Geof. Int. Vol. 20-3, 1981, pp. 235-248.

PRELIMINARY RESULTS OF PALAEOMAGNETIC MEASUREMENTS OF TERTIARY-QUATERNARY IGNEOUS ROCKS FROM THE EASTERN PART OF THE TRANS MEXICAN VOLCANIC BELT

H. BOHNEL*

J. F. W. NEGENDANK**

RESUMEN

Resultados paleomagnéticos de aproximadamente 500 muestras orientadas colectadas en 59 sitios de la sección este del eje volcánico trans-Mexicano se presentan en este trabajo. Las rocas ígneas estudiadas son del Plioceno y Cuaternario, con la excepción del macizo de Palma Sola, de edad Mioceno. Los resultados paleomagnéticos se usan para correlacionar con resultados geoquímicos y geológicos del área y con resultados paleomagnéticos de Norteamérica y México. Los resultados no indican movimiento relativo significante entre Norteamérica y la sección central-este de México en el período estudiado.

ABSTRACT

About 500 oriented samples were taken from 59 sites in the eastern part of the Trans Mexican Volcanic Belt. The investigated igneous rocks are of Pliocene to Quaternary, and additionally in the Palma Sola Massif of Miocene age. Besides correlations with geochemical and geological results it was the intention to determine the mean poles from the palaeomagnetic directions for the Quaternary and upper Tertiary. The results indicate no significant relative motion between North America and eastern Mexico during this time.

* *Institut für Geophysik, Universität Münster Gievenbecker Weg 61, D-4400 Münster, Germany.*

** *Abteilung Geologie der Fachgruppe Geographie, Universität Trier, Trier-Tarforst, D-5500 Trier, Germany.*

INTRODUCTION

During 1979 and 1980 extensive geological field work was carried out in the area between Cd. Serdán, Jalapa and Palma Sola (N of Veracruz), belonging to the eastern part of the Trans Mexican Volcanic Belt (TMVB) (Fig. 1). The work included aerial-photography interpretation, mapping and sampling for geochemical investigations and radiometric datings. Also in 1980, about 500 oriented samples were taken for palaeomagnetic work. Besides special investigations in conjunction with the geochemical and geological investigations it was the aim of those measurements to obtain new data for the secular variation of the earth's magnetic field at this latitude, as well as to search for possible tectonic motions between the sampling area and North America.

The plate tectonic evolution of Mexico is still unknown because only a few reliable palaeomagnetic data are available today. Starting from reconstructions of the continental drift as e.g. the well known "Bullard-fit", Mexico obviously could not have been part of the North American plate in former times, as this would imply large overlapping with South America. Therefore, several models were proposed which allow Mexico to arrive at the today position by movements along different postulated shear zones (e.g. Dickinson and Coney, 1980; Gose *et al.*, 1980). Most authors assume that the main movement occurred soon after the opening of the Atlantic. Other researchers assume movements until Tertiary times (e.g. Walper, 1980). Some palaeomagnetic results seem to support this idea (Urrutia-Fucugauchi and Pal, 1977; Urrutia-Fucugauchi, 1981b) as well as the concept of microplate rotations near the TMVB (Urrutia-Fucugauchi, 1981a). Samples were, therefore, taken from the eastern part of the TMVB, dating back to the upper Tertiary, to examine if such movements could be detected in this region.

GEOLOGICAL SETTING

Fig. 1 shows the geological situation of the eastern area of the Trans Mexican Volcanic Belt. The area is characterized by the Massif Cofre de Perote - Pico de Orizaba, which borders the Altiplano area to the east and forms the mountain range dipping to the coast.

In this discussion 4 geological units are used (Negendank *et al.*, 1982):

1. The Altiplano-area is characterized by basaltic and rhyolitic volcanoes overtopping Cretaceous mountain ranges and monogenetic cones and maars lying inside flat undrained basins. The igneous rocks are of Quaternary age.

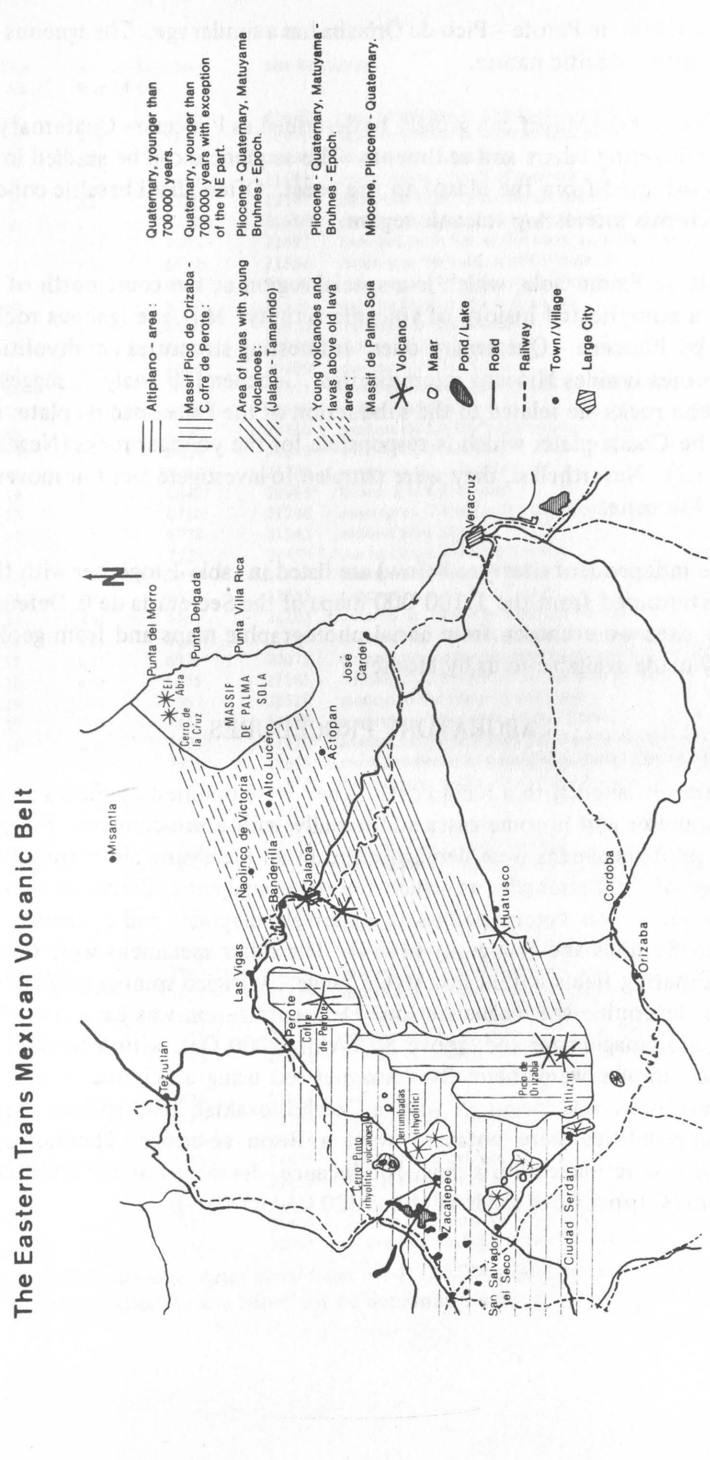

Fig. 1. Geological sketch map of the investigated area of the Trans Mexican Volcanic Belt.

2. The Massif Cofre de Perote - Pico de Orizaba has a similar age. The igneous rocks are of andesitic - dacitic nature.

3. The area east of the Massif can grossly be described as Pliocene - Quaternary lava-units interfingering lahars and sediments. The sequences can be studied in steep barrancas oriented from the Massif to the coast. Often alkali basaltic cones and lavas enrich this interesting volcanic region.

4. The Massif de Palma Sola, which is a special region at the coast north of Veracruz, has a complicated history of volcanic activity. Miocene igneous rocks are overlayn by Pliocene - Quaternary ones. Interesting structures are rhyolitic "silexitic" domes besides Miocene microdiorites. Geochemical analyses suggest that the Miocene rocks are related to the subduction of the Palaeopacific plate, rather than to the Cocos plate, which is responsible for the younger rocks (Negendank *et al.,* 1982). Nevertheless, they were sampled to investigate tectonic movements since the Miocene.

Fifty five independent sites (see below) are listed in table 1 together with the coordinates determined from the 1:100 000 maps of the Secretaria de la Defensa Nacional. The sites were chosen from aerial photographic maps and from geological maps kindly made available to us by Mooser.

LABORATORY PROCEDURES

Samples were obtained with a hand corer. They were oriented by means of a magnetic inclinometer and in some cases additionally with a sun-compass. From each site 2 or 3 pilot-specimens were demagnetized in an increasing alternating field to get the range of field strengths, at which the palaeomagnetic directions were most stable. This range was determined using Zijderveld diagrams and a stability index according to Symons and Stupavsky (1974). The other specimens were demagnetized in alternating fields within this stable range. A Digico spinner magnetometer was used to determine the magnetization. Demagnetization was carried out with a Schonstedt af-demagnetizer and, above 80 kA/m (1000 Oe), with a tumbler apparatus. Some samples were thermally demagnetized using a Schonstedt apparatus; their magnetization was measured with a Czechoslovakian JR-3 spinner magnetometer. Susceptibilities were obtained with a Bison ac-bridge. Thermomagnetic measurements were made with a magnetic balance, developed at the Ruhr-Universität Bochum (Germany), at fields of about 320 kA/m (4 kG).

Table 1

Site No.	Site coordinates Map 14 Q –			Site description
1	i(2)	7328	21679	way Almolonga to Alto Lucero, creek-bed near Almolonga
2	i(8)	6820*	20970*	way Atzitzintla to Atlitzin volcano, ca. 5 km SSE of summit
3	i(8)	6780*	20900*	roadcut near Atzitzintla
4	i(2)	7155	21692	creek-bed ca.1 km N of Banderilla
5	i(2)	7180	21741	creek-bed between Banderilla and Naolingo de Victoria
6	i(2)	7222*	21685*	outcrop ca. 6 km E of Banderilla on the way to Actopan
7	i(5)	7206	21497	river-bed from Rio de Cozalapa, ca. 6 km ESE of Coatepec
8	i(5)	6972	21556	outcrop at the summit of Cofre de Perote
9	i(5)	6971	21556	outcrop ca. 100 m downhill of site 8
10	i(5)	6970	21556	outcrop further 100 m downhill
11	i(7)	6660*	20920*	outcrop S of Cd. Serdan
12	i(7)	6620*	20930*	outcrop S of Cd. Serdan
13	i(7)	6640*	20980*	outcrop S of Cd. Serdan
14	i(2)	7047	21711	outcrop between Las Vigas and La Joya Chica
15	i(2)	7209	21605	quarry E of Jalapa
16	i(2)	7235	21760	roadcut ca. 1.5 km N of Naolingo de Victoria
17	i(4)	6669	21340	outcrop ca. 5 km NE of C. Derrumbadas
18	i(2)	7062	21709	quarry ca. 2 km E of site 14
19	i(7)	6640*	20965*	quarry S of Cd. Serdan
20	i(4)	6710	21296	outcrop ca. 7 km E. of C. Derrumbadas
21	i(5)	6778	21343	roadcut near Saltillo
22	i(5)	7129	21459	roadcut ca. 2 km NNW Teocelo
23	i(2)	7018	21717	roadcut ca. 3 km W of site 14
24	i(4)	6677	21335	outcrop ca. 1 km SE of site 17
25	i(4)	6560	21103	outcrop ca. 3 km E of San Juan Atenco
26	i(5)	6761	21335	roadcut ca. 1 km E of Guadalupe Victoria
27	i(5)	6827*	20075	outcrop near mountain-climber cottage N of Pico de Orizaba
28	i(4)	6455	21185	outcrop ca. 3 km NE of San Salvador el Seco
29	i(5)	7365	21529	roadcut in the village Corral Falso
30	i(5)	7311	21562	roadcut ca. 3 km WNW of Dos Rios
31	i(2)	7005*	21710*	roadcut on the way from Las Vigas to Microondas
32	i(2)	7000*	21685	creek-bed nearer to transmitting station than site 31
33	i(6)	7531	21575	outcrop near bridge across Rio Actopan
34	i(4)	6568	21353	outcrop ca. 1 km S of Portes Gil
35	i(3)	7726	21813	roadcut ca. 2 km SW of Punta Limon
36	i(3)	7713	21757	roadcut W of Laguna Cameron
37	i(3)	7604	21913	river-bed W of Villa Candelaria
38	i(3)	7604	21883	river-bed W of Colorado
39	i(3)	7709	21837	quarry W of Punta Limon
40	i(3)	7631	21787	river-bed S of C. Veinticuatro
41	i(3)	7704	21825	outcrop on way for high tension line W of Punta Limon
42	i(3)	7707	21876	roadcut 1.5 km S of Palma Sola
43	i(3)	7691	21831	outcrop on the same way as site 41
44	i(3)	7635	21891	roadcut ca. 5 km SE of C. de la Cruz
45	i(2)	6951	21750	roadcut at the way from Las Vigas to Tatatila
46	i(3)	7548	21872	roadcut ca. 2 km WNW of Topilito de Zaragoza
47	i(3)	7731	21702	roadcut W of Punta Mancha
48	i(3)	7698	21837	outcrop on the same way as site 41
49	i(3)	7719	21766	roadcut W of C. Metates
50	i(3)	7723	21858	dike at Punta Delgada
51	i(3)	7723	21857	dike at Punta Delgada
52	i(3)	7723	21857	dike at Punta Delgada
53	i(4)	6641	21413	roadcut ca. 7 km E of C. Pinto
54	i(5)	7315	21409	roadcut ca. 5 km WNW of Jalcomulco
55	i(3)	7554	22055	quarry ca. 2 km WSW of Rancho Nuevo

Table 1. Site locations as determined from the 1:100 000 map (Secretaría de la Defensa Nacional). * indicates that the site could not be determined with an accuracy of 0.1 km from these maps.

MAGNETIC PROPERTIES

The magnetization, obtained in the magnetically stable range giving smallest variations, was chosen as the characteristic remanent magnetization (CARM). The site mean CARM is listed in Table 2 together with other parameters as natural remanent magnetization (NRM), susceptibility χ_{SI}, Königsberger factor Q, median destructive

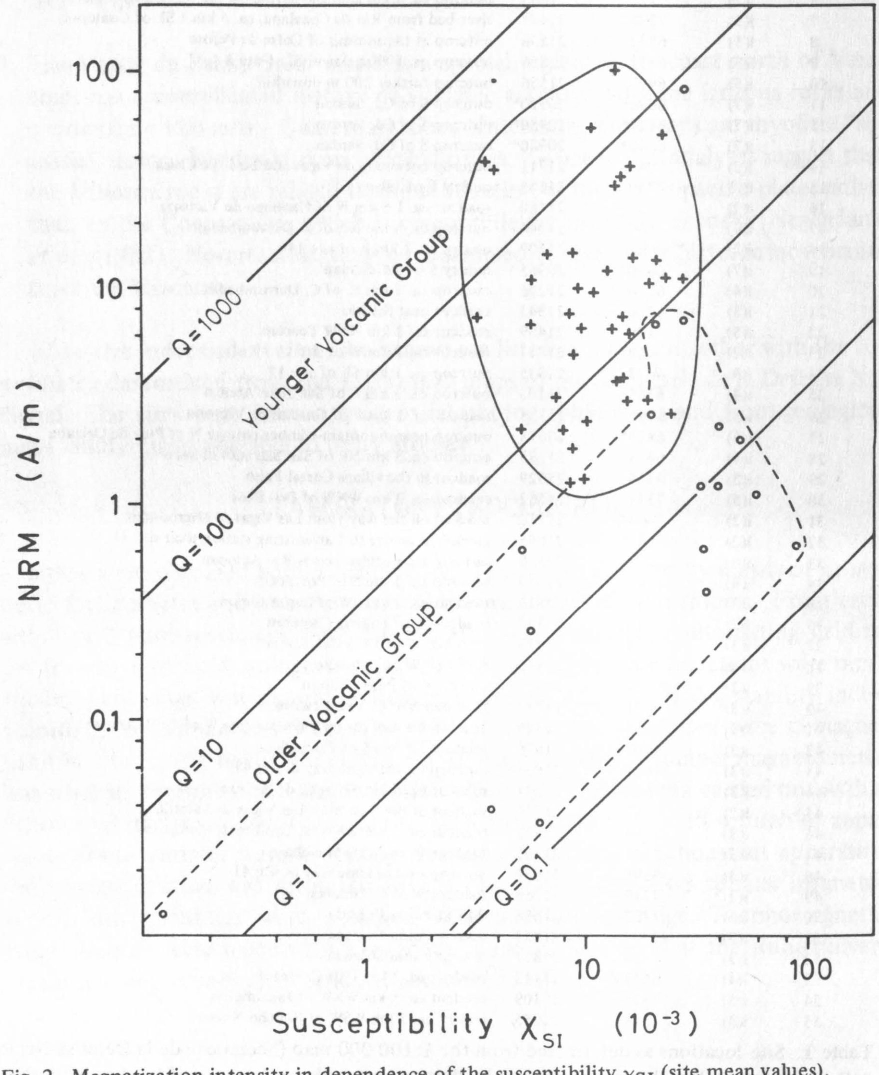

Fig. 2. Magnetization intensity in dependence of the susceptibility χ_{SI} (site mean values). Circles denote old volcanics, crosses young volcanics.

Table 2

Site No	N	M_o A/m	H_{af} kA/m	M A/m	M/M	χ_{SI} 10^{-3}	Q	MDF kA/m	Paleodirection Dec./Inc.	α_{95}	k	Poleposition Long./Lat.	dp/dm
1	7	2.187	24	1.247	0.57	7.86	7.7	26.9	353.3/ 23.2	1.7	1265	124.9/ 80.1	1.0/ 1.8
2	9	33.076	32	3.814	0.12	14.24	62.7	15.1	25.5/ 18.1	20.0	8	10.7/ 63.5	10.8/ 20.8
3	6	12.668	24	3.391	0.27	15.97	27.9	20.4	357.9/ 45.8	7.0	92	246.5/ 83.1	5.5/ 8.8
4	8	2.981	16	2.519	0.85	15.34	10.6	25.2	359.5/ 21.7	2.5	501	86.8/ 81.6	1.4/ 2.6
5	9	6.694	24	3.045	0.45	5.58	23.1	26.9	4.4/ 25.0	2.4	452	49.2/ 82.3	1.4/ 2.6
6	9	10.890	24	5.724	0.53	5.61	55.8	28.2	338.9/ 39.8	11.6	21	185.6/ 70.1	8.4/ 13.9
7	9	11.130	16	7.965	0.72	22.62	13.4	24.8	1.4/ 33.4	2.6	401	33.0/ 88.2	1.7/ 2.9
8	8	1.295	36	0.651	0.50	9.69	4.2	42.0	349.3/ 27.4	2.0	799	148.6/ 78.6	1.2/ 2.1
9	7	1.263	8	1.089	0.86	8.41	4.3	22.3	352.1/ 32.5	1.9	1032	160.0/ 82.3	1.2/ 2.1
10	9	2.372	12	2.015	0.85	10.04	8.2	63.9	343.2/ 19.0	3.7	190	144.3/ 71.1	2.0/ 3.9
11	9	6.357	24	4.323	0.68	12.96	17.0	39.1	351.0/ 27.0	13.9	15	146.0/ 80.2	8.2/ 15.1
12	8	7.283	12	5.927	0.81	14.68	14.0	43.0	16.5/ 1.7	15.0	15	38.9/ 65.8	7.5/ 15.0
13	7	9.466	24	3.480	0.37	10.78	26.1	35.6	216.8/ 55.2	79.5	2	230.1/−25.2	80.4/113.0
14	6	13.356	40	2.829	0.21	20.54	16.7	19.2	312.1/ 36.8	25.5	8	182.7/ 45.2	17.4/ 29.8
15	7	7.165	16	5.648	0.79	3.22	73.0	29.7	346.1/ 23.9	8.9	47	147.5/ 74.9	5.1/ 9.5
16	8	11.952	20	2.079	0.17	12.37	27.6	15.7	351.9/ 24.1	12.0	22	132.1/ 79.5	6.9/ 12.9
17	9	29.299	32	22.326	0.76	13.28	62.6	54.4	19.2/ 59.9	9.7	29	295.8/ 63.0	11.1/ 14.7
18	7	10.548	28	3.266	0.31	19.02	17.1	18.4	1.7/ 21.4	6.7	82	71.3/ 81.3	3.7/ 7.1
19	7	36.400	64	2.905	0.08	15.23	64.9	26.0	350.5/ 39.1	6.7	83	194.0/ 80.6	4.8/ 8.0
20	8	2.583	48	0.992	0.38	23.82	3.1	26.2	28.6/−12.0	18.0	50	124.8/ 57.0	4.1/ 8.1
21	7	6.528	32	1.447	0.22	9.47	17.3	23.0	16.7/ 50.7	4.9	153	310.7/ 70.7	4.4/ 6.6
22	10	3.849	40	0.892	0.23	14.58	8.0	21.9	358.4/ 44.2	2.4	407	250.3/ 83.3	1.9/ 3.0
23	8	9.890	12	7.017	0.71	9.11	29.4	22.0	348.3/ 33.5	3.4	272	168.1/ 78.9	2.2/ 3.8
24	5	54.586	40	2.949	0.05	10.36	163.9	16.7	338.1/ 41.8	32.6	7	189.7/ 69.1	24.4/ 39.9
25	22	53.638	120*			10.88	145.3	24.3	352.0/ 41.9	9.1	9	208.1/ 81.0	6.8/ 11.1
26	15	9.538	36*			6.80	41.0	16.2	12.1/ 51.8	5.4	51	299.8/ 73.0	5.0/ 7.4
27	16	4.339	48*			10.87	19.4	29.3	358.6/ 30.8	2.4	239	110.6/ 87.2	1.5/ 2.7
28	15	36.654	48*			3.63	313.9	23.7	19.1/ 16.6	6.5	36	19.7/ 68.7	3.5/ 6.7
29	8	14.265	40	1.103	0.08	8.27	50.4	20.8	7.7/ 19.6	7.6	54	43.9/ 78.0	4.1/ 7.9
30	11	1.842	40	1.023	0.56	8.68	6.4	44.3	2.8/ 20.0	1.9	576	66.3/ 80.4	1.0/ 2.0
31	8	11.072	12	6.456	0.58	26.91	11.0	20.3	8.3/ 30.7	3.7	220	12.6/ 81.5	2.3/ 4.2
32	10	6.183	28	3.078	0.50	15.37	8.7	45.5	178.2/−35.1	6.6	55	346.1/−88.3	4.4/ 7.6
33	7	3.008	32	0.331	0.11	10.01	4.3	12.0	180.4/−25.5	5.8	111	259.4/−83.9	3.3/ 6.2
34	9	2.273	40	0.332	0.15	12.53	5.4	18.6	334.5/ 37.0	9.7	29	180.1/ 66.0	6.7/ 11.4
35	6	2.15#	500°C	1.27#	0.59	0.23	17.9		349.8/−26.8	16.5	17	100.8/ 54.7	
36	5	12.4 #	56	6.5 #	0.52	0.12	188.7	98.8	191.8/−23.9	20.0	16	204.4/−76.6	11.4/ 21.4
37	8	1.026	var.			70.83	0.25	11.2	152.4/−33.2	10.3	30	354.4/−63.9	
38	9	0.263	40	0.179	0.68	5.57	2.4	84.6	203.6/ 11.8	9.5	31	219.0/−55.3	4.9/ 9.6
39	6	0.392	28	0.028	0.07	34.52	0.44	4.2	160.6/−44.3	6.5	108	16.7/−71.1	5.1/ 8.1
40	8	0.615	16	0.173	0.28	33.70	0.56	8.9	345.5/ 40.5	5.2	113	190.4/ 76.1	3.8/ 6.3
41	12	82.013	40	1.378	0.02	27.27	84.1	14.5	348.0/ 34.2	21.5	5	170.9/ 78.6	14.1/ 24.6
42	7	1.958	12	0.879	0.45	38.30	1.6	10.6	347.1/ 25.0	5.0	149	147.5/ 76.0	2.9/ 5.3
43	6	5.81#	64	4.28#	0.74	0.13	129.6	43.6	179.0/−38.3	13.0	27	55.9/−87.9	9.2/ 15.4
44	8	7.139	24	2.725	0.38	27.24	10.6	16.7	177.9/−20.4	2.9	367	276.1/−80.5	1.6/ 3.0
45	11	2.641	32	1.204	0.46	19.24	4.1	36.8	182.6/−27.9	3.2	209	235.7/−84.5	1.9/ 3.5
46	8	6.775	32	1.416	0.21	20.65	9.3	18.4	184.7/−22.2	5.0	125	234.2/−80.6	2.8/ 5.3
47	8	0.384	28	0.146	0.38	3.74	1.9	35.7	354.8/ 31.3	5.8	92	145.5/ 84.4	3.6/ 6.5
48	4	0.608	64	0.046	0.08	5.14	0.9	27.7	154.3/−66.0	37.0	7	53.7/−54.7	49.4/ 60.5
49	6	0.033	500°C	0.128		6.27			191.6/−38.5	3.5	367	161.1/−78.9	
50	7	2.342	32	0.215	0.09	38.65	1.7	12.6	357.6/ 38.5	4.9	154	213.6/ 87.0	3.4/ 5.8
51	7	1.179	24	0.310	0.26	38.50	0.9	13.4	358.6/ 44.8	5.4	127	252.5/ 83.3	4.3/ 6.8
52	8	1.108	24	0.253	0.23	57.80	0.6	20.7	336.5/ 51.0	8.2	46	207.7/ 65.8	7.5/ 11.1
53	4	2.78#	500°C	1.8 #	0.65				366.5/ 35.7	10.9	71	179.5/ 86.7	
54	9	2.174	48	0.357	0.16	5.08	12.4	24.6	160.5/−38.5	2.1	588	4.6/−71.6	1.5/ 2.5
55	7	1.193	24	0.529	0.44	32.02	1.0	22.6	132.1/ 64.0	9.2	44	295.3/ 11.3	11.7/ 14.7

Table 2. Magnetic properties and palaeomagnetic results (site mean values). N: samples used for statistic; M_o: NRM-intensity; H_{af}: peak af-demagnetizing field; M: magnetization intensity at H_{af}; χ_{SI}: susceptibility in SI-units; Q: Koenigsberger factor; MDF: median destructive field; α_{95}: confidence circle; k: precision parameter; dp/dm: axes of confidence oval. Remarks: = intensity in 10^{-3} A/m; * different H_{af}-values. Quaternary sites: 1 to 33, Tertiary sites: 35 to 55.

field (MDF, inter- or extrapolated), site mean directions, poles (VGP) and the Fisherian statistical parameters.

In Fig. 2 the NRM-values are plotted against the susceptibility χ_{SI}. The range of the magnetization (NRM) is 0.002 A/m to 99.7 A/m and $0.12 \cdot 10^{-3}$ to $77.8 \cdot 10^{-3}$ for the susceptibilities. Most interesting is the difference between old and young volcanics, mainly due to lower magnetization intensity. Since the carriers of magnetization are believed to be the same for both (see below), it is supposed that the older rocks contain minor amounts of magnetic material, resulting in a smaller NRM. Chemical analyses and ore-microscopic investigations are in preparation.

Königsberger's Q-factor varies between 0.25 and 362. Most volcanics exceed values of 0.5, thus indicating that more or less single domain particles govern the magnetic properties. This can also be argued from the MDF-values which often are greater than 32 kA/m (400 Oe).

Initial measurements on specimens from old and young volcanics with a magnetic balance resulted in Curie-temperatures between 507°C and 575°C. In one case a second component with $T_C = 144°C$ was observed. Thus titanomagnetites with strong tendency to magnetite seem to be the magnetic carriers. Measurements of the Curie-temperatures will be completed on other specimens.

From the magnetic properties it can be concluded that the measured magnetization predominantly is caused by titanomagnetites with a considerable amount of single-domain particles. Therefore, the CARM-directions are believed to be primary, stable and reliable.

MEAN POLES

To calculate the mean poles for the Quaternary and upper Tertiary the sites were treated according to available K/Ar dates and stratigraphic correlations (Mooser, 1980) as two age groups. The volcanics investigated are either of Quaternary or Tertiary age (Massif de Palma Sola, 3.0 to 12.3 million years).

The data from three sites were discarded, because they show intermediate directions (No.55), extremely scattered directions (No.33) or the age of the site is unknown (No.34). Four sites could be related to the same volcano. So, 52 independent poles remained, 32 of Quaternary and 20 of Tertiary age.

Fig. 3 shows the VGP's together with their confidence ovals. For both periods considered the poles approximately scatter around the north geographic pole. This would be expected for a tectonically undisturbed region in the case of an axial geocentric dipole as source of the magnetic field.

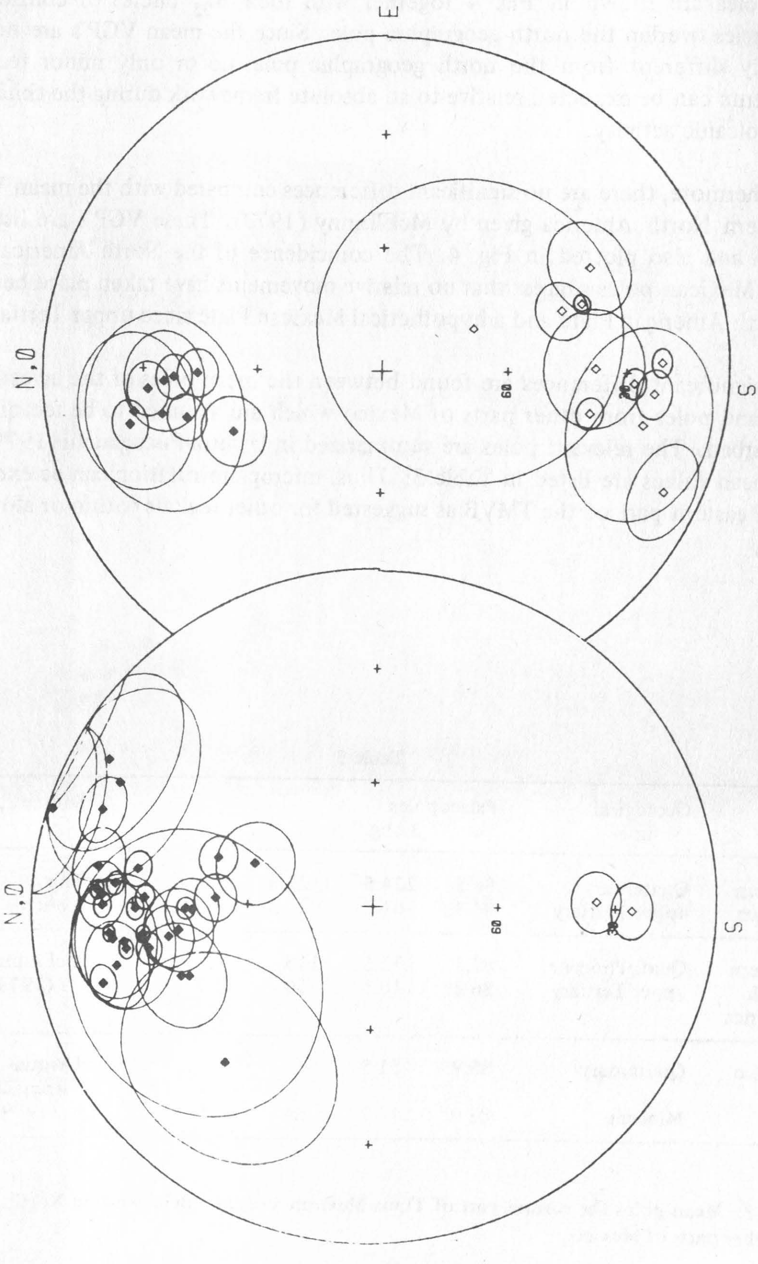

Fig. 3. Site mean VGP's with A_{95} confidence limits.

Giving unit weight to all site mean VGP's, mean VGP's for the Quaternary and Tertiary are calculated yielding 86.5N/234.5E and 84.3N/161.2E, respectively. The mean poles are shown in Fig. 4 together with their A_{95} circles of confidence. Both circles overlap the north geographic pole. Since the mean VGP's are not significantly different from the north geographic pole, no or only minor tectonic movements can be expected relative to an absolute framework during the time span of the volcanic activity.

Furthermore, there are no significant differences compared with the mean VGP's of western North America given by McElhinny (1973). These VGP's are listed in Table 3 and also plotted in Fig. 4. The coincidence of the North American and eastern Mexican poles suggest that no relative movements have taken place between the North American Plate and a hypothetical Mexican Plate since upper Tertiary.

No significant differences are found between the mean poles of the investigated region and poles from other parts of Mexico which are assumed to be tectonically undisturbed. The relevant poles are summarized in Urrutia-Fucugauchi (1979) and their mean values are listed in Table 3. Thus, microplate rotation can be excluded for the eastern part of the TMVB as suggested for other regions within or along the TMVB.

Table 3

	Geological time	Palaeopoles Lat.	Long.	k	A_{95}	N	Source
Eastern Mexico	Quaternary	86.5	234.5	23.8	5.3	32	This work
	upper Tertiary	84.3	161.2	20.6	7.3	20	
Western North America	Quat./Pliocene	82.1	172.5	113	8.7		McElhinny (1973)
	upper Tertiary	86.8	140.1	56	7.0		
Mexico	Quaternary	85.9	51.5				Urrutia-Fucugauchi (1979)
	Miocene	82.0	147.7	94	7.9		

Table 3: Mean poles for eastern part of Trans Mexican Volcanic Belt, western North America and other parts of Mexico.

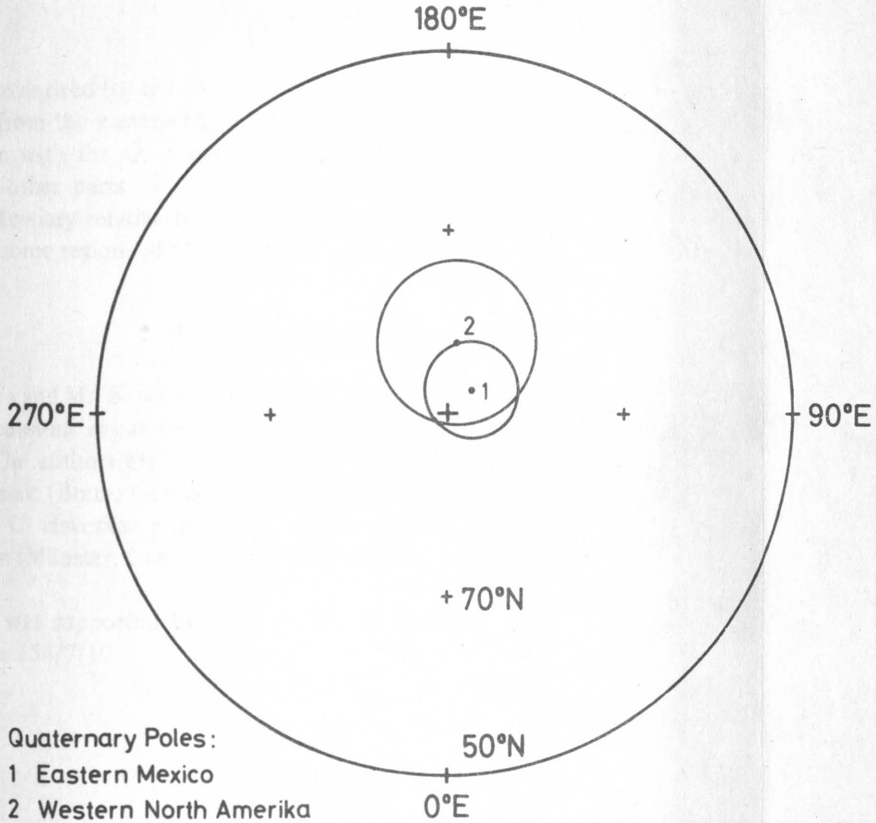

Fig. 4

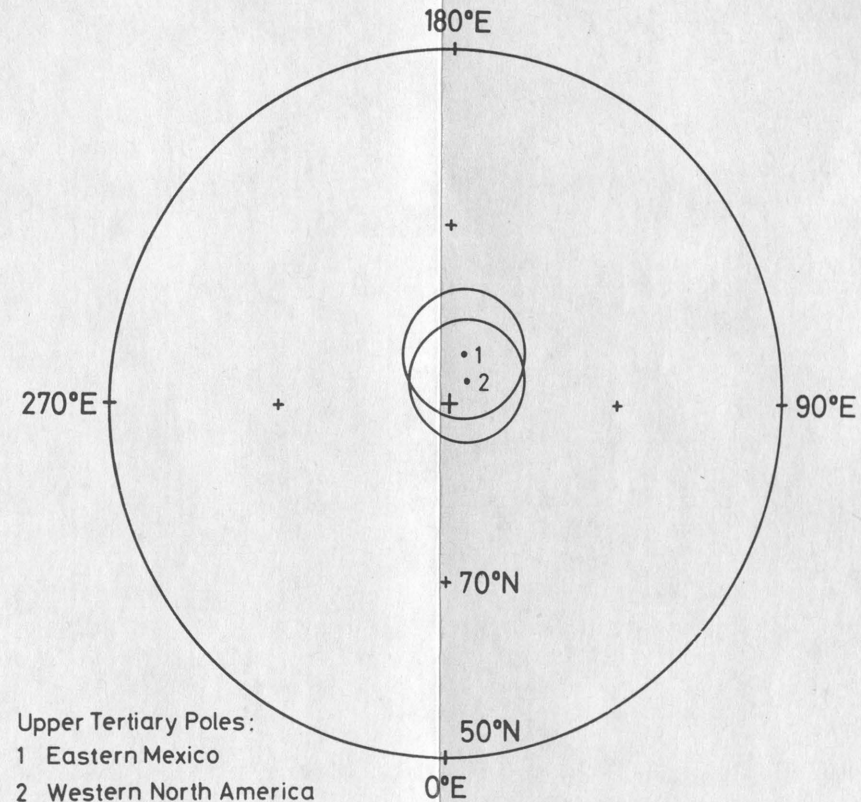

Fig. 4. Mean poles of eastern part of the Trans Mexican Volcanic Belt and western North America for Tertiary and Quaternary.

CONCLUSION

Mean poles are derived for the Quaternary and upper Tertiary using 32 and 20 sites, respectively, from the eastern part of the Trans Mexican Volcanic Belt. The mean poles coincide with the Quaternary and Tertiary poles of western North America and those of other parts of Mexico. Therefore, no significant movements are assumed since Tertiary relative to the North American plate. Microplate rotation as suggested for some regions of Mexico unlikely occurred in the investigated region.

ACKNOWLEDGEMENTS

Dr F. Mooser's and Mr. S. Soto-Pineda's (Mexico-City) support with maps, informations and discussions about the geology of the investigated region is greatfully acknowledged. The authors are also indebted to Dr. U. Bleil (Bochum, Germany) and Dr. K. Krumsiek (Bonn, Germany) for enabling us to use their laboratory equipment, and to U. Haverkamp (Münster, Germany), who assisted during field work. Dr. H. Kohnen (Münster, Germany) carefully read the manuscript.

The work was supported by funds of the Deutsche Forschungs Gemeinschaft (Un 29/24, Ne 154/7/10.

BIBLIOGRAPHY

DICKINSON, W. R., and P. J. CONEY, 1980. Plate tectonic constraints of the origin of the Gulf of Mexico, In: Pilger, R. H. (ed.). The origin of the Gulf of Mexico. Proceedings of a symposium. Baton Rouge, 1980.

GOSE, W. A., G. R. SCOTT and D. K. SWARTZ, 1980. The aggregation of Mesoamerica: Paleomagnetic evidence, In: Pilger, R. H. (ed.). The origin of the Gulf of Mexico. Proceedings of a symposium. Baton Rouge, 1980.

McELHINNY, M. W., 1973. Palaeomagnetism and plate tectonics, Cambridge University Press, Cambridge.

MOOSER, R., 1980. Geology of Laguna Verde. Report of Comisión Federal de Electricidad, Mexico-City.

MOOSER, F., A. E. M. NAIRN and J. F. W. NEGENDANK, 1974. Palaeomagnetic investigations of the Tertiary and Quaternary igneous rocks: VIII. A palaeomagnetic and petrologic study of volcanics of the Valley of Mexico, *Geol. Rudsch., 63,* 2, 451-483.

NAIRN, A. E. M., J. F. W. NEGENDANK, H. C. NOLTIMIER, and T. J. SCHMITT, 1975. Palaeomagnetic investigations of the Tertiary and Quaternary igneous rocks: X. The ignimbrites and lava units west of Durango, Mexico. *N. Jb. Geol. Palaeont. Mh., 11*, 664-678.

NEGENDANK, J. F. W., H. BOHNEL, R. EMMERMANN, R. KRAWCZYK, F. MOOSER, S. SOTO-PINEDA and H. J. TOBSCHALL, 1982. Der Ostteil des Transmexikanischen Vulkanguertels und seine Position im Gesamtguertel, *Naturwiss.*, in press.

SYMONS, D. T. A. and M. STUPAVSKY, 1974. A rational palaeomagnetic stability index, *J. Geophys. Res., 79*, 1718-1720.

URRUTIA-FUCUGAUCHI, J. 1979. Preliminary apparent polar wander path for Mexico, *Geophys. J. R. Astr. Soc., 56*, 227-235.

URRUTIA-FUCUGAUCHI, J., 1981. Palaeomagnetism of the Jantetelco granodiorites and Tepexco volcanic group and inferences for crustal block rotations in central Mexico, *Tectonophysics, 76*, 149-168.

URRUTIA-FUCUGAUCHI, J. 1981b. Paleomagnetic evidence for tectonic rotation of northern Mexico and the continuity of the Cordilleran orogenic belt between Nevada and Chihuahua, *Geology, 9*, 178-183.

URRUTIA-FUCUGAUCHI, J. and S. PAL, 1977. Paleomagnetic data from Tertiary igneous rocks, northeast Jalisco, Mexico. *Earth Planet. Sci. Letters, 36*, 202-206

WALPER, J. L., 1980. Tectonic evolution of the Gulf of Mexico, In: Pilger, R. H. (ed.). The origin of the Gulf of Mexico. Proceedings of a symposium. Baton Rouge, 1980.

(Received June 2, 1981)
(Accepted March 12, 1982)