*Geof. Int. Vol. 22-1, 1983,* pp. 87-110

# *PRELIMINARY PALAEOMAGNETIC STUDY OF LOWER TERTIARY VOLCANIC ROCKS FROM MORELOS AND GUERRERO STATES*

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## RESUMEN

Resultados de un estudio paleomagnético preliminar de siete unidades volcánicas del Terciario Temprano, expuestas en los estados de Morelos y Guerrero, aparentemente no concuerdan con datos similares del norte de México. Las unidades estudiadas son dos lavas de la Formación Balsas (Paleoceno-Eoceno), dos tobas de la Riolita Tilzapotla (edad K-Ar de 49 ± 3 m.a.) y dos tobas y una lava andesítica del Mioceno (?). Los resultados paleomagnéticos, suponiendo que representan el campo magnético ambiental al tiempo del emplazamiento de las unidades, podrían ser explicados en términos de rotaciones tectónicas de las áreas estudiadas en sentido contrario a las manecillas del reloj. Dichas rotaciones estarían asociadas con compresión regional a lo largo de un sistema de fallas laterales izquierdas, aparentemente siguiendo la traza del eje volcánico mexicano. Los resultados son considerados insuficientes para una interpretación tectónica y se requiere de más datos paleomagnéticos para apoyar la posibilidad de rotaciones tectónicas en el área.

## ABSTRACT

Mean palaeomagnetic directions and pole positions derived from seven lower Tertiary volcanic units exposed in central-southern Mexico after alternating field and thermal demagnetization diverge from corresponding data of northern Mexico. The studied units are two lavas of the Palaeocene-Eocene Balsas Formation, two tuffs of the Riolita Tilzapotla (K-Ar date of 49 ± 3 m.y.) and two tuffs and an andesitic lava of Miocene (?) volcanics. The results could be explained in terms of relative counterclockwise tectonic rotations of the sampling areas, possibly associated with regional compression and shear acting on blocks cut by large lateral strike-dip faults. However, we feel that more data are required to support this interpretation before a tectonic model can be put forth.

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## INTRODUCTION

Major portions of Mexico are covered by thick sequences of subduction-related igneous rocks of various ages, which suggests that plate convergence between parts of Mexico and oceanic lithospheric plates has been a common feature since the Mesozoic and probably since older times. Relative tectonic movements between parts of Mexico and the rest of the North American plate, and the destruction of the geologic record on the oceanic side by plate subduction, make the study of the tectonic evolution of the area rather difficult. Present-day plate convergence is occurring between the southwestern part of Mexico and the Cocos plate at the Middle America Trench (Fig. 1). Volcanic activity is concentrated in the Mexican volcanic belt (MVB), which traverses central Mexico from the Pacific Ocean to the Gulf of Mexico. The belt is not parallel to the trend of the trench, but extends some $15^o$ - $20^o$ obliquely with respect to it (Molnar and Sykes, 1969). This anomalous geometric arrangement had led many workers to examine alternatives in which the MVB is not genetically related to plate subduction (Molnar and Sykes, 1969; Mooser, 1969, 1972; Gunn and Mooser, 1970; Negendank, 1977; Watkins *et al.*, 1971; Bloomfield, 1973). The general chemical composition of the belt is dominated by dacitic and andesitic rocks (Dickinson, 1968; Watkins *et al.*, 1971; Whitford and Bloomfield, 1976; Urrutia Fucugauchi and Del Castillo, 1977) which supports that the belt is related to plate subduction. Molnar and Sykes (1969) suggested that the magmatic activity is controlled by a zone of crustal weakness. Gastil and Jensky (1973) reported that right-lateral strike-slip displacements have occurred along the trace of the MVB during late Cretaceous-early Tertiary and late Tertiary times. On the other hand, Walper (1980) has suggested that the movements along the trace of the belt are predominantly of left-lateral strike slip nature. Pal and Urrutia-Fucugauchi (1977) also presented a model suggesting large-scale movements in the zone, but involving compression and rotations. Direct palaeomagnetic evidence on this problem is not available, as all studies on Cretaceous and Cenozoic rocks had been made in areas within or towards the north of the MVB (Urrutia-Fucugauchi, 1979). Data for older rocks are not enough to define, without ambiguity, the tectonic evolution of the area. Thus, palaeomagnetic investigations of Mesozoic and Cenozoic rocks from southern Mexico seemed worthwhile; this paper reports some results from lower Tertiary volcanic rocks exposed in central-southern Mexico. As such it is a preliminary report on a continuing effort directed toward the understanding of the tectonic evolution of Middle America.

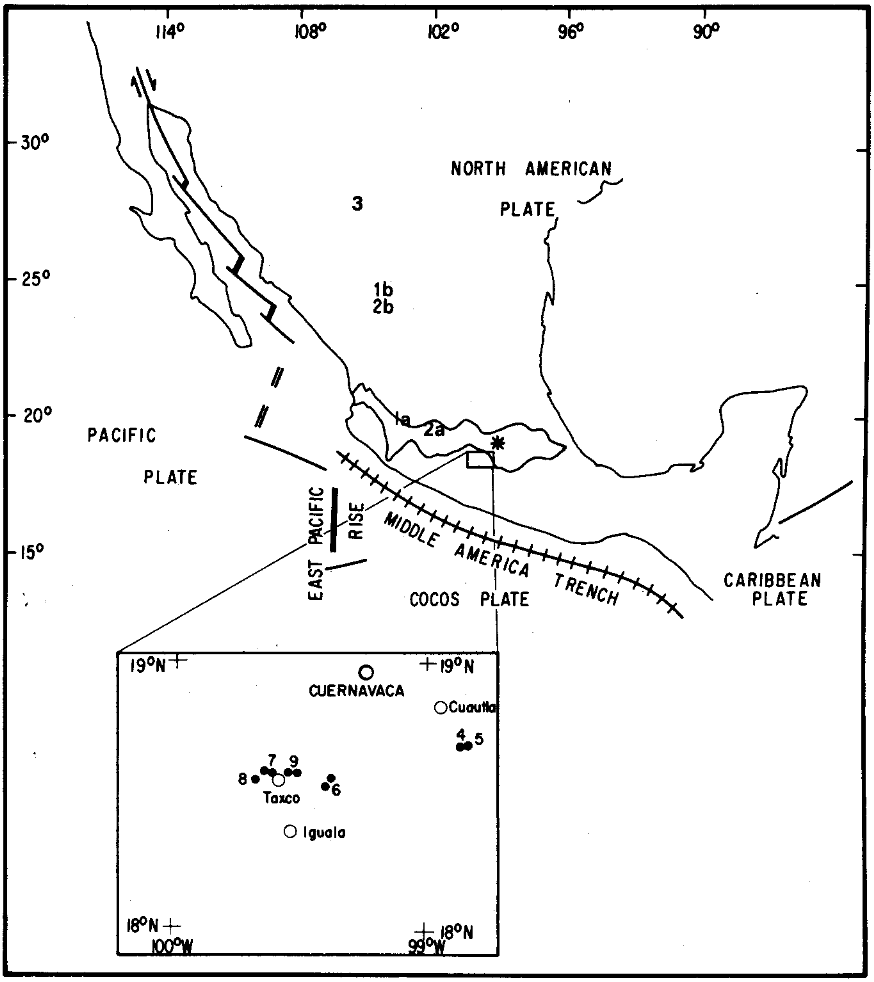


Fig. 1. Schematic tectonic map of Mexico showing location of palaeomagnetic sampling areas (indicated by numbers): (1a) Santiago volcanics; (1b, 2b) Durango volcanics; (*) Valley of Mexico Miocene volcanics, 1c, e; (2d) Jalisco volcanics; (3) Capping series, Chihuahua; (*) Valley of Mexico Oligocene volcanics, 2a, c; and (□) Central-southern Mexico. This last group is composed of: (4) Jantetelco granodiorites; (5) Tepexco volcanics; (6) Miocene volcanics; (7) Tilzapotla formation; (8) Balsas group volcanics; and (9) Balsas group red sediments. See table 4 for details.

## GEOLOGY AND SAMPLING

Recent geological studies (Ortega-Gutiérrez, 1980; de Cserna *et al.*, 1980) indicate that the oldest subaerial volcanism (Tetelcingo Formation) exposed in central - northern Guerrero and Morelos States, southern Mexico occurred during the late Cretaceous (Maestrichtian). This volcanism of calcalkaline character was followed by a thick continental sequence, the Balsas Formation (Fries, 1960), which comprises conglomerates, evaporites, sandstones, siltstones, tuffs and volcanic flows forming a typical molasse deposit (de Cserna, 1965). Local and regional stratigraphic correlations suggested an age of Eocene to early Oligocene for the Formation (Fries, 1960, 1966). This has been recently modified by de Cserna *et al.* (1980), who suggest an age of Palaeocene to early Oligocene; the lower limit is extended down based on two K-Ar dates from volcanics immediately below the Balsas deposits. The age range may actually be Palaeocene to Eocene, which is supported by K-Ar dating from the Riolita Tilzapotla, which, in one of the sampling areas near Taxco village northern Guerrero (Fig. 1) covers deposits of the Balsas Formation. There, hand samples were collected from four different units: two rhyolitic tuffs of the Riolita Tilzapotla (TT), and two dacitic-rhyodacitic lava flows probably of the Balsas Formation (BG). In a second sampling area, hand samples were collected from three units in exposures along the road between Iguala and Cuernavaca City (Fig. 1). These units, two tuffs (MV1, MV2) and an andesitic lava flow (MV3), have been assigned to the Miocene (Fries, 1960). Samples were oriented in the field with magnetic compass. In the laboratory, a total of 87 specimens, 2.5 cm diameter and 2.5 -2.2 cm height, were cut from the 49 samples.

## POTASSIUM - ARGON DATING

Whole-rock K-Ar dating was carried out on a hand sample from one of the rhyolitic tuffs (tuff number TT1). This yielded a date of 49 ± 3 m.y. (Linares and Urrutia-Fucugauchi, 1981), which indicates an Eocene age for the volcanic activity of the Riolita Tilzapotla. The Late Oligocene age previously assigned to Tilzapotla (Fries, 1960) was based on a Pb-$\alpha$ dating on zircons of samples from a locality in Morelos State. The date of 26 m.y. (Jaffe *et al.*, 1959) is not considered to be representative for the Tilzapotla; consequently the age assigned to this volcanism is Eocene as indicated by the new K-Ar date. The radiometric study was carried out in the Instituto de Geocronología y Geología Isotópica (INGEIS) of the Universidad de Buenos Aires, Argentina; the equipment and techniques used are those described by Linares and Valencio (1975). I should also mention that further studies may be necessary to support the age of the volcanism, since Ortega-Gutiérrez (pers. comm., 1982) indicates that unpublished Rb-Sr and K-Ar dates on samples from an area in Morelos state give an age of 36 m.y.

## PALAEOMAGNETIC STUDY

The remanence direction and intensity were measured with a Digico spinner magnetometer and the axial susceptibility was measured with a low-field susceptibility bridge. The stability and vectorial composition of the natural remanent magnetization (NRM) were investigated for one or two pilot specimens, chosen from characteristic groups formed according to initial NRM data, by alternating field (AF) and thermal demagnetization. Results are described separately for each unit.

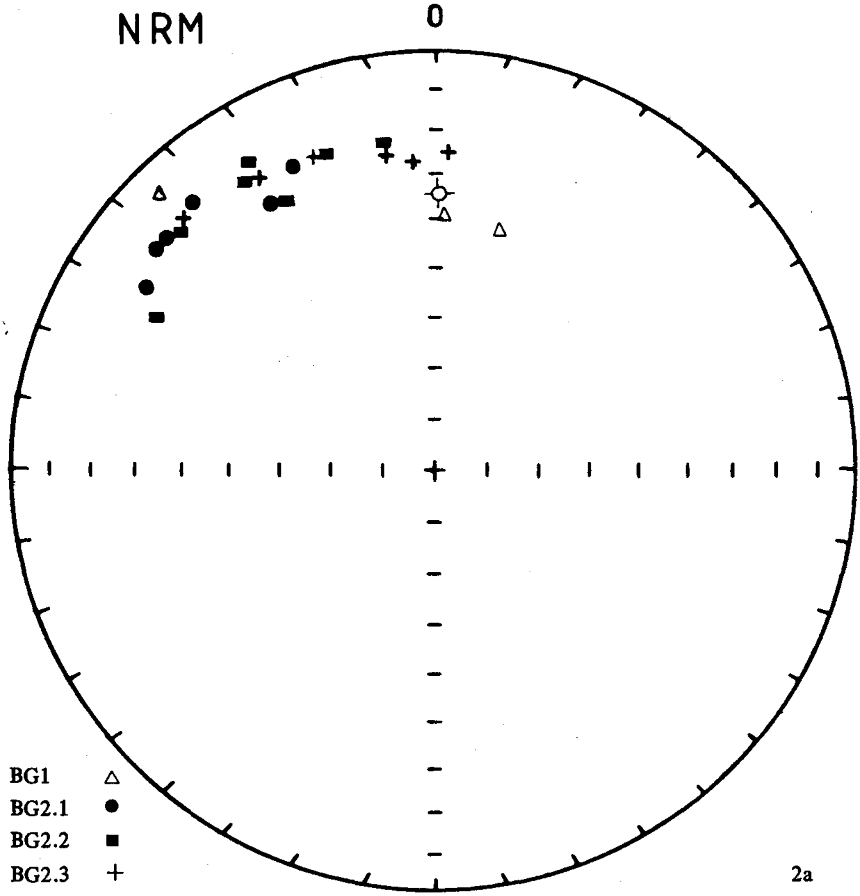
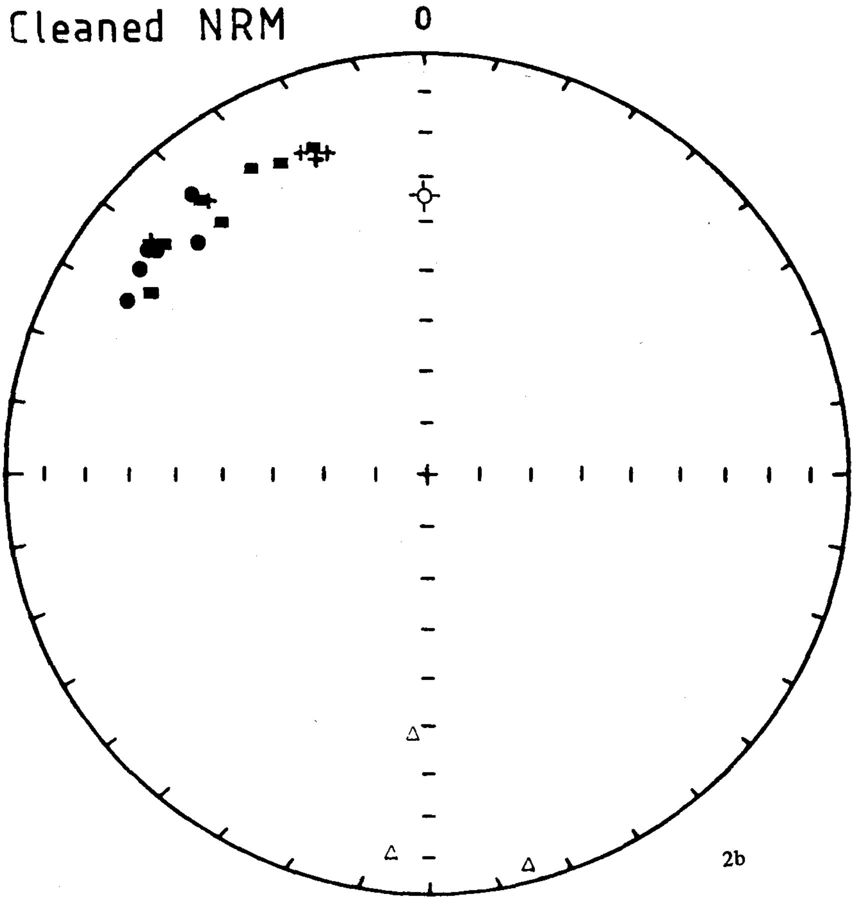
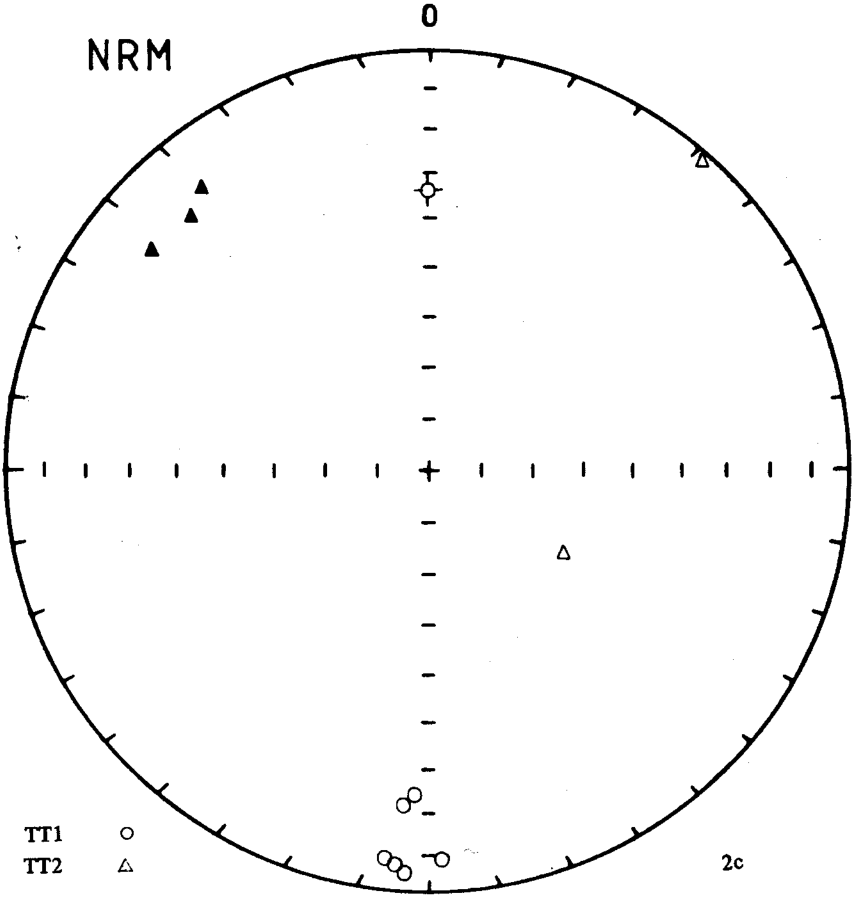


Fig. 2. Summary of palaeomagnetic results. Directions plotted on equal area stereonets, closed symbols represent positive inclinations and open symbols represent negative inclinations. The present site dipolar direction is indicated by ○. (a) Initial remanent directions of BG1 and BG2 lava flows of the Balsas group. (b) Cleaned remanent directions of BG1 and BG2. (c) Initial remanent directions of TT1 and TT2 tuffs of the Riolita Tilzapotla. (d) Cleaned remanent directions of TT1 and TT2. (e) Initial remanent directions of MV1 and MV2 tuffs and MV3 lava flow of the Miocene volcanics. (f) Cleaned remanent directions of MV1, MV2 and MV3.



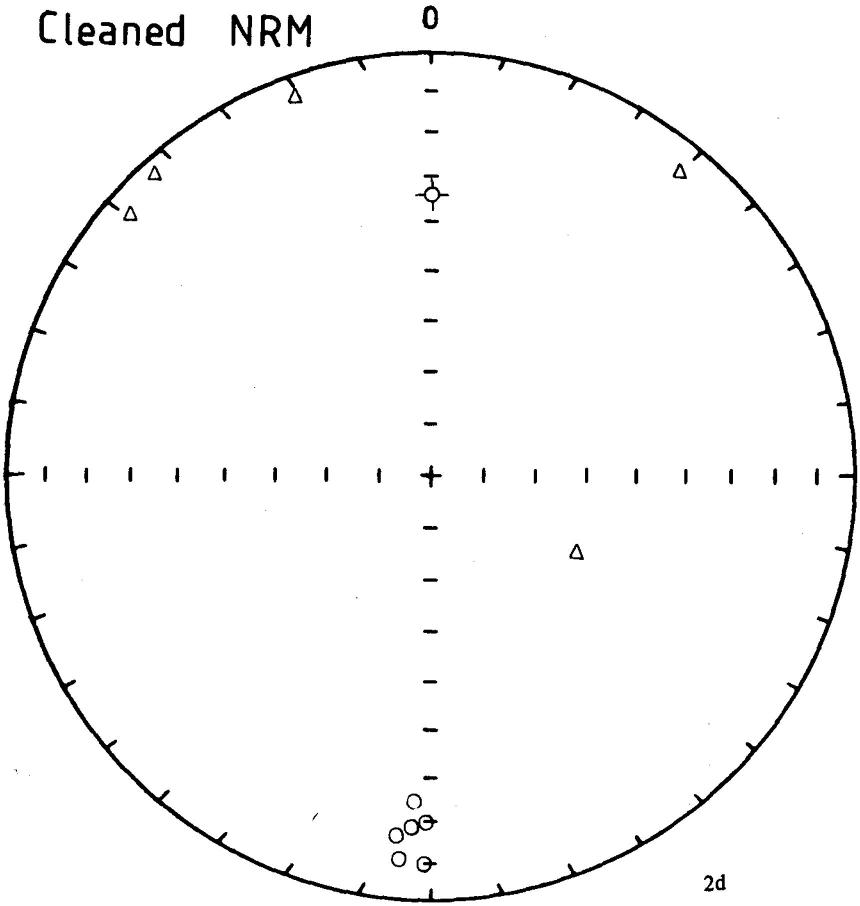
The initial remanence directions from the lava flow (BG1) of the Balsas Formation presented a normal polarity with two samples close to the present dipolar direction (Fig. 2a). The samples were collected some few centimeters apart from a contact between the lava flow and a small narrow vertical dike, within the apparently affected zone in the lava flow (darker colour of baked zone). Thermal demagnetization of one pilot specimen from each hand sample revealed a high-blocking temperature component (Fig. 3). With the thermal treatment the directions moved from the normal northerly direction to an intermediate southerly direction (Fig. 2b), which indicates the effects of the intrusion. The initial remanent directions from the second lava flow (BG2) of the Balsas Formation present a normal polarity (Fig. 2a). AF demagnetization of three pilot specimens revealed high directional stability. Bulk AF demagnetization of the remaining specimens improved the directional grouping (Fig. 2b). The mean direction of BG2 diverges from that of BG1 (Table 1).

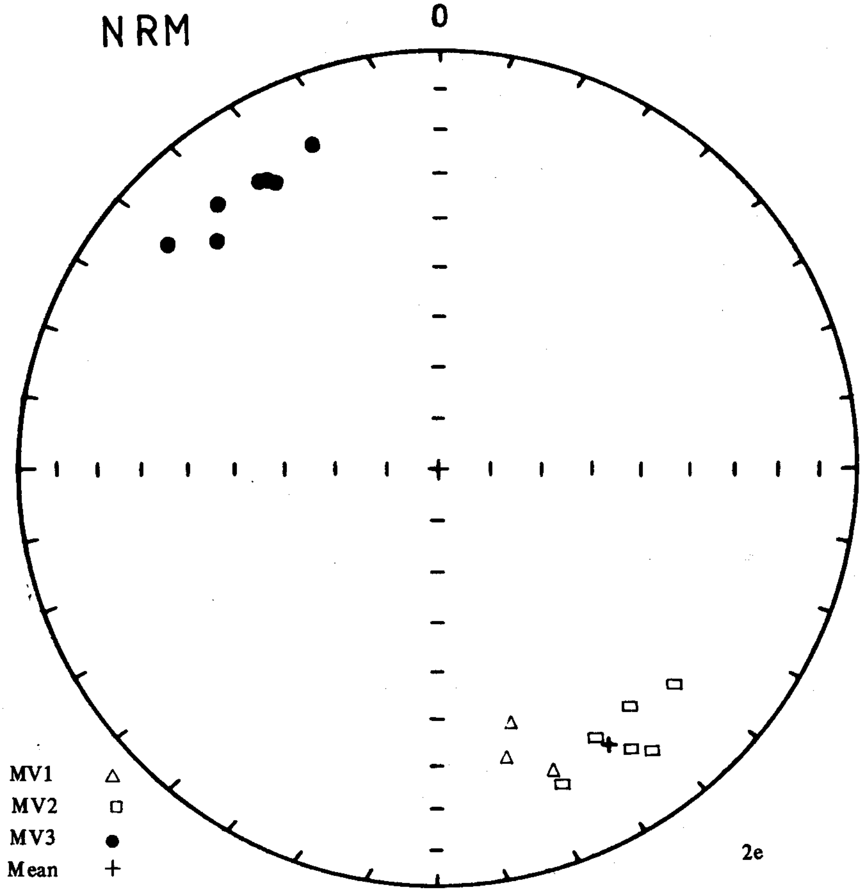
The initial remanent directions from the Tilzapotla tuff (TT1) were well grouped about a reverse direction of low inclination (Fig. 2c). AF and thermal demagnetizations of four pilot specimens revealed high directional stability (Fig. 4a, b). AF demagnetization of the remaining specimens improved the grouping of the directions



2c

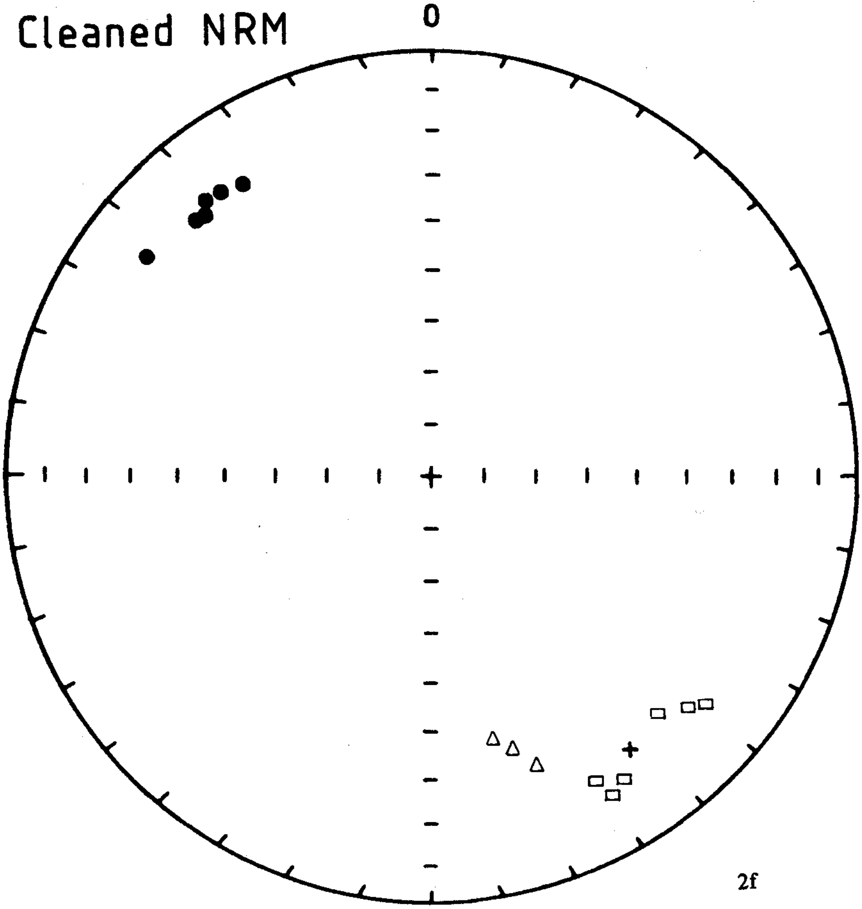
(Fig. 2d), and a mean direction and pole position were then calculated. Results are summarized in Table 2. In contrast, the initial directional results from the other tuff (TT2) were poorly grouped (Fig. 2c). AF demagnetization produced some directional movement resulting in directions with north-westerly declinations and low negative inclinations, although two samples retained intermediate directions (Fig. 2d). Results are summarized in Table 2. The mean direction calculated after editing the two divergent samples deviates considerably from that obtained for the other tuff. The initial remanent directions from the first tuff (MV1) presented a reverse polarity (Fig. 2e). AF demagnetization of one pilot specimen revealed high stability, and demagnetization of the remaining specimens improved the grouping (Fig. 2f). Results from the second tuff (MV2) gave similar results to MV1, with the two sites showing reverse magnetizations (Fig. 2e). AF demagnetization of two pilot





2e

specimens showed a univectorial behaviour, and again treatment of the remaining specimens improved the groupings (Fig. 2f). Finally, the results from the andesitic lava flow showed normally polarized directions for both sites (Fig. 2e). AF demagnetization of two pilot specimens revealed high stability and treatment improved the grouping, its mean direction is almost opposite to those obtained for the other sites (Fig. 2f). All results are summarized in Table 3; the overall mean-result was computed giving unit weight to site results.



## DISCUSSION

Pole positions calculated from the mean directions of all units (Tables 1, 2 and 3) are different from results obtained from areas within or towards the north of the MVB (Urrutia-Fucugauchi, 1979). Although the number of individual results investigated is small, the sense of divergence is very uniform (Fig. 5). The tuffs and flows show both normal and reverse polarities, and high directional stability. The within-unit scatter is low, but the between-unit scatter is high, with one tuff (TT1) and one lava (BG1) of higher polar latitude (~62°-80°N), and the remaining tuffs (TT2, MV1 and MV2) and lavas (BG2 and MV3) of lower polar latitude (~43°-53°N).

Table 1

Summary of palaeomagnetic data for lava flows of the Balsas Group.

| Unit | Site | No. of Samples | Natural remanent magnetization DEC | INC | $\alpha_{95}$ | k | Cleaned remanent magnetization DEC | INC | $\alpha_{95}$ | k | Pole position Lat(N) | Long(E) | (dp, dm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BG1 | 1 | 3 | 347.6 | 33.0 | 54.4 | 6. | 178.3 | 17.7 | 32.6 | 15. | 62.3 | 83.9 | (32.4, 24.9) |
| BG2 | 1 | 6 | 317.1 | 19.8 | 10.5 | 42. | 310.0 | 18.5 | 6.2 | 120. | 40.8 | 166.9 | ( 3.3, 6.4) |
| | 2 | 7 | 327.2 | 22.6 | 12.5 | 24. | 323.1 | 20.6 | 9.6 | 41. | 53.5 | 163.1 | ( 5.3, 10.1) |
| | 3 | 6 | 341.7 | 22.0 | 14.1 | 24. | 327.0 | 19.3 | 12.5 | 30. | 56.9 | 159.9 | ( 6.3, 13.0) |
| BG2 | (mean)* | 19 | 326.2 | 21.5 | 16.2 | 29. | 322.4 | 19.9 | 3.5 | 295. | 52.7 | 166.8 | ( 1.8, 3.7) |

* Mean for Balsas Group flow number 2 (TF2) given unit weight to site results (3 sites).

Table 2

Summary of palaeomagnetic data for tuffs of the Riolita Tilzapotla

| Unit | K-Ar age | No. of Samples | Natural remanent magnetization DEC | INC | $\alpha_{95}$ | k | Cleaned remanent magnetization DEC | INC | $\alpha_{95}$ | k | Pole Position Lat(N) | Long(E) | (dp, dm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TT1 | 49±3 m.y. | 6 | 183.1 | −13.5 | 7.0 | 92. | 182.7 | −17.1 | 4.9 | 184. | 79.8 | 64.7 | (4.9, 3.2) |
| TT2 | – | 5 | 329.9 | 26.3 | 46.5 | 4. | 334.7 | 6.2 | 52.1 | 3. | 60.7 | 141.4 | (49.6, 39.8) |
| | | 3* | 315.7 | 17.2 | 9.8 | 157. | 323.4 | − 6.4 | 23.1 | 29. | 47.9 | 143.0 | (22.0, 17.7) |

* Mean results without the two most divergent sample-mean directions (see Figures 2c, d).

Table 3

Summary of palaeomagnetic data for tuffs and lava flows of Miocene northern Guerrero Volcanics.

| Unit | Site | No. of Samples | Natural remanent magnetization DEC | INC | $\alpha_{95}$ | k | Cleaned remanent magnetization DEC | INC | $\alpha_{95}$ | k | Pole position Lat(N) | Long(E) | (dp, dm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MV1 | 1 | 3 | 162.9 | –30.4 | 11.1 | 126. | 163.2 | −33.4 | 7.6 | 264. | 74.1 | 172.2 | (4.9, 8.6) |
| MV2 | 1 | 3 | 150.3 | –21.4 | 12.8 | 94. | 149.3 | −20.2 | 7.1 | 30. | 59.2 | 159.7 | (4.2, 7.4) |
|  | 2 | 3 | 139.6 | –24.1 | 10.7 | 134. | 131.5 | −19.5 | 9.2 | 182. | 42.4 | 167.4 | (7.0, 9.6) |
| MV3 | 1 | 4 | 325.7 | 20.9 | 11.2 | 69. | 322.2 | 19.2 | 4.2 | 477. | 52.4 | 162.6 | (2.3, 4.4) |
|  | 2 | 3 | 322.7 | 20.3 | 17.0 | 53. | 314.9 | 19.1 | 9.8 | 160. | 45.5 | 165.8 | (5.0, 10.2) |
| Mean* | – | – | 148.0 | –23.6 | 8.7 | 78. | 144.2 | −22.4 | 8.6 | 81. | 54.8 | 164.5 | (4.8, 7.8) |

* Mean results for Miocene volcanics (MV) given unit weight to site results (5 sites).

Table 4

Summary of pole positions for the Early Tertiary of Mexico.

| Pole number | Pole explanation (S Lat, N, S Long, W) | Age (m.y.) | B | N | P Lat (N) | P Long (E) | (DP, DM) | $A_{95}$ | k | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Miocene mean pole position for northern Mexico. It includes: | M | (5) | – | 82.0 | 147.7 | | 7.9 | 94 | (1) |
| | a) Santiago volcanics (20.8, 103.3) | IM(8.7–9.5 | 4 | 45 | 79.1 | 180.6 | (16, 27) | | | (2) |
| | b) Durango volcanics (24.0, 105.0) | IM(12) | 2 | 13 | 81.0 | 87.5 | (10, 18) | | | (3) |
| | c) Guadalupe Group – Lower Sierra Group (19.5, 99.2) | IM(14.6–15.0) | 18 | 102 | 83.2 | 146.9 | (7, 12) | | | (4) |
| | d) Durango volcanics (24.0, 105.0) | EM(23.5±5) | 12 | 69 | 71.4 | 150.4 | (11, 20) | | | (3) |
| | e) Xochitepec Group (19.5, 99.2) | 1 0-EM | 10 | 74 | 88.7 | 213.8 | (9, 15) | | | (4) |

*Table 4 (Continued)*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2. | Oligocene mean pole position for northern Mexico. It includes: | 0 | (4) | – | 70.5 | 168.1 | | 10.7 | 74 | (1) |
| | a) Tezontlalpan Group (19.5, 99.2) | 1 0 | 9 | 59 | 82.5 | 185.2 | (12, 21) | | | (4) |
| | b) Durango volcanics (24.0, 105.0) | 1 0(28.5–31.5) | 18 | 114 | 63.9 | 163.5 | (7, 12) | | | (3) |
| | c) Tepalcate Navios volcanics (24.0, 105.1) | 1 0(28) | 8 | – | 66.6 | 155.6 | (11, 20) | | | (5) |
| | d) Jalisco volcanics (20.7, 102.3) | 0(2) | 7 | 48 | 68.1 | 181.1 | (7, 12) | | | (6) |
| 3. | Capping Series sediments and volcanics, Chihuahua (28.6, 105.8) | E | 12 | 36 | 67.3 | 171.1 | | 3.5 | 27 | (7) |
| 4. | Jantetelco granodiorites (JG) (18.7, 98.8) | O-M | 7 | 37 | 35.1 | 176.8 | | 12.4 | 25 | (8) |
| 5. | Tepexco volcanics (TV) (18.7, 98.8) | O-M | 2 | 12 | 31.1 | 177.8 | | – | – | (8) |
| 6. | Miocene volcanics (MV) (18.6, 99.4) | M | | 16 | 54.8 | 164.5 | (4.8, 7.8) | | | (9) |

*Table 4 (Continued)*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 7. | Tuffs Tilzapotla Fm.<br>(18.55, 99.6) | E(49±3) | | | | | | (9) |
| | a) TT1 tuff | | 1 | 6 | 79.8 | 64.7 | (5, 3) | |
| | b) TT2 tuff | | 1 | 3 | 47.9 | 143.0 | (22, 18) | |
| 8. | Balsas Group volcanics<br>(18.55, 99.7) | Pa-E | | | | | | (9) |
| | a) BG1 flow | – | 1 | 3 | 62.3 | 83.9 | (32, 25) | |
| | b) BG2 flow | – | 3 | 19 | 52.7 | 166.8 | (2, 4) | |
| 9. | Red sediments Balsas Group<br>(BF) (18.55, 99.5) | Pa-E | 14 | 14 | 54.1 | 183.4 | (11, 20) | (10) |

B = number of sites (studies); N = number of samples; S Lat, S Long = Site coordinates; P Lat, P Long, polar coordinates; DP, DM = semi-axes of the oval of confidence about the pole position at the 95% probability level; $A_{95}$, k = semiangle of the cone of 95% confidence about the mean pole and Fisher precision parameter; Age (m.y.) = geologic age and radiometric dates in million of years (m.y.). Symbols are: l, e = Late and Early; M = Miocene; O = Oligocene; E = Eocene; Pa = Palaeocene.

References: (1) Urrutia-Fucugauchi (1979), (2) Watkins *et al.* (1971), (3) Nairn *et al.* (1975), (4) Mooser *et al.* (1974), (5) Guerrero (1973), (6) Urrutia-Fucugauchi and Pal (1977), (7) Urrutia-Fucugauchi (1981b), (8) Urrutia-Fucugauchi (1981a), (9) this study, and (10) Urrutia-Fucugauchi (1980). See reference (1) for further details.

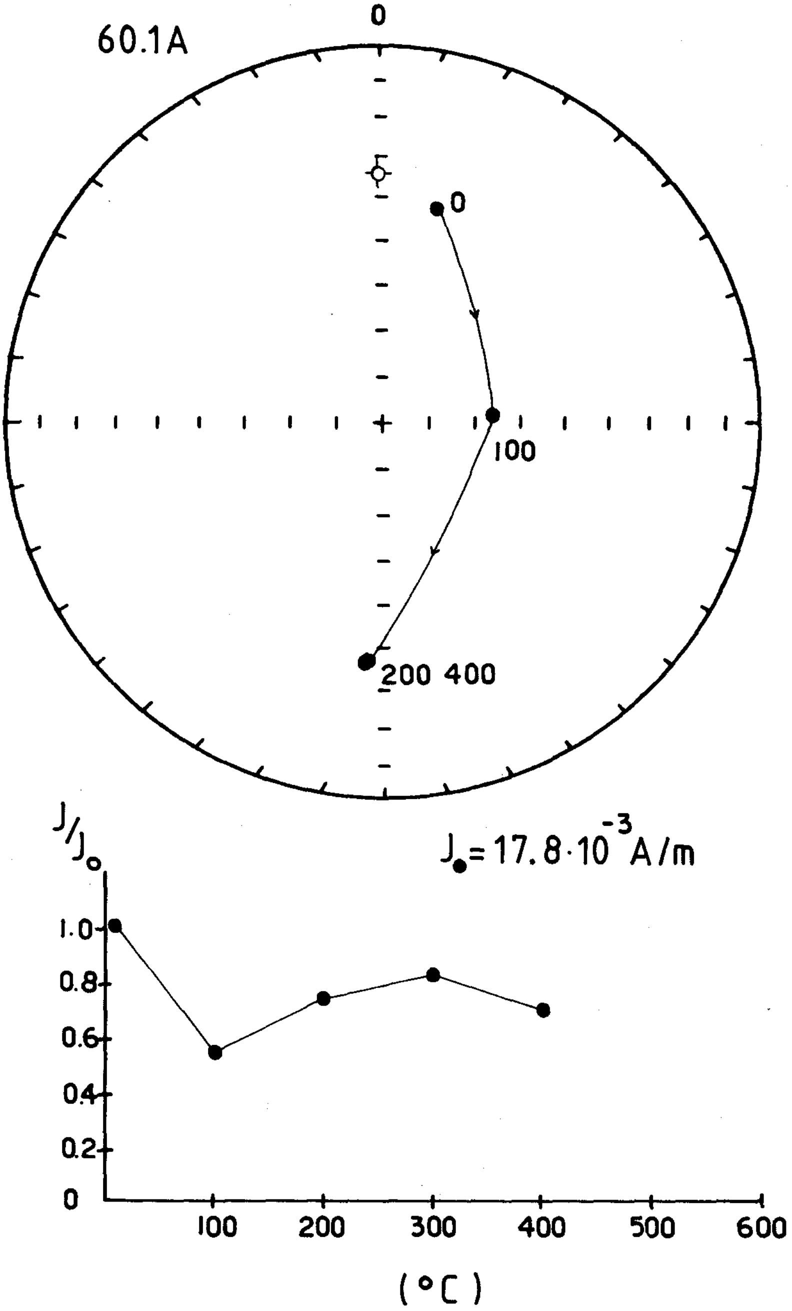


Fig. 3. Thermal demagnetization of a pilot specimen from BG1 lava flow. Note the presence of a low blocking temperature component which is destroyed by the treatment.

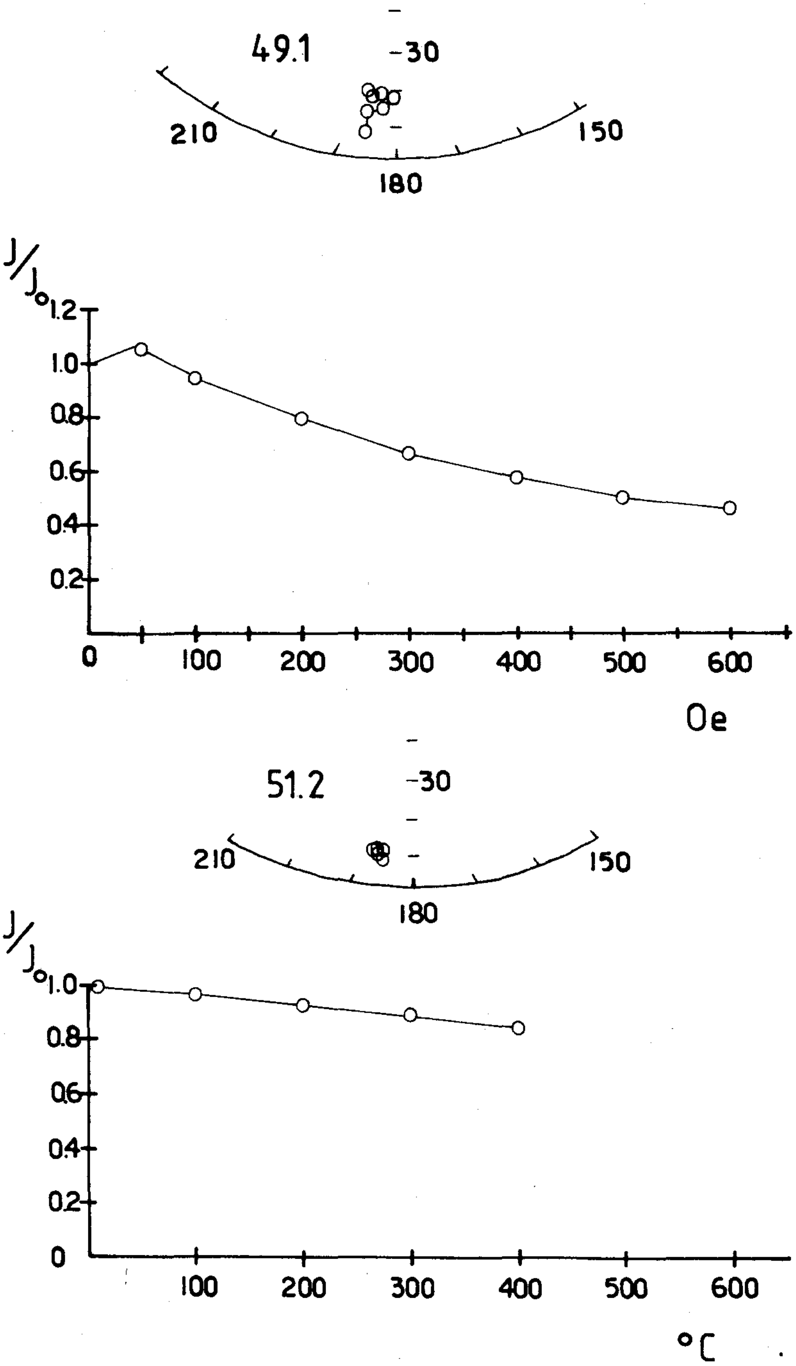


Fig. 4. Typical examples of demagnetization of tuffs from Riolita Tilzapotla (a) AF demagnetization, and (b) thermal demagnetization.

The results agree with results derived from red sediments of the Balsas Formation (BF) sampled in a nearby locality (Urrutia-Fucugauchi, 1980), and mean pole positions derived from three intrusive bodies of the Oligocene-Miocene Jantetelco Granodiorites (JG) and two lava flows of the Oligocene-Miocene Tepexco volcanic group (TV) (Urrutia-Fucugauchi, 1981a). K-Ar dating of samples from the granodiorite and the lavas is in progress. A radiometric study was considered necessary, since Ortega-Gutiérrez (pers. comm., 1982) indicates that unpublished K-Ar dates for the granodiorite suggest a Pliocene age. Such a young age is not apparently supported by the geologic observations, and an Oligocene-Miocene age is more in agreement with the palaeomagnetic data. Poles BG1 and TT2 (this study) are not considered for discussion, because of the high statistical uncertainties.

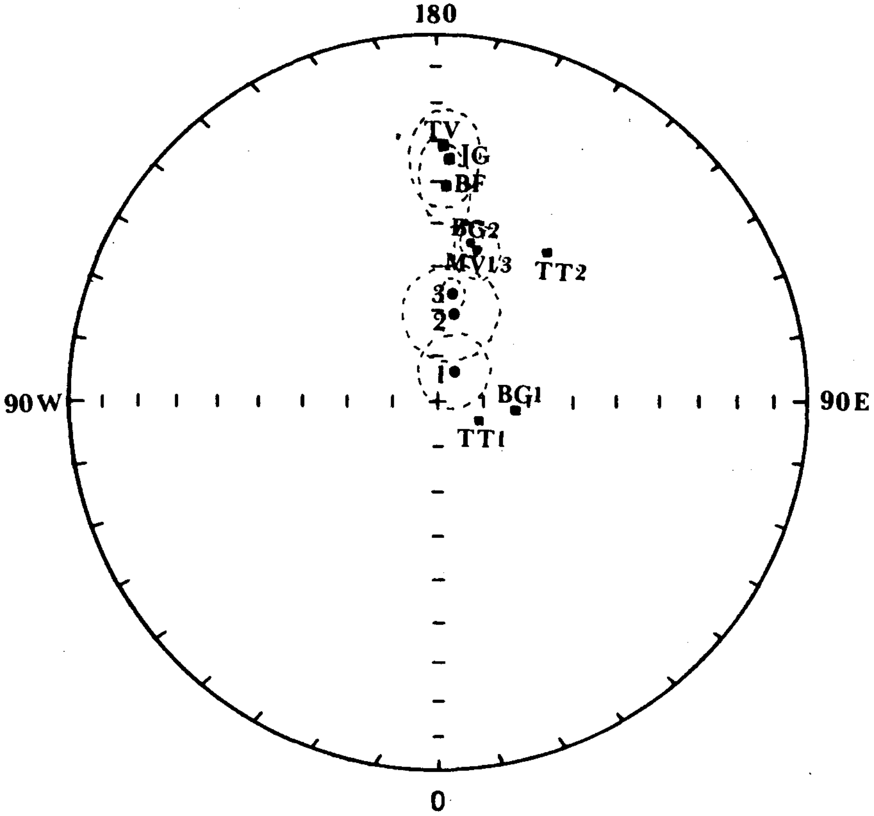


Fig. 5. Summary of early Tertiary palaeomagnetic pole positions. Northern Mexico poles (●) are (1) Miocene mean pole, (2) Oligocene mean pole, and (3) Eocene (?) pole. Southern Mexico poles (■) are BG1 and BG2 lava flows of Balsas group, and BF red beds of Balsas group (Palaeocene-Eocene); TT1 and TT2 tuffs of Riolita Tilzapotla (Eocene, 49 ± 3 m.y.): MV1-3 Miocene volcanics; JG Jantetelco granodiorites (Oligocene-Miocene); and TV Tepexco volcanics (Oligocene-Miocene).

Freund (1974) suggested that rotation of crustal blocks in areas subjected to compressional and shear stress is a common process. Palaeomagnetic studies have found support for his conclusions (Kamerling and Luyendyk, 1979; Freund and Tarling, 1979; Greenhaus and Cox, 1979); the mechanisms suggested are however complex. An area extensively studied is that of western North America; there palaeomagnetic data have long been interpreted in terms of relative tectonic movements of small blocks (Irving, 1964, 1979; Beck, 1976). Beck (1976) interpreted anomalous palaeomagnetic data in terms of rotation of small rigid microcontinental blocks and northward translations, the so-called 'ball bearing' hypothesis (Fig. 6c). Greenhaus and Cox (1979) suggested that the rotation of crustal blocks may be due to the formation of pull-apart basins (Fig. 6d). These basins develop (Crowell, 1974)

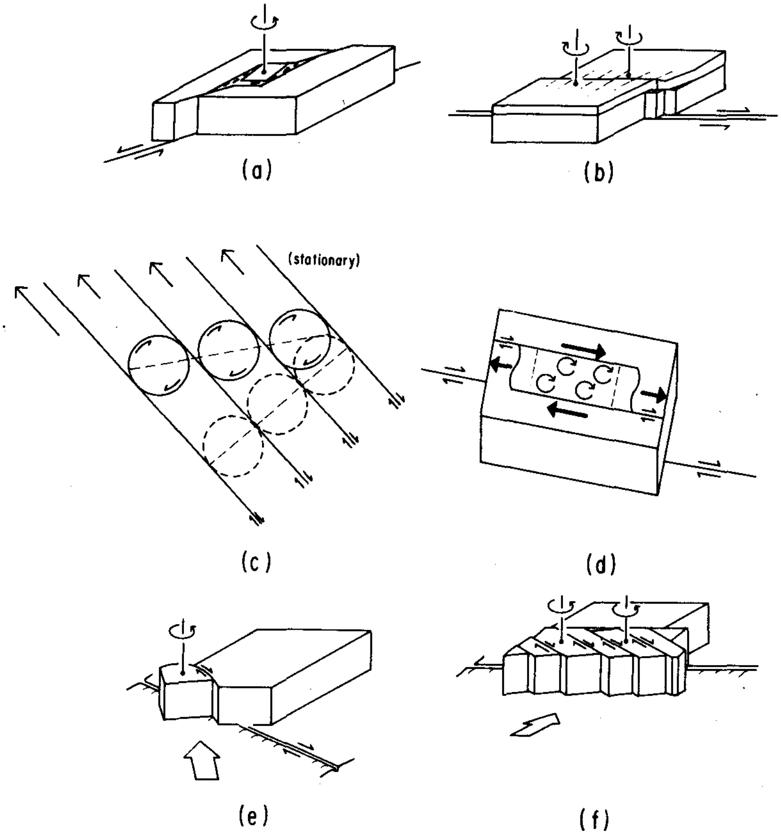


Fig. 6. Summary of models proposed for tectonic rotation of crustal blocks associated with lateral regional shear (modified after MacDonald, 1980 and Beck, 1976). See text for discussion.

where a strike-slip forms a double bend and continued motion along the fault produces separation of the blocks along the oblique segment of the fault. The dimensions are related to the initial length of overlap of the faults, their separation, and the amount of strike-slip displacement (Fig. 6d). Close examination of the data from Mexico reveals that those for the intrusives and lavas (JG and TV, Fig. 5) of Morelos can be explained in terms of rotation of a crustal block within a pull-apart basin, as the remanence declinations appear displaced counterclockwise by some 50°–55° whereas there is only a small change in inclination. The angular deflection can be explained by rotation of the block about a vertical pivot located somewhere nearby (Urrutia-Fucugauchi, 1981a). It is, however, difficult to interpret 'anomalous' palaeomagnetic data in terms of a given model (MacDonald, 1980); the data (Fig. 5) suggest a more-or-less uniform (i.e. poles, JG, TV, BF, MV, TT2 and BG2) sense of rotation which give support to the occurrence of movements, but which do not necessarily imply structural rigidity over the area. The apparent counterclockwise rotations suggest if associated with strike-slip movement only, that the sense of slip is left-lateral (Fig. 6a, b); which does not agree with some models (Karig and Jensky, 1973; Gastil and Jensky, 1973), but is compatible with other models (Walper, 1980). One may note that most rotations observed in western North America are in the opposite sense to those observed here; which, in turn, are in agreement with right-lateral strike-slip (e.g. Beck, 1976). This may suggest that the mechanism acting in Mexico is fundamentally different, perhaps involving left-lateral strike slip (Walper, 1980). Alternative explanations involving right-lateral strike-slip are in terms of regional compression and strike-slip motion (Fig. 6 e, f). For instance, plate convergence given by oblique subduction acting on blocks cut by right-lateral strike-slip faults approximately parallel to the subduction zone axis, may give counterclockwise rotation of the blocks (Fig. 6e) (e.g. see Fitch, 1972; Freund, 1970). Another possible model involves a system of right-lateral strike-slip faults (Fig. 6f) which give a series of crustal blocks, all subjected to regional compression. In this case the boundary faults rotate with the blocks. This model (Fig. 6) may well apply to the Mexican volcanic belt (Fig. 1), where the regional compression is due to the subduction of the Cocos plate and an oblique regional fault system has been mapped in the field (e.g. Mooser, 1969, 1972, 1975). In this case, the apparent 'zig zag' pattern of the volcanic manifestations (Mooser, 1975) is directly related to the fault system, and the pattern reflects the size and geometry of the different crustal blocks. It should be emphasized, however, that the interpretation of the palaeomagnetic results is strongly model dependent, and that at present is difficult to select a model. The results available support that regional tectonic movements resulting in counterclockwise tectonic rotations of crustal blocks about vertical pivots have affected central Mexico. The broad fault zone may have acted as an efficient structural control for the magmas, which may explain why the MVB is not parallel to the trend of the trench but forms an angle with respect to it (Fig. 1).

## ACKNOWLEDGMENTS

Laboratory work was carried out in the School of Physics, University of Newcastle-upon-Tyne, U. K. and Departamento de Geología, Universidad de Buenos Aires, Argentina, and I would like to thank the academic and technical staff for giving me free access to their facilities. Thanks are also due to Dr. D. H. Tarling for comments on an earlier version of this manuscript. The work is supported by the Consejo Nacional de Ciencia y Tecnología and the Instituto de Geofísica, U. N. A. M., México.

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*(Received: Oct. 15, 1981)*
*(Accepted: March 12, 1982)*