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JOINT ORIENTATIONS IN CENTRAL MEXICO

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RESUMEN

Orientaciones de diaclasas fueron medidas en México Central. Hemos hallado que las orientaciones preferidas son muy consistentes; si las diaclasas son tomadas como planos de cizallamiento en un campo de esfuerzos, corresponden a una máxima compresión con acimut de N 34° E. Esto se acuerda bien con el movimiento supuesto de la Placa de Cocos contra América Central.

ABSTRACT

Joint orientations were measured in Central Mexico, in a region reaching from the Paso de Cortés to Acapulco. It was found that the preferred joint orientations were very consistent: if the joints are interpreted as shearing planes, they would correspond to a maximum compression direction oriented horizontally with an azimuth of N 34° E. This corresponds exactly to the relative motion direction of the Cocos Plate against Middle America.

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1. INTRODUCTION

During a short visit to Mexico, the writer was able to measure some joint orientations in the central part of that country.

Inasmuch as the Institute of Geophysics of the Technical University of Vienna has an ongoing program of evaluation of joint orientations, the Mexican joints were processed according to the method developed in Vienna by Kohlbeck and the writer (Kohlbeck and Scheidegger, 1977). This method is based on the fitting (by computer) of, if possible, two Dimroth-Watson distributions (in some outcrops only one distribution was present) to the data and determining their parameters by a numerical maximum likelihood procedure. In this fashion the preferred orientations contained in a set of measured joint-data can be obtained. The standard listing of the ensuing results is made in tables, in which the columns consequently represents the area, the number of joints in the set, the preferred orientations (dip direction N → E and dip), the angle between those two orientations and the maximum (P) and minimum (T) compression directions (azimuth N → E/plunge) calculated therefrom. Our tables and diagrams refer to *magnetic* North. In this fashion, it was hoped that a preliminary idea of possible consistencies that might be present in the joint patterns of Central Mexico, would be obtained.

2. DESCRIPTION OF OUTCROPS

2.1 General remarks

The area investigated is shown in the sketch map of Fig. 1. The outcrops were taken in groups; on a map of the scale necessary to show the whole region it is not possible to indicate the individual locations. However, the centres of the groups are indicated in Fig. 1 as "Ciudad de México", "Acapulco", "Paso de Cortés", and "Xinantécatl" (Nevado de Toluca). The rocks in question ranged from recent lavas to plutonic granites and tonalites. The individual regions will now be described in detail.

2.2 Ciudad de México

Within the confines of Ciudad de México, two outcrops were investigated. The first (designated by "1") was on Cerro del Agua near the entrance to Ciudad Universitaria. The rock was from a recent lava flow. (Fig. 2). The second location (loc. "2") was in ropy lava of recent origin outcropping in front of the Geophysics Building of the Universidad Autónoma de México.

The individual results for these outcrops are given in Table 1 in standard fashion; the result for the group is shown in Table 2. The results for the two outcrops are quite consistent, which is also evident from the results for the group. Fig. 3 shows a pole-density diagram for the group.

2.3 Bahía de Acapulco.

During a day's stay at Acapulco, joints were measured on 4 locations in the vicinity of the Bay of Acapulco. Fig. 4 shows a sketch map of the Bay with the locations marked.

The rocks were light-colored, coarse-grained intrusives (Fig. 5); usually they were much affected by weathering (Fig. 6), but occasionally, as near La Quebrada, forming steep, high cliffs (Fig. 7).

The results of the evaluation of the individual outcrops are listed in Table 1, those from the whole group, in Table 2.

An inspection of these results reveals considerable uncertainties (in one outcrop only one preferred orientation is defined) and scatter. Location D (La Quebrada) appears somewhat anomalous. Nevertheless, the combined evaluation of all 4 locations gives a fairly consistent picture; Fig. 8 presents the pole-density diagram. In it, the anomaly from Loc. D appears as a very weak tertiary maximum at about 140°.

2.4 Paso de Cortés

An excursion was made to the Paso de Cortés, and thence to the slopes of Popocatepetl (Loc. P) and Iztaccíhuatl (Loc. I). In both cases, the rocks were extrusions of andesitic type. The outcrops formed ridges (Fig. 9); a closeup of the rock is shown in Fig. 10.

The joint orientations were very consistent (see Table 1, 2), except that only one preferred joint set was defined on Iztaccíhuatl. The combined pole density diagram is shown in Fig. 11.

2.5 Xinantécatl

Finally, one outcrop (Loc. X) was investigated on the road leading to the crater of Xinantécatl (Nevado de Toluca), at the point where it crosses the crater wall. Evidently, the material consisted of pyroclasts embedded in lava; the photograph (Fig. 12) shows that the individual clasts are cut through by the joints.

The evaluation of the results is given in Tables 1 and 2; the data are very consistent as is evident from the pole density diagram shown in Fig. 13.

2.6 All Mexico

Finally, a combined evaluation was made of all the joints measured in Mexico. The results from the various regions agree very well with each other; therefore the combined results for the region as a whole are also very definite. Fig. 14 shows the corresponding pole density diagram.

3. DISCUSSION

The results given in the last section refer to magnetic North. The declination was, in 1979, about 12° W; hence 12° must be substracted from all the azimuth values listed in the Tables, if a comparison with geographic-geological data is to be made. For easy reference, we list once more the values corrected for declinations (without errors) in Table 3.

We then have plotted the preferred strike directions of the sets of joints, as well as the (projections of the) principal stress directions on a map (see Fig. 15).

An inspection of this Figure and Table 3 shows a great consistency of the results from Toluca to the Paso de Cortés. In these regions, the maximum compression is directed at an azimuth of N 46-55° E. Of course, the angle between joint planes beeing around 85°, it is not absolutely certain that this is the *maximum* compression. Nevertheless, it is interesting to remark that this direction is normal (and the conjugate is parallel) to the general strike of the continent in Mexico.

The principal stress directions in Acapulco are slightly rotated in comparison with the central region, inasmuch as we here have an azimuth of only N 30° E. The computer gives this as the direction of *minimum* compression, but the angle between preferred joint orientations is 89°, so that the identification of minimum and maximum compression is very questionable indeed. The directions are, in any case, normal and parallel to the trend of the coast. In the combined evaluation of all the joints measured in the region, the result is a maximum compression in the direction N 34° E. This, of course, fits together in an excellent fashion with the plate boundaries and relative motions (Fig.16) postulated previously for this area from seismological evidence (Dean and Drake, 1978; Molnar and Sykes, 1969).

Table 1: México, individual outcrops. Magnetic North

Region	Location	No.	Max. 1	Max. 2	angle	P	T
Ciudad de	1	21	104±16/88±14	181±18/89±16	77	232/1	322/2
México	2	23	87±17/86±16	4±16/87±15	82	316/0	226/5
Bahía	A	27	269±22/85±17	0±24/90±18	89	134/4	44/4
de	B	17	27±26/89±18				
Acapulco	C	21	76±16/80±14	148±22/76±18	70	23/3	292/15
	D	21	240±11/83±10	145±18/78±17	87	13/14	282/4
Paso de	P	21	279±18/84±17	3±16/90±15	84	51/4	141/4
Cortés	I	21	284±30/86±18				
Xinantécatl	X	22	99±12/88±12	354±15/84±14	75	226/6	136/3

Table 2: Mexico, Groups. Magnetic North

Region	Loc.	No.	Max. 1	Max. 2	Angle	P	T
Ciudad de México	1,2	44	96±14/87±12	2±13/88±11	86	229/3	319/1
Acapulco	A,B,C,D	86	75±10/90± 9	165±13/83±11	89	300/5	30/5
Paso de Cortés	P,I	42	8±12/88±11	283±10/85± 9	85	55/2	145/5
Xinantécatl	X	22	99±12/88±12	354±15/84±15	75	226/6	136/3
all México		194	92± 9/90± 6	180± 9/90± 7	88	46/0	316/1

Table 3: Values corrected for declination

Region	Max.1	Max.2	Angle	P	T
Ciudad de México	84/87	350/88	86	217/3	307/1
Acapulco	63/90	153/83	89	288/5	18/5
Paso de Cortés	354/88	271/85	85	43/2	133/5
Xinantécatl	87/88	352/84	75	214/6	124/3
All	80/90	168/90	88	34/0	304/1

Fig. 1: Sketch map of Mexico showing locations of measurements.

Fig. 2: Location 1 in Mexico City: recent lava flow.

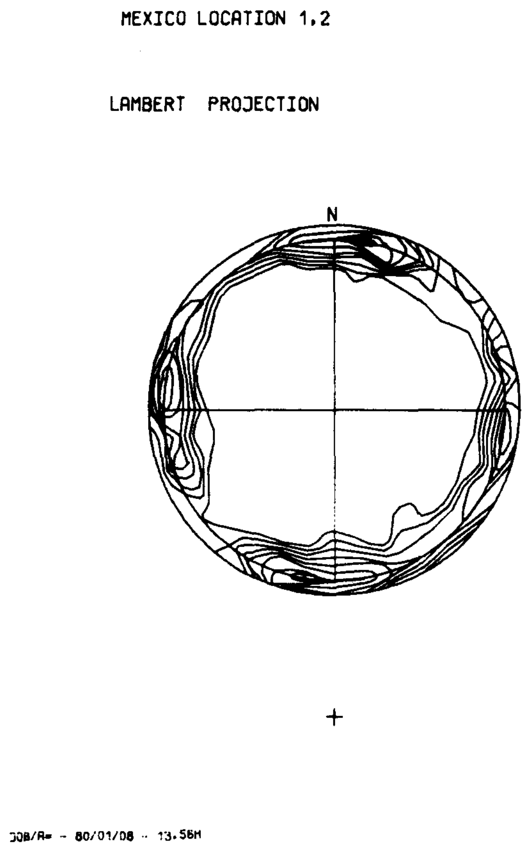

Fig. 3: Pole density diagram for Ciudad de México.

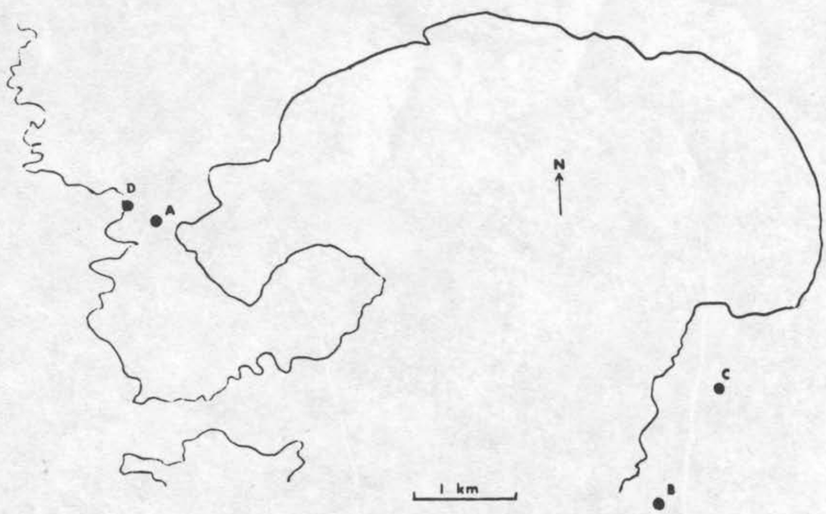

Fig. 4: Sketch map of the Bay of Acapulco, showing the locations A, B, C, D.

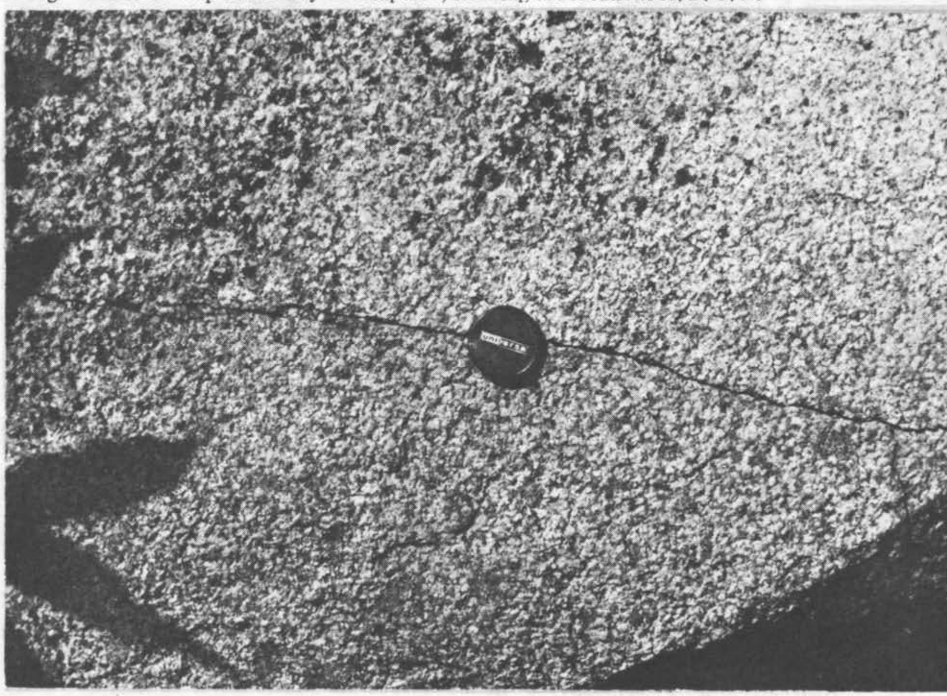

Fig. 5: Granite-tonalite near Acapulco (Loc. A)

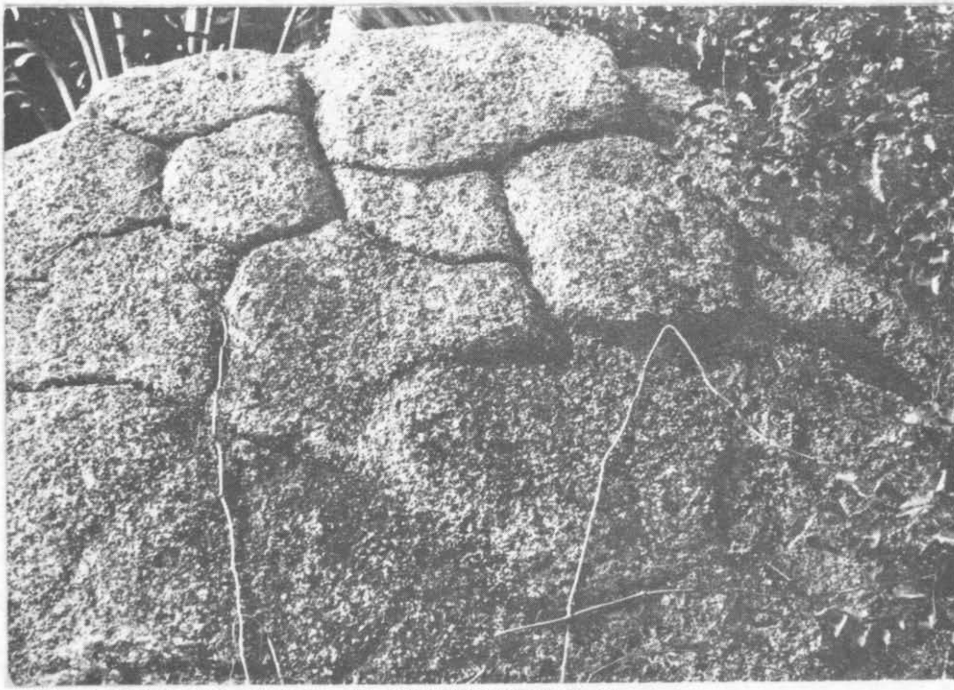

Fig. 6: Effects of weathering on Acapulco intrusives (Loc. A).

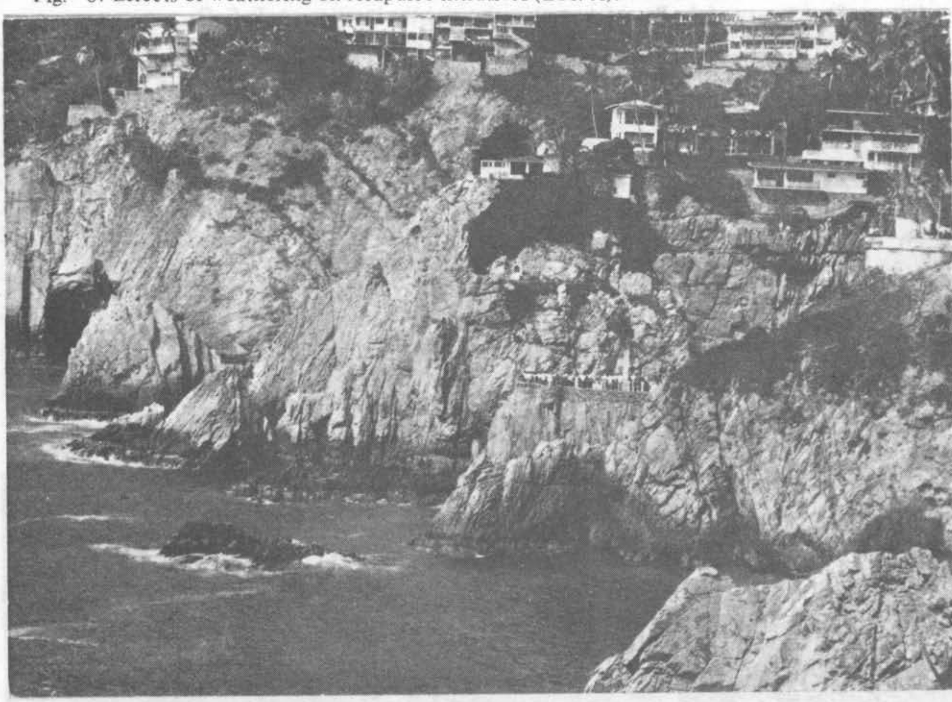

Fig. 7: High cliffs near La Quebrada (Loc. D).

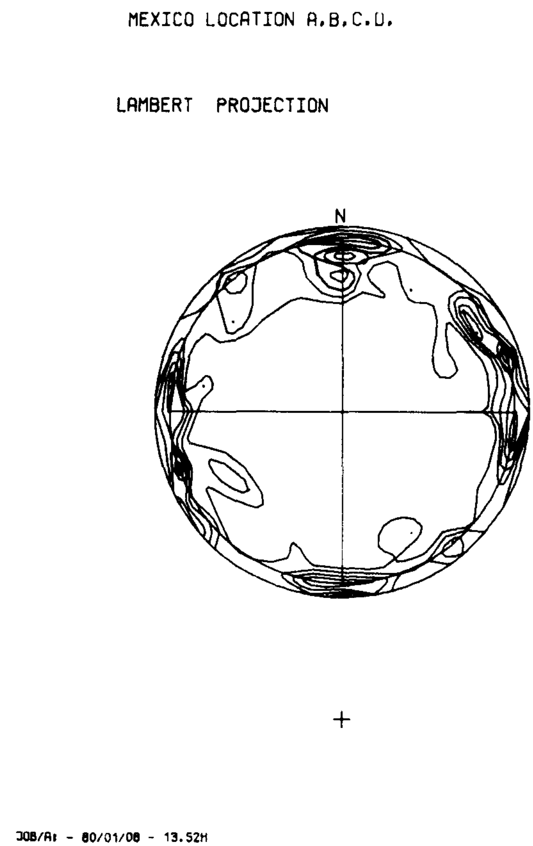

Fig. 8: Pole-density diagram for Acapulco.

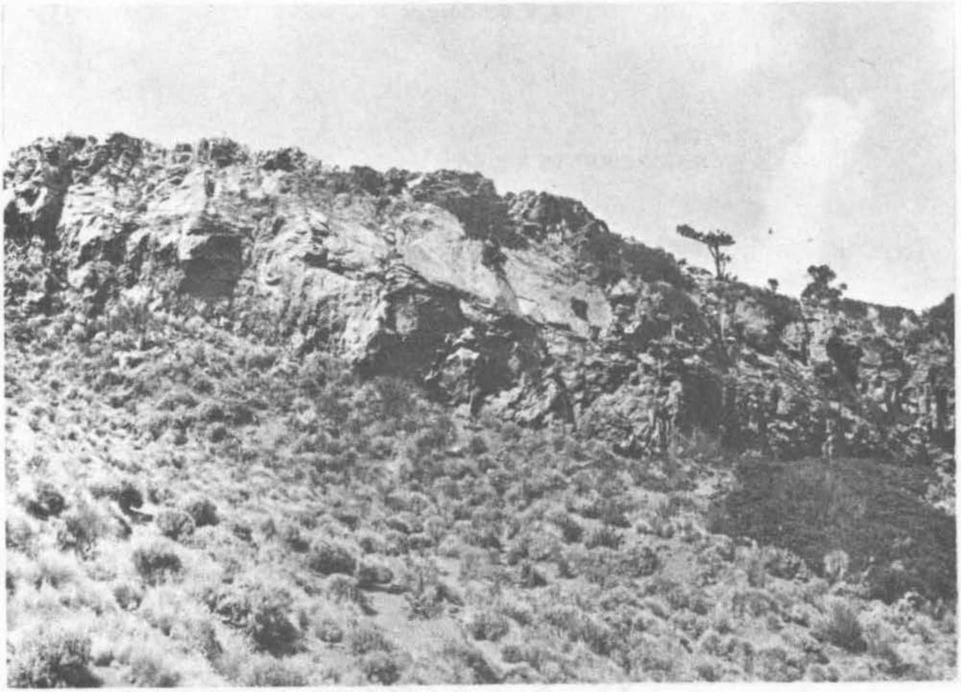

Fig. 9: Outcrop ridge on Iztaccíhuatl (Loc. I).

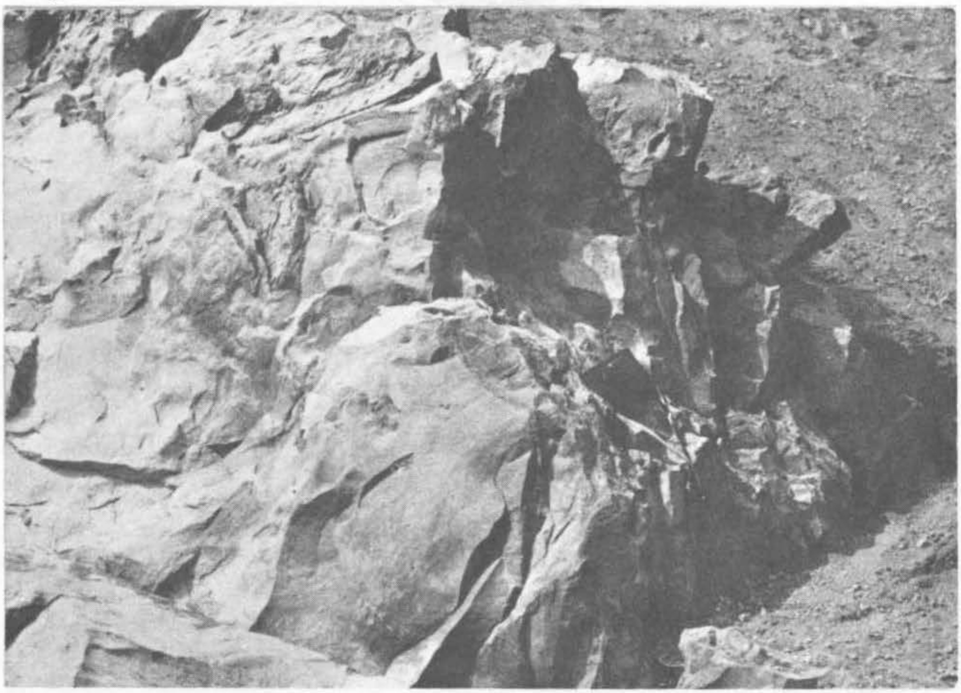

Fig. 10: Closeup of rock, Loc. I: Andesitic extrusive.

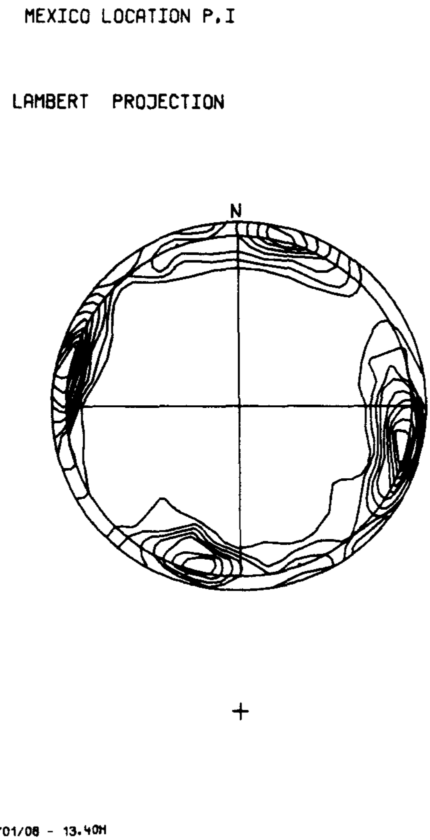

Fig. 11: Pole density diagram for Paso de Cortés.

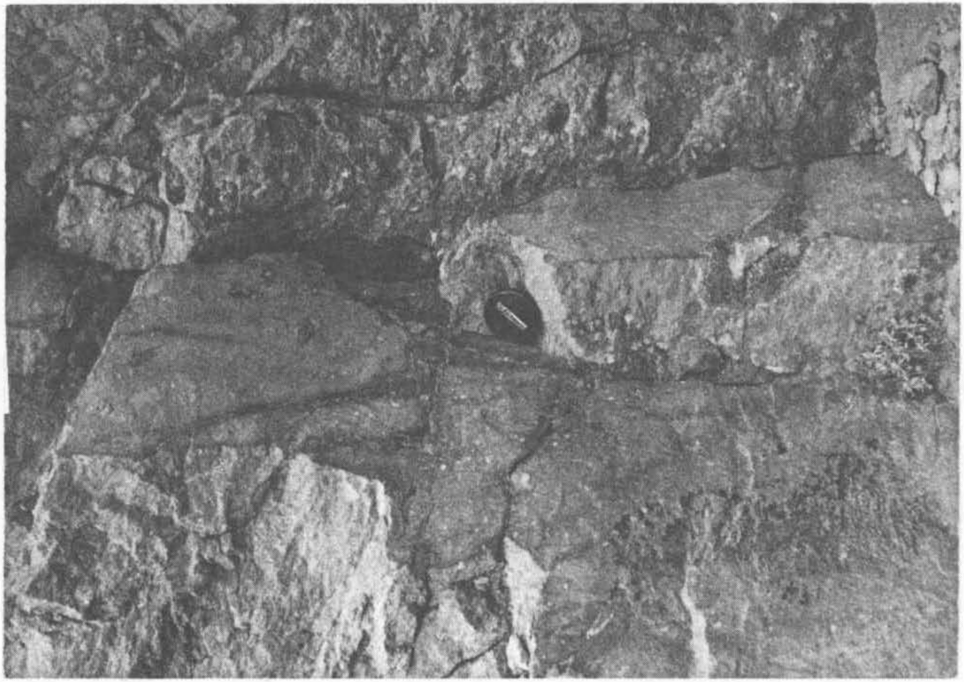

Fig. 12: Pyroclasts of the Xinantécatl (Nevado de Toluca).

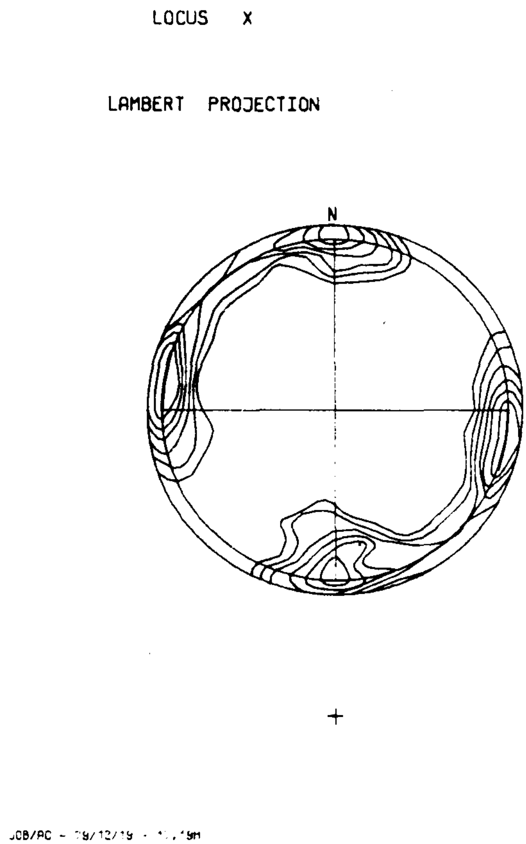

Fig. 13: Pole density diagram for Xinantécatl.

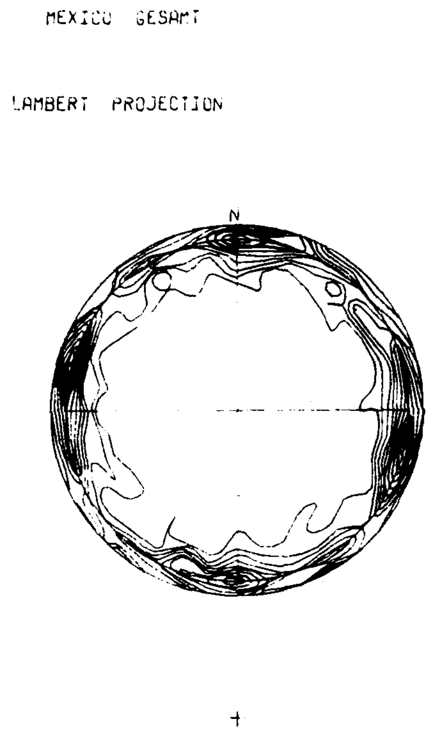

Fig. 14: Pole density diagram for all Mexico.

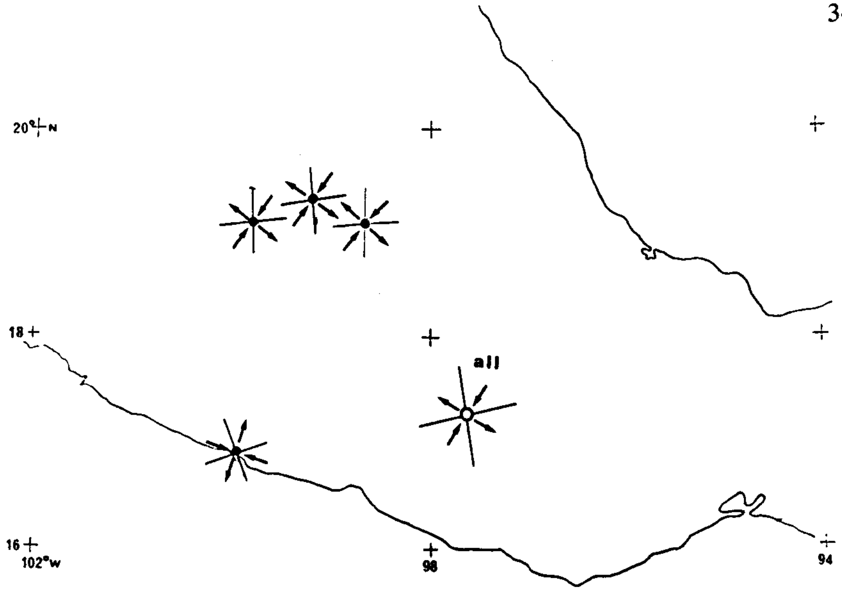

Fig. 15: Results for Mexico.

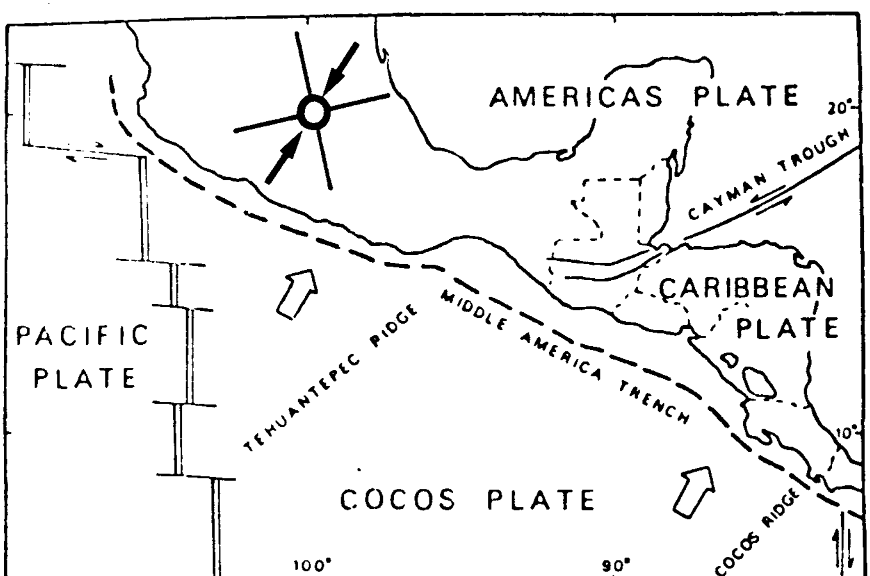

Fig. 16: Tectonics of Central America after Dean *et al.*, 1978 and Molnar *et al.*, 1969, compared with results from present study.

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