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PALEOMAGNETIC INVESTIGATION OF QUATERNARY SEDIMENT AT TLAPACOYA, MEXICO, AND AT VALSEQUILLO, PUEBLA, MEXICO[1]

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RESUMEN

Resultados paleomagnéticos para sedimentos del Pleistoceno y Holoceno de dos localidades en el eje transversal mexicano indican una polaridad normal durante ese periodo. No obstante que los resultados para Tlapacoya, Mexico son detallados para el periodo de 25 000 - 5 000 años antes del presente, la dispersión alta de las direcciones de magnetización remanente para la mayoría de los 61 horizontes estudiados indica que el campo paleomagnético no fue registrado con suficiente fidelidad como para permitir la estimación del patrón de variación secular. Resultados para los sedimentos de Valsequillo, Puebla indican que partes de estos son adecuados para investigaciones magnetoestratigráficas. Estos resultados se utilizaron en un intento fallido de datar artefactos del sitio arqueológico de Hueyatlaco.

ABSTRACT

Paleomagnetic data for Pleistocene and Holocene sediments at two localities in Mexico's Transverse Volcanic Belt record normal polarity. Although the data for Tlapacoya, Mexico, are detailed for about 25,000 - 5,000 yrs B. P., the high scatter of directions within most of the 61 horizons indicates the paleomagnetic field was not recorded well enough that inferences can be made about the pattern of secular variation. Samples from Valsequillo, Puebla, demonstrate that portions of the Valsequillo Gravels are suitable for a magnetostratigraphic investigation, and were used in an unsuccessful attempt to date artifacts at the Hueyatlaco archeological site.

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INTRODUCTION

When we sought a locality in Mexico for an investigation of secular variation of the paleomagnetic field, the Instituto Nacional de Antropología e Historia (INAH) of Mexico recommended an archeological site (Tlapacoya I) near the village of Tlapacoya in the southeastern part of the Basin of Mexico. Attractions of the site included stratigraphic and tephrochronologic studies that were recently completed, and age control by numerous ^{14}C dates.

The paleomagnetic data from our field season in 1973 identified a possible microchron ("excursion") of the paleomagnetic field (Liddicoat *et al.*, 1974). Subsequent sampling revealed that the anomalous paleomagnetic directions are probably of some other origin that remains a puzzle, and a recommendation was made that henceforth they should not be cited (Liddicoat *et al*, 1979). Additional paleomagnetic dada were also discussed but not presented in tabular form; we include them here to meet the intent of this volume.

While working in Mexico, our attention was also directed to archeological excavations at the Hueyatlaco site on the north shore of the Valsequillo Reservoir near Puebla. Our search there was for a reversal of the paleomagnetic field (Laschamp Reversed Subchron) that, if found, might limit the age of the artifacts (Szabo *et al.*, 1969; Steen-McIntyre *et al.*, 1973, 1981). The paleomagnetic data, published for the first time, are for fine-grained sediment from the unit called the Valsequillo Gravels, which is well exposed in the area.

TLAPACOYA, MEXICO

In 1973 and 1976, we collected paleomagnetic samples from 61 horizons in two parallel trenches at the Tlapacoya I archeological site. The trenches trend southeast from the base of Cerro Tlapacoya (Fig. 1) and expose a 10-meter section of paludal and lacustrine mud interbedded with air-fall and reworked volcanic ash and pumice lapilli (Lambert, in press). The deposits formed on the margin of ancient Lake Chalco when Cerro Tlapacoya was an island. They are rich in epiclastic sediment derived from Cerro Tlapacoya, the core of an eroded Miocene volcano, and in material reworked from tephra of late Quaternary age that fell on the slopes of the hill. The presence of the volcanic debris results in a relatively strong natural remanent magnetization (NRM) (Fig. 2), and the ^{14}C dates provide the age control that is essential in a study of paleomagnetic secular variation.

Except for a few unconsolidated tephra layers, there are paleomagnetic data for vertical intervals of about 10 centimeters or less throughout the portion of the section that is pre-10,000 yrs B.P.; 51 of the 61 horizons are in the part older than

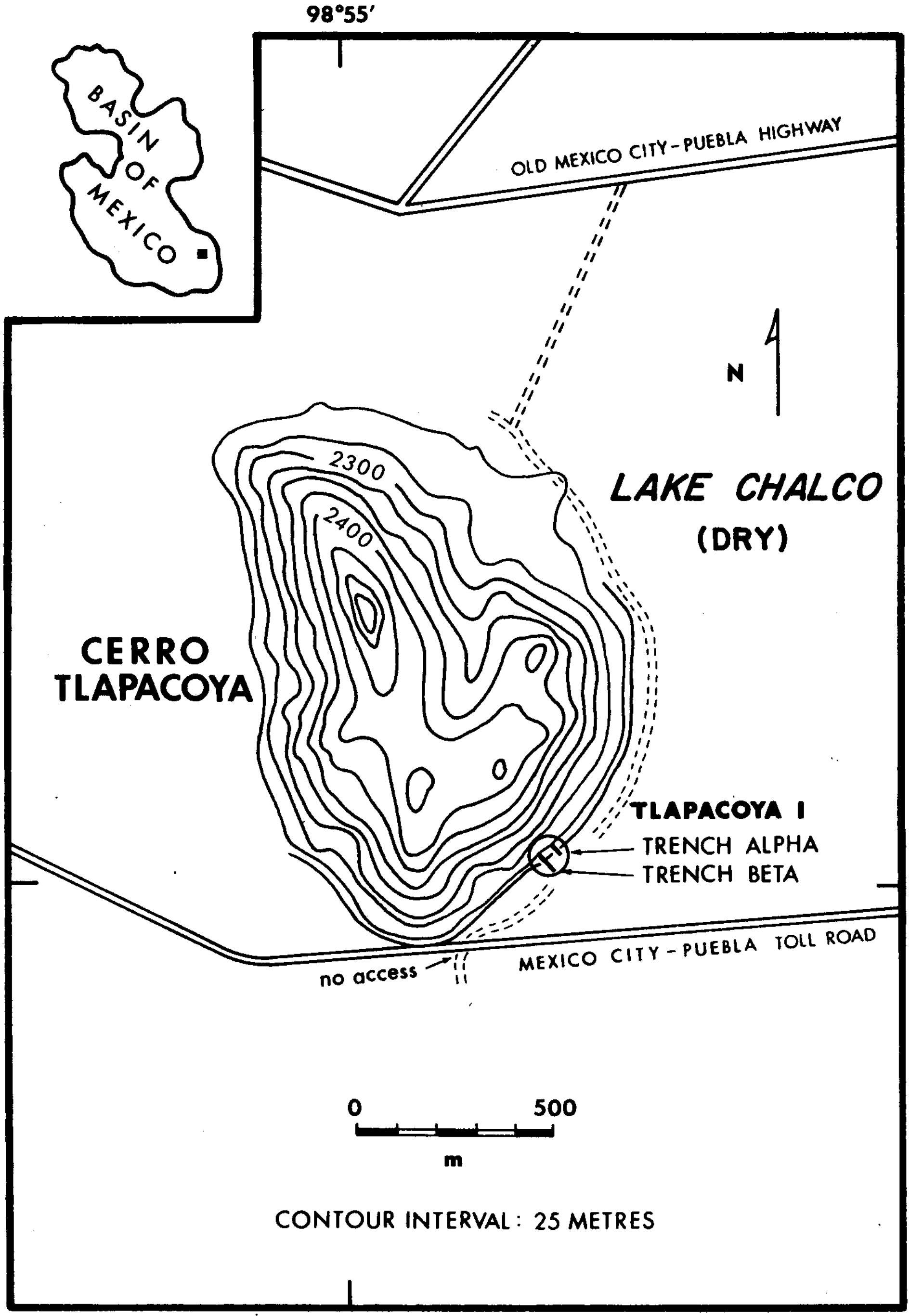

Fig. 1. Topographic map of Cerro Tlapacoya showing sampled trenches (circled) at the Tlapacoya I archeological site on the southeast margin of Cerro Tlapacoya, an island in ancient Lake Chalco. The locality is approximately 28 kilometers southeast of the Zocalo in Mexico City. Modified after an unpublished map by INAH.

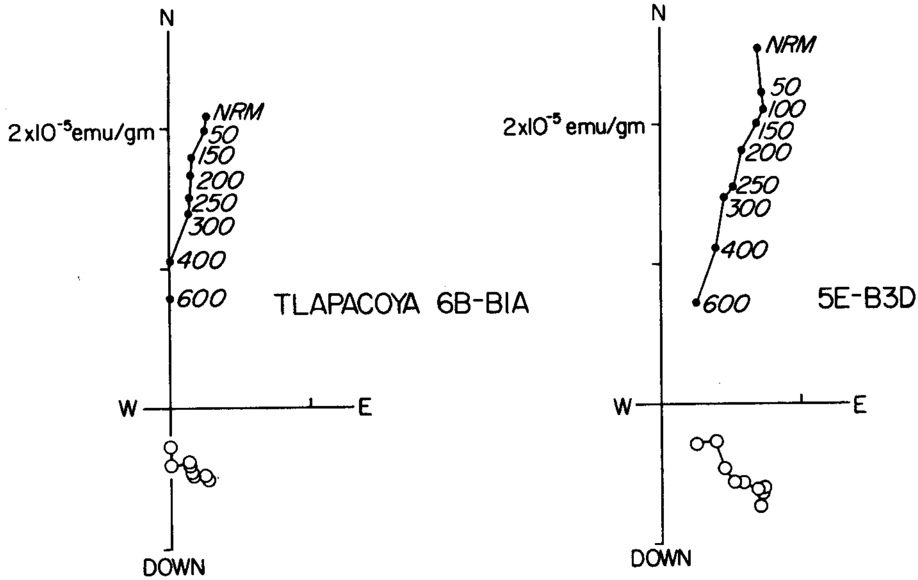

Fig. 2. Vector plots of paleomagnetic directions during progressive alternating field (a.f.) demagnetization for samples from Unit 5 (5E-B3D, mud) and Unit 6 (6B-B1A, ash) at Tlapacoya I. The median destructive field for both samples is about 250 oersteds (25 mTesla). Numbers in the plot indicate the level of demagnetization in oersteds. Open circles are projections on the EW-Vertical plane, filled circles are projections on the NS-EW plane.

15,000 yrs B.P. (Fig. 3). There are six samples for the great majority of horizons, and never is there less than three (Table 1). All the samples record normal polarity, and as noted, the identification of a microchron was suspected. However, because we were not able to establish beyond doubt the validity of the microchron, and in fact have substantial evidence to the contrary (Liddicoat *et al.*, 1979), we have omitted the anomalous data from Table I; for comparison, though, we include them in Figure 4.

At first glance, the curves of declination and inclination (Fig. 3) seem representative of the behavior of the paleomagnetic field that is often recorded in lacustrine sediments. For example, the fluctuation of twenty degrees or so around a northerly declination and a similar swing in inclination are to be expected (see Turner and Thompson, 1981, for records of Holocene secular variation in Britain). We caution, however, that the data for Tlapacoya are of poor quality, as indicated by the scatter for data within each horizon (Alpha-95; Table 1). Therefore, any claim that the paleomagnetic field was accurately recorded other than in polarity is inappropriate and would be misleading.

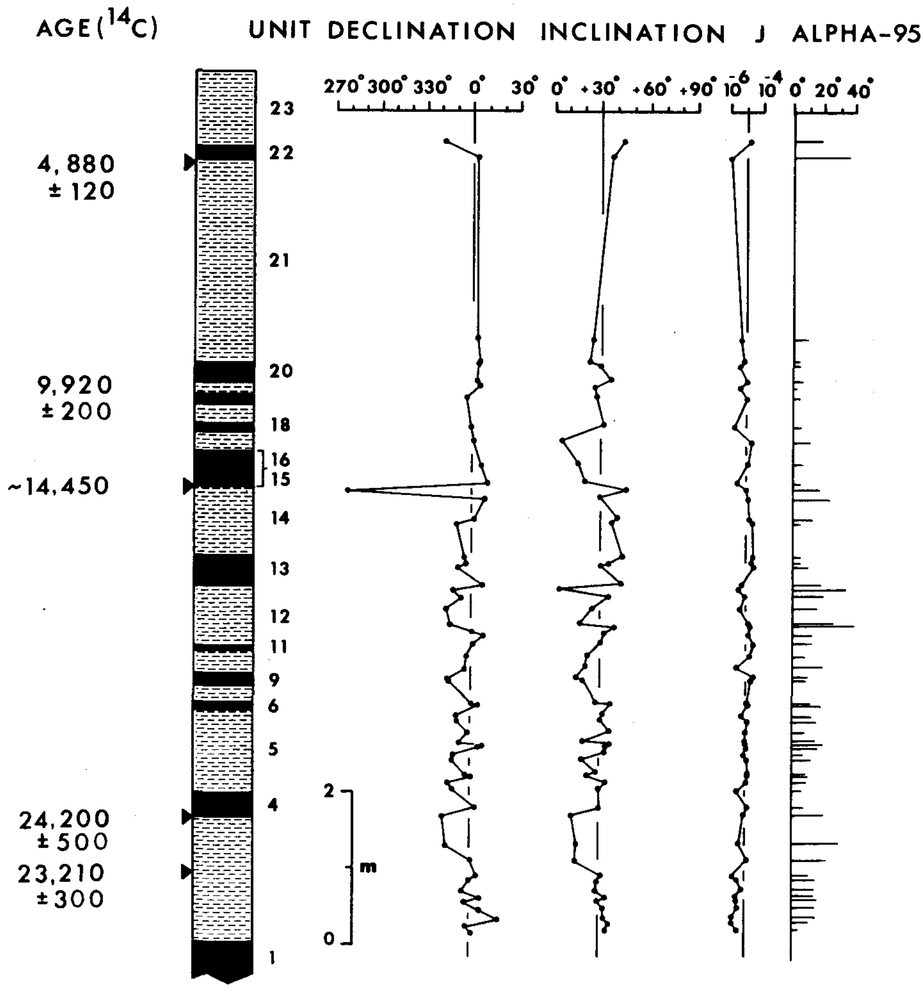

Fig. 3. Columnar section of sediment exposed in the trenches at Tlapacoya I and paleomagnetic data after a.f. demagnetization at 100-150 oersteds. Each point represents an average of three to six samples. Note the large ewing in declination to the west in the upper part of Unit 14 (age about 14,450 yrs B.P.); this is the possible microchron that is discussed in the text. Because of the scale, the microchron is shown as occurring at only one horizon; see Figure 4 for more detailed data in that part of the section, including additional ^{14}C dates. In the lithologic column, black represents ash and the pattern represents lacustrine and marsh deposits, mainly mud. Intensity (J) is in emu/cc.

Table 1. Paleomagnetic data for Tlapacoya I, Basin of Mexico

Unit	Lithology	Location	Incl	Decl	Int	Field	N	k	α_{95}	Lat	Long
22	A	0.0	43.9	342.1	2.16	100	6	13.7	18.7	72.1	196.3
21E	M	4.0	27.5	348.3	0.143	100	6	4.2	37.1	78.0	151.1
21B	M	240.0	25.4	2.7	0.628	100	6	54.9	9.1	83.8	55.7
20E	A	2.0	23.0	4.4	0.797	150	6	541.0	2.9	81.8	49.1
20D	A	7.0	29.6	3.3	0.557	150	6	1120.8	2.0	85.6	35.6
19G-1	M	4.0	35.9	2.5	1.17	100	6	184.9	4.9	87.5	330.4
19G-2	M	11.0	26.4	4.8	0.600	100	6	938.9	2.2	83.2	38.3
19D	M	20.0	27.5	356.9	1.06	100	6	290.4	3.9	84.7	115.9
17H	M	0.0	31.7	359.0	0.214	100	6	128.0	5.9	87.9	109.3
17CB	M	20.0	6.9	0.0	3.38	100	5	40.3	12.2	74.5	81.0
15B	A	0.0	16.8	5.1	1.57	100	7	102.7	6.0	78.5	55.0
14B	M	3.0	27.6	1.5	1.29	100	6	324.5	3.7	85.4	62.0
14B	M	5.0	30.2	9.5	0.499	100	6	59.0	8.8	80.6	6.7
14B	M	7.0	23.6	5.6	2.51	100	6	28.4	12.8	81.4	41.1
14B	M	9.0	26.9	3.3	2.03	100	6	192.1	4.9	84.3	46.9
14B	M	11.0	23.2	4.8	1.01	100	6	62.8	8.5	81.7	46.3
14B	M	13.0	28.7	8.8	1.07	100	6	22.3	14.5	80.9	13.5
14B	M	15.0	30.9	7.0	1.84	100	6	57.1	8.9	82.9	9.1
14B	M	17.0	28.7	4.4	1.39	100	6	67.2	8.2	84.4	31.5
13-1	A	8.0	43.3	355.4	4.25	100	6	186.4	4.9	82.5	227.5
13-2	A	17.0	35.9	356.0	4.08	100	6	202.8	4.7	86.1	185.0
13-3	A	21.0	30.7	351.1	4.31	100	6	45.3	10.1	81.2	156.2
12E-1	M	7.0	26.4	9.9	0.770	100	6	3.9	39.1	79.2	17.6
12E-2	M	14.0	9.8	1.9	0.575	100	6	2.4	55.2	75.8	73.3
12E-3	M	24.0	35.4	353.9	0.951	100	6	12.7	19.6	84.2	177.6
12E-4	M	39.0	30.6	343.9	0.673	100	6	18.0	16.2	74.5	164.2

Table 1 (Cont.)

Unit	Lithology	Location	Incl	Decl	Int	Field	N	k	α_{95}	Lat	Long
12C	M	59.0	18.0	359.9	1.89	100	4	6.9	37.9	80.2	81.6
12A-1	M	63.0	39.7	8.1	2.32	100	3	12.7	36.1	81.6	324.5
12A-2	M	73.0	33.0	7.7	1.59	100	6	29.3	12.6	82.6	357.6
11	A	0.0	31.0	0.5	4.33	150	4	48.5	13.3	87.7	69.1
10A-1	M	13.0	28.1	357.1	2.16	150	6	66.2	8.3	85.1	115.8
10A-2	M	28.0	21.6	355.8	4.25	150	6	13.7	18.8	81.2	109.0
9	A	8.0	20.0	354.2	4.97	100	6	7.0	27.4	79.7	114.6
8C	M	13.0	20.3	346.3	3.46	100	6	63.9	8.5	74.3	140.2
6B	A	4.0	28.3	0.2	1.33	100	6	32.6	11.9	86.1	78.2
5E-1	M	0.0	37.9	5.4	1.11	100	6	13.7	18.8	84.4	326.0
5E-2	M	16.0	32.5	351.2	0.796	100	6	27.0	13.1	81.5	163.3
5E-3	M	23.0	31.6	351.4	1.28	100	6	18.8	15.9	81.6	159.3
5E-4	M	38.0	36.9	358.0	1.50	100	6	79.6	7.6	87.5	211.3
5E-5	M	51.0	20.6	352.5	1.15	100	6	21.7	14.7	78.9	123.0
5E-6	M	55.0	37.6	8.3	1.24	100	6	13.9	18.6	81.9	334.9
5E-7	M	57.0	34.9	5.4	1.53	100	6	17.5	16.5	84.9	347.5
5E-8	M	67.0	34.0	349.5	0.963	100	6	72.6	7.9	80.1	170.6
5C	M	74.0	20.0	348.9	1.32	100	5	36.6	12.8	76.2	133.6
5A-1	M	92.0	28.7	356.3	1.16	100	6	48.8	9.7	84.9	125.3
5A-2	M	94.0	23.7	1.6	1.40	100	6	46.1	10.0	83.2	67.7
5A-3	M	104.0	34.2	346.0	1.28	100	6	56.0	9.0	76.8	172.3
5A-4	M	113.0	30.7	349.1	0.669	100	6	101.4	6.7	79.3	159.3
4A	A	20.0	30.3	3.7	1.86	100	5	101.9	7.6	85.2	28.0

Table 1 (cont.)

Unit	Lithology	Location	Incl	Decl	Int	Field	N	k	α_{95}	Lat	Long
3/2-1	M	7.0	14.5	342.9	0.924	100	6	11.3	20.9	69.7	138.3
3/2-2	M	43.0	20.7	352.6	0.624	100	6	5.8	30.6	79.0	122.8
3/2-3	M	66.0	17.5	0.7	1.17	100	6	9.3	23.2	79.9	77.0
3/2-4	M	84.0	34.2	4.8	0.337	100	6	38.1	11.0	85.5	353.1
3/2-5	M	89.0	30.8	359.5	0.538	100	6	18.3	16.1	87.6	92.3
3/2-6	M	102.0	30.0	354.7	0.860	100	6	25.1	13.6	84.2	142.0
3/2-7	M	110.0	35.9	6.3	0.429	100	6	20.6	15.1	84.0	341.4
3/2-8	M	115.0	30.8	356.3	0.504	100	6	17.1	16.7	85.7	137.3
3/2-9	M	125.0	34.0	6.6	0.545	100	6	20.4	15.2	83.7	353.3
3/2-10	M	138.0	35.1	18.2	0.260	100	6	18.6	15.9	72.8	346.8
3/2-11	M	145.0	37.8	357.2	0.285	100	6	30.9	12.3	86.8	214.5
3/2-12	M	155.0	36.0	1.5	0.564	100	6	159.1	5.3	88.3	316.5

Unit: Stratigraphic unit at Tlapacoya I; numbering is after Lambert (in press); first number refers to unit, letter refers to subunit, last number is horizon within the unit or subunit.

Lithology: A: ash, M: mud.

Location: Centimeters below boundary with overlying unit.

Incl: Mean inclination (degrees) after a.f. demagnetization.

Decl: Mean declination (degrees) after a.f. demagnetization.

Int: Mean intensity ($\times 10^{-5}$ emu/cc) after a.f. demagnetization.

Field: Peak a.f. demagnetizing field (oersteds).

N: Number of specimens used.

k: Fisher precision parameter.

α_{95}: Alpha-95: semi-angle (degrees) of cone of 95% level of confidence.

Lat: North latitude of Virtual Geomagnetic Pole (VGP) using site coordinates: 19°N, 261°E.

Long: East longitude of VGP.

VALSEQUILLO, PUEBLA

A controversy over the age of artifacts from the Hueyatlaco site, Valsequillo, Puebla, led to several attempts to establish a valid chronology by as many methods as possible (Szabo *et al.*, 1969; Steen-McIntyre *et al.*, 1973, 1981). Paleomagnetism was one method used, and in 1973 samples for that purpose were collected during renewed excavations (Steen-McIntyre *et al.*, 1981).

Two of the four sampled horizons (73SM16: unweathered clay, 73SM17: silty ash) are separated vertically by about 30 centimeters in the wall of an east-west trench (Fig. 5); the other two horizons (73SM15: clay, 73SM18: ash) are also in the excavations but in other trenches (Fig. 6 in Steen-McIntyre *et al.*, 1981, shows the location of the horizons relative to each other). The horizons (six samples each, Table 2) record normal polarity following a.f. demagnetization, and changes in paleomagnetic directions are small for progressively higher fields (Figure 6). The laboratory test of thermal demagnetization could not be done because the samples were fragile and had to be encased in polythyrene boxes. On the basis of the demagnetization data, we interpret the vectors to be of primary magnetization, and the polarity to be Brunhes age (less than 0.73 m.y. old).

Table 2. Paleomagnetic data for Hueyatlaco, Valsequillo, Puebla

Number	N	Lithology	Incl	Decl	Int	k	α_{95}	Test
73SM15	6	C	19.4	346.2	.80	12.6	19.6	150
73SM16	6	C	30.4	0.3	2.0	84.4	7.3	150
73SM17	6	A	5.3	0.3	11.7	1953.8	1.5	150
73SM18	6	A	30.7	338.4	10.5	57.8	8.9	150

Number: Sample number.
N: Number of samples used.
Lithology: A: ash, C: clay.
Incl: Mean inclination (degrees) after a.f. demagnetization.
Decl: Mean declination (degrees) after a.f. demagnetization.
Int: Mean intensity ($\times 10^{-5}$ emu/cc) after a.f. demagnetization.
k: Fisher precision parameter.
α_{95}: Alpha-95: semi-angle (degrees) of cone of 95% level of confidence.
Test: Peak a.f. demagnetizing field (oersteds).

At about the time of our investigation, work has being done in several laboratories to establish whether the Laschamp Reversed Subchron is a reversal (Cox *et al.*, 1975) of the paleomagnetic field, and if so, its correct age. The age as originally set was 20,000-8,730 yrs B.P. (Bonhommet and Zahringer, 1969); it is now believed to be closer to 40,000 yrs B.P. (Hall and York, 1978; Condomines, 1978;

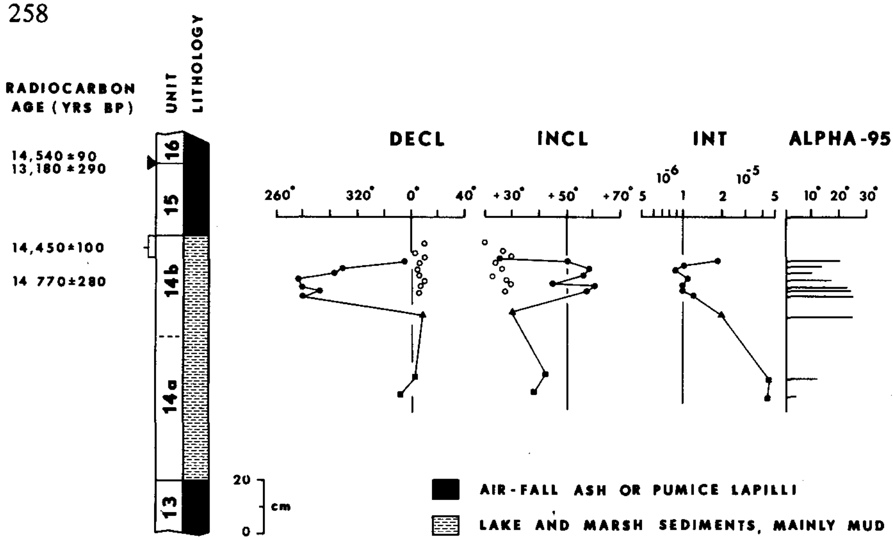

Fig. 4. Paleomagnetic curves following a.f. demagnetization at 100 oersteds showing the anomalous (microchron) and normal data for Unit 14 at Tlapacoya I; the data are for sections separated laterally by about 2 meters in the same trench (Sites A and B in Liddicoat *et al.*, 1979). The scatter of directions (Alpha-95) for the normal data is about the same as that for the anomalous data, which is shown in the bar scale. Intensity is in emu/cc. The anomalous data are represented by the solid symbols, the normal data by the open symbols.

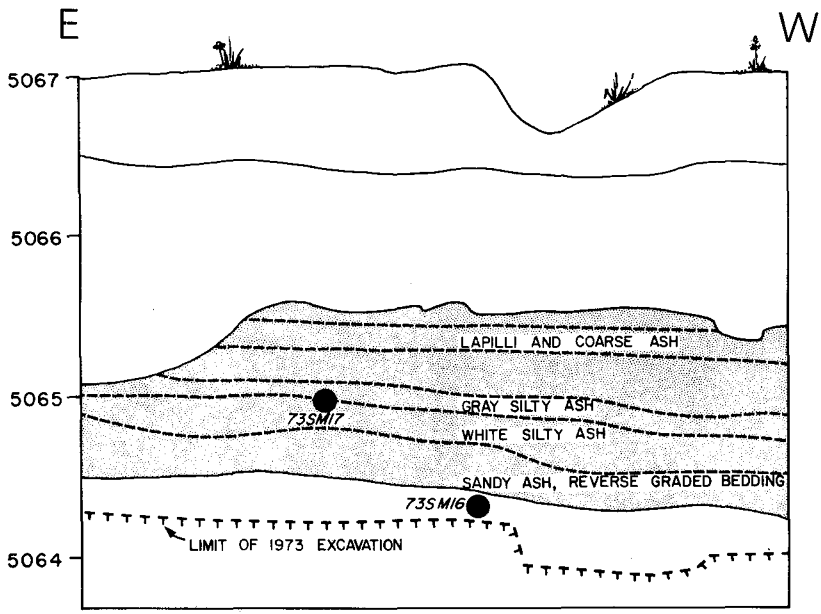

Fig. 5. Sketch of the wall of the southernmost east-west trench opened during the 1973 excavations at the Hueyatlaco archeological site, Valsequillo, Puebla; the exact location of the trench is shown in Steen-McIntyre *et al.*, 1981. The location of paleomagnetic samples 73SM16 (unweathered clay) and 73SM17 (ash) is indicated by the solid circles. The dot pattern represents volcanic ash and white represents clay.

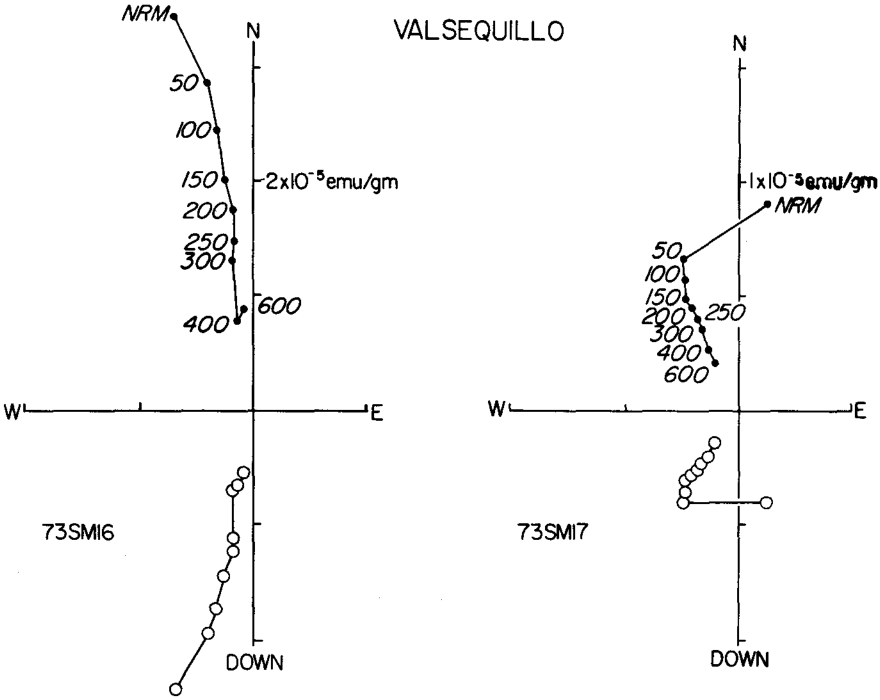

Fig. 6. Vector plots of paleomagnetic directions during progressive a.f. demagnetization for samples from horizons 73SM16 (unweathered clay) and 73SM17 (silty ash). The median destructive field for both samples is about 150 oersteds. Symbols are the same as in Figure 2.

Gillot *et al.,* 1979). Although the reversed polarity in lava flows at Laschamp is documented (Bonhommet and Zahringer, 1969; Gillot *et al.,* 1979), the possibility of a self reversal has been raised (Heller, 1980; Heller and Peterson, 1981); certainly, worldwide occurrence of a reversal of that age is not fully accepted. We need only consider western North America to raise doubt because there are ample data of normal polarity (and none of reversed polarity) for lake sediments that bracket about 35,000-12,000 yrs B.P. (Denham and Cox, 1971; Liddicoat, 1976; Verosub, 1977; Liddicoat and Coe, 1979; Lajoie *et al.,* 1980; Verosub *et al.,* 1980), and, as described above, the sediments at Tlapacoya record normal polarity exclusively. Thus, our search for the Laschamp Reversed Subchron might have been fruitless from the outset because it is either nonexistent in North America or it was of such short duration that the likelihood is small of encountering it in only four horizons of uncertain age.

Finally, the age of nearly 250,000 years B.P. presented in Steen-McIntyre *et al.* (1981), for the deposits that overlie those of archeological interest at Valsequillo, and from which our samples came, is consistent with the paleomagnetic data because the Brunhes Normal Chron (0.73 my - Present; Mankinen and Dalrymple, 1979) is almost entirely of normal polarity.

CONCLUSIONS

1. Paleomagnetic data for a section of interbedded lacustrine and paludal mud and tephra at Tlapacoya I record normal polarity for about 25,000-5,000 yrs B.P. Although paleomagnetic polarity is correctly documented, no attempt should be made to use the data in studies of secular variation in central Mexico.

2. Fine-grained units of the Valsequillo Gravels exposed at Hueyatlaco record normal polarity. As a result, the sediments can not be dated using the paleomagnetic method other than to demonstrate they are of Brunhes age.

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