50 mT interval. Unblocking temperatures range from 550 to 570°C, which points to almost pure magnetite as remanence carrier. These results permit a direct correlation with the reference geomagnetic polarity time scale. The mean paleodirections calculated after discarding intermediate polarity units are concordant with the expected directions for the Mio-Pliocene time. According to Rock-magnetic data and remanence measurements, more than 100 samples were pre-selected for Thellier paleointensity experiments.

RAPA-08

SINGLE GRAIN THELLIER PALEOINTENSITY EXPERIMENTS ON OLIGOCENE VOLCANICS FROM YEMEN

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Oligocene flood volcanism in Yemen was erupted from 31-26 Ma producing ca. 2-3 km of basaltic lava flows, rhyolitic ignimbrites and airfall deposits, and minor andesitic lava flows. The large feldspar phenocrysts available all through the stratigraphic column were often found to be only very weakly magnetic. For preliminary Thellier-Thellier paleointensity experiments we selected

26 plagioclase single crystals with magnetic moments ranging from 10-6 to 10-8 emu. We obtained acceptable results from 40% of the samples with paleofield estimates varying from 50 to 80 mT. Analysis of magnetic separates by transmission electron microscopy revealed that the crystals contain single to pseudo-single-domain inclusions of equant to rectangular shape. Magnetic hysteresis measurements were used to test possible magnetic anisotropy by rotating crystals on the AGFM probe and comparing hysteresis parameters. Unblocking temperatures (more than 90% loss of NRM intensity by 300 to 400ºC) suggest the inclusions are titanomagnetites.

RAPA-09

NON-IDEAL BEHAVIOUR IN SIMULATED THELLIER PALAEOINTENSITY EXPERIMENTS

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The Thellier palaeointensity method is known to produce non-ideal results when it is performed on samples with assemblages dominated by multi-domain (MD) or large pseudo-single domain (PSD) grains of magnetite. To further understand the nature of this non-ideal behaviour, two simulated Thellier experiments, incorporating pTRM (partial thermoremanent) and 'NRM' (natural remanent magnetisation) checks, were performed on rock samples with a range of magnetic grain sizes that had previously been given a complete TRM in the laboratory.The first experiment was performed on samples with remanence carriers dominantly in the PSD size range and used the same magnetic field as was used to impart the original TRM. It was observed that most of the samples underwent some irreversible alteration upon heating to the Curie temperature of magnetite during the experiment. Nevertheless, some interesting observations, pertinent to the use of the Thellier method on untreated rock samples were made.The application of a suite of commonly used acceptance criteria was found to produce nine estimates (from the 14 samples used) with moderate q (quality) factors that would normally be regarded as reliable. However, these consistently overestimated the actual 'palaeointensity' because they invariably utilised the initial steep portion of the Arai plot where pTRM checks agreed well with original measurements. The mean of these estimates was found to be 40% higher than the correct result and well outside of error bounds.Conversely, the TRMs imparted to nine of the samples in the final stage of the experiment were observed to agree with their inital TRMs to within 10%. These results were considered to be sufficiently accurate but were accompanied by conventionally unacceptable degrees of scatter of points about the best-fit lines, 'failing' pTRM and NRM checks, and high slope curvatures. Any suite of acceptance criteria developed to maximise the accuracy and precision of the mean estimate produced by the samples in this experiment would appear to be remarkably relaxed with respect to those previously advocated. However, it is necessary to remember that these samples were thermally pre-treated and therefore far less prone to irreversible alteration during the experiment than natural samples would be. Nevertheless, it highlights a strong need to further investigate the issue of what constitutes a reliable palaeointensity estimate.The second experiment was performed on samples which contained predominantly MD grains. The samples experienced only very limited irreversible alteration of their magnetic properties. Consequently 9 of the 14 samples gave 'palaeointensity' estimates to within 1% of the actual value when only the end-points were used and the maximum error observed was 13%. Nevertheless, between the end-points of the Arai plots, a great deal of non-ideal behaviour was observed. In addition to the convex-down shape of the plots, which is a widely reported facet of MD behaviour during Thellier experiments, most of the samples exhibited two other phenomena previously unreported in the context of Thellier experiments.The first of these is referred to as NRM annihilation and appears to be most prevalent at low temperatures. The heating step involved in the remagnetisation stage appears to cause the sample to spontaneously lose 'NRM' despite the sample already being thermally demagnetised to that temperature during the previous stage. This affects a number of samples to the extent that some points on their Arai plot appear to have acquired a negative pTRM. I.E. More TRM is lost through this process than is imparted by the remagnetising field.The second phenomenom is referred to as pTRM cohabitation and is most noticeable at high temperatures. The samples appear to acquire high temperature pTRM tails that coexist with the 'NRM' and allow the samples to retain a greater magnetisation than the original, and final, full TRM. Both of these phenomena, together with the overall convex-down shape of the Arai plots appear to be related to the evolution of pTRM and NRM check discrepancies through the experiment although the precise details of how are not presently apparent.

RAPA-10

FURTHER CONSTRAINTS FOR MIOCENE GEOMAGNETIC FIELD STRENGTH: CASE STUDY OF BAJA CALIFORNIA VOLCANICS

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From a large collection of Baja California Sur Mio-Pliocene volcanic units sampled for tectonics, magnetostratigraphy and magnetic anisotropy studies, 68 samples were selected for Thellier paleointensity experiments because of their low viscosity index, stable remanent magnetization and close to reversible continuous thermomagnetic curves. Altogether 48 samples, coming from 14 individual lava flows, yielded reliable paleointensity estimates with the flow-mean virtual dipole moments (VDM) ranging from 3.69 to 8.75 x1022 Am2. Our results, although not numerous, are of high technical quality and comparable to other paleointensity data recently obtained on younger lava flows. The NRM fractions used for paleointensity determination range from 32 to 79% and the quality factors varies between 4.5 and 26.5, being normally greater than 6. Obtained VDM values are slightly higher than those recently reported from Mio-Pliocene submarine basaltic glasses. More data are needed to better understand the behaviour of the Miocene geomagnetic field strength and to constrain the transition mode between Mesozoic low and the Neogene high field.

RAPA-11

SECULAR VARIATION DATA FOR MEXICO FOR THE LAST ~40,000 YEARS

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Mexico counts with several different and independent archives of the secular variation (SV) of the earth's magnetic field during the last few ten thousand years. These are volcanic rocks, lake sediments, cave deposits, and archeological materials. The number of paleomagnetic studies of such archives is very variable though, as well as their quality and the reliability of the age determinations of these archives. In this paper we review the available paleomagnetic data from Mexico, which may be used together with new unpublished data for constructing a SV curve. For the last ~4000 years data are available from all archives, with a large number of archeomagnetic results. The data show similar directional variations, but great age uncertainties of some of the archives, specially the archeological materials, makes it difficult to determine a precise trend of the SV. Directional data from speleothemes apparently provide good remanence directions, but so far they only cover the last ~1200 years.

For older ages, only lake sediment and volcanic rock data are available. The lake sediments come from the Basin of Mexico and are heavily influenced by climatic and environmental processes. Furthermore, different age model may be derived from 14C age determinations so that the resulting directional variations vs. time are considered to be unreliable. Volcanic rocks from different places but of similar age show a good coincidence of remanence directions, thus indicating their excellent potential for constructing a more reliable SV curve. Unfortunately, their temporal coverage is not yet satisfactory which may change in the near future by dating additional young volcanoes. Such data may be complemented by lake sediment studies from maar lakes, which have proved to provide better results than shallow lakes. Such maar-lake sediment studies are in progress. Absolute paleointensities obtained from volcanic rocks (and for the more recent past also from archeological materials) may be used in favorable cases to calibrate relative paleointensities obtained from lake sediments, to define as well SV curves for that parameter of the field. Absolute paleointensity experiments are in progress, using the microwave technique.

RAPA-12

CAN LOW TEMPERATURE DEMAGNETIZATION REMOVE THE REMANENCE CARRIED BY MULTIDOMAIN MAGNETIC GRAINS? POSSIBLE IMPLICATIONS FOR THE THELLIER PALEOINTENSITY DETERMINATION

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Low temperature demagnetization (LTD) is the process of cooling a sample through the isotropic temperature Ti = 120-135 K, of magnetite, usually to liquid nitrogen temperature (77 K) and heating back to room temperature, all in zero field. It was theoretically shown that the low-temperature demagnetization (LTD) should destroy the remanence carried by multidomain grains of magnetite or Ti-poor titanomagnetite. At ~ 130 K, the magnetocristalline anisotropy K1 changes its sign and the easy magnetization axis its orientation. This transition is accompanied by abrupt changes in coercivity, remanence and susceptibility.

In this study, new continuous thermomagnetic curves were obtained using VSTM (vibrating sample thermomagnetometer) apparatus, which allows estimation of the magnetic domain structure of opaque minerals through the study of partial thermoremanent (pTRM) magnetizations. pTRMs were also subjected to the low-temperature treatments in order to remove the part of remanent magnetization carried by multidomain grains. In general, 10 to 40% of 'multidomain pTRM remanence' were removed during this treatment, which may help to increase the success of paleointensity measurements.

RAPA-13

ESTUDIO COMPARATIVO DE LOS MÉTODOS PARA LA ESTIMACIÓN DE PALEOINTENSIDADES DEL CAMPO MAGNÉTICO TERRESTRE : APLICACIÓN A ROCAS VOLCÁNICAS MEXICANAS CUATERNARIAS

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Se muestrearon trece flujos de lava cuaternarios de la Cuenca central de México para determinar sus características magnéticas y su paleointensidad absoluta. Las muestras estudiadas cubren un intervalo de edades desde 0.78 Ma hasta aproximadamente 2000 años. Varios experimentos de magnetismo de rocas fueron realizados a fin de identificar los portadores magnéticos y para obtener información de su estabilidad paleomagnética. Mediciones continuas de la susceptibilidad contra temperatura dieron en la mayoría de los casos curvas razonablemente reversibles con puntos de Curie cercanos a aquel de la magnetita, lo cual es compatible con las tinanomagnetitas resultantes de la oxi-exsolución. A juzgar por los cocientes de los parámetros de las curvas de histéresis, pareciera que todos los especímenes caen en la región de los dominios pseudo sencillos (PSD), indicando probablemente una mezcla de granos de multidominio (MD) y una cantidad significativa de granos de dominio sencillo (SD).

Las determinaciones de paleointensidad se obtuvieron empleando el método de Thellier modificado por Coe,(Coe, 1967) y los métodos alternativos de Shaw (Kono, 1978, Rolph & Shaw, 1985). Se comparan los resultados de 6 unidades de enfriamiento las cuales dieron estimaciones de paleointensidad absoluta aceptables por el método de Thellier. Existen diferencias entre dichas estimaciones que invitan a reconsiderar sobre la confiabilidad de los métodos alternos mencionados.

RAPA-14

ESTUDIO MAGNÉTICO DE ROCAS Y DE PALEOINTENSIDAD DE FLUJOS DE LOS VOLCANES IZTACCÍHUATL Y POPOCATÉPETL: ENFOQUE METODOLÓGICO

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Se muestrearon nueve flujos de lava de zonas adyacentes a los volcanes Iztaccíhuatl y Popocatépetl, pertenecientes al campo volcánico de la Sierra Nevada, parte central de México, para determinar sus características magnéticas y su paleointensidad absoluta. Las muestras estudiadas cubren un rango de edades aproximado entre 0.27 a 0.41 Ma. Diferentes experimentos de propiedades magnéticas de roca fueron realizados a fin de identificar los portadores de la magnetización y para obtener información acerca de su estabilidad magnética. Las determinaciones de paleointensidad se obtuvieron empleando los métodos modificados de Shaw (Kono, 1978, Rolph & Shaw, 1984). La comparación de éstos resultados contra aquellos obtenidos por métodos alternativos (Thellier and Thellier, 1959, Coe, 1967) fue imposible ya que de éstos últimos no se pudo hacer estimación alguna.

RAPA-15

GEOMAGNETIC PALEOSECULAR VARIATION DURING MIOCENE, FROM THE TEPIC AREA (NAYARIT, MEXICO)

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Records of the geomagnetic paleosecular variation provide crucial information for the understanding of the mechanism generating the geomagnetic field. For this reason, numerous paleomagnetic investigation in the last three decades have addressed this question and have progressively contributed to a wide documentation of the paleosecular variation with increasing precision in time and geographical coverage (Szeremeta et al., 1999). Despite this continuous effort new data are still important, because the time-space coverage is as yet far from complete (Johnson and Constable, 1997). Moreover, a recent IAGA resolution recommends that attention be given to study important sections using modern laboratory techniques. Despite the abundance of thick lava sequences with rather high extrusion rate, Nayarit volcanics have been relatively little studied from a paleomagnetic point of vue. We have sampled a sequence of 44 Miocene consecutive lava flows around Tepic City. All the samples were stepwise demagnetized, partly with alternating field, partly thermally with very similar results. The large majority of the samples are characterized by a single stable paleomagnetic component. ChRM isolated after the first steps of demagnetization are all normal polarity. Directional and VGP scatter calculated from all lava flows are consistent with recent models of paleosecular variation.

RAPA-16

ARCHAEOMAGNETIC INVESTIGATIONS IN MEXICO

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A review of currently available archaeomagnetic data from Mexico is presented. These data belong to ceramics, baked floors, historic lava flows and the orientation of buildings providing information about the direction and intensity of the geomagnetic field. New data from unburned limeplasters (Hueda, 2000) and they comparison with previous results from Teotihuacan, obtained by Wolfman (1990) will be also discussed. Finally we present an updated paleosecular variation master curve for Central Mexico.

RAPA-17

PALEOMAGNETIC AND ANISOTROPY OF MAGNETIC SUSCEPTIBILITY STUDIES OF OLIGOCENE FLOOD VOLCANISM IN YEMEN

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Oligocene flood volcanism in Yemen was erupted from 31-26 Ma producing ca. 2-3 km of basaltic lava flows, rhyolitic ignimbrites and airfall deposits, and minor andesitic lava flows. During the autumn of 1999 we sampled altogether 104 flows, drilling 7-10 cores per flow and using both magnetic and sun compass for orientation. In the present study we will compare the magnetostratigraphy and paleomagnetic pole of Oligocene Yemen flood volcanism with data from the Ethiopian Traps on the conjugate margin. Anisotropy of magnetic susceptibility data will be combined with isotopic fingerprinting of rhyolitic pyroclastic rocks and exhumed granite centres to identify the eruptive centres of the large volumes of rhyolitic magmas produced in this large igneous province.

RAPA-18

PALEOMAGNETISMO, MAGNETISMO DE ROCAS Y MICROSCOPÍA DEL CAMPO VOLCÁNICO DE CAMARGO (CHIHUAHUA, MEXICO)

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Reportamos resultados detallados de magnetismo de rocas, paleomagnéticos y microscópicos de rocas Pliocénicas del Campo Volcánico de Camargo. La edad de las rocas en estudio varía entre 5 y 1 Ma de acuerdo a datos radiométricos disponibles. Los experimentos de magnetismo de rocas revelan que la remanencia la portan en muchos casos las titanomagnetitas pobres en Ti,

resultantes de procesos de oxi-exsolución a partir de titanomagnetita original durante el proceso de enfriamiento. Para algunas unidades, la remanencia parecen portarla titano(hematitas), sugerido por los espectros de temperatura o por titano(maghemita) secundaria. Los parámetros de histéresis sugieren que la mayoría de muestras caen en la región de tamaño de grano de dominio pseudo-sencillo probablemente indicando una mezcla de multidominio con una cantidad significativa de granos de dominio sencillo. La dirección media paleomagnética obtenida para el Campo Volcánico Camargo es I=28.8°, D=340.3°, k=16, α_{95}=13.2, la cual esta desviada en sentido contrario a las manecillas del reloj de la dirección esperada estimada de la curva de desplazamiento polar aparente para Norteamérica. Esto sugiere un rotación tectónica sobre eje-vertical en el sentido mencionado de aproximadamente 20° relativa al cratón de Norteamérica. La paleodeclinación obtenida concuerda con los resultados efectuados previamente en rocas del Eoceno y Oligoceno del norte de México. Esto puede indicar que la rotación tectónica no esta relacionada a la compresión de la orogenía Laramide o a la extensión de la región Cuencas y Sierras del Terciario temprano.

RAPA-19

PRELIMINARY PALEOMAGNETISM AND MAGNETIC MINERALOGY FROM COTIJA VOLCANIC FIELD (MICHOACAN, MEXICO)

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We report a preliminary paleomagnetic and rock-magnetic study of Mio-Pliocene volcanic rocks from the Cotija volcanic field around of border between Jalisco and Michoacan States. A total of 40 sites (336 oriented samples) were collected. Several rock-magnetic experiments were carried out in order to identify the magnetic carriers and isolate the primary magnetization components. Microscopic observations on polished sections show that the main magnetic mineral is low-Ti titanomagnetite associated with exsolved ilmenite, probably formed as a result of oxidation of titanomagnetite during initial cooling. These intergrowths typically develop higher than 600°C and consequently, the NRM (natural remanent magnetization) carried by these samples should be a thermoremanent (TRM) magnetization.

Low-field susceptibility measurements (using Bartington MS2 system), performed on one sample per flow, yield two different types of behavior. More than half of the curves shows the presence of a single magnetic/ferrimagnetic phase with Curie point compatible with relatively low-Ti titanomagnetite. However, the cooling and heating curves are not perfectly reversible. In other cases, the curves yield two different thermomagnetic phases during heating. The lower Curie point ranges between 350-450°C, and the highest one is about 570°C. The cooling curve shows only a single phase, with a Curie temperature close to that of magnetite. Such irreversible curves can be explained by titanomaghemite, which probably transformed into magnetite during heating. Hysteresis measurements were performed on samples from all flows using an AGFM 'Micromag', in fields up to 1T. Curves were rather symmetrical in all cases. Near the origin, no potbellied and wasp-waisted behavior was detected, which probably reflects very restricted dual ranges of the opaque mineral coercivities. IRM (isothermal remanent magnetization) acquisition curves were found also very similar for all samples. Saturation is reached in moderate fields of the order of 100-200 mT, which reveals that a cubic phase is principal remanence carriers. The primary remanent magnetization has been isolated after detailed AF and thermal demagnetization of all samples. A characteristic magnetization was determined by the least square method, with 4 to 9 points used for this determination. The directions were averaged by flow and the statistical parameters calculated assuming a Fisherian distribution. The flow mean paleodirections are overall well-determined. Almost all a95 values are less than 10°. The mean paleomagnetic directions obtained from all sites only slightly differ from that expected for the Middle Miocene paleodirections derived from the north American polar wonder.

RAPA-20

THE MAGNETIC STRUCTURE AND DEHYDRATION PRODUCTS OF GOETHITE

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Goethite is a common weathering product of iron-bearing minerals and an important constituent of soils, ore deposit, red sandstones and marine sediments. Goethite is antiferromagnetic with a weak ferromagnetism below the Néel temperature Tn=120°C. Thermoremanence (TRM) produced parallel and perpendicular to the goethite c-axis, indicates that the ferromagnetism of "-FeOOH is not due to spin canting as in hematite. It is probably due to unbalanced numbers of spins on the A and B sublattices, resulting from random lattice vacancies.

When heated, goethite loses its water and dehydrates to hematite. The transformation involves two main processes: removal of water molecules and atomic rearrangements for formation of a rhombohedral phase. The process does not involve oxidation. However, recent study reveals an intermediate spinel-like phase forming in the process. The transformation of goethite has been studied by low-temperature induced magnetization (LTIM) and X-ray diffraction on well characterized acicular crystals. The fresh samples were heated in air to temperatures between 150 and 600°C. Goethite and hematite were the magnetically dominant phases after all runs except 500 and 600°C, for which hematite was the only remanence carrier. However, the partially dehydrated goethites after the 240-400°C runs showed broad magnetization peaks or inflections around 120 K in the LTIM curves, suggesting the formation of magnetite. The formation of small amount of magnetite has serious implications for paleomagnetic studies of goethite-bearing sediments and rocks. CRM of strongly magnetic intermediate phase could significantly modify the original goethite CRM.

RAPA-21

ROCK-MAGNETIC PROPERTIES OF LAKE SEDIMENTS FROM LAGO VERDE, LOS TUXTLAS, MEXICO

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In order to investigate the late Quaternary climatic and environmental change in the eastern sector of Central Mexico, we carry out a multidisciplinary research project in lake sediments from several of the maars surrounding the San Martin volcano in Los Tuxtlas, Veracruz. This project includes the analysis of proxy records such as diatoms, pollen, and organic content. Additional information about the environment can be achieved analyzing the magnetic properties of the sediments. The aspects of the magnetic signal we are examining are the magnetic mineralogy, the concentration of magnetic minerals and the grain-size distribution of the magnetic fraction. In this work we present the preliminary results of analysis of rock-magnetism record from Lago Verde.

A core 5.8 m long was recovered in the central part of Lago Verde, Los Tuxtlas. The sediments, probably of mid to late Holocene in age, are composed by organic silts in the upper half of the core, and by volcaniclastic materials in the lower half. Measurements of Curie temperatures, low temperature (<300 K) phase transitions, and S300 ratios are used to identify the mineralogy of magnetic carriers. Concentration of magnetic material is estimated from susceptibility and several laboratory-induced remanences such as SIRM and ARM. The magnetic grain-size distribution is estimated by the frequency-dependence of susceptibility (ultrafine, superparamagnetic grains), the anhysteric remanence magnetization, and by measuring the hysteresis loops and plotting the magnetization and coercivity ratios.

The preliminary results indicate that in the volcaniclastic deposits, two different magnetic assemblages are present: relatively moderate concentration of pseudo-single domain (PSD) magnetic grains in the lowest 2 meters, and more abundant fine, single domain grains (SD) in the upper part of volcaniclastic deposits. The organic silts are characterized by low concentrations of fine, SD magnetic minerals. Determinations of magnetic mineralogy are still in progress.

RAPA-22

ROCK MAGNETISM OF COOL WATER CARBONATE SEDIMENTS FROM ODP LEG 182: GREIGITE AND MAGNETITE CONTRIBUTIONS TO THE NRM

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Leg 182 of the Ocean Drilling Program was undertaken in the shelf, slope, and continental rise of the Australian Bight. The sequence recovered consists of Late Pleistocene carbonate ooze very rapidly accumulated and an incomplete Eocene through Miocene succession. Whilst much is known about the magnetic carriers and their modification in warm water carbonates, the magnetic mineralogy of cool water carbonates is poorly understood. Rock magnetic and demagnetization data indicate that the remanence carriers of these cool-water carbonate rocks are magnetite and greigite. ARM/IRM ratios as high as 0.35 suggest that contributions from single domain particles are important, supporting a biogenic origin of the remanence carriers. The majority of the samples, however, give hysteresis parameters in the pseudo-single-domain (PSD) range. Systematic variations in rock magnetic properties, laboratory remanence, and NRM intensity indicate down core modification of the remanence carriers. For instance, down core trends indicate that contributions to the IRM from a low coercivity phase increase down hole. Although this trend is generally interpreted to reflect preferential dissolution of fine-grained magnetic particles, similar down core increases in the ARM/IRM ratio suggest that concentrations of coarse multi-domain grains decrease down hole. Low temperature remanence measurements and Curie temperature determinations can easily explain these trends. Contributions from a sulfide phase (of high coercivity) are evident at shallow to intermediate depths. Below about 100 meters below sea floor, only contributions from magnetite are important. This depth roughly coincides with a zone of steep geochemical gradients in pore water chemistry, which in the Pleistocene sequence shows high concentrations of H2S. Repetitive measurements of the saturation remanence show notable decrease on a time scale of several days. This ?vanishing? remanence is thus attributed to the destruction of the meta-stable greigite phase, and is accompanied by a gradual reduction in coercive force. This sulfide bearing samples show strong decrease in remanence between 20 and 100°K, suggesting thermal unblocking of superparamagnetic (SP) grains. However, frequency dependency of magnetic susceptibility is negligible indicating that SP particles are not abundant. The decrease in remanence may thus be associated with intrinsic behavior of the magnetic sulfides.

RAPA-23

ANÁLISIS MAGNÉTICO EN SEDIMENTOS MARINOS DE LA ZONA COSTERA DE COATZACOALCOS VERACRUZ, MÉXICO

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Dentro de las regiones más contaminadas de México se considera el Río Coatzacoalcos. La actividad de la industria petrolera y petroquímica desecha una gran cantidad de metales, característica de esta contaminación son las altas concentraciones de metales (Fe y Mn) en los sedimentos. Sin embargo, estudios recientes muestran que la región del río y la zona del puerto de Coatzacoalcos no muestran este patrón. El sistema de ríos y el puerto pueden ser exportadores de contaminantes hacia la región costera, ya sea a través de flujos de metales disueltos (principalmente durante la temporada de lluvias) o a través del dragado de material sólido producido. Para el presente estudio se obtuvieron de la zona costera de Coatzacoalcos Veracruz, de la desembocadura del río Grijalva y de la zona de plataformas petroleras, ocho núcleos con longitudes entre 10 y 40 cm. De los cuales se obtuvieron 143 muestras, compuestas básicamente de arenas finas y lodos. Las muestras de sedimento fueron colectadas (abril de 2000 y abril del 2001) con la ayuda de un muestreador de caja de acero inoxidable a profundidades entre 21 y 141 m de

profundidad, a bordo del Buque Oceanográfico Justo Sierra, como parte de los cruceros oceanográficos PROMEBIO III y IV. Se determinó para cada muestra la susceptibilidad magnética a altas y bajas frecuencias y magnetización remanente natural (NRM). Se efectuaron experimentos de magnetización remanente isotermal (IRM), anhistérica y lavado magnético con campo alternos. Se observó un aumento de la susceptibilidad (k) con la profundidad, lo que implica un aumento de los minerales ferromagnéticos, en las zonas fuertemente impactadas, como también un aumento en el tamaño de partícula. Los valores de susceptibilidad obtenidos están entre los 40.2 - 76.7 x 10-6 los cuales corresponden a esquistos (Dearing, 1994). Se observó una relación entre la ubicación de las estaciones y el comportamiento de las propiedades magnéticas, que puede ser correlacionadas a los patrones de circulación de corrientes del Golfo de México, como también a los dragados efectuados sobre el Río Coatzacoalcos.

RAPA-24

APPLICATION OF MULTI-MODEL PHOTOGRAMMETRY IN PALEOMAGNETIC STUDIES OF WEST GREENLAND FLOOD VOLCANICS

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Precise estimate of the structural attitude of beds at the sampling site plays major role in obtaining precise paleomagnetic poles. The structural strike and dip are often particularly difficult to determine in flood volcanic provinces due to lack of inter-bedded sediments. During paleomagnetic field work in the West Greenland flood volcanic province in 1999 sampling sites were photographed from helicopters with stereoscopic overlap and in colour. These photographs have been set up for multi-model photogrammetry allowing three-dimensional mapping of lithological profiles and precise determination of strike and dips of distinct flow boundaries that can be traced for several hundreds of meters. Although structural dips are only from 2 to 8 degrees for the profiles we study, it is important to recognize that if not corrected, this will result in a paleomagnetic pole off-set by several degrees. In light of present discussions regarding exotic features like true polar wander and non-dipole fields, such an off-set could lead to erroneous conclusions.

RAPA-25

CARACTERIZACIÓN MINERALÓGICA, GEOQUÍMICA, Y ESPECTROSCOPÍA MÖSSBAUER DE LAS MENAS DE FIERRO Y CLORITAS ASOCIADAS DE PEÑA COLORADA, COLIMA, MÉXICO

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El mineral “Normal” está representado por magnetita masiva y magnetita diseminada. La magnetita masiva forma vetas que dan un aspecto brechado a la roca encajonante, la magnetita diseminada, está en cristales bien desarrollados que llegan a medir hasta 7 mm homogéneamente diseminados en la roca. El mineral “Amorfo” se presenta como magnetita de grano muy fino y de forma subredondeada, individual ó en agregados granulares, intercrecida con clorita de la variedad chamosita-bertierina. Ambos minerales están afectados por hidrotermalismo con depositación de magnetita, cuarzo, apatito, calcita, pirita, calcopirita, pirrotita, galena, marmatita y covelita. La Espectroscopía Mössbauer muestra diferencias estructurales marcadas en ambos tipos de magnetitas. La magnetita del mineral “Normal” tiene una estructura definida y estable, con dos Fe en estado de oxidación III (Fe_2O_3) y un Fe en estado de oxidación II (FeO). La magnetita del mineral “Amorfo” contiene radicales oxhídrilo (OH^-), en posiciones correspondientes al oxigeno, cuya ligadura puede fluctuar, cambiando alternadamente la “mezcla” de Fe II a Fe III. Por análisis térmico diferencial y gravimétrico se observó, en la magnetita del mineral “Normal” un comportamiento térmico correspondiente a una magnetita típica, es decir con una oxidación total a hematita a los 615 0 C, lo que no sucede con la magnetita del mineral “Amorfo”, que tiene una oxidación más lenta y marcada a ciertas temperaturas, oxidándose completamente a los 750 0 C. En el análisis por Microsonda Electrónica de barrido, existe una ligera disminución del contenido de fierro en la magnetita del mineral “Amorfo”, en comparación a la magnetita del mineral “Normal”. Los resultados obtenidos por estas dos últimas técnicas vienen a corroborar lo visto por espectroscopía Mössbauer, ambas magnetitas presentan un comportamiento físico y químico a nivel estructural diferente.

La clorita criptocristalina asociada a la magnetita del mineral “Amorfo” presentó también diferencias estructurales, que por difracción de rayos X, reportó una pobre cristalinidad (semiamorfa a amorfa) y valores de reflexión d = 7 A°. Esto la clasifica como una chamosita de la variedad bertierina, que al ser analizada por termoanálisis sugiere un comportamiento térmico diferencial semejante al caolín, atribuyéndole un ambiente de formación diagenético, que se mantiene en condiciones reductoras y en presencia de materia orgánica en descomposición. Nuestros resultados sugieren que el ambiente geológico y geoquímico prevaleciente durante la formación del yacimiento de Peña Colorada, fue de tipo pirometasomático de contacto, con una fase final hidrotermal, con depositación de magnetita en vetas, representado claramente por el mineral “Normal”. No así para el mineral “Amorfo” de origen principalmente hidrotermal, depositado en un ambiente que incluye la presencia y el contacto con un medio acuoso, con un PH mayor a 7. Esto explicaría el enfriamiento drástico que da lugar al minúsculo tamaño de grano de esta magnetita, así como su transporte en un medio acuoso a través de la clorita (bertierina), lo que provocó un ataque químico de la magnetita por sus bordes, dándoles un aspecto corroído y el consecuente redondeamiento de los granos. Todo indica que el mineral “Normal” y el mineral “Amorfo” poseen una evolución geoquímica similar y ambientes de depósito diferentes.

RAPA-26

ESTIMACIÓN DEL ESTADO DE DOMINIO DE MINERALES MAGNÉTICOS: CRITERIO DE HISTÉRESIS MAGNÉTICA VS CRITERIO TERMOMAGNÉTICO

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El análisis de curvas termomagnéticas continuas, obtenidas por medio de un termomagnetómetro de vibración (VSTM), nos permite la estimación del estado de dominio de minerales magnéticos mediante el estudio de magnetizaciones termorremanentes parciales (pTRM). Alternativamente se obtuvo una estimación del estado de dominio sobre muestras "hermanas" mediante el empleo de parámetros de histéresis magnética a temperatura ambiente, en términos de gráficas de cocientes de magnetizaciones contra cocientes de coercitividades (Day, 1977). La interpretación difiere dependiendo del método empleado. Esta discrepancia se debe, probablemente, al hecho de que la estimación del estado de dominio usando parámetros de histéresis magnética no tiene resolución para mezclas de diferentes tamaños de grano de un solo mineral magnético, o bien, para un conjunto de diferentes minerales magnéticos. En la mayoría de las muestras naturales es muy probable la aparición de sistemas complejos de minerales magnéticos con más de un estado de dominio característico.

RAPA-27

MICROSCOPÍA DE FUERZA MAGNÉTICA DEL MINERAL DE FIERRO DE PEÑA COLORADA, COLIMA, MÉXICO

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En microscopía de fuerza magnética (MFM) hay varias opciones de aplicación: medir el estado de una partícula magnética, determinar la estructura magnética de una transición de pared de dominio, o determinar las variaciones espaciales de la magnetización. La física de los granos con comportamiento pseudo-simple (PSD) y multi-dominio (MD) es de gran interés en paleomagnetismo porque muchos granos de óxidos ferrimagnéticos son demasiado grandes para estar en equilibrio de dominio-simple (SD, >0.1 micrones). Estos tamaños de grano se estimaron a partir de estudios de propiedades magnéticas en el mineral de fierro de Peña Colorada. Excepto por las partículas de tamaños más pequeños debajo de 0.1 micrones de SD casi uniformemente magnetizados, la magnetización remanente natural es portada por las partículas que contienen estructuras micromagnéticas no-uniformemente magnetizados, PSD o pequeños MD. Estas estructuras afectan el origen de la magnetización remanente natural y la fidelidad del registro paleomagnético contra las remagnetizaciones termoviscosas y magnetoquímicas.

Las imágenes del MFM nos proveen de rasgos micromagnéticos en nuestros granos PSD y MD de forma que entonces es posible analizar el enlace entre estructuras micromagnéticas de granos individuales y propiedades magnéticas macroscópicas de las rocas como remanencia, coercitividad y temperaturas de bloqueo. Resultados obtenidos para el mineral "normal" muestra rasgos que sugieren la presencia de una magnetización en los dominios magnéticos normal a la superficie de la muestra. También se infiere, por la forma que presentan dichos dominios magnéticos, que estos corresponden a granos con dominios de PSD a pequeños MD. En la imagen del mineral «amorfo» se pueden igual observar características semejantes al anterior, esto es: el mismo tipo de magnetización en los dominios magnéticos perpendicular a la superficie de la muestra y la correspondencia con dominios PSD y MD. Sin embargo, hay tendencia de los dominios magnéticos a agrandarse, predominando los granos MD. Además, se observa falta de claridad en la imagen (es más difusa). Ambos efectos se atribuyen a procesos de alteración (cloritización) sucedidos a este tipo de mineral, que tienen inferencia directa tanto en sus propiedades físicas como químicas y por consecuencia en sus propiedades magnéticas, debido escencialmente a cambios magnetoestáticos producidos por los granos magnéticos (anisotropía de forma de los granos) y a cambios en la estructura de los cristales (anisotropía magnetocristalina).

RAPA-28

PALEOMAGNETISMO Y TECTÓNICA EN LAS CORDILLERAS BÉTICAS

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Las Cordilleras Béticas, junto con las cadenas alpinas del Norte de África y el mar de Alborán, constituyen el segmento intracontinental más occidental de la frontera de placas entre África y Eurasia. Se pueden diferenciar en el orógeno Bético las Zonas Internas, las Zonas Externas y las unidades de Flysch. Las Zonas Externas consisten de rocas sedimentarias Mesozoicas y Terciarias mientras que las Zonas Internas estan formadas principalmente por rocas metamórficas de edad Paleozoica y Triasica. La edad de las unidades de Flysch es Cretácica a Paleógena. El orógeno Bético se desarrolló durante la convergencia entre África e Iberia entre el Mesozoico superior y el Terciario.

La región Bética ha sido objeto de diversos estudios paleomagnéticos. En la parte central y occidental de las Zonas Externas, se ha reconocido un patrón homogéneo de rotaciones en sentido horario de 40º a 60º grados de magnitud. Estas rotaciones tuvieron lugar entre el Burdigaliense (22.5 Ma) y la actualidad. En la parte oriental de las Zonas Externas, el patrón de rotaciones observado es más heterogéneo. Aunque la mayor parte de estas rotaciones sea también de carácter dextral, en determinados casos se observan rotaciones de gran magnitud, y así mismo se distinguen zonas que no han sufrido rotación alguna. Los resultados paleomagnéticos obtenidos en las Zonas Internas son mucho más escasos. En su parte occidental y central se cuenta con resultados de las peridotitas de Ronda (rotaciones en sentido horario de 46º) y de diques máficos de la región de Málaga (rotaciones de carácter dextral entre 90 y 140º). Estas rotaciones tuvieron lugar después del Mioceno inferior a medio.

Al igual que las Zonas Externas, las Zonas Internas orientales ofrecen un comportamiento más complejo y heterogéneo. El extremo sureste de la Península Ibérica se caracteriza por la presencia de paleodeclinaciones giradas en sentido horario así como antihorario, hallándose, en algunos casos, rotaciones de gran

magnitud y áreas no rotadas. En ocasiones, se observa un comportamiento dispar en áreas adyacentes.

Se presentarán resultados paleomagnéticos, y se expondrán algunos de los modelos propuestos para explicar la evolución geodinámica de las Cordilleras Béticas.

RAPA-29

THE EOCENE KRABI BASIN (SOUTHERN THAILAND): PALEONTOLOGY AND MAGNETOSTRATIGRAPHY

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We present the magnetostratigraphy of the late Eocene Krabi section from the Krabi Basin. The investigated section is about 105 m thick and consists of red and yellow siltstones, sandstones, gray claystones, lignites and limestones. 86 samples at 43 different stratigraphic levels were collected from the 105-m-thick section. The samples yielded a paleomagnetic direction, and paleomagnetic analyses give favorable demagnetization behaviors, with two magnetic components which can be isolated. Rock magnetic experiments show that the NRM generally results from the presence of (titano-) magnetite. The first component has roughly the direction of the present-day field. The second component displays only reversed polarity, with a mean direction: D = 192.34, I= -15.5, N= 71, a 95= 4.7, k= 14 (after bedding correction). Mammalian Biostratigraphy indicates a late Eocene age. Correlation to the Geomagnetic Polarity Time Scale (GPTS) relies on biostratigraphic data previously proposed for the fauna found in the same section. These correlations have been achieved by comparing variations in the sedimentation rate derived from the alternative correlation. The proposed correlation puts the Krabi section in Chron C12r or Chron C13r. This suggests sedimentation rates of 4.9 and 9.4 cm/ky respectively. This correlation suggest that the Krabi section is older than 31 Ma and younger than 34 Ma.

Keywords: Thailand; magnetostratigraphy; biostratigraphy; Eocene; mammals.

RAPA-30

SOBRE LA ENSEÑANZA DE LA DIAGRAMA DE ZIJDERVELD A LOS ALUMNOS DE PALEOMAGNETISMO

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El diagrama vectorial o de Zijderveld es una herramienta gráfica que sirve para analizar la estabilidad en la dirección y el modo del decaimiento de la intensidad de la magnetización remanente. Por ello es necesario la clara y total comprensión de esta técnica para entender el paleomagnetismo moderno. Sin embargo, el diagrama de Zijderveld aún no es ampliamente entendido por la mayoría de los miembros de la comunidad de las geociencias. Nosotros observamos sistemáticamente, durante las clases de paleomagnetismo, que la mayoría de los estudiantes tienen diversos problemas en el manejo y comprensión de este diagrama ortogonal. Más aún, es prácticamente imposible leer sobre el gráfico la declinación e inclinación magnéticas. Con estos antecedentes proponemos una representación más simple de los datos paleomagnéticos. Esta representación tiene las siguientes ventajas: 1) es mucho más sencillo, lo que permite que sea comprendido aún por personas no familiarizadas con el paleomagnetismo, 2) permite la lectura directa de la declinación e inclinación como también su estabilidad durante los tratamientos y 3) se puede obtener información acerca de la intensidad (temperatura o campo de desbloqueo) directamente de las curvas de decaimiento de la intensidad de la remanencia. Esta presentación únicamente tiene el propósito de ayudar a los estudiantes y principiantes en paleomagnetismo para un mejor entendimiento del diagrama de Zijderveld y de los procesos de desmagnetización de las rocas.

RAPA-31

A RECONNAISSANCE MICROFOSSIL AND MAGNETIC STRATIGRAPHY OF A MIOCENE SAYULA-ISLA SEQUENCE, VERACRUZ, MEXICO

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A pilot Bio-magnetostratigraphic study has been performed on the paleontologically well constrained Early-Middle Miocene sequence at Sayula-Isla (Southern Veracruz, Mexico). Rock magnetic investigations indicate the presence of both, high and low coercivity minerals. Specimens subjected to progressive thermal demagnetization procedures, show that nearly all of them exhibit a low temperature magnetization component, close to the present-day field before bedding correction, and a high temperature one, keeping almost the same direction and polarity, considered as the characteristic Miocene magnetization. The comparison of the Sayula-Isla polarity zonation poses some problems because of scarce microfossil content in studied sections. Although, more data are required to better constrain the local GPTS (Geomagnetic Polarity Time Scale), reasonably good correlation was obtained for the Early-Middle Miocene biozones in the Salina del Itsmo basin. Valuable data to the construction of a standard magnetostratigraphic and paleontological scale are contributed by the results from this leading study.

RAPA-32

NEW PALEOMAGNETIC RESULTS FROM THE ORDOVICIAN OF THE QINLING BELT, CENTRAL CHINA

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We have obtained paleomagnetic results from early Ordovician basaltic rocks (the Erlangping ophiolite Formation) sampled over two areas in the Qinling belt, central China. After removal of a low-temperature component that resembles both Tertiary and present field directions and fails a fold test, a well-grouped characteristic component (ChRM) remains in Early Ordovician basalts that is of dual polarity. The ChRM passes a middle Ordovician (480+/-7 Ma) fold test at more than 95% confidence level. The corresponding paleopole places Qinling belt at paleolatitude of 14°S in early Ordovician time. The paleopole position of the Erlangping formation is different from the coeval poles for the North and South China Blocks, suggesting that the sampling localities in Qinling belt are remains of an independent terrane between the NCB and SCB. The late Mesozoic to Recent remagnetization found from the samples of the Erlangping Formation re-emphasizes the extent of magnetic overprinting in eastern China. The remagnetization is probably related to the magmatic activities of the Yanshanian orogeny, which coincide with the subduction of the Kula plate beneath the Asian continental margin and the opening of the Bohai Sea, both of which began in the Juro-Cretaceous and continued to the Cenozoic time.

RAPA-33

FIRST MAGNETOSTRATIGRAPHY STUDY OF THE CONTINENTAL MIDDLE MIOCENE OF MEXICO: (SUCHILQUITENGO FORMATION CENTRAL MEXICO)

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New paleomagnetic data from central Mexico provide a magnetostratigraphic framework to correlate the Suchilquitongo Formation to the Geomagnetic Polarity Time Scale (GPTS). One hundred and eighty paleomagnetic samples were collected from 38 sites belonging to two sections. The sections were characterized by a succession of cream to light pink to gray color, thin to medium bedded tuffaceous sand and siltstone, partly silicifed limestone and dominantly light green ignimbrite deposited in a fluviolacustrine environment. Remanences are generally characterized by two components, a present day field component with low unblocking temperature up to 350°C, and a characteristic component with unblocking temperature up to 580-610°C. The characteristic component is interpreted as primary based on antipodal polarity directions. Six sites at the top of the section (incl.=40.5°; decl.=11.3°, a95= 1.4 and K= 471) have a mean paleomagnetic direction rotated clockwise about 15° with respect to the expected Miocene direction derived from the North American polar wander curve (incl.=354°, decl.=30°). According to the biochronologic age, the magnetostratigraphic results from mammals bearing Middle Miocene continental section in the Suchilquitongo type area indicate that the composite section can be correlated with chron C5Dn-C5Cn3n. An age of 16.97 Ma can be assigned to the fossilifereous sequence.

RAPA-34

ESTRATIGRAFIA MAGNETICA DE LAS PROVINCIAS VOLCANICAS DE GEORGIA (CAUCASO DEL SUR)

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Se presentan resultados de un estudio paleomagnético y de magnetismo de rocas en muestras de las regiones de Djavakheti, Khrami y Kazbeki, en Georgia (Cáucaso). Se tomaron muestras de 247 coladas volcánicas subaéreas y de 3 estratos sedimentarios lacustres intercalados entre éstas, pertenecientes a 44 localidades. El objetivo del trabajo consistía en el estudio de la estabilidad magnética y paleomagnética de muestras para determinar su potencial en estudios de magnetoestratigrafía y paleointensidad. Los experimentos de magnetismo de rocas demostraron que la magnetización remanente está asociada principalmente a la presencia de magnetita de tipo PSD. 113 coladas volcánicas y un estrato sedimentario dieron como resultado una magnetización de polaridad normal, mientras que otras 130 coladas volcánicas presentaron una magnetización de polaridad inversa. 4 coladas volcánicas y 2 estratos sedimentarios se caracterizan por mostrar direcciones correspondientes a una polaridad intermedia. Se determinó una dirección paleomagnética media para todas las unidades volcánicas, salvo las de polaridad intermedia, de D=4.7º, I=58.3°, k=28 y a95=3.7º y se estableció una magnetoestratigrafía preliminar de las provincias volcánicas georgianas.

RAPA-35

LATE PALEOZOIC PALEOMAGNETISM AND PALEOGEOGRAPHY OF OAXAQUIA REVISITED

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Paleogeographic reconstructions of western equatorial Pangea must incorporate crystalline basement terranes of Mexico and Central America. This remains a taxing prospect because available paleomagnetic data for the region are limited. An exception is the Late Paleozoic, for which data are available for several terranes in southern Mexico. In Oaxaca, southeast directed and shallow magnetizations have been reported for the Paleozoic cover of the Oaxaca Complex and for sites in paragneisses of the Oaxaca Complex north of the Huitzo granite. These magnetizations have been interpreted as Late Paleozoic secondary magnetizations but the evidence for this interpretation is not conclusive. These directions

indicate relative stability with respect to the North America craton. Here we report similar directions for 3 sites in anorthosites of the Oaxaca Complex and for 3 sites in La Carbonera stock, a small mid-Permian intrusion exposed along the toll-road Tehuacán-Oaxaca. A discordant U-Pb age of 275±4 Ma (interpreted as the crystallization age) has been reported for the La Carbonera stock. Six additional sites were collected in the Huitzo granite and in charnockites and gneisses of the Oaxaca complex, but they did not yield useful data. Magnetizations of La Carbonera intermediate compositions are nearly univectorial and of moderate coercivity and moderate laboratory unblocking temperatures, suggesting that they reside in a cubic phase such as magnetite. Associated mafic rocks are overprinted by viscous components; partially overlapping coercivity spectra precludes isolation of the characteristic remanence but great-circle trajectories can be used to estimate its direction. Combined, all compositions give a mean of D=168°, I=6° (n=3 sites, alpha95=15°). We interpret the magnetization of La Carbonera stock as a primary thermal remanence, thus further supporting previous interpretations of Late Paleozoic partial remagnetization of the Oaxaca Complex and its sedimentary cover. Rocks of the Carbonera stock do not provide sufficient data to average secular variation, but combined with the anorthosite sites and four sites in the paragneisses north of the Huitzo granite, provide a good estimate of the mid-Permian time averaged paleofield direction. The pole derived from these data indicates that displacement of the Oaxaca terrane relative to North America is limited to movement along a line of equal latitude, displacement that cannot be recognized by paleomagnetic data.

RAPA-36

MAGNETOSTRATIGRAPHY AND PALEONTOLOGY OF THE CONTINENTAL MIDDLE MIOCENE OF THE AÏT KANDOULA BASIN (MOROCCO)

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The Aït Kandoula basin is one of richest known Miocene mammal localities in the South of the High-Atlas. Research of the fossiliferous levels undertaken in the past several years in this basin has yielded some micromammal associations and a limited quantity of large mammals.

A magnetostratigraphic study has been carried out on a Middle Miocene fluviatile/lacustrine deposit of the Aït Kandoula basin. 55 samples in 48 different stratigraphic levels were collected from a thickness of 206 m of the section. These paleomagnetic samples were analyzed, and rock magnetic experiments show that the natural remanence magnetization (NRM) generally results from the presence of magnetite or hematite. The Azdal section that has been sampled displays three reversed and four normal polarities. The correlation to the Geomagnetic Polarity Time Scale (GPTS) relies on the biostratigraphic data previously proposed for the fauna found in the levels of same section. The proposed correlation puts the Azdal section in the Chron C5Ar and in the upper part of C5AAn. This suggests sedimentation rates of 25.6 cm/ky.

The Beni-Mellal fossiliferous layer is the first one known in the Middle Miocene of North Africa. This correlation makes it possible to allow an age of 13 My for the Beni-Mellal layer whose fauna is identical to the level 1 of the Azdal section.

RAPA-37

MAGNETOSTRATIGRAPHY AND ROCK-MAGNETISM OF THE CRETACEOUS/TERTIARY BOUNDARY SECTION OF LA CEIBA, NORTHEASTERN MEXICO

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Results of a magnetostratigraphic and rock-magnetc study of the Cretaceous/Tertiary (K/T) boundary section of La Ceiba are reported. La Ceiba is located in the Tampico-Mizantla carbonate basin in Puebla State, northeastern Mexico. The section is characterized by three sedimentary clastic units, which have been described in detail in previous studies of K/T sections of northern Mexico. Its basal unit is formed by an alternation of calcareous reddish-greenish to gray shales, with calcareous clay layers. Unit II is 1.10-m thick and includes a shperulitic layre at the base and four sandstone layres. The top of the K/T sediments is marked by a clay layer and is covered by the Paleocene Velazco Formation. The Palaeocene is represented by 0.7-m dark brown-gray calcarenites with interbedded greenish-gray fine-grained material. Twenty-eight oriented cores were drilled from several beds in the K/T clastic units and the Paleocene sediments. All samples were measured in the laboratory (low-field magnetic susceptibility, NRM intensity and direction). Af and thermal demagnetization was used to investigate on the vectorial composition and stability. The magnetic mineralogy was further studied by imparting samples an isothermal remanent magnetization (IRM) and measuring magnetic hysteresis parameters using the MicroMag system. Well-defined characteristic magnetizations were isolated and used to construct a polarity stratigrapphy for the K/T section. The clastic unit II and Paleocene sediments present a reverse polarity magnetization, which correlates with the expected polarity within 29r chron that includes the K/T boundary at 65 Ma.

RAPA-38

MAGNETOSTRATIGRAPHY AND THE AFRICAN-EUROPEAN LATE MIOCENE TERRESTRIAL FAUNA EXCHANGES

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A magnetostratigraphic study has been carried out on a middle Miocene to upper Pliocene lacustrine sedimentary deposit in the central part of the Aït Kandoula basin, which contains micromammal faunas and is situated in the southern High Atlas (Morocco). On the whole, 113 samples were subjected to paleomagnetic analysis: 60 out of the 113 studied samples representing 52 different stratigraphic levels yielded a paleomagnetic direction and at least the polarity could be recognized in 42 specimens. 11 specimens were submitted to AF demagnetization. The mean direction for normal-polarity samples was D=349.4, I=50.7 (N=36, a95=4.5, k=27) and for reversed polarity samples D=191.2, I=-53.4 (N=16, a95= 12.32, k=9). These results yielded a polarity sequence which we interpret as spanning

from Chron C5n.2n to the beginning of Chron C3n.4n. This interpretation relies on biostratigraphic data previously proposed for a part of the continental fauna found in the basin. This result is in agreement with the 40Ar/39Ar dating previously carried out on a volcanic ash layer, which provided an age of 5.9±0.5 Ma [1] and which is shown here to be reversely magnetized. This layer is correlated here with the reverse polarity zone corresponding to Chron C3r.

Biostratigraphic studies on the same section have shown that the micromammal levels extend here only from Middle Vallesian to Upper Turolian (Upper Miocene). Four localities have yielded western European species of micromammals, indicating transmediterranean terrestrial faunal exchanges between these two continents during the late Miocene. The European murid rodent Occitanomys is recorded for the first time in North Africa in level 8 of the Afoud section, an age younger than 5.32 Ma being assigned to this level by the present study. Level 1 of the same section yields the lagomorph Prolagus cf. michauxi, with an age of 6.1 Ma.

The magnetostratigraphic data suggest therefore that the beginning of terrestrial faunal exchanges between North Africa and Western Europe took place in subchron C3An.1n, at about 6.1 Ma, some 0.4 Myr before the beginning of the Messinian salinity crisis.

RAPA-39

PALEOMAGNETISMO DE LA SECUENCIA VOLCÁNICA DEL RÍO GRANDE DE SANTIAGO (FAJA VOLCÁNICA MEXICANA): REVISITADO

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Realizamos un estudio paleomagnético, de magnetismo de rocas y de paleointensidad de ls secuencia volcánica Miocénica de la Faja Volcánica Mexicana cercana a Guadalajara. Un total de 37 flujos de lava consecutivos (mas de 300 núcleos paleomagnéticos estándar orientados) se colectaron en la localidad de Lazo. Se efectuaron varios experimentos de magnetismo de rocas para identificar los portadores magnéticos y obtener información sobre su estabilidad paleomagnética. Esos experimentos combinados con estudios microscópicos muestran que el principal mineral magnético es titanomagnetita pobre en Ti asociada con exsoluciones de ilmenita. Mediciones contínuas de suscptibilidad con la temperatura y experimentos de histéresis, resultaron en muchos casos en curvas razonablemente reversibles con puntos de Curie cercanos a los de magnetita con dominios pseudo-sencillo. Se observaron dos inversiones geomagnéticas en la sección compuesta de 300 m de espesor. De acuerdo a la dispersión de direcciones medias de flujo, la variación paleosecular fue menor que la observada en general durante el Cenozoico superior. Considerando nuestros resultados paleomagnéticos junto con datos radiométricos disponibles, parece que las unidades volcánicas se han emplazado durante un tiempo relativamente corto de 1 o 2 Ma. La dirección media paleomagnética calculada de todos los datos es I=31.1°, D=354.6°, k=124 y a95=2.1°. 61 muestras con mineralogía magnética primaria aparentemente preservada y sin magnetizaciones secundarias, que principalmente pertenecen a la zona de polaridad inversa se usaron para determinación de paleointensidad por el método de Thellier. Nuestros resultados al respecto sugieren la existencia de un bajo relativo en la intensidad del campo geomagnético con variaciones ligeras.

RAPA-40

MAGNETOSTRATIGRAPHY OF THE K/T BOUNDARY FROM THE CHICXULUB IMPACT CRATER

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We report the magnetostratigraphy of K/T boundary and the first 15 meters of the Tertiary sedimentary sequence recovered from the Chicxulub Impact Crater by the UNAM Scientific Shallow Drilling Program. Three geomagnetic polarities were determined from the upper Cretaceous to the first 15 meters of the lower Tertiary sedimentary sequence. The Polarities recorded span from the magnetochron 29R to 27R in a 15 m interval, ~2.5 Ma time span, yielding sedimentary rates of 1 m/170 ky for boreholes UNAM-5 (110 km from the center of the crater) and UNAM-7 (127 km from the center of the crater). In these boreholes we found a 50 cm interval between the 29R and the 29N chrons, suggesting that the sedimentation during the 100,000 years from the K/T boundary to the polarity shift, was either interrupted or eroded. Within borehole UNAM-6 (152 km from the center of the crater) it appears that the sedimentary sequence containing magnetochron 29N is missing, the lack of the suevite-like unit, the long duration of a reversal event within the base of the sequence and an unusually low sedimentary rate of 1 m/300 ky, indicate an important hiatus within the K/T boundary and the sedimentary sequence.

RAPA-41

PALEOMAGNETISM AND TECTONICS OF MEXICO, CENTRAL AMERICA, CARIBBEAN AND NORTHERN SOUTH AMERICA

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Paleomagnetic data for widely distributed localities from Mexico, Central America, northern South America and Caribbean are summarized and discussed in terms of their tectonic and paleogeographic implications. Large-scale continental collision of North and South America, including intervening terranes, provide constraints for the plate reconstructions of Atlantic bordering continental landmasses. Most paleoreconstructions imply an allochthonous nature for most of Mexico, Central America and Caribbean. Mesozoic and early Cenozoic evolution of the region was dominated by the drift apart of the major continental plates of North and South America following break up of the Pangea supercontinental assembly. The evolution of the Gulf of Mexico and Caribbean Sea is associated with the relative motion history of North and South America, which creates the space for the oceanic basin development. However, documentation of the origin and development of the two basins has proved difficult to decipher for a variety of factors including that oceanic crust of the Caribbean plate is allocthonous. Estimation of relative positions and flow lines or motion history for continental plates separated by ocean basins

created by in situ seafloor spreading can be easily determined from the magnetic anomalies and transform fracture zones. Finite plate rotation parameters can be derived, and trajectories of one continent relative to the other can be estimated. Paleomagnetic studies provide quantitative information on paleolatitude, latitudinal translations and relative rotations of large and small tectonic blocks, assisting in distinguishing and characterizing the various tectonic domains in the region. Separation of North and South America is associated with development of the Gulf of Mexico and Caribbean Sea, translation of terranes now forming Mexico, Central America and western North America, eastward motion of the proto Caribbean plate, drift of Cuba and Haiti and formation of Antilles island arc.

RAPA-42

ROTATED AND TILTED DOMAINS AROUND THE COSO GEOTHERMAL FIELD, CA; PALEOMAGNETISM AND GEOCHEMICAL CORRELATION OF PLIOCENE LAVAS REVEALS THE TECTONICS DRIVING A GEOTHERMAL ANOMALY

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Paleomagnetic analysis and geochemical correlation of Pliocene basalts and andesites of the Coso Range, California have allowed us to discern clockwise vertical-axis rotations and down-to-the-west tilting of different domains within the study area since about 3.2 Ma. We have accomplished this by measuring the paleomagnetic remanence of chemically distinctive lavas and comparing mean directions between localities. This reveals about 11.2º±6.5º of clockwise rotation and no tilting of three localities in a heavily faulted region previously considered to be accomodating pure extension, relative to two nearby localities outside the heavily faulted region. This clockwise rotation probably results from Eastern California shear zone dextral motion through the area.

In addition we have determined paleomagnetically that one locality in the Coso geothermal field has tilted between 25º and 52º down to the northwest – a significant result considering the lack of Pliocene paleohorizontal indicators in the geothermal field. This flow also provides a marker, revealing at least 200 m of vertical offset along a range front fault which loosely bounds the Coso geothermal field on the east. This normal faulting, and tilting in the geothermal field probably results in upwards advection of heat in some regions relative to the surroundings while clockwise block rotation in the adjacent region result in no such advection and thus, no known geothermal potential.

RAPA-43

THE PALEOINTENSITY DATASET: STRENGTHS AND WEAKNESSES

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IAGA Working Group I-3 (Paleomagnetism) and I-4 (Rock Magnetism) c group initiated in the 1989 the establishment of various paleomagnetic databases among which a paleointensity data base. This paleointensity database was initially constructed by Maseru Kono and Hidefumi Tanaka. Since 1995, Mireille Perrin took in charge the keeping of the database with the help of Elisabeth Schnepp for the update of the 0-5 Ma interval and Valeri Shcherbakov (Russia) for Russian data. Only absolute paleointensity determinations from igneous rocks and baked contacts are registered in the database and each entry corresponds to a mean result for a given cooling unit. Archaeological artifacts are not included. All methods of paleointensity determinations are taken into account as well as all field configurations (normal, reverse or transitional polarity). More than 2000 data are now available from almost 200 references. Although entries almost doubled in the past 5 years which indicates a renewed interest in this type of studies, the quality of the data as well as their temporal and geographic distributions remains extremely uneven and a proper time-averaging of the paleomagnetic field cannot yet be expected, except maybe for the first Ma. However long term features of the dipole field as the existence of a period of low field during most of the Mesozoic are now firmly established even though the transition mode between this Mesozoic low and the Quaternary high field remains unclear. The available paleointensity data set, with its strengths and weaknesses, will be reviewed.

RAPA-44 CARTEL

ESTUDIO PALEOMAGNÉTICO Y DE PALEOINTENSIDAD DE LAS ROCAS VOLCÁNICAS DEL OLIGOCENO EN CUAHÚTEMOC-LA JUNTA, CHIHUAHUA (NORTE DE MÉXICO)

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Se realizaron estudios detallados paleomagnéticos, de paleointensidad y de magnetismo de rocas en formaciones volcánicas de Oligoceno en Chihuahua (norte de Mexico) para obtener las condiciones específicas que nos ayuden a descifrar la evolución tectónica del sur del Cinturón Orogénico Coordillerano de Norteamérica y la intensidad del campo geomagnético durante ese período de tiempo. La edad de las unidades volcánicas varía entre 33 y 25 Ma de acuerdo a datos disponibles. Los experimentos de magnetismo de rocas revelan que en muchos casos la remanencia la porta la magnetita resultante de oxi-exsolución de la titanomagnetita original durante el enfriamiento inicial de las rocas. Los espectros de temperaturas de desbloqueo y las altas coercitiviades apuntan relativamente a pequeños granos magnéticos

de dominio pseudo-sencillo para esas titanomagnetitas. También en muchos casos se observaron componentes únicas en las gráficas del proceso de desmagnetización. Nueve sitios muestran magnetización con polaridad inversa, tres normal y una unidad intermedia. Evidencia de una fuerte remagnetización producida por relámpago se detectó en un sitio. Combinando todos los datos actualmente disponibles para el norte de México, obtuvimos una dirección media paleomagnética bien definida para el Eoceno-Oligoceno con I=48.5°, D=337.1°, k=20, a95=6.8, N=24, la que esta desviada en sentido contrario a las manecillas del reloj de la dirección esperada estimada de la curva de desplazamiento polar aparente de Norteamérica. Esto sugiere una rotación tectónica sobre eje-vertical en el sentido mencionado de alrededor de 16° relativa al cratón de Norteamérica. La transición de compresión Laramide a extension de Cuencas y Sierras ocurrió durante el Oligoceno, alrededor de 32-30 Ma. La rotación tectónica puede entonces reflejar una extensión este-noreste durante el Cenozoico medio-tardío.

Se seleccionaron 23 muestras para experimentos de paleointensidad de Thellier en razón a su bajo índice de viscosidad, estabilidad en su magnetización remanente y razonable reversibilidad en las curvas termomagnéticas continuas. Solo 12 muestras, provenientes de tres flujos de lava basáltica, dieron estimaciones de paleointensidad confiables con un momento dipolar virtual (VDM) medio que varía de 3.96 a 4.65 x1022 Am2. La combinación de datos mexicanos con los resultados de paleointensidad disponibles de igual calidad dan un VDM medio de 4 x 1022 Am2, lo que es comparable o ligeramente mayor que los VDMs medios calculados para el período de “campo bajo” del Mesozoico, pero significativamente más bajo que el valor actual. Esta baja intensidad puede correlacionar con la relativamente alta razón en variación paleosecular propuesta para alrededor de los 30 Ma por varios autores.

RAPA-45 CARTEL

MAGNETISMO DE ROCAS Y PALEOINTENSIDAD DE UNA SECUENCIA DE FLUJOS BASÁLTICOS

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Se reportan resultados de diez flujos secuenciales de lava pertenecientes al volcán Xitle (2000 BP) con 124 núcleos que cubren un espesor total aproximado de 35 m. Se midieron propiedades magnéticas de muestras seleccionadas de cada flujo: temperatura Curie, magnetización de saturación, susceptibilidad magnética vs. temperatura, intensidad de remanencia y parámetros de histéresis. La desmagnetización por campos alternos muestra una sola componente (característica) que coincide con la dirección de campo geomagnético actual. Los VDM calculados muestran todos la esperada polaridad normal. Observaciones de los óxidos magnéticos indican que se trata de titanomagnetitas oxidadas deutéricamente. Resultados de propiedades magnéticas indican titanomagnetitas pobres en Ti como portadores de la magnetización. Se determinó paleointensidad por el método de Thellier modificado usando doble calentamiento y chequeos de la pTRM, obteniéndose resultados de razonable buena calidad según los parámetros de calidad (f-, g- y factor-q). El valor promedio de paleointensidad es de 52 mT que es consistente con los datos globales para este período.

RAPA-46 CARTEL

PALEOMAGNETIC AND PALEOINTENSITY STUDIES IN THE POPOCATEPETL VOLCANO, CENTRAL MEXICO

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We report on a paleomagnetic and paleointensity study of volcanic units of the Popocatepetl volcanic complex, at the volcanic front of the Trans-Mexican volcanic belt. Popocatepetl is one of the largest composite calc-alkaline active volcanoes of the magnetic arc, and it has been active since 1994. It is formed by thick sequences of lava flows, tuffs, breccias and unconsolidated pyroclastic deposits, which represent repetitive periods of construction separated by periods of destruction of the volcanic complex. Rock-magnetic experiments reveal that remanence is carried in most cases by Ti-poor titanomagnetites, resulting of oxy-exsolution of original titanomagnetite during the initial flow cooling. Unblocking temperature spectra and relatively high coercivities point to ‘small’ pseudo-single domain magnetic grains for these (titano)magnetites. Single-component, linear demagnetization plots were observed in most cases. All studied sites yield normal polarity magnetization, in agreement with previous studies. An evidence of strong lightning-produced magnetization overprint was detected for one site. Combining all paleomagnetic data currently available for the lava flows associated to Popocatepetl Volcano, we obtained a mean paleodirection N=15, I=35.4, D=345.7°, k=21, a95=8.5. Twenty-five samples were pre-selected for Thellier palaeointensity experiments because of their stable remanent magnetization and reasonably reversible continuous thermomagnetic curves. Only 14 samples, coming from 4 individual basaltic lava flows, yielded reliable paleointensity estimates with the flow-mean virtual dipole moments (VDM) ranging from 5.9 to 9.2 x 1022 Am2. Our results, although not numerous, are of high technical quality and comparable to other paleointensity data recently obtained on younger lava flows. NRM fractions used for paleointensity determination range from 35 to 96% and the quality factors varies between 3.4 and 46.9, being normally greater than 6. Mean VDM obtained in this study is 7.2 ± 1.4 which is slightly lower than present day value.

RAPA-47 CARTEL

RECONOCIMIENTO PALAEOMAGNÉTICO DEL TERRENO GUANIGUANICO, OESTE DE CUBA

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Se realizó un estudio paleomagnético y de magnetismo de rocas en el Terreno Guaniguanico (Jurásico-Cretácico; 15 sitios, 112 núcleos orientados) para establecer la magnetoestratigrafía de forma preliminar y obtener algunas condiciones restrictivas de la evolución tectónica del oeste de Cuba. Los experimentos de magnetismo de rocas indican que los principales portadores de remanencia son las titanomagnetitas pobres en titanio. En unas cuantas muestras parecen estar presentes dos fases magnéticas: algunas espinelas, que saturan en campos magnéticos moderados y goetita, con coercitividades mayores. En dos unidades es evidente la presencia de hematita (o mezcla de espinelas y hematita). En muchos casos las paleodirecciones características pudieron determinarse sobre 300°C. Once sitios dan polaridad normal y cuatro inversa. Las zonas de polaridad pueden correlacionar tentativamente con los crons CM29 - C24 en la escala de referencia geomagnética de tiempo-polaridad. La paleodirección media calculada para todos los sitios es Dm=335.7°, Im=43.1°, k=11, a95=12.3 y N=15. El paleopolo correspondiente es Plat=66.4°, Plong=205.8°, K=13 y A95=11.1. Este polo no es significativamente distinto de los polos para el Jurásico-Cretácico de Norteamérica. Esto sugiere que no han ocurrido ni grandes desplazamientos latitudinales ni deformación desde el Jurásico, en contraste a modelos tectónicos previamente propuestos.

RAPA-48 CARTEL

MICROPULSACIONES GEOMAGNETICAS DURANTE EL PASO DE EJECCIONES DE MASA CORONAL INTERPLANETARIAS (ICME)

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En este trabajo presentamos observaciones micropulsaciones geomagneticas registradas en la superficie de la Tierra usando magnetometros flux gate diseñados por la Universidad de Los Angeles, UCLA. Las pulsaciones fueron medidas durante el paso de 17 estructuras relacionadas con ejecciones de masa coronal interplanetarias. Nosotros investigamos las micropulsaciones antes del choque, y durante la funda y el ejecta. Antes del choque no hubo ocurrencia de Pc3 en todos los eventos pero vimos ocurrencia de Pc4 y Pc5. Durante la funda las Pc3 aparecen y hay un incremento en el numero de Pc4 y Pc5, finalmente durante el ejecta el numero de pulsaciones Pc3 se incrementa pero no mucho el numero de pulsaciones en las bandas Pc4 y Pc5. No encontramos claras diferencias en la distribuciones de amplitudes durante las tres fases. Pero en la distribución de la duración de las pulsaciones se muestra un claro cambio durante las tres fases mostrando un corrimiento de la distribución de cortas duraciones de las pulsaciones antes del choque a duraciones largas de las pulsaciones durante la funda y el ejecta.