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Constraints on Brunhes low-latitude paleosecular variation – Iztaccíhuatl stratovolcano, basin of Mexico

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RESUMEN

Los datos paleomagnéticos para lavas del volcán Iztaccíhuatl permiten analizar la variación paleosecular del campo geomagnético en la región central de México. La parte superior del volcán fue formada durante el Cron de Brunhes, lo que es apoyado por la polaridad normal y la posición polar media (Steele, 1985). El período de actividad es del orden 580 000 a 76 000 años, sugerido en los datos de K-Ar (Nixon *et al.*, 1986). Las discrepancias en las estimaciones reportadas por Steele (1985) y Böhnel *et al.* (1990) dependen de las diferentes metodologías y características estadísticas asumidas para la población de polos geomagnéticos virtuales (VGP). El polo medio es 88.1°N, 34.0°E (B=21, K=88, A_{95}=3.4°). La distribución de VGPs es alargada y no Fisheriana, lo que sugiere efectos adicionales a los de variación secular. Estos pueden incluir efectos tectónicos locales o excursiones geomagnéticas. La dispersión de VGPs que caracteriza mejor la variación paleosecular es 7.4°, relativamente baja (7° menor) en comparación con los datos estimados de modelos globales con dependencia de latitud. Este valor es similar a los estimados para la región del Pacífico central, en las islas de Hawaii, Pagan y Marianas. El centro de México parece formar parte de esta región de bajo campo no dipolar del Pacífico.

PALABRAS CLAVE: Paleomagnetismo, variación secular, estratigrafía volcánica, Cron Brunhes, Volcán Iztaccíhuatl, cuenca de México.

ABSTRACT

The upper Iztaccíhuatl stratovolcano formed during the Brunhes chron, which is supported by the normal polarity and the overall mean paleomagnetic pole (Steele, 1985). The period involved is probably long, in the range suggested by K-Ar dating studies (Nixon *et al.*, 1986) of 580 000 to 76 000 years ago. Apparent discrepancy in paleosecular variation estimates for the Basin of Mexico reported by Steele (1985) and Böhnel *et al.* (1990) depends on the methods and assumptions made concerning the statistical characteristics of the virtual geomagnetic pole (VGP) data populations. The mean pole is 88.1°N, 34.0°E (B = 21, K = 88, A_{95} = 3.4). The overall VGP population distribution is elongated and non-Fisherian. The VGP dispersion is affected by sources other than those of secular variation and may include undetected local tectonic effects or excursions/events of the geomagnetic field. The best estimate S_F is 7.4°, some 7° smaller than that derived from latitude-dependent paleosecular variation models, but similar to values for the Hawaii, Pagan and Marianas islands and to a previous study in the Basin of Mexico. The region of central Mexico may form part of the central Pacific Brunhes low non-dipole region.

KEY WORDS: Paleomagnetism, geomagnetic secular variation, volcanic stratigraphy, Brunhes Chron, Iztaccíhuatl volcano, basin of Mexico.

1. INTRODUCTION

In this paper some new paleomagnetic data for volcanic units of the Iztaccíhuatl stratovolcano (Figure 1) are reported and implications for its evolution and for the estimation of the paleosecular variation of the geomagnetic field during the Brunhes Chron are discussed. Steele (1971) reported paleomagnetic data for the Iztaccíhuatl that provided constraints for its history. He reported that the volcano is characterized by normal polarity and, based mainly on limited K-Ar dates and the morphological characteristics of the volcanic complex, he considered that it formed during the Quaternary, with an early extrusion episode (southern section) occurring during an earlier normal (Gauss) polarity chron. These conclusions were revised in the light of new K-Ar dates, all less than 1 Ma old (Nixon *et al.*, 1986). In a later revision Steele (1985) suggested that all of Iztaccíhuatl formed during the Brunhes Chron, over an interval of at least 10 000 years. This conclusion is based on a comparison of virtual geomagnetic pole (VGP) dispersion with angular dispersions predicted by latitude-dependent global paleosecular dispersion models.

The application of secular variation amplitude analysis offers a possible temporal constraint for volcanic activity on the eruptive rates of stratovolcanoes and volcanic fields, but there are several other potential sources of angular dispersion (e.g., Urrutia-Fucugauchi, 1985; Böhnel *et al.*, 1990). While Steele's conclusion is sound in the context of the evolution of stratovolcanos, the paleomagnetic argument might not be strictly valid. It has been long realized (e.g., McElhinny and Merrill, 1975) that the mean angular VGP dispersion does not always adequately represent average secular variation effects for any given region. Other factors, such as secondary components of remanence, local magnetic field anomalies, local and regional tectonic effects, and serial correlation of VGP data points may result in a biased estimate of VGP angular dispersion.

Steele (1985) estimated the VGP angular dispersion for Iztaccíhuatl as 14.2°, similar to the range predicted for paleosecular variation models for the latitude of the volcano. This assumes that central Mexico was characterized by 'normal' paleosecular variation during the Brunhes Chron

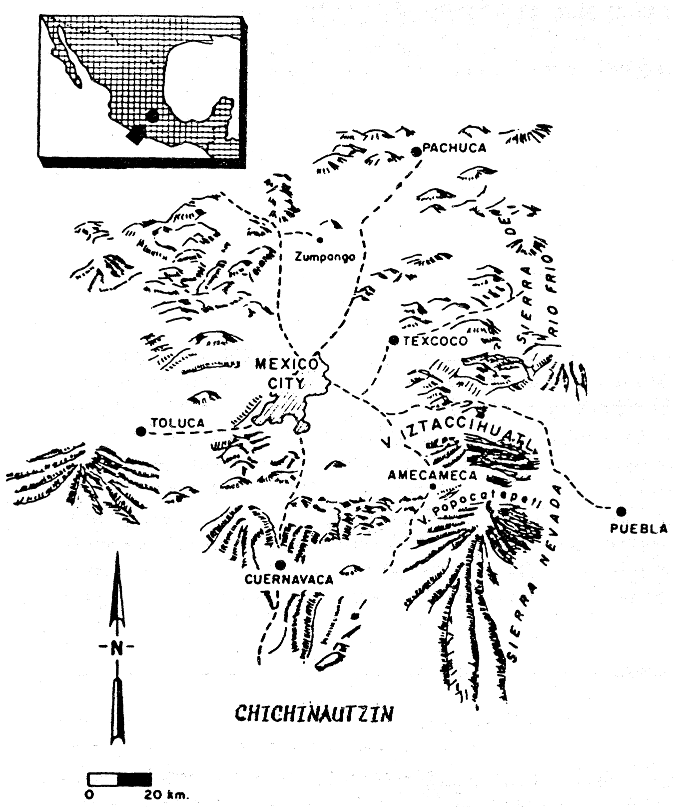


Fig. 1. Schematic map for the Basin of Mexico with the major stratovolcanoes and cinder cone fields (modified after Mooser, 1957).

and that no anomalous dispersion sources were present. However, several studies have documented regions of different dispersion estimates. The central Pacific ocean features low dispersion values (Doell and Cox, 1971; Bingham and Stone, 1972; Cox, 1975; McWilliams *et al.*, 1982), and central Mexico has been included in the low-secular variation region (Doell and Cox, 1972). A recent study of paleosecular variation in central Mexico (Böhnel *et al.*, 1990) found that the Basin of Mexico is characterized by low-angular VGP dispersion, in agreement with data for the Hawaiian Islands.

It is important to determine the paleosecular variation of the geomagnetic field at low-latitudes, the extension or exclusion of the area of central Mexico in the low-non dipole component of the central Pacific, and the potential constraints on the volcanic history of the stratovolcano. A project to re-study the paleomagnetic characteristics of Iztaccíhuatl volcano has recently begun.

2. GEOLOGIC SETTING AND PREVIOUS STUDIES

Iztaccíhuatl (White Lady) is a large stratovolcano in the eastern sector of the Basin of Mexico (Figure 1). It forms the central portion of the Sierra Nevada that includes the active Popocatépetl stratovolcano at its southern end. Iztaccíhuatl is composed of numerous lava flows of dominantly andesitic composition that were erupted from several vents. Morphologically it can be divided into four units (north to south): "Head", "Breast", "Knees" and "Feet", and these units have been retained for the geological and volcanology studies.

The volcanic complex is over 5200 m high and has large glaciers. The Basin of Mexico is within the tropical zone and the tall volcanoes have been subjected to past glaciations and intense tropical weathering (White, 1962, 1986; Nixon, 1989). Attempts to document the volcanic history of the Sierra Nevada have usually relied on present-day activity of Popocatépetl (historical eruptions and an active fumarole system) and on the morphological characteristics of the mountain range. Mooser (1957) distinguished two main Pliocene andesitic series named Sierra Nevada and Iztaccíhuatl. Later, Mooser *et al.* (1974) revised the stratigraphy based on paleomagnetic studies and some K-Ar dates; they distinguished a Miocene Lower Sierra Group (basic complex of Sierra Nevada) and a Miocene-Pliocene Upper Sierra Group. They proposed that the summit cones of Iztaccíhuatl and Popocatépetl were of Plio-Pleistocene to Recent age.

Steele (1971) found that Iztaccíhuatl is characterized by normal magnetic polarity lavas. He suggested that most of the volcano formed during the Quaternary. Three K-Ar dates, 5.1±0.5, 8.7±0.8 and 13.3±1.2 Ma supported Miocene-Pliocene activity. The erosion of the "Feet" unit suggests an older age, possibly during an earlier normal polarity chron.

Steele (1985) revised the paleomagnetic data set and estimated a secular variation dispersion value (S_F) of 14.2° (Table 1), which was within the range expected for the latitude from global paleosecular variation models. This suggested that the period covered by the extrusion of lavas was long enough compared with the rates of secular variation. Steele (1985) also re-considered the age assignment for the "Feet" lava units and considered them as extruded during the Brunhes Chron, in agreement with the new K-Ar dates provided by Nixon *et al.* (1986).

Table 1

Dispersion statistics for Iztaccíhuatl volcano lavas

B	LAT(°N)	LONG (°E)	A_{95}	δ	k	S_F	C*
24	86.9	333.2	5.5	14.6	29.6	14.2	20
22	87.0	342.6	6.0	15.0	28.0	14.7	12-17

* within-site α_{95} cutoff

3. METHODOLOGY AND RESULTS

We consider possible sources of angular dispersion that may contribute to the paleosecular variation estimates. These include factors associated with sample collection and orientation, secondary remanent components, local structural disturbances and data selection for secular variation calculations. Results from 50 samples corresponding to seven additional sites from the southern sectors of the volcano, in the "Feet" and Altzomoni areas are reported. They come from the units F7, F8, K1 and K2 of Steele (1971).

One possible source of angular dispersion is the magnetic effect on sample orientation when using a magnetic compass. This factor may become important for mafic volcanic rocks and in areas affected by lightning. Steele (1985) mentioned that some samples rejected for the paleosecular variation analysis showed evidence of lightning, a common problem in high-topography outcrops. Both solar and magnetic compasses were used in orienting our new samples. Angular differences between the magnetic and solar azimuths were large, up to 20° (Figure 2), but there is no apparent relationship with the intensity of magnetic remanence, except for a few samples of very high intensity where the effects on the magnetic compass were already noticeable during sample collection. The within-site dispersion is reduced using solar orientation, but there is no significant effect on the site mean direction (i.e., both 'magnetic' and 'solar' directions are not statistically different).

The intensity and direction of natural remanent magnetization (NRM) were measured using a Molspin spinner magnetometer. The vectorial composition and stability of NRM were analyzed using detailed stepwise alternating field (AF) and thermal demagnetizations. AF demagnetization was carried out in 8-10 steps up to maximum fields of 100 mT using a reverse tumbling Schonstedt demagnetizer. Thermal demagnetization was carried out in 8-12 steps up to maximum temperatures of 560-600°C in a non-inductive Schonstedt thermal demagnetizer. AF coercivity spectra was generally dominated by low coercivity components (e.g., Figure 3a), with median destructive fields (MDF) of less than 20-30 mT, and the occurrence of a small component of high coercivity (that sometimes remained after 100 mT demagnetization). Unblocking temperature spectra show maximum temperatures of around 560-580°C, with high median destructive temperatures (MDT) of around 450°C (e.g., Figure 3b). This agrees with the report by Steele (1971), who also used thermal demagnetization to investigate the magnetic mineralogy. Unblocking temperature spectra show a discrete behaviour, with maximum temperatures around 550-570°C, suggesting low titanium titanomagnetites and magnetite as dominant magnetic carriers (Steele, 1971). The low AF coercivities suggest the occurrence of multi-domain state behaviour. The high coercivity components may correspond to small quantities of hematites.

In some samples the NRM shows secondary components (e.g., Figure 4). The characteristic magnetization (chNRM) has been calculated from the last linear segment going through the origin in the vectorial plots or from principal component analysis (PCA). Unfortunately, no vectorial composition data in the forms of vector plots or sterograms were published for the Iztaccíhuatl in the previous studies (Steele, 1971, 1985; Mooser *et al.*, 1974), which makes it difficult to assess the importance of incompletely removed secondary components and the effects for the within-site and between-site scatter.

Results for the new sites are summarized in Table 2. The magnetic polarity for all sites is normal. The sites present different amounts of angular dispersion, with three sites having low dispersion, two having intermediate dispersion, and two having large dispersion.

Table 2

Further paleomagnetic results for Iztaccíhuatl volcano

SITE	n	DEC	INC	k	α_{95}	R	PLAT	PLONG
IZTA-1	6	354.9	35.8	223	4.1	5.973	85.1	180.5
IZTA-3	7	347.0	38.7	502	2.7	6.988	77.5	186.1
IZTA-4	6	349.2	33.3	8	25.5	5.364	79.7	167.8
IZTA-5	5	110.4	37.5	8	28.3	4.514	11.0	144.4
IZTA-7	7	15.7	29.5	169	4.7	6.964	74.7	1.5

Note: n=number of samples; DEC/INC=site-mean declination/ inclination of characteristic remanent magnetization; k=Fisher precision parameter; α_{95}=cone of confidence at 95% probability; R=resultant vector; PLAT/PLONG=latitude (N)/longitude (E) of site-mean virtual geomagnetic pole.

4. DISCUSSION

We first examine the paleosecular variation estimates of Steele (1985) and Böhnel *et al.* (1990); next the constraints provided by the re-analyzed complete data set, and finally the implications of paleomagnetic data for the volcanic history of the stratovolcano.

4.1. Previous data set

Steele (1971) reported paleomagnetic data for 35 sites. Some of the sites showed large within-site angular dispersion of remanence directions and Steele (1985) decided to discard those sites that had cones of 95% confidence larger than 20°. This assumes that large within-site angular dispersions reflect anomalous sources, but it is not clear which rejection threshold is most appropiate. In the absence of a physical model, the procedure could be based on a statistical examination of the dispersion parameter distribution (e.g., Issacson and Heinrichs, 1976; Hamilton and Evans, 1983). Figure 5 illustrates a histogram of site-mean α_{95} values for Steele (1971) data set (after Urrutia-Fucugauchi, 1985). The α_{95} values separate into three apparent groups: group A with values between 2° and 12°, group B with values between 17° and 29°, and group C with values larger than 50°. If a rejection threshold based on the α_{95} values is to be used, then one in the range of 12° to 17° may be appropiate, rather than the chosen value of 20°. This distribution remains after inclusion of the new data obtained (Figure 5). This criterion results in accepting 22 sites of the original Steele (1985) list and a total of 24

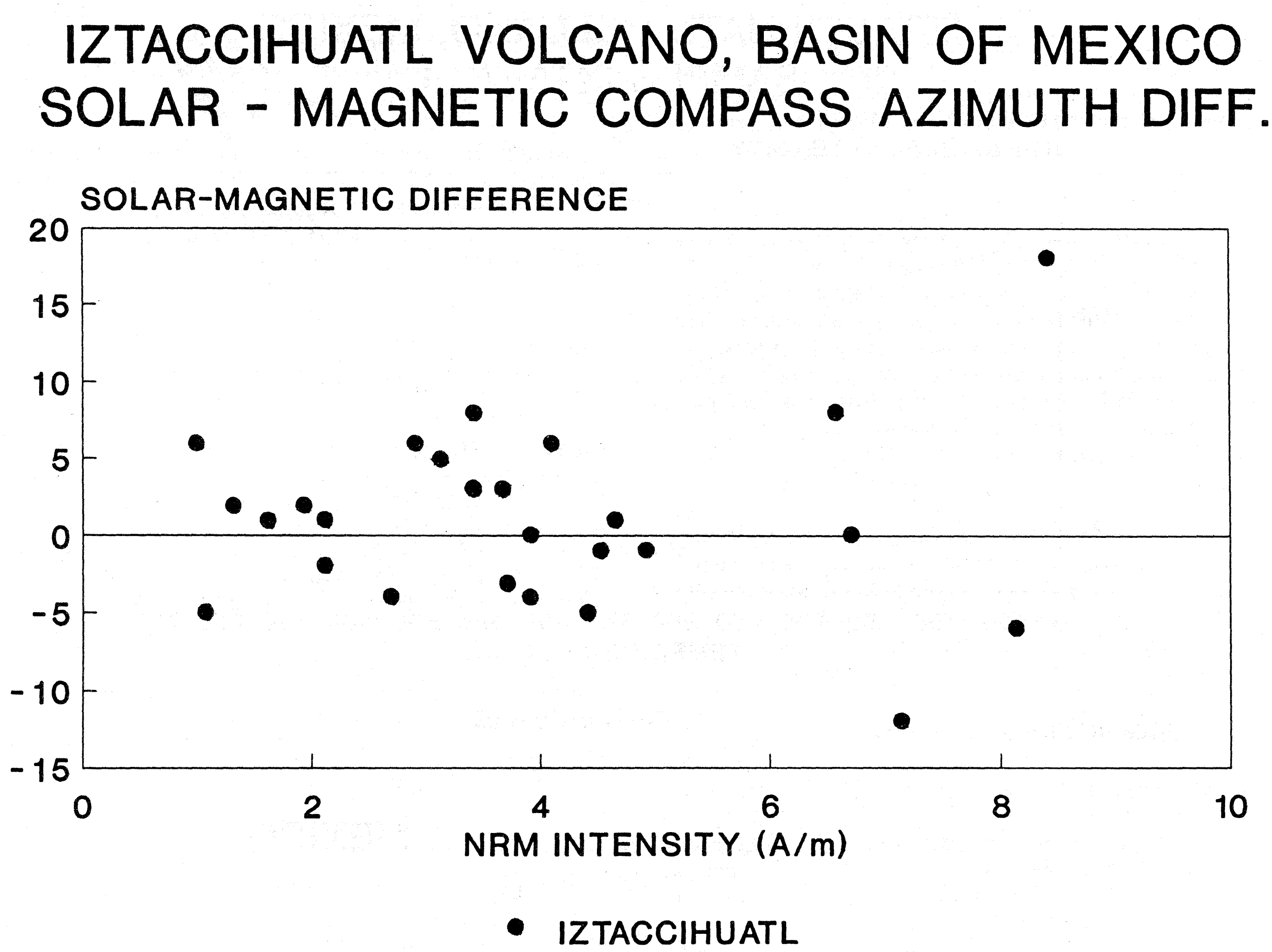


Fig. 2. Angular differences in azimuths calculated for solar and magnetic compasses orientations plotted as a function of remanence intensity.

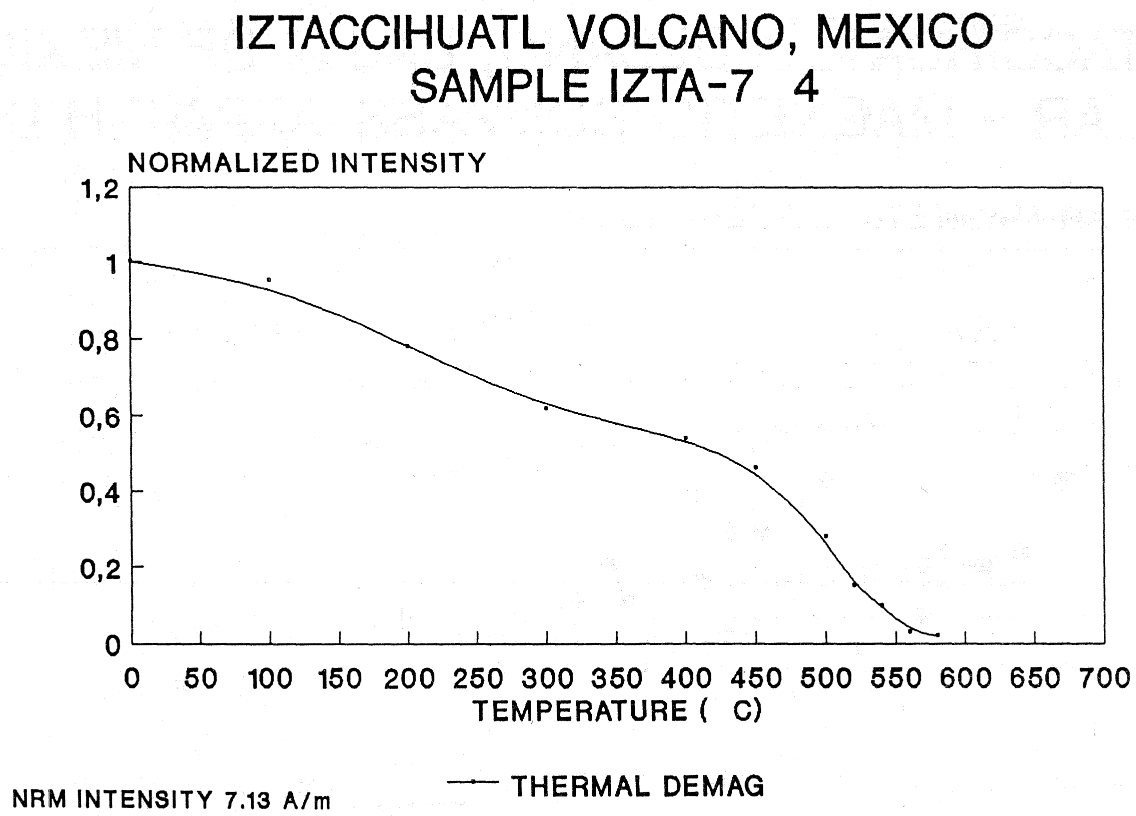
sites for the final analysis (Table 1). Re-calculation of the paleosecular variation results in an increase of the dispersion estimates, with a S_F parameter of 14.7°, close to the 14.2° value given by Steele (1985). Thus, different rejection criteria were not the cause of the apparent discrepancy in the estimation of the paleosecular variation.

Urrutia-Fucugauchi (1985) examined the distribution of site-mean directions and VGP positions and found that both data sets appear elongated and non-Fisherian (e.g., Figure 6). Use of methods that assume a Fisherian distribution is not justified and shape analyses of VGP and directional distributions are required (e.g., Baag and Helsley, 1974; Fisher *et al.*, 1981; Lewis and Fisher, 1982). Steele (1985) applied both Fisher and Bingham statistics. However, direct comparison of precision estimates and scatter parameters can only be made for circular distributions, which is not the case for the Iztaccíhuatl. For circular distributions the k_1 and k_2 estimates of Bingham statistics are equal and for given α_{95} values, they present numerical values smaller than those of the Fisher k parameter (e.g., Figure 6.10, p. 129 of Tarling, 1983). Thus, the numerical values of parameters cannot be simply compared. In any case, Fisher statistics for elongated elliptical distributions give values of k that depend on the density and distribution of data points (Urrutia-Fucugauchi, 1980). This occurs when (a) data points are uniformly distributed or are concentrated closer to the mean, (b) high density clusters exist away from the mean, or (c) outlier data points for small-sized data sets are present (e.g., Baag and Helsley, 1974).

The confidence limits for S_F estimated by Steele (1985) used the methods given by Cox (1969). McFadden (1980a) later concluded that the confidence limits for k provided by Cox (1969) are inappropiate for determining whether secular variation had been averaged out in any particular study. The test derived by Cox (1969) gives confidence limits deduced from a sample and do not test the hypothesis that the observed k could be obtained by random sampling from a population with a given k.

4.2. Paleosecular variation and shape analysis

A new analysis of the original data set by Steele (1985) has been carried out. Paleosecular variation analyses gen–



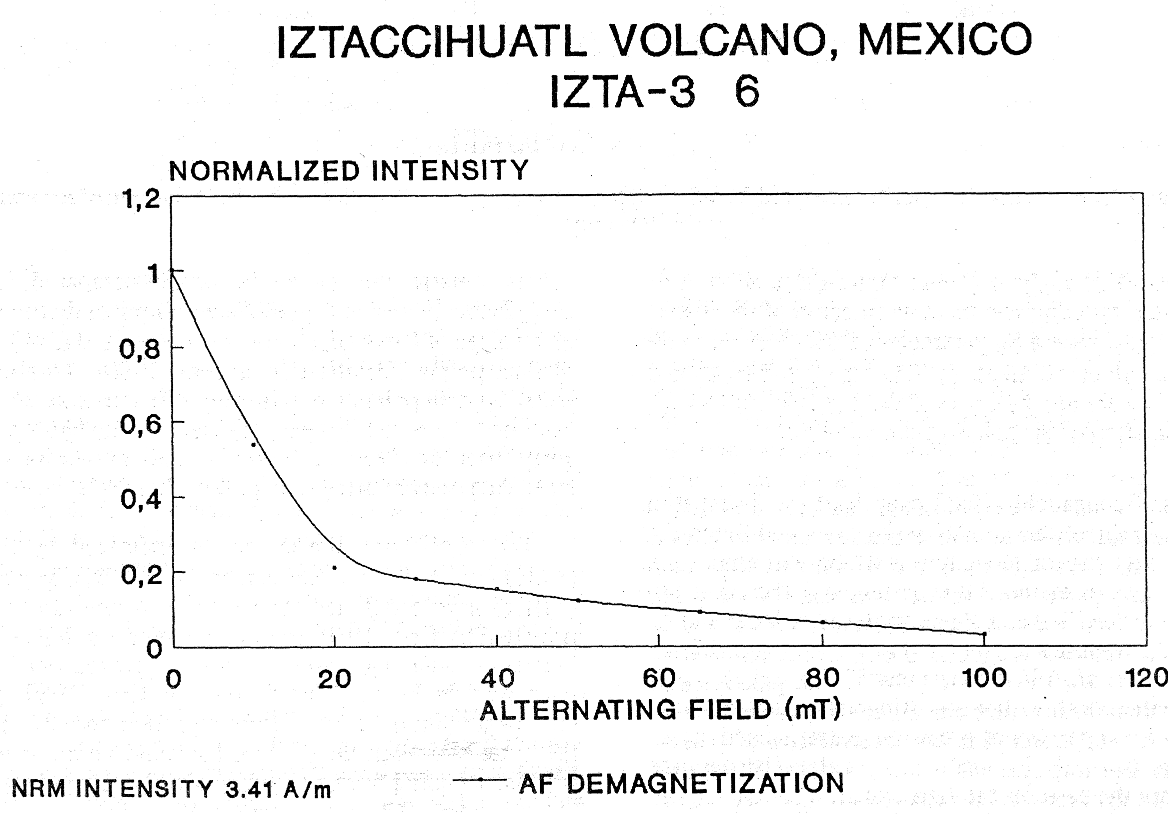


Fig. 3. Examples of normalized intensity curves for samples of the Iztaccíhuatl volcano (a) after alternating field demagnetization, and (b) after thermal demagnetization.

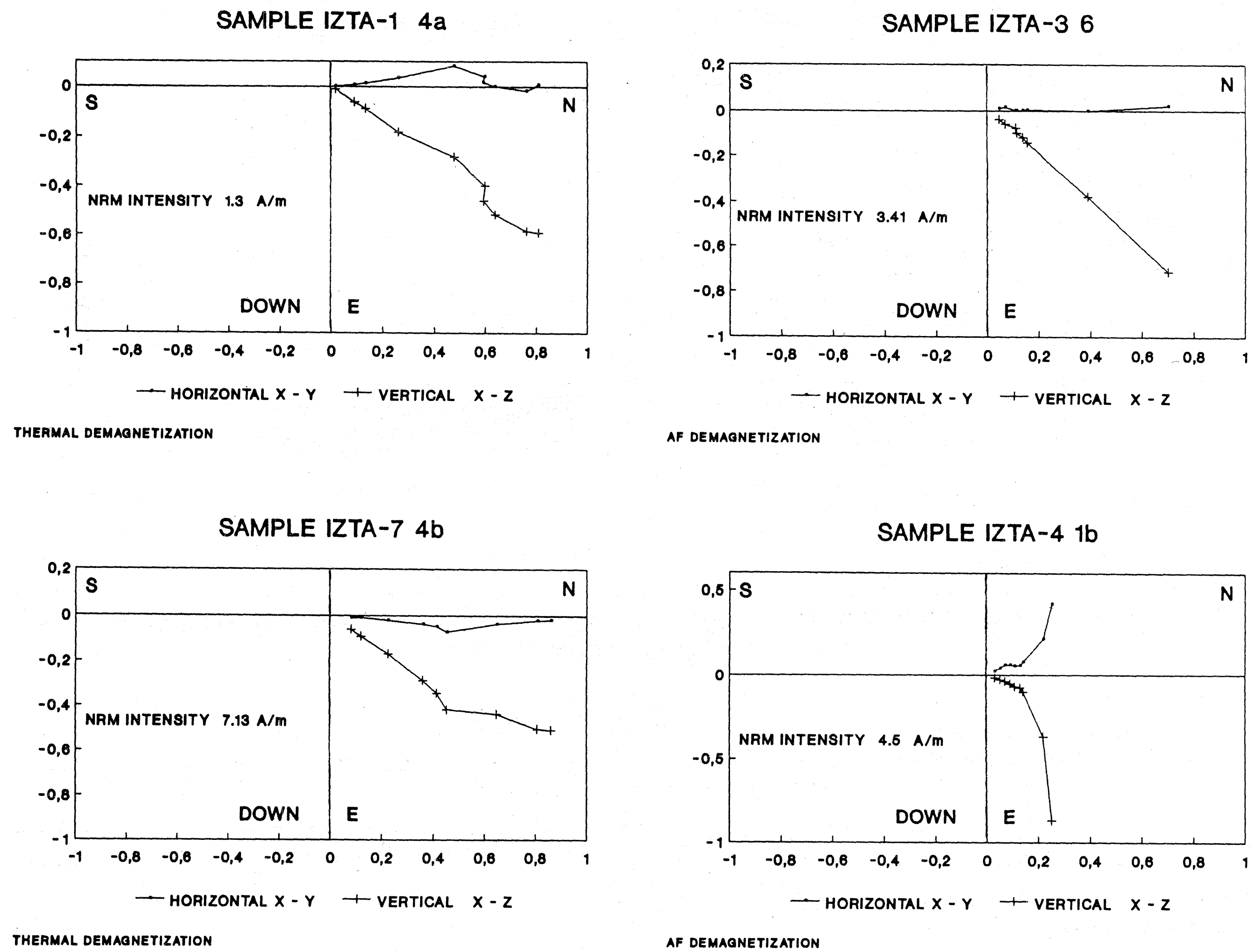


Fig. 4. Examples of vector plots for four samples of the Iztaccíhuatl volcano (a) and (b) after thermal demagnetization, (c) and (d) after alternating field demagnetization.

erally use VGP data rather than mean directions (McFadden *et al.*, 1988). There are several angular dispersion estimates and such data sets are usually parameterized using standard deviations S or the precision parameter *k* (Fisher, 1953; Irving, 1964). The overall dispersion (S_T or k_T) of a data set is the resultant of several potential sources such as the within-site dispersion (Sw and *k*w) and between-site dispersion (S_B and k_B) (Watson and Irving, 1957; Irving, 1964). There are other smaller contributions such as regional magnetic anomalies (S_A and k_A) (Doell and Cox, 1963). For this study the within-site dispersion was calculated using the two-tier analysis (Watson and Irving, 1957; Cox, 1969; and modifications by McFadden, 1982) and the regional magnetic effects were estimated by the method of Doell and Cox (1963). The paleosecular variation was estimated in terms of the dispersion parameters S_F and k_F. Shape analyses have been discussed in several studies. For this analysis the eccentricity **E** and axis ratio **A/B** of Engebretson and Beck (1978) have been used, where **A** and **B** are the major and minor axes of an ellipse fitted to the VGP distribution. The distribution is assumed to be Fisherian; the larger **E** and **A/B**, the larger is the deviation from a random distribution.

VGP data points that are not independent estimates of the geomagnetic field (i.e., representing the same volcanic event) must be excluded from the analysis. This is sometimes difficult to decide and statistically criteria need to be applied. In the case of the Iztaccíhuatl, sites come from different lava flows but the time involved between given extrusion events is still difficult to evaluate. Tectonic effects and the presence of excursions or events of the geomagnetic field also result in non-random VGP distributions which need to be considered in the analysis (McFadden *et al.*, 1988). To identify data points that are not part of the Fisherian distribution the criteria derived by McFadden (1980b), at the 95 % probability level has been applied.

Results are summarized in Table 3. The new value for the S_F parameter is 14.2° which corresponds to the estimate derived earlier by Steele (1985). However, the VGP distribution is non-Fisherian (see Figure 6 and eccentricity and axis ratio values). Application of McFadden (1980b) criteria results in the identification of 6 outliers in the VGP population. The selected data set gives an estimate for the paleosecular variation S_F of 6.4°, with smaller eccentricity and axis ratio parameters (Table 3). That is, the paleosecu–

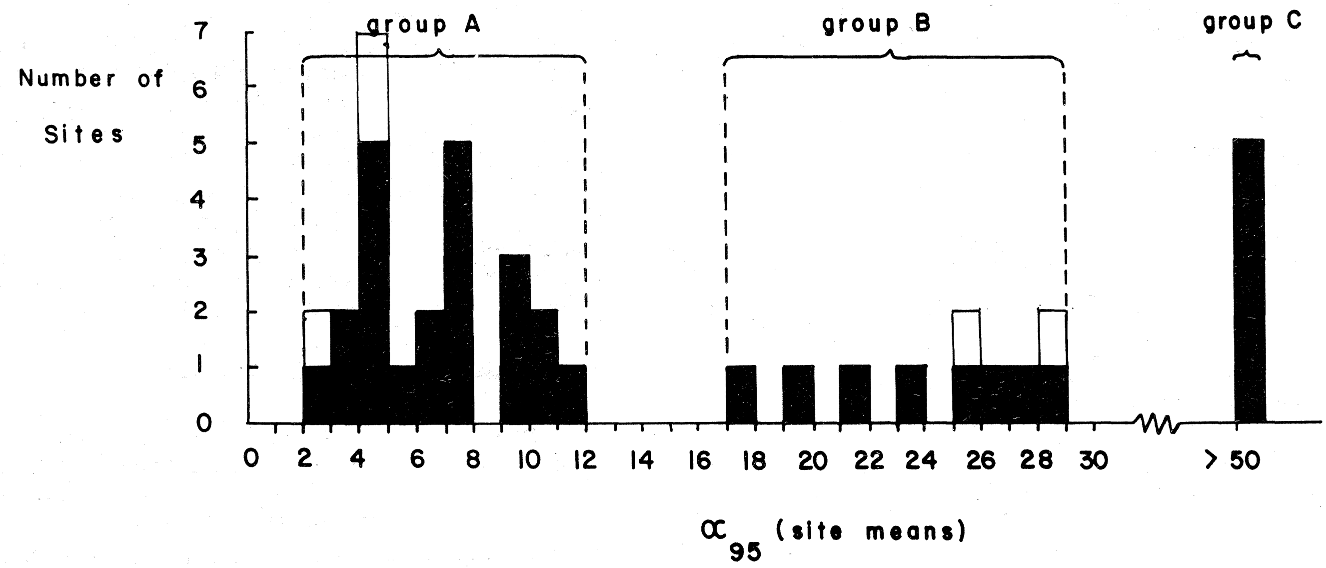


Fig. 5. Histogram of α_{95} values for site mean directions. Data in black are taken from Steele (1971) and data in white are from this study. Note that the site-mean α_{95}'s separate into three groups.

Table 3

Virtual geomagnetic pole dispersion parameters and Brunhes paleosecular variation for the Iztaccíhuatl volcano and Chichinautzin/Iztaccíhuatl, Basin of Mexico.

Data Set	B	PLAT	PLONG	K	A_{95}	Nm	S_T	S_W	S_B	S_F	E	A/B
Iztaccíhuatl volcano												
S-85	24	86.9	333.2	30	5.5	6.7	14.9	11.4	14.2	14.2	0.88	2.12
R-85	18	87.7	33.5	105	3.4	6.7	7.9	11.6	6.5	6.4	0.83	1.79
E-93	21	88.1	34.0	89	3.4	6.7	8.7	11.0	7.5	7.4	0.86	1.95
Chichinautzin/Iztaccíhuatl												
B-90	74	88.3	72.4	27	3.3	7.4	15.9	9.7	15.4	15.4	0.76	1.53
S-90	68	87.9	95.1	44	2.6	7.4	12.3	9.8	11.7	11.7	0.68	1.36

Note: Data sets: S-85=Steele (1985) set; R-85=Steele (1985) data set without outliers; E-93=expanded data set with three additional sites and without outliers; B-90=Böhnel *et al.* (1990) data set for Bruhnes volcanics of the Basin of Mexico; S-90=selected data set for Bruhnes volcanics from the Basin of Mexico. B=number of site VGPs; PLAT/PLONG=Latitude (N) and Longitude (E) of paleomagnetic pole; K=Fisher precision parameter for mean VGP; A_{95}=cone of confidence at 95% probability level for mean VGP; Nm=average number of samples per site; S_T, S_W, S_B, S_F=angular dispersion parameters corresponding to total (T), within-site (W), between-site (B) and field (F) (paleosecular variation estimate is given by S_F); E=eccentricity; A/B=ratio of major to minor axis of ellipse that approximates the VGP distribution. See text for discussion of results and interpretation.

lar variation estimate is dependent on the inclusion or exclusion of outliers. Removing the outliers eliminates the apparent discrepancy between Böhnel *et al.* (1990) and Steele (1985), which is therefore due to different methodology and criteria.

Inclusion of the three VGP data with site-mean α_{95} values less than 12° gives essentially the same results (Table 3). The best estimate for the paleosecular variation S_F is 7.4° (Table 3), which is smaller than that predicted by global paleosecular variation models (including recent model G of McFadden *et al.*, 1988) and the estimates for the Basin of Mexico and Hawaiian islands (Böhnel *et al.*, 1990). It is similar to the estimate derived for Pagan Islands (US-Japan Program, 1975) (see Figure 7). In comparing the data sets published by Steele (1971, 1985) and Mooser *et al.* (1974) some minor discrepancies are noted, including the presence of a site apparently not included by

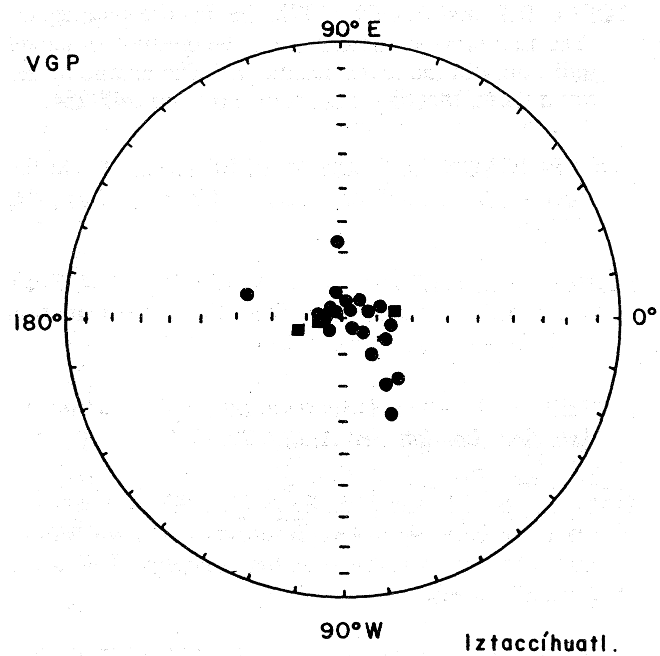


Fig. 6. Site-mean virtual geomagnetic poles (VGP) for the Iztaccíhuatl units plotted in an equal-area net. Data taken from Steele (1985) are represented by dots and data reported here are given by squares. Note the the VGP distribution is non-Fisherian. The corresponding site-mean directions (not shown) result in a distribution similarly elongated.

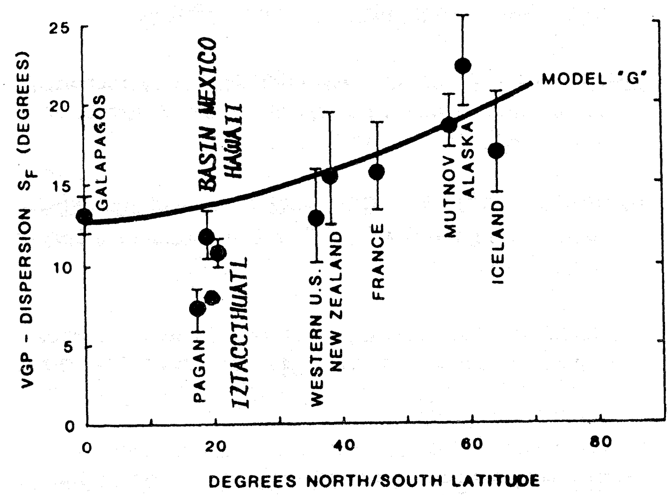


Fig. 7. Variation of paleosecular variation in terms of S_F VGP angular dispersion as a function of latitude for various paleomagnetic data sets (references in Lund, 1985). The solid line represents the fit of paleosecular variation model G of McFadden *et al.* (1988) to the 5 Ma average results (Böhnel *et al.*, 1990). Note that the S_F data for Hawaii, Pagan, Basin of Mexico and Iztaccíhuatl fall below the paleosecular variation model curve. The interpretation is in terms of a low non-dipole region in the Pacific basin during the Brunhes polarity chron.

Steele (1985) (site 24 in Mooser *et al.*, 1974 list). This site is based on only 3 samples and was not considered useful for the analysis, but the test incorporating this result gives the same results with identical S_F value and similar mean VGP and shape estimates (**E** = 0.84 and **A/B** = 1.87).

The dipolar inclination for the Iztaccíhuatl volcano (the volcanic structure is elongated in a north-south trend) varies from about 34.7° to 34.9°. The corresponding ΔI value (i.e., the difference between the observed mean inclination and the mean dipolar inclination, 34.8°) is -2°. The global pattern of the ΔI anomaly roughly estimates how well the axial dipole hypothesis represents the paleomagnetic field during a given period (e.g., Lund, 1986). The value derived from the Iztaccíhuatl volcano is relatively small.

4.3. Paleomagnetic and volcanic history

The main conclusions reached by Steele (1985) concerning the volcanic history of Iztaccíhuatl volcano appear well supported: (1) the normal magnetic polarity and K-Ar dates (Nixon *et al.*, 1986) support the construction of the volcano during the recent Brunhes chron; and (2) the time represented by the lava flows studied is likely to be long (but the paleomagnetic argument in terms of normal paleosecular variation recorded by the lavas does not seem valid). The estimate of paleosecular variation, as discussed above, depends essentially on the method and assumptions made. This is also the case for Basin of Mexico data analyzed by Herrero-Bervera *et al.* (1986) and Böhnel *et al.* (1990) (i.e., the Chichinautzin data set, which includes the Iztaccíhuatl data). The corresponding data are given in Table 3. If the best paleosecular variation estimate corresponds to the selected data set, then the VGP dispersion value is smaller than the value for the expanded data set for the Basin (S_F=11.7° for Chichinautzin and Iztaccíhuatl data). Using the arguments adopted by Steele (1985), this should mean that the time involved by the Iztaccíhuatl lavas is small compared to the secular variation for the region. Such conclusions and application of the paleomagnetic data require further examination.

5. CONCLUSIONS

The observation by Steele (1985) that all lava flows in the upper section of Iztaccíhuatl are of normal polarity and were extruded during the Brunhes Chron seems well established. The time period involved is likely large, which is supported by the K-Ar dates that cover the range 580 000 to 76 000 years ago (Nixon *et al.*, 1986), but the paleomagnetic argument previously used to support these conclusions does not appear to be valid. The VGP distribution is elongated and non-Fisherian and current methods for calculation of paleosecular variation results cannot be used. Shape analyses of the VGP population and application of selection methods for Fisher distribution outliers (Engebretson and Beck, 1978; McFadden, 1980a,b; McFadden *et al.*, 1988) result in restricted data sets and a low paleosecular variation estimate. The observed overall VGP dispersion for Iztaccíhuatl appears to include sources of scatter other than those for paleosecular variation of the geomagnetic field. Such dispersion sources may include local undetected tectonic effects or excursions/events of the geomagnetic field.

The new analysis eliminates the apparent discrepancy between the conclusions of Steele (1985) and those of Böhnel *et al.* (1990) concerning the characteristic paleosecular variation for the Basin of Mexico during the Brunhes chron. The discrepancy was due to the different methodology and assumptions on the statistical distribution of VGP data. Application of shape analysis and assumptions for a Fisherian distribution of VGP data give an estimate of paleosecular variation lower than the values predicted by global latitude-dependent models (Figure 7). The Basin of Mexico seems characterized by a low paleosecular variation of the geomagnetic field during the Brunhes chron and thus appears to form part of the low non-dipole region of the central Pacific.

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