Geofísica Internacional (1994), Vol. 33, Num. 1, pp. 153-160

Paleomagnetism of the Talpa de Allende and Mascota grabens, western Mexico: A preliminary report

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Received: October, 25, 1993; accepted: November 29, 1993.

RESUMEN
Varios autores han propuesto que el Bloque de Jalisco del oeste de México ha sido sometido a deformaciones internas asociadas con un movimiento hacia el noroeste con respecto a la placa Norteamericana. Estas deformaciones habrían resultado en la formación de varias fosas tectónicas dentro de la parte norte del Bloque. Dos de estas fôsas son la de Mascota y la de Talpa de Allende.

Los análisis de datos paleomagnéticos de seis distintos flujos de lava recientes encontrados en las fosas de Mascota y Talpa no indican movimientos estadísticamente significativos en la zona. Más precisamente, la dirección esperada (campo dipolar axial, D=0°, I=37°) se encuentra dentro del cono de confianza de 95% de la dirección paleomagnética promedia (D=352.2°, I=24.0°, α_{95}=16.8°).

Sin embargo, la proximidad del polo de referencia Norteamericano y del límite de confianza a 95% del polo paleomagnético indica que datos adicionales podrían permitir la definición de un movimiento significativo hacia el Norte, de la parte del Bloque de Jalisco, o la definición de un basculamiento local de la zona.

PALABRAS CLAVE: Paleomagnetismo, tectónica, Jalisco, México.

ABSTRACT
The Jalisco Block of Western Mexico is thought to be undergoing internal deformation associated with its proposed NW translation relative to the North American plate. This deformation has resulted in the formation of several graben structures within the northern portion of the Jalisco Block; two of which are the Talpa de Allende and Mascota grabens.

An analysis of paleomagnetic data collected at six distinct, recent, lava flows within the Talpa de Allende and Mascota grabens fail to indicate any statistically significant (95% confidence level) motions in this area. Specifically, the expected direction of the geocentric axial dipole field at the site location (D=0°, I=37°) lies within the 95% confidence cone associated with the mean direction calculated for these six sites (D=352.2°, I=24.0°, α_{95}=16.8°).

However, the flattening parameter associated with the mean direction of these six sites (12.8° ± 13.1°), along with the close proximity of both the North American reference pole and the expected field direction at the sites to the corresponding 95% confidence cones of the paleomagnetic results, indicates that additional data may allow for the resolution of the proposed northward movement of the Jalisco Block or of local tilting associated with faulting.

KEY WORDS: Paleomagnetism, tectonics, Jalisco, Mexico.

INTRODUCTION

The Jalisco Block of Western Mexico is thought to be a forearc sliver torn from, and translated northwest relative to, the North American plate as a result of either oblique convergence between the Rivera and North American plates (Serpa *et al.*, 1989; Bandy, 1992) or the initiation of seafloor spreading within the Colima graben which forms the SE boundary of the Jalisco Block (Figure 1), (Luhr *et al.*, 1985; Allan *et al.*, 1991). Associated with its separation from the North American plate, the Jalisco Block has undergone recent internal deformation (Wallace *et al.*, 1992; Richter and Carmichael, 1992) produced by either a relocation of subduction related arc volcanism (Pardo and Suárez, 1993) or by trench parallel extension due to a northeastward progressive increase in the obliquity of convergence between the Rivera and North American plates (Bandy, 1992). This deformation consists of several fault (both normal and dextral strike slip) bounded basins which contain recent (<6Ma) alkaline lavas (Luhr *et al.*, 1989; Lang and Carmichael, 1990, 1991; Righter and Carmichael, 1992; Bandy and Maillol, unpublished data). Two such basins, the Talpa de Allende graben (herein referred to as the Talpa graben) and Mascota graben (Figure 1), are the focus of this report.

At present, paleomagnetic data collected along the boundaries of the Jalisco Block (Figure 1) (Campos-Enríquez *et al.*, 1987; Urrutia-Fucugauchi *et al.*, 1988; Böhnel *et al.*, 1992) fail to indicate latitudinal displacements or rotations which are significant given the uncer-

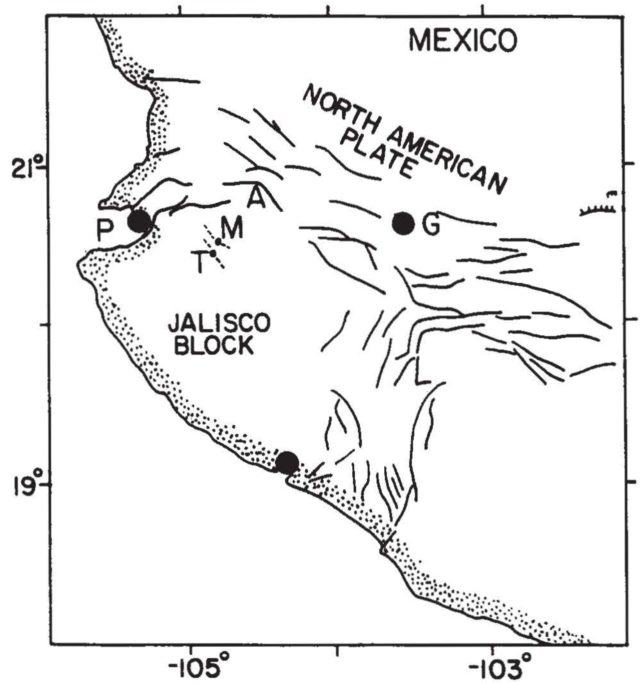

Fig. 1. Location map of study area. M= Mascota, T= Talpa de Allende, G= Guadalajara, P= Puerto Vallarta, A= Ameca River Tectonic Depression.

tainties inherent in these studies; except for a small clockwise rotation for the Puerto Vallarta batholith (Böhnel *et al.*, 1989). However, local block rotations are resolvable in the paleomagnetic data from the Ameca River Tectonic Depression located along the northeast boundary of the Jalisco Block (Nieto-Obregón *et al.*, 1992). Thus, if significant movement has occurred along the faults associated with the internal deformation of the Jalisco Block, or if there has been recent NW motion of the Jalisco Block relative to the North American plate, then local block or tectonic rotations may be discernible in paleomagnetic studies of the recent alkaline laves associated with this deformation.

The purpose of this study is to determine via paleomagnetic studies whether or not the recent lavas located within the Talpa de Allende and Mascota grabens show any evidence for rotations since their emplacement. Further, if significant rotations have occurred, is their sense consistent with either the proposed NW movement of the Jalisco Block relative to the North American plate, or the proposed faulting within these grabens?

GEOLOGICAL SETTING

The Mascota and Talpa grabens are located west of Guadalajara, approximately 160km from the Middle America trench, in the State of Jalisco. These NW-SE oriented grabens lie within the deeply eroded ignimbrite province of the Sierra Madre Occidental. They are separated from one another by a narrow (approximately 5km) horst block of the Sierra El Arrastradero which consists of Oligocene silicic arc volcanics. Within both grabens, numerous alkaline lava flows were erupted primarily as small cinder and lava cones. The orientation of both these lava cones and the two rivers (Río Talpa and Río Mascota) which flow through the two valleys suggest that these lavas erupted along NW oriented normal and right lateral-strike slip faults (Lange and Carmichael, 1990; Bandy and Maillol, unpublished data). Lange and Carmichael (1990) report that one flow in the Talpa valley exhibits a right lateral offset across the Río Talpa, indicating recent right lateral strike slip motion along the fault which controls the location of the river.

The flows within these two valleys are characterized by a great variety of lava types: hydrous potassic lavas (minette, absarokite, leucitite, spessartite and kersantite) associated with basaltic andesites. The petrology of these lavas has been studied by Lange and Carmichael (1990). These authors propose a very recent age for the alkaline volcanic activity, based primarily on the morphology of the flows. No radiometric dating is available for the Talpa graben, but recent datations indicate ages younger than 0.5Ma for the Mascota graben flows (Carmichael, pers. comm.). In particular, one flow, north of the town of Mascota and mainly unvegetated has yielded an age of 3,000 y.

DATA

Samples were obtained at six sites representing six distinct flows; three in the Mascota valley and three in the Talpa valley (Figure 2, Table 1). Our sites 1, 3 and 6 correspond to flows sampled by Lange and Carmichael (1990). No suitable and accessible sampling site could be found in the 3,000 year flow (see Geological Setting section).

Standard cores, 2.5 cm in diameter and 6 to 10 cm long, were drilled using a portable gas powered corer and oriented with an inclinometer and magnetic compass. Local magnetic declination was measured at each site by taking sun bearings, and these values were used to correct magnetic readings. The cores were subsequently cut in the laboratory into 2.5x2.5cm cylindrical specimens. The number of specimens, their distribution among the six sites and their lithologies are given in Table 1.

PALEOMAGNETIC RESULTS

For each of the six sites, four specimens were chosen for a detailed pilot experiment involving both alternating field (AF) and thermal demagnetization. AF demagnetization was carried out in a Schonstedt demagnetizer and thermal demagnetization in a specially designed oven. All remanences were measured in a Geofysika JR5 spinner magnetometer.

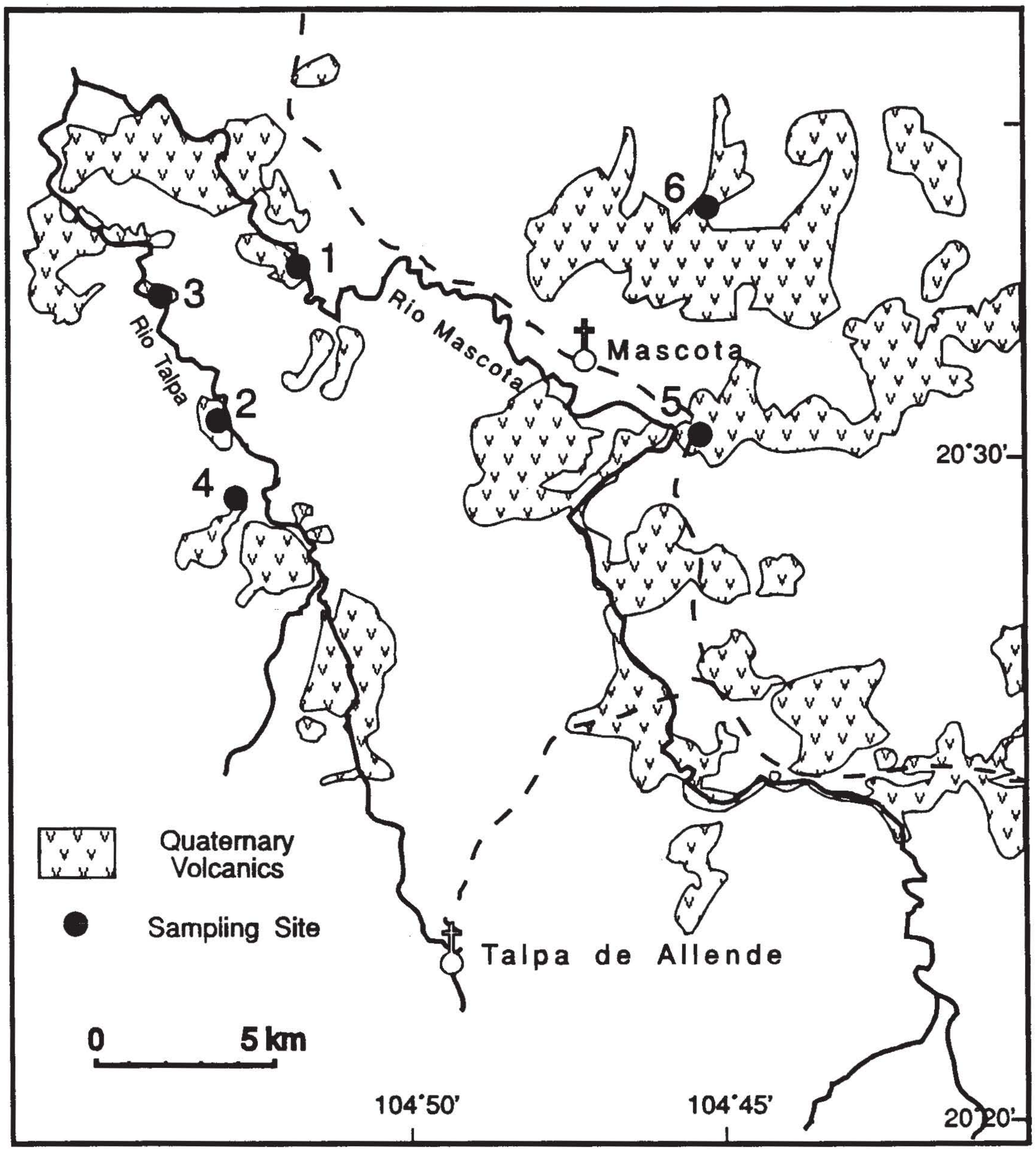

Fig. 2. Simplified geological map of the sampling area illustrating site locations.

Table 1

Detail of sampling sites.

Site Name	Geog. Coord.	n/N	Lithology
MAS-1	20°33.25'N / 104°51.9'W	8/20	Basaltic Andesite
MAS-2	20°30.6'N / 104°53.25W	6/15	Minette
MAS-3	20°32.60'N / 104°53.8W	7/19	Basaltic Andesite
MAS-4	20°29.4'N / 104°52.7'W	8/19	Minette
MAS-5	20°30.7'N / 104°.45.5'W	7/18	Kersantite
MAS-6	20°34'N/ 104°45.7'W	8/21	Kersantite

n/N: number of cores/specimens collected at each site; lithology from Lange and Carmichael (1990).

The results of this pilot experiment show that all specimens exhibit a simple behavior during demagnetization, which is characteristic of only one or two components of magnetization (Figures 3, 4). When present the secondary component is removed between 0 and 20mT. Thermal and AF demagnetization show similar results when performed on specimens from the same core, but thermal treatment appears less effective due to overlapping of the blocking temperature spectra of the two components (Figure 4). Most of the magnetization is destroyed at temperatures between 550°C and 580°C, which indicates titanomagnetite as the most likely magnetic carrier.

After the pilot experiment, the remaining samples were AF demagnetized at 3 or 4 different steps, between 30mT and 90mT according to the results of previous experiments. Among the 112 specimens, 107 yielded stable characteristic directions of remanence; the other 5 did not respond satisfactorily to treatment due to intensive weathering and were, therefore, not used in the paleomagnetic analysis. Characteristic directions were calculated using principal component analysis (Kirshvink, 1980) and least squares line fitting using at least three points. The site mean directions are given in Table 2 and their stereographic projection are shown in Figure 5a. The resulting virtual geomagnetic pole (VGP) for each site and the paleomagnetic pole for the combined sites are shown in Figure 6.

The most immediate result is that two sites located in the Talpa Valley have reversed polarities (MAS2 and MAS4), the other four are normal (Figure 5a). The presence of these two reversed flows indicates that the age of the volcanism, at least in the Talpa graben, extends back to at least the Matuyama chron (>0.78 Ma).

The mean direction for the six sites is D=352.2°, I=24.0°, k=16.9, α_{95}=16.8°. The rather large scatter of the directions already evidenced by the large value of α_{95} becomes more apparent in a stereographic projection (Figure 4b). The low internal dispersion of individual site directions (Table 2) indicates that this scatter cannot be due to large uncertainties in the determination of paleomagnetic directions.

As mentioned above, the rocks studied here are thought to be recent, and if no tectonic rotations are involved, one would expect the mean paleomagnetic direction to coincide with that of the geomagnetic axial dipole field. For the region of interest (latitude=20°N), this corresponds to D=0° and I=36.8°. The comparison shows a discrepancy of 7.8° in declination and 12.8° in inclination between the observed and expected paleomagnetic directions. However, these differences are not statistically significant since the expected direction (dipole field) still falls within the 95% confidence cone of the paleomagnetic result. This is also reflected in the values for the apparent rotation (R) and the apparent flattening (F) parameters (Demarest, 1983); R= -7.8° ± 14.4°, F= 12.8° ± 13.1°.

SUMMARY

The results of the paleomagnetic study at six sites within the Talpa and Mascota valleys do not indicate any statistically resolvable rotation or tilting of the sites since the emplacement of the lavas. This suggests that if local block rotation are associated with movement along the faults in the area of the Talpa and Mascota valleys or if the Jalisco Block has undergone a NW motion relative to the North American plate, the magnitude of these rotations must be small.

However, even though these results show no statistically significant motions, two observations suggest that the addition of more sites is warranted. First, the North American reference pole location (Figure 6) and the mean field direction at the sites (Figure 5b) lie very close to the boundary of the 95% confidence cone associated with the paleomagnetic pole and mean paleomagnetic field direction at the sites, respectively. Given the small number of sites used in the present study and the large value of α_{95} associated with the mean paleomagnetic field direction and the paleomagnetic pole, the additional sites may reduce the size of the 95% confidence cones, perhaps resulting in a significant difference between the observed and expected values. Given the available data, the apparent flattening parameter is only 0.3° too low to allow us to propose either that the Jalisco Block has undergone a northward displacement relative to the North American plate or that the area has been tilted, plunging toward the South.

A northward displacement is consistent with the proposal of a NW translation of the Jalisco Block relative to the North American plate (Luhr *et al.*, 1985), keeping in mind that only N-S motions can be detected by paleomagnetic methods. Reasonable estimates of the amount of NW motion (Allen *et al.*, 1991) suggest a maximum of 50 km during the last 10 Ma, which is probably too small to be detected by paleomagnetism. Therefore, if the addition of more data allows us to resolve a significant movement, its most likely interpretation will be a local tilting of the area after emplacement.

Second, although the relatively large dispersion of the results may be caused by secular variation, it is also possible that it may be produced in part by differential rotations between the sites. Thus, a more dense sampling around the individual sites may permit us to resolve whether or not differential rotations took place. Presently, the collection of additional data is underway.

Table 2

Detail of paleomagnetic results.

Site Name	NRM intensity (A/m)	N	Dec/Inc (deg.)	R	k	α95 (deg.)	VGP Long/Lat (deg.)
MAS-1	5.11	20	2.6 / -3.4	19.89	175.1	2.5	68.3E /67.6N
MAS-2	2.51	15	180.4 / -50.0	14.96	312.8	2.2	103.0W / 79.7N
MAS-3	1.06	18	342.0 / 20.1	17.94	287.3	2.0	137.4E /69.9N
MAS-4	6.54	19	173.6 / -19.3	18.95	353.3	1.8	106.4E / 77.8N
MAS-5	5.92	16	341.9 / 20.1	15.79	69.9	4.4	137.7E /69.8N
MAS-6	2.11	19	355.2 / 36.7	18.73	67.9	4.1	164.4E / 85.5N
MEAN		**6**	**352.2 /24.0**	**5.70**	**16.9**	**16.8**	**122.0E /79.9N**

N: number of specimens used in calculating the mean directions; R, k, α_{95}: Fisher statistics parameters; VGP: virtual geomagnetic pole corresponding to the site mean direction.

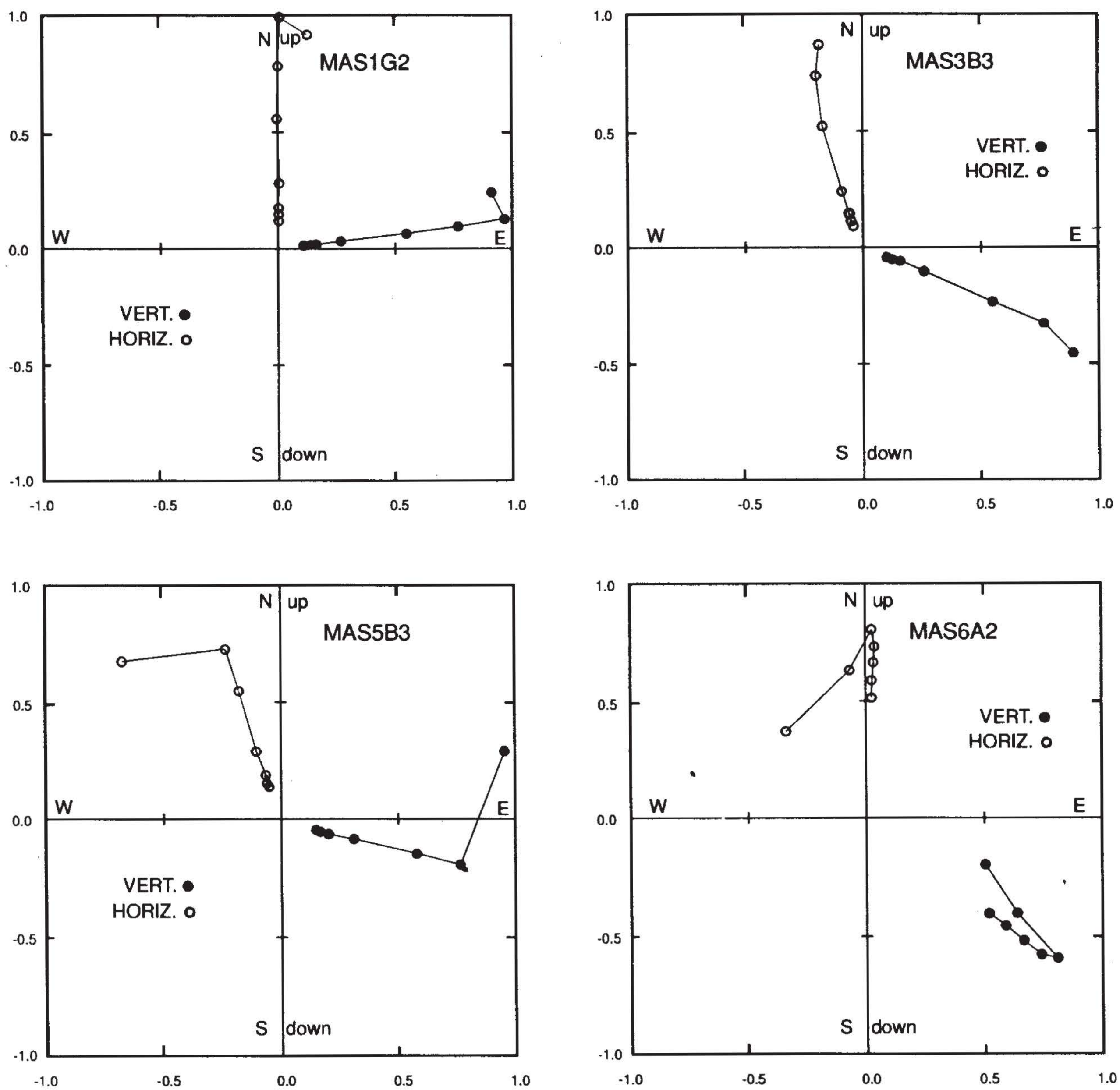

Fig. 3. Examples of normalized orthogonal component plots showing the behavior of two samples during AF demagnetization. Demagnetization steps are: 0, 10, 20, 40, 60, 80, 100 mT.

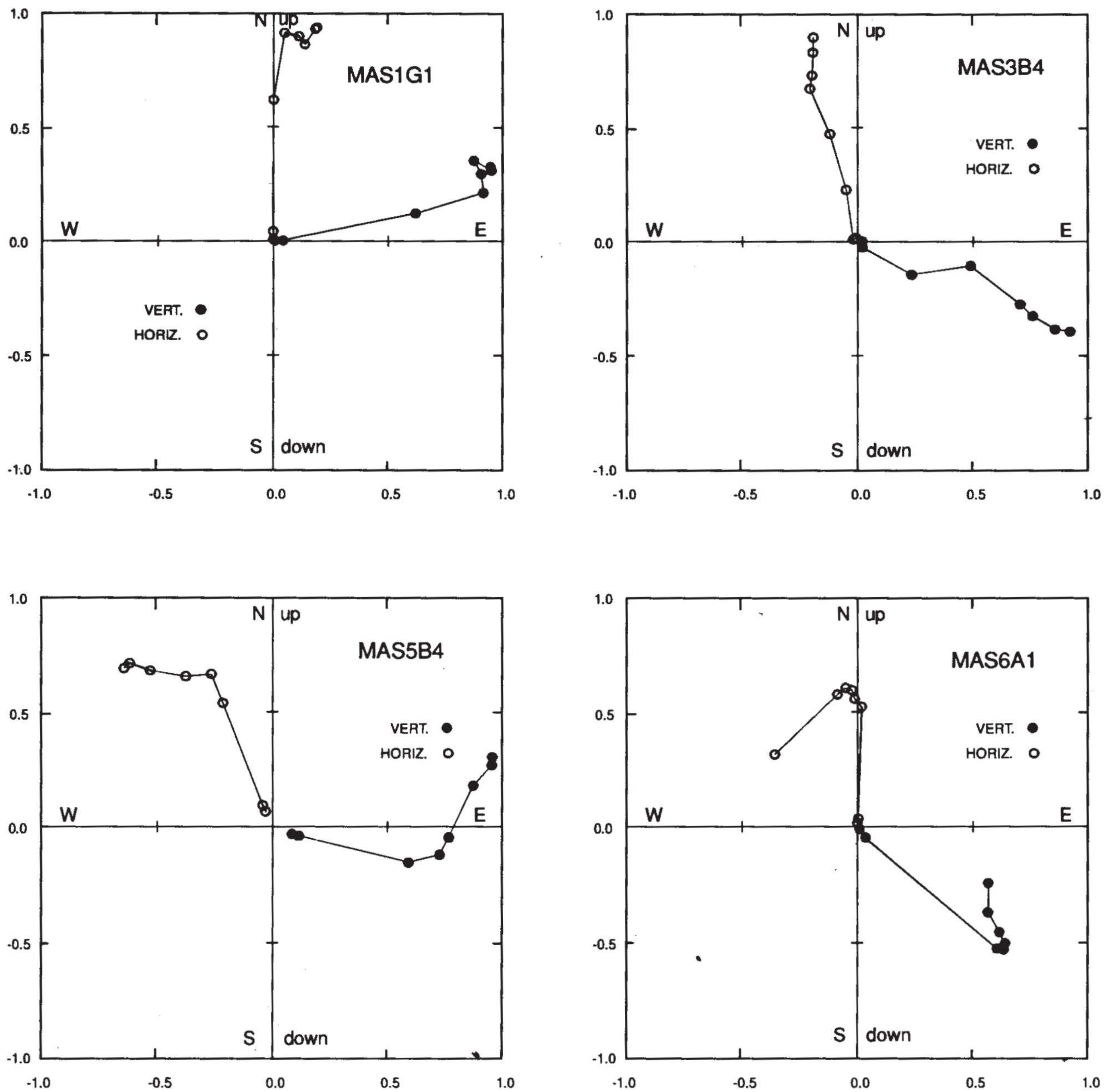

Fig. 4. Examples of normalized orthogonal component plots showing the behavior of two samples during thermal demagnetization. Demagnetization steps are: 0, 100, 200, 300, 400, 500, 550, 580 °C.

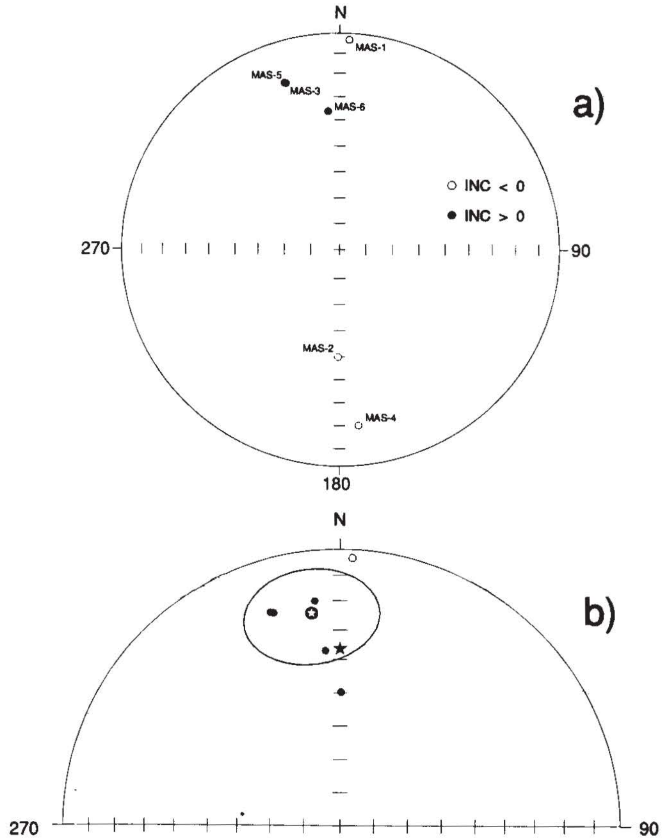

Fig. 5. Stereographic projection of (A) individual site directions and (B) individual site directions (circles) (reversed polarity directions are inverted to allow comparison with normal sites), mean direction (circled star) and its 95% confidence cone, and direction of the axial dipole field (star) at the mean site location.

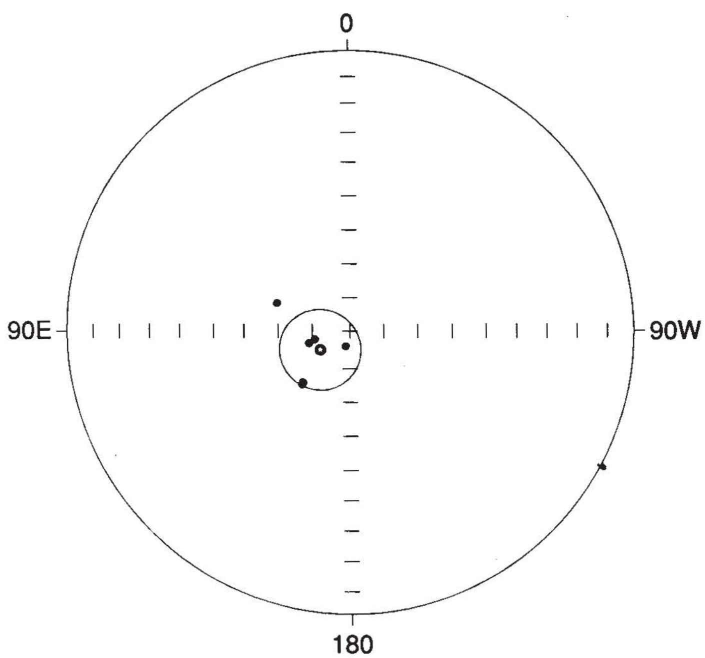

Fig. 6. Stereographic projection illustrating the VGP's (circles) and the mean paleomagnetic pole (circled star) for the six sites and its 95% confidence cone. The 0.0 Ma North American reference pole lies at 90°N (cross).

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