MAGNETIC COMPARISON OF EXPLOSION CRATERS AND VOLCANIC CONES

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RESUMEN

Las respuestas magnéticas de varias estructuras volcánicas muestran que los conos cineríticos presentan sistemáticamente las respuestas más intensas, mientras que los cráteres de explosión con bordes de ceniza volcánica parecen tener una débil magnetización. Las estructuras de colapso, que pueden o no estar asociadas a un origen explosivo, no muestran un comportamiento magnético sistemático. Los resultados presentes sugieren que aparecerá un cráter de explosión con bordes de ceniza cuando la explosión inicial sea superficial, mientras que las explosiones profundas tenderán a producir estructuras superficiales de tipo colapso. Se hace la inferencia de que el instrusivo riolítico conocido como Las Derrumbadas en la cuenca Oriental-Serdán puede ser una fuente geotérmica.

ABSTRACT

The magnetic responses of various volcanic structures show that cinder cones systematically present the strongest magnetic responses, while explosion craters with ash rings appear to be weakly magnetized. Structures that are of the collapse type, which may or not be associated with an explosive origin, do not show systematic magnetic behavior. These results suggest that ash rings appear when the initial explosion is shallow, while deep explosions tend to produce surface features of the collapse type. The inference is made that the intrusive rhyolites known as Las Derrumbadas in the Oriental-Serdan Basin may be a geothermal source.

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INTRODUCTION

Phreatic explosions are known to occur when a rising magma encounters a body of water at shallow depth; the details of the mechanism, however, are largely unknown (McBirney, 1973). Furthermore, it often happens that explosion craters and cinder cones are intermingled in the same volcanic field, with separation between different structures being as low as a few hundred meters. Examples of such coexistence are not uncommon in Mexico, either in the Mexican Volcanic Belt or outside of it (Wood, 1974), and instances are found at many other locations in the world (Noll, 1967).

Which parameters ultimately control the surface manifestations of a rising magma? Such a question cannot be given a detailed answer at present, however it appears to us that, given a magma, local physical properties and physical conditions of shallow rock formations are the determining factors of the nature of the eruption. In this respect, Wood (1974) believes that water availability is an all important factor, but finds it difficult to understand the processes that quickly change water availability and hence the nature of the eruption. Few studies appear to have tackled the problem of determining the physical property differences between explosion craters and volcanic cones, although geophysical techniques can be readily applied to it (e.g., Civetta *et al.*, 1974; Wood, 1974).

The present study originated in the suggestion that one of the reported explosion craters (Tepexitl) was of meteoritic origin (Maupomé, 1974). Further study of this and similar structures in the area showed that the crater was formed by a phreato-magmatic explosion (Maupomé *et al.*, 1975). However, initial geophysical surveys yielded favorable results in support of an impact origin for Tepexitl since its magnetic response differed from the response of other structures in the area. Once the volcanic origin of the crater was clarified, the problem reduced to determining the causes of different magnetic responses among volcanic features that apparently originate from the same magma source.

THE VOLCANIC FIELD

The area surveyed is located at the south-eastern portion of the Oriental-Serdan Basin (19°-05'N to 19°-15'N and 97°-25'W to 97°-33'W approximately), which in turn is located on the eastern limits of the Mexican Volcanic Belt; Figure 1 shows the area from an ERTS image. The basin mean altitude is 2400 m and its perimeter is delimited by three important peaks: Naucampatepetl or Mountain With Four Sides (Cofre de Perote) with an elevation of 4282 m, Matlalcueyatl or Blue Slope (Malinche) 4461 m, and Citlaltepetl or Star Mountain (Pico de Orizaba), the latter being the highest peak in Mexico (5700 m). Scattered throughout the basin area (5000 Km^2) one finds numerous quaternary volcanic manifestations ranging from basaltic lava flows and cinder cones to calderas and explosion craters. The latter were recognized by the early Mexicans and were generically designated as *xalapazcos* or sand pots if they did not contain water and *axalapazcos* if they did contain a lake. Axalapazco is thus generally equivalent to the word maar (Ordóñez, 1906).

Bazán (1959) has made a general geomorphologic, geohydrologic and geologic description of the basin. He notes that the basin drainage has no exterior outlet and that rain water forms shallow lakes and a considerable groundwater system; these facts unquestionably favor the occurrrence of phreato-magmatic explosions in the area. Whether a crater has a lake in its interior depends only on the position of the local water table; a lake will appear when the crater's depth is greater than the depth to the water table.

Near the surveyed area there are two rhyolite bodies that deserve special mention since they are each associated with an explosion crater. The structures are Cerro Pinto and Cerro Pizarro, the former about 10 km north, and the latter about 26 km north of the surveyed area. Cerro Pizarro has an altitude of 3039 m and constitutes one of the highest elevations within the Oriental-Serdan Basin. In both cases the rhyolite intrusive appears to post-date the explosion crater; in the case of Cerro Pizarro it is very obvious that the intrusive emerged after the crater was formed, since today the intrusive pierces the crater at its center (Figure 2a, 2b). At Cerro Pinto (its associated crater is known as Tepeyahualco, Maupomé *et al.*, 1975) the ryholite dome is located on the southern part of the rim of a 3 km diameter explosion crater of complex characteristics; the southern part of the rim is known as Sierra Blanca, owing to the abundance of white pyroclastics in that area. Although not as prominent as the intrusive in Cerro Pizarro, the intrusive in Tepeyahualco constitutes its highest elevation (approximately 2750 m).

The association of intrusives and explosion craters discussed above makes it probable that other similar cases may occur or have already occurred, where the explosion crater is present but the intrusive has not yet outcropped. According to our observations, one would expect that the intrusives have been the heat sources that furnished the energy necessary for the explosions.

AEROMAGNETIC RESPONSES

Figure 3 shows the location of the main structures, volcanic and otherwise, in the area of interest (compare to Figure 1). The structures over which aeromagnetic determinations were made can be divided in two groups: the northern group with (1) Tepexitl, (2) Campana, (3) Buenavista, (4) Volcán and (5) Hacienda and the southern group with (6) Tecuitlapa, (7) Aljojuca, (8) Zotoltepec Cones, and (9) Xalapazcos. Structures (1), (3), (5) and (9) are generically known as xalapazcos (i.e. dry craters), (6) and (7) are axalapazcos (i.e. they have a lake), (2) is a limestone reef, and (4) and (8) are cinder cones.

When the survey was originally planned the main interest was, as previously mentioned, to discriminate between the response of the presumed meteoritic crater Tepexitl (Maupomè, 1974) and the responses of neighboring volcanic structures. Owing to limitations in available flying time a systematic coverage of the whole area could not be made and we had to restrict flying lines to the vicinity of each structure. It will later become apparent that in several instances additional data is required in order to make an adequate interpretation of the anomalies obtained; a subsequent study should fill the gaps left by the present one; in the mean time a qualitative discussion of the magnetic anomalies will be made.

Total magnetic field measurements were made at elevations ranging from 100 m to 300 m; a ground magnetometry (vertical component) was also made on Tepexitl for control purposes. Total field intensity contours (in gammas) are plotted for each structure. Only altitude corrections were made for the total intensity data. Flight lines and points where field values were read are shown for each plot.

A discussion of the magnetic response of each structure shall next be made following the group subdivision and the ordering established above.

The Northern Group

1. Tepexitl

Figure 4 is an aerial view of the explosion crater Tepexitl and the limestone reef La Campana. Figure 5a shows the total field intensity map of the crater. Tepexitl has been described by Maupomé (1974) and by Maupomé *et al.* (1975). Contour interval is 10 gammas, total field values are given by the contour value plus 43660 gammas.

The general characteristics of Tepexitl's magnetic response are: (1) a magnetic low approximately coinciding in shape with the crater's shape and (2) showing a minimum on the southern portion of the rim, (3) the field increases radially outwards except for a small portion on the northern part of the rim, (4) comparing the background field values at surrounding structures to the corresponding value (43660 gammas) at Tepexitl, a regional tendency is shown suggesting that Tepexitl may be on top of a broad magnetic maximum. Whether this is true should be confirmed by additional measurements north of Tepexitl.

In Table 1 it can be appreciated that the magnetic signature associated with Tepexitl is one of the smallest among the group; this fact as well as the young age estimated for Tepexitl according to erosional features (about 10 000 years, R. S. Dietz, 1975, personal communication) suggest a possible association between a partially molten magma and Tepexitl.

Figure 5b shows contours of the vertical component of the magnetic field obtained in a ground magnetometry over Tepexitl and its environs;

small circles denote reading stations. The most obvious features in Figure 5b are a maximum coinciding with the crater's center, an elongation of the central anomaly toward the W and toward the NE, and two strong gradients NW of the crater leading to what appear to be two maxima; whether these responses are associated with nearby intrusives cannot be ascertained with the present data.

Comparing Figures 5a and 5b one can see some correlations between the total field and the vertical componet values; (a) the two gradients to the NW of the crater in Figure 5b correlate with a single, broader

TABLE 1. Surface Structure and Magnetic Gradient Data of the Surveyed Structures.

NAME	SURFACE STRUCTURE	APPARENT SURFACE GRADIENT (GAMMAS/KM)	APPARENT SURFACE GRADIENT ORIENTATION.
Northern Group			
Tepexitl	Xalapazco*	148	(?)
Campana	Limestone Reef	115	N
Buenavista	Xalapazco	108	NNW(?)
Volcán	Cinder Cone	205	NNE
Hacienda	Xalapazco	661	NNE
Southern Group			
Tecuitlapa	Axalapazco**	1646	NE
Aljojuca	Axalapazco	396	NE (?)
Zotoltepec:			
Western Cone	Cinder Cone	2380	NNE
Central Cone	Cinder Cone	1234	NNW
Eastern Cone	Cinder Cone	1346	E (?)
Xalapazco Grande	Xalapazco	56	NEE (?)
Xalapazco Chico	Xalapazco	174	NNW

* *Dry crater*
** *Crater with a lake.*

tendency to increase of the total field(Figure 5a), (b) the maximum at the center of the crater (Figure 5b) disappears when measuring at low altitude (Figure 5a) suggesting that the ground level response is due to a small, shallow, magnetized body. Such a body might be the plug that obliterated the exhaust vent (Maupomé *et al.*, 1975). Estimates, based on the data of Figure 5b, for the depth of burial of such a magnetized body range from 125 to 175 m. (c) On the eastern side of the crater there is a tendency of the total field (Figure 5a) to increase, which correlates well with a similar trend in the vertical component data (Figure 5b).

2. La Campana.

La Campana (Figure 4) is a cretaceous limestone reef (Bazán, 1959) approximately 1.5 Km south of Tepexitl. Figure 6 shows its aeromagnetic response. Total field is given by the contour value plus 43560 gammas. Only two flight lines crossed this structure; they suggest a magnetic low associated with La Campana, in agreement with the expected response for a limestone. We believe that a third flight line, crossing the central part of the structure, would have shown a better correspondence between the magnetic low and the shape of the structure. In any event, one can expect similar responses from other limestone formations within the basin.

3. Buenavista.

Although this explosion crater (Figure 7) has three flight lines over its C-shaped structure (i.e., the rim disappears at the southern portion of the crater), the total field data are difficult to interpret since no well defined minima or maxima appear in the map (Figure 8), thus reflecting a weak underground magnetization (compare with Tepexitl's data).

4. Volcán.

Volcán is the largest structure surveyed (Figure 7). It may have had up to four vents, possibly due to succesive obliteration: some of these vents show up in Figure 7. Consequently various magnetized necks are expected near the top of the volcano. However, the total intensity map (Figure 9) does not show much magnetic structure near the top of the volcano; rather, this response suggests the presence of a large, magnetized body at depth. Particularly interesting is the observation that Volcán shows no intense magnetic gradients (see Table 1), contrasting with those observed in the other cinder cones surveyed.

5. Hacienda

This structure is called Xalapasquillo de la Hacienda (Figure 7): its appearance suggests collapse rather than explosion; it has a very small rim (apparently not constructional) and has an approximate depth of 25 m with respect to the flat surrounding terrain. In a preliminary report Ohngemach (1973) dates the original profile of this xalapasquillo between 30 000 and 35 000 years old, on the basis of extrapolation of C^{14} dates; this is apparently the only attempt at dating a structure in the area considered herein. Ohngemach refers to this structure as "a maar filled up by sediments", probably to justify its shallow depth; however, he gives no further explanation for the use of the word maar.

Figure 10 shows the total intensity contours; a well defined maximum approximately coincides with the center of the structure; however, the existence of the corresponding minimum to the south cannot be considered with certainty owing to the lack of values in the area.

Summary for the Northern Group

The structures in this group can be subdivided in three groups according to the relative intensity of its magnetic response: (1) La Campana shows no magnetization, (2) Tepexitl and Buenavista, the two explosion craters with constructional rims show small magnetic anomalies and (3) the Xalapasquillo de la Hacienda and the Volcán yield the largest anomalies.

The interconnection between the last two structures is suggested by a similarity in magnetic responses and by the fact that both appear to be over the same geologic fault; if interconnection indeed exists, the proposed collapse at Hacienda might well be due to pressure release through the Volcán vents from a common magma chamber. This geologic fault approximately trends in the SE-NE direction and is quite evident in satellite imagery (not shown in this work); in fact it is this fault that appears to cut in two the rhyolite intrusives called Las Derrumbadas.

Las Derrumbadas.

Las Derrumbadas are located 1.5 Km north of Volcán and 1.5 Km NW of tepexitl; with an altitude of approximately 3200 m they are the most prominent structures within the Oriental-Serdan Basin (see Figures 1 and 3). Together with Cerro Pinto and Cerro Pizarro they constitute a system of intrusives in the area; but unlike Pinto and Pizarro, Derrumbadas have no obviously associated explosion crater. It is tempting however, to try to find remanents of a crater that might have been destroyed by the outgrowing of the intrusive, as may eventually happen to the crater at Cerro Pizarro if the rhyolite intrusive continues to grow. The possibility that such a crater once existed is strengthened by the presence of other explosion craters that exist in the periphery of Derrumbadas (i.e., Tepexitl, Buenavista and one to the north named Atexcaqui).

The intense activity around Derrumbadas implies that heat has been reaching the surface in anomalous quantities in that area for a period of tens of thousands of years (e.g. between Xalapasquillo de la Hacienda (Ohngemach, 1973) and Tepexitl (Dietz, personal communication) there is a tentative age difference of 20 000 years and it appears that Buenavista may have an intermediate age between the two). In addition, vapors emanating from a place at the base of one of the Derrumbadas have been reported by Ordóñez (1905). Consequently the area around Las Derrumbadas is worth further study as a potential geothermal source.

The Southern Group

6. Tecuitlapa

Ordóñez (1905) describes this structure as an axalapazco (Figure 11a), therefore it contains a lake. The shape of this structure is that of an ellipse with a maximum diameter of 1500 m approximately and a mean depth of 95 m from the top of the rim to the water level. The lake inside the axalapazco is shallow (i.e., 10 m depth approximately) and it may eventually disappear owing to slumping from the structure's inner walls. A little offset from the crater's center there is a dome and three small craters (diameters from 25 to 50 m), all of them close together and that, according to Ordóñez (1905), represent the last active stages of this crater.

Figure 11b shows the total magnetic intensity map of Tecuitlapa, contour interval is 50 gammas; it represents the strongest magnetic response among the surveyed structures. It shows a magnetic low a little to the west of the crater's center, and a high is suggested SW of the structure, corresponding thus to a dipole-like response; magnetization in this case appears to be normal. Ordóñez (1905) describes the central dome as constituted by thick lavas, and relates this axalapazco to the nearby lava flows known as Malpaís (Figure 11a). Malpaís appears to be associated with the same fault that links Hacienda, Volcán and Derrumbadas. Therefore, it is plausible that the materials giving rise to the anomalous responses at Tecuitlapa and Volcán originate from a deep, common magma source and consequently might have similar compositions.

7. Aljojuca and Zotoltepec Cones

Discussion of these four structures (Figure 12a) will be made together given their proximity to each other. For the Zotoltepec cones only two closely spaced lines were flown. Results are shown in the total intensity map of Figure 12b. The response suggests that magnetized plugs are responsible for the dipole-like signature of the two western cones. A similar response is assumed for the eastern cone, although contour lines do not define the dipolar response as clearly as for the western cones.

Aljojuca is another axalapazco; Ordóñez (1905) describes it as having an almost circular lake with a mean diameter of 1 Km approximately. The lake coincides with the original shape of the crater, which after erosion became elongated in the NE side of the rim. The average depth is of 190 m for this structure, although in places it reaches only 105 m. Two lava flows are apparent on the crater walls; one is a black, basaltic lava with a tendency to columnar structure, which may correspond to one of the oldest eruptions of the Zotoltepec cones, and the other, at a higher elevation, appearing only on the eastern walls. From these observations it is clear that Ordóñez (1905) considered the cones older than the axalapazco.

The total intensity map for Aljojuca appears in Figure 12b; a low is located on the circular portion of the structure. The total intensity contours also suggest the presence of a high north of the structure and a low to the east; however, there is not enough information to delimit their actual positions. In any event, there appears to be an alignment between the elongated (NE) portion of the rim and the total intensity contours in that area.

8. Xalapazcos

The Xalapazco Chico and the Xalapazco Grande (Figure 13a) are located approximately 4 Km east of the Zotoltepec cones. As the name implies they have no water, contrasting with the neighboring axalapazcos of Tecuitlapa and Aljojuca. Ordóñez (1905) also describes these structures and gives the following data for them: the Xalapazco Grande (north) has a 700 m diameter and a depth of 70 m; the Xalapazco Chico (south) has a diameter of 600 m and a depth of 150 m; they are separated 1 Km from each other. The walls of these structures consist of gray tuffs containing basalt fragments and hornblendic and hypersthenic andesite boulders, probably carried from alluvial beds located at greater depths. Beneath these materials there are yellowish tuffs that are also found uniformly extended outside the Xalapazcos; the deepest observable beds consist of interbeded tuffs and alluvial lenses.

Figure 13b shows the total intensity map for the two Xalapazcos. The northern structure shows a weak gradient while the southern one shows a definite anomaly. Notice, however, that the contour interval is 10 gammas; consequently, the intensity of the anomaly is not comparable to those of the other structures in the southern group.

Summary for the Southern Group

The structures of the northern group showed three qualitatively different degrees of magnetization: negligible, weak and strong magnetization. The structures of the southern group can also be divided in three degrees of magnetization: negligible for the Xalapazco Grande, weak for the Xalapazco Chico and strong for the rest of the structures. It is not clear whether Aljojuca belongs in the strong category. Thus, with the exception of Xalapazco Grande, there appears to be a correlation between surface structures and underground magnetized bodies.

Xalapazco Grande does not show a magnetic anomaly; two posibilities shall be mentioned regarding its origin. As a first instance consider that a collapse occurred at the site of Xalapazco Grande when an explosion produced Xalapazco Chico. In favor of this possibility one can cite the collapse that has been observed in the vicinity of the site of an underground atomic explosion (e.g. Short, 1965). We may add that Ordóñez (1906) believed that the origin of the two Xalapazcos was simultaneous and that they were formed by a single explosion; if such was the case, and since there was little or no subsequent activity that could produce a constructional rim, one is inclined to believe that the explosion had to occur at a considerable depth. For Tepexitl (Maupomé *et al.*, 1975) we have estimated a depth of 150 to 200 m for the center of the initial explosion; accordingly, we would expect a depth in excess of 400 m for the explosion that formed Xalapazco Chico.

An alternative origin for these Xalapazcos could be a common magma chamber underlying them and connected to the Zotoltepec cones; owing to pressure release through the cones, collapse without explosion occurred at the Xalapazco Chico. The collapse of the Xalapazco Chico could have induced a smaller collapse creating nearby the Xalapazco Grande. A similar case involving a cone and two pit craters is found in the Kau Desert, Kilauea Volcano, Hawaii (Fiske, 1971); these structures are smaller than the structures under discussion but are also supposed to be connected at depth by a lava tube.

CONCLUSIONS

Aeromagnetometry flown over a series of volcanic structures in the eastern portion of the Mexican Volcanic Belt allow for the following observations: (1) Volcanic cones show the strongest magnetic responses; they resemble the response of a magnetic dipole (Volcán, Tecuitlapa, and Zotoltepec Cones), (2) explosion craters with an ash ring show weak magnetic anomalies (Tepexitl, Buenavista), a fact that corroborates some of the results obtained by Wood (1974) at the Pinacate volcanic field, and (3) collapse structures with no obvious ash ring may show a strong anomaly, a weak anomaly, or no anomaly at all (Hacienda, Xalapazco Chico, Xalapazco Grande and Aljojuca).

Comparing explosion craters with an ash ring and those without it, there is some evidence pointing to the possibility that the explosions of the former type are shallow (possibly 200 meters or less), while those of the latter type may originate on explosions occurring at greater depths, in such a way that little or no pyroclastics can scape from the pit.

Finally, an indirect analysis has been made of some intrusives of the basin that led us to propose Las Derrumbadas as a potential geothermal field.

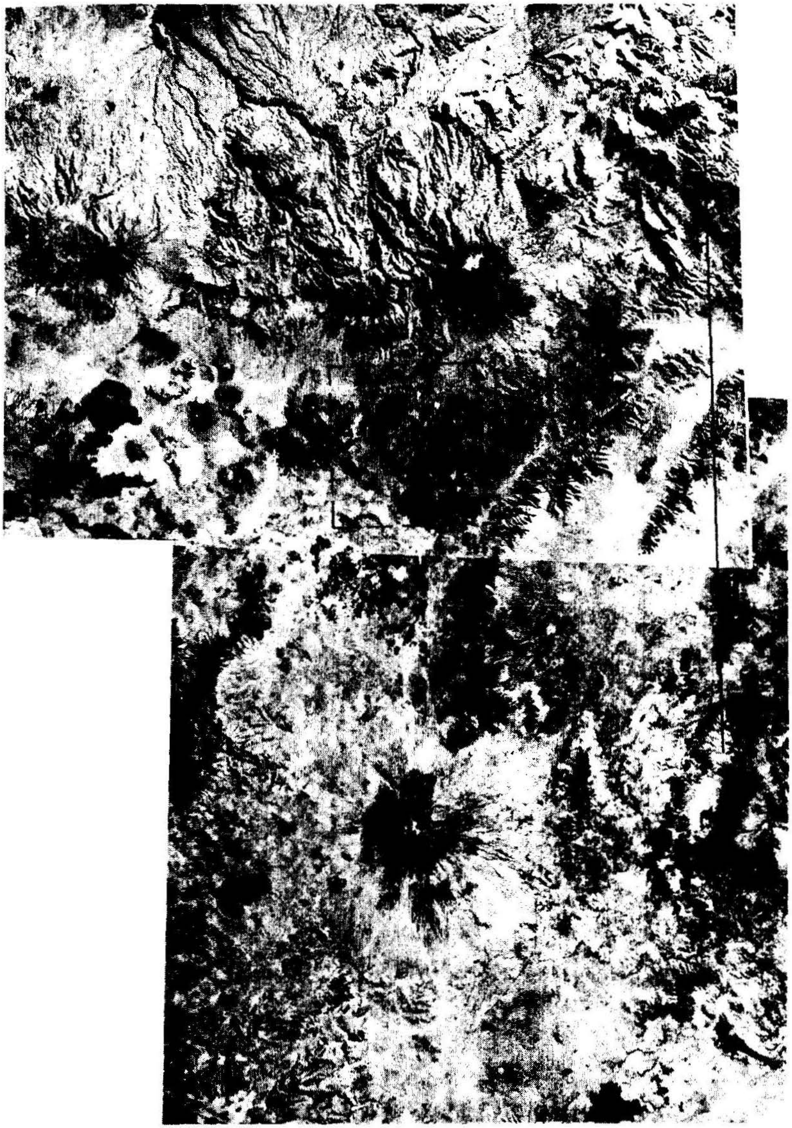

Fig. 1 (b) Satellite image in the infrared band (ERTS, E-1180-16225-7 and E-1199-16285-7) of the studied area and its vicinity. The area is bounded by three important peaks: Citlaltepetl (5 700 m) and Naucampatepetl (4 282 m) on the eastern side of the image, the former showing its snowed peak; and Matlalcueyatl (4 461 m) on the western side.

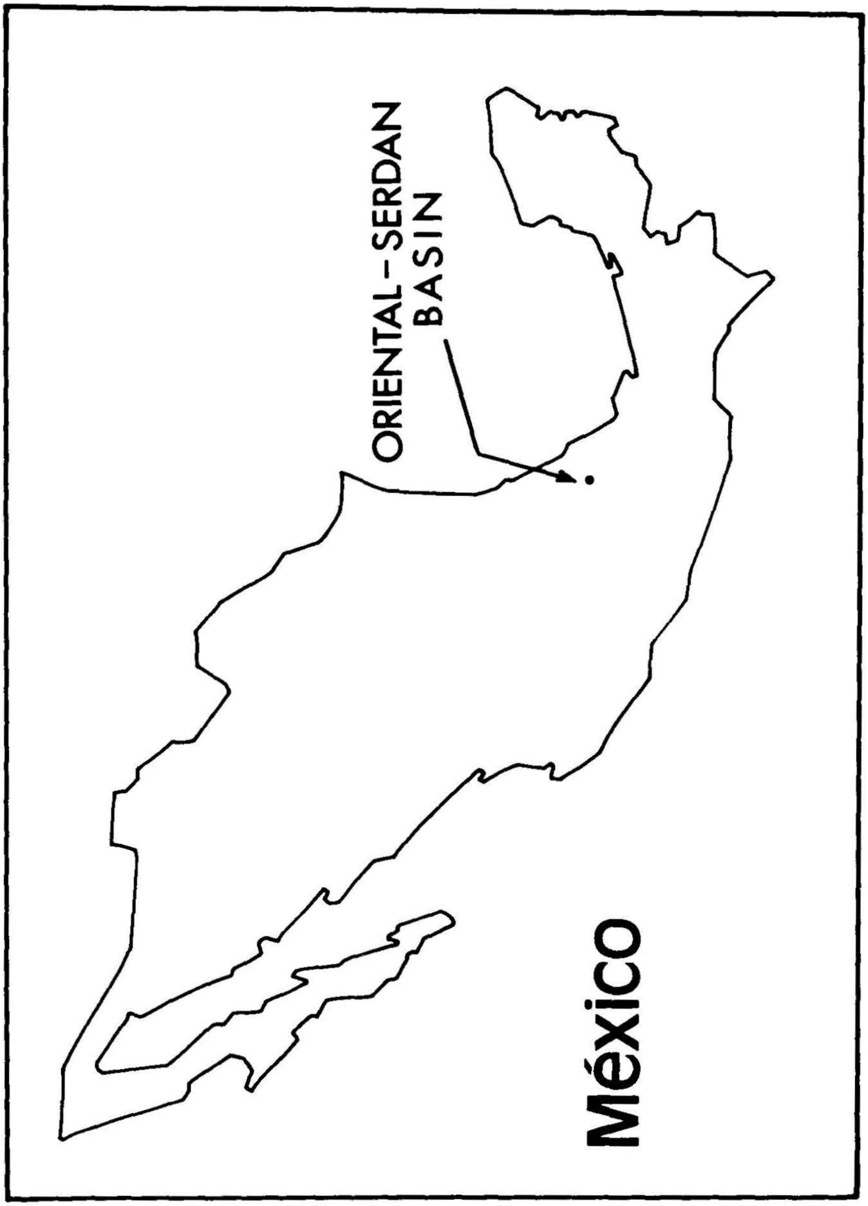

Fig. 1 (a) Location map of the Oriental-Serdan basin.

Fig. 2 (b) The rim of the explosion crater is well preserved at various locations; the intrusive rises from within the crater.

Fig. 2 (a) Cerro Pizarro consists of an explosion crater of approximately 2.5 Km diameter and a rhyolite intrusive.

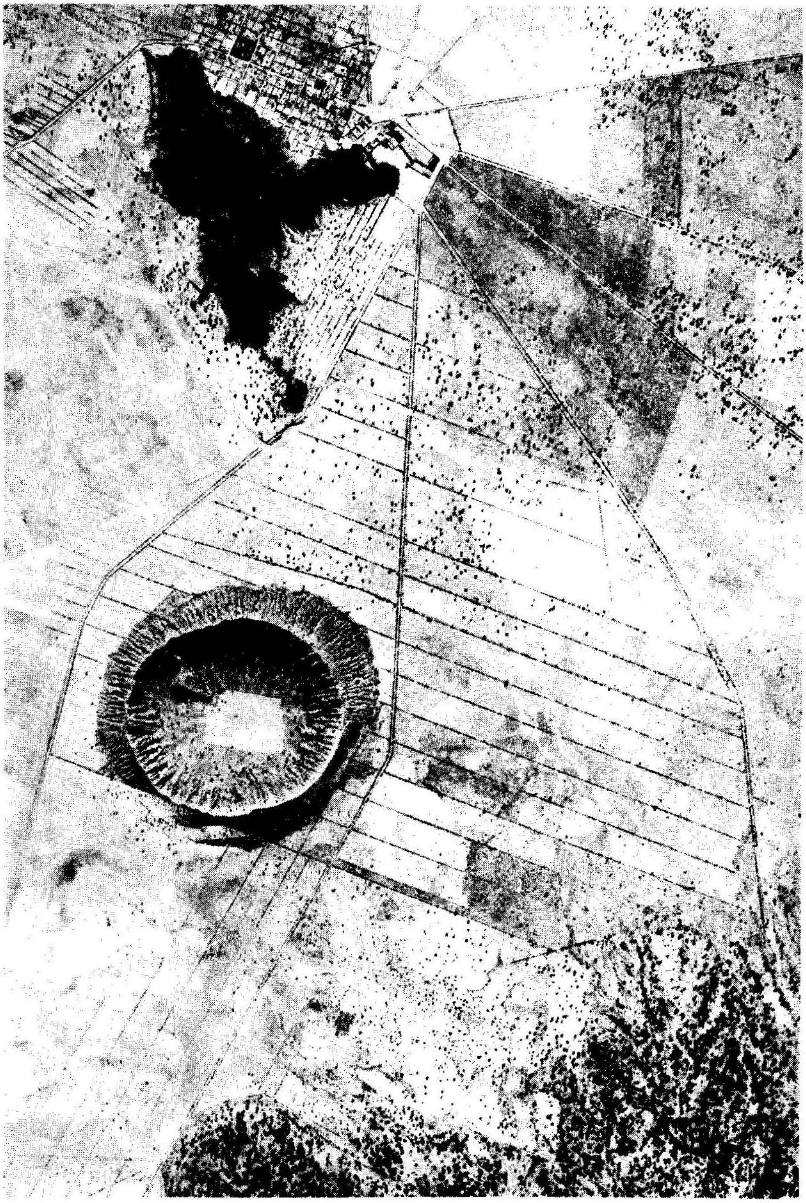

Fig. 4 Aerial view of the explosion crater Tepexitl and the nearby limestone reef known as La Campana. The diameter of Tepexitl measures 1180 m.

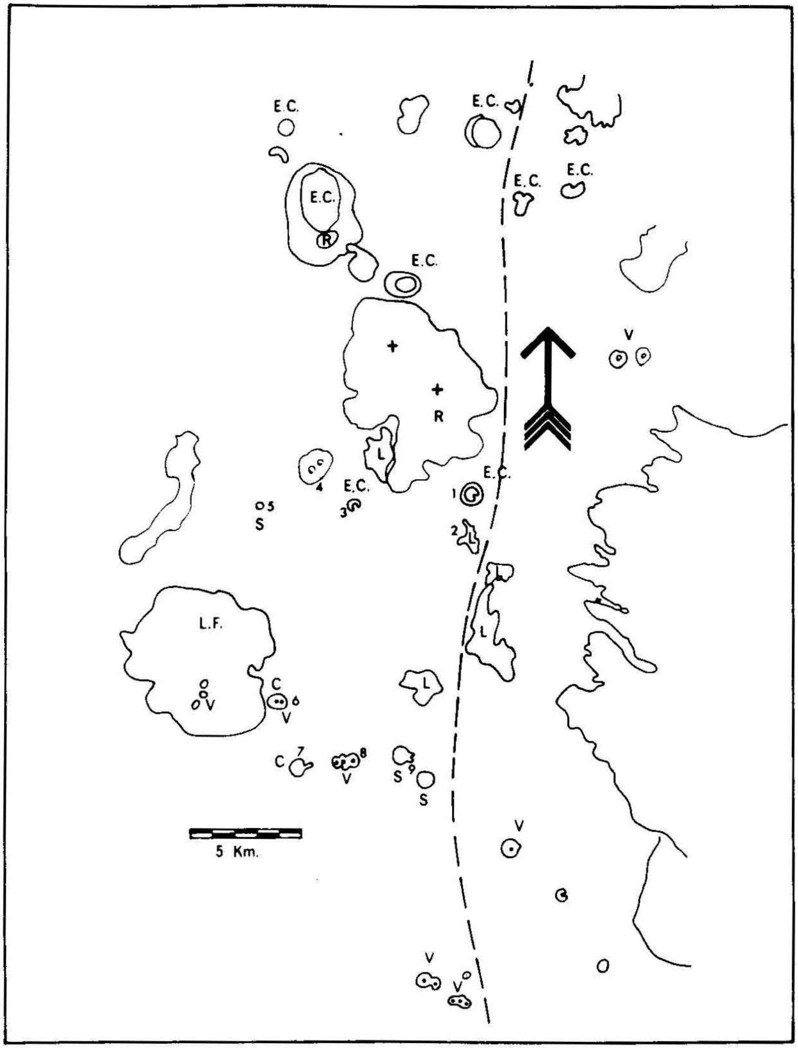

Fig. 3 Area showing the structures studied (numbered) as well as other prominet structures. R. denotes intrusive rhyolites, L limestone, V volcano, LF lava flows, EC explosion crater, S collapsed structures and C calderas. The dashed line corresponds to an inferred section of the Transcontinental Fault (Alvarez and Del Río, 1975). The rhyolites immediately north of structures 1, 3, and 4 are known as Las Derrumbadas. NNW of Las Derrumbadas are shown an explosion crater and an intrusive rhyolite: The former is known as Tepeyahualco and the latter as Cerro Pinto. The southern portion of the rim of Tepeyahualco is known as Sierra Blanca.

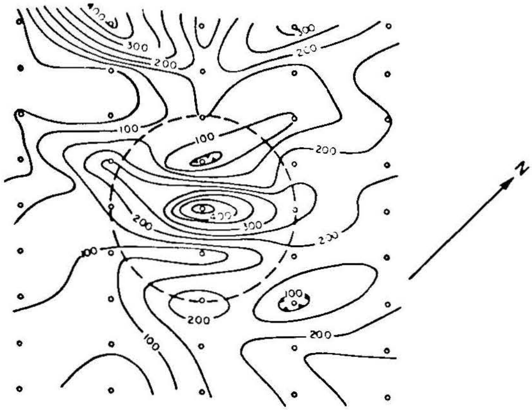

Fig. 5 (b). Vertical component map of the magnetic field (ground survey). Small circles denote reading stations; station interval is 300 m and line interval 600 m. Contour interval is 50 gammas.

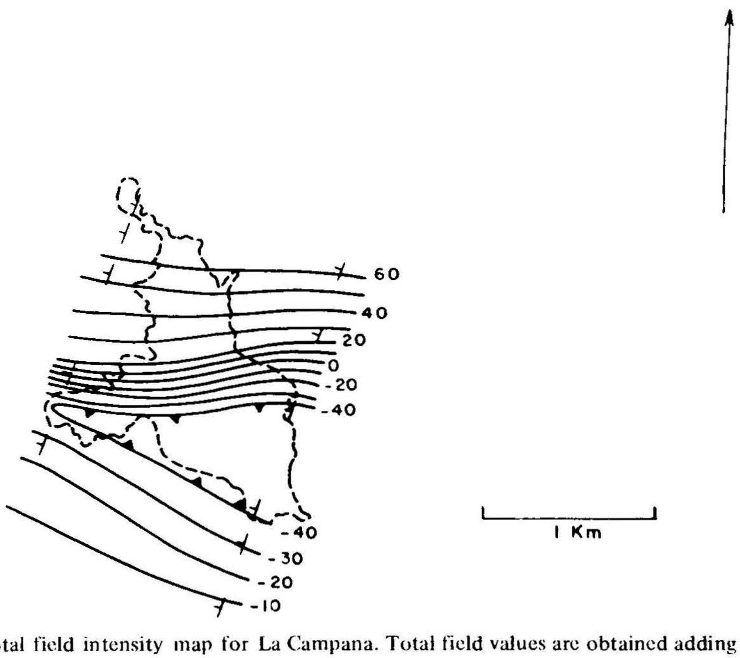

Fig. 6. Total field intensity map for La Campana. Total field values are obtained adding 43 560 gammas. Only two lines were flown; the response of this structure is a magnetic low.

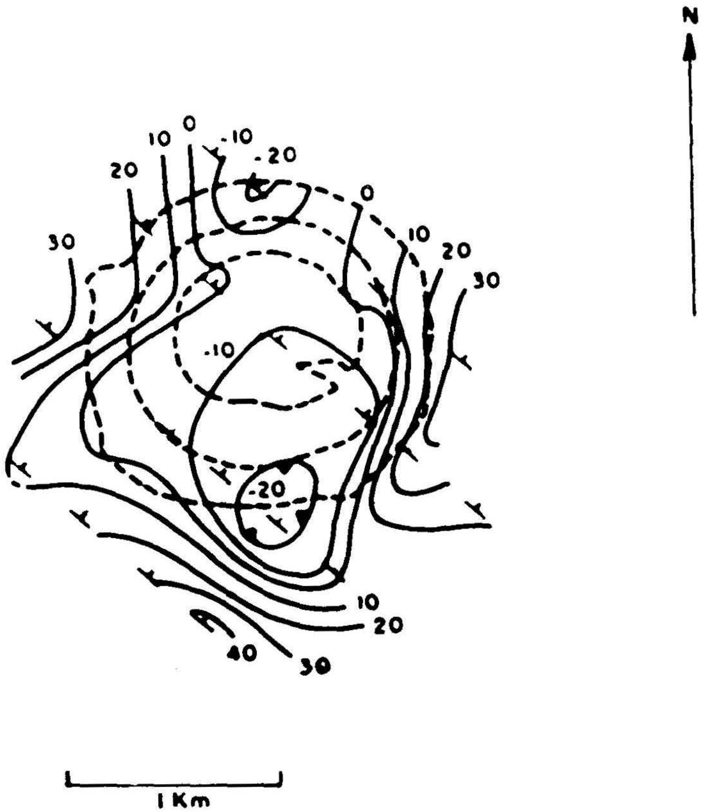

Fig. 5 (a). Total field intensity map for Tepexitl. Contour interval is 10 gammas. Total field values are obtained adding 43 660 gammas. Flight lines and points where readings were made are shown by fiducials. Concentric dashed lines delimit the rim of the structure.

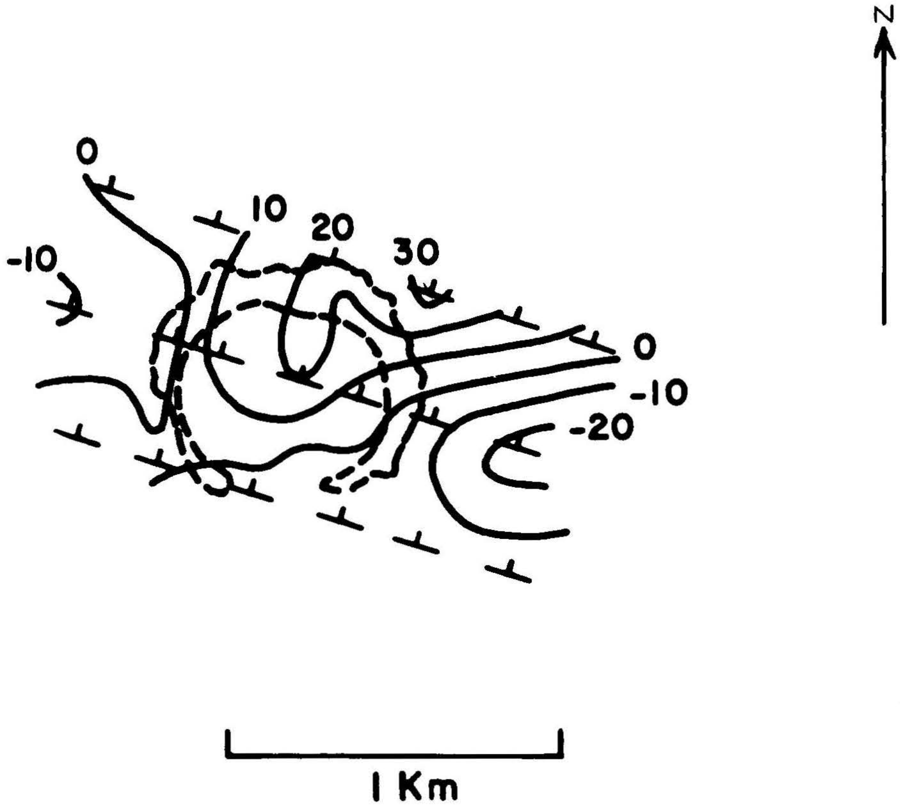

Fig. 8. Total field intensity map for Buenavista. Contour interval is 10 gammas. Total field values are obtained adding 43 560 gammas.

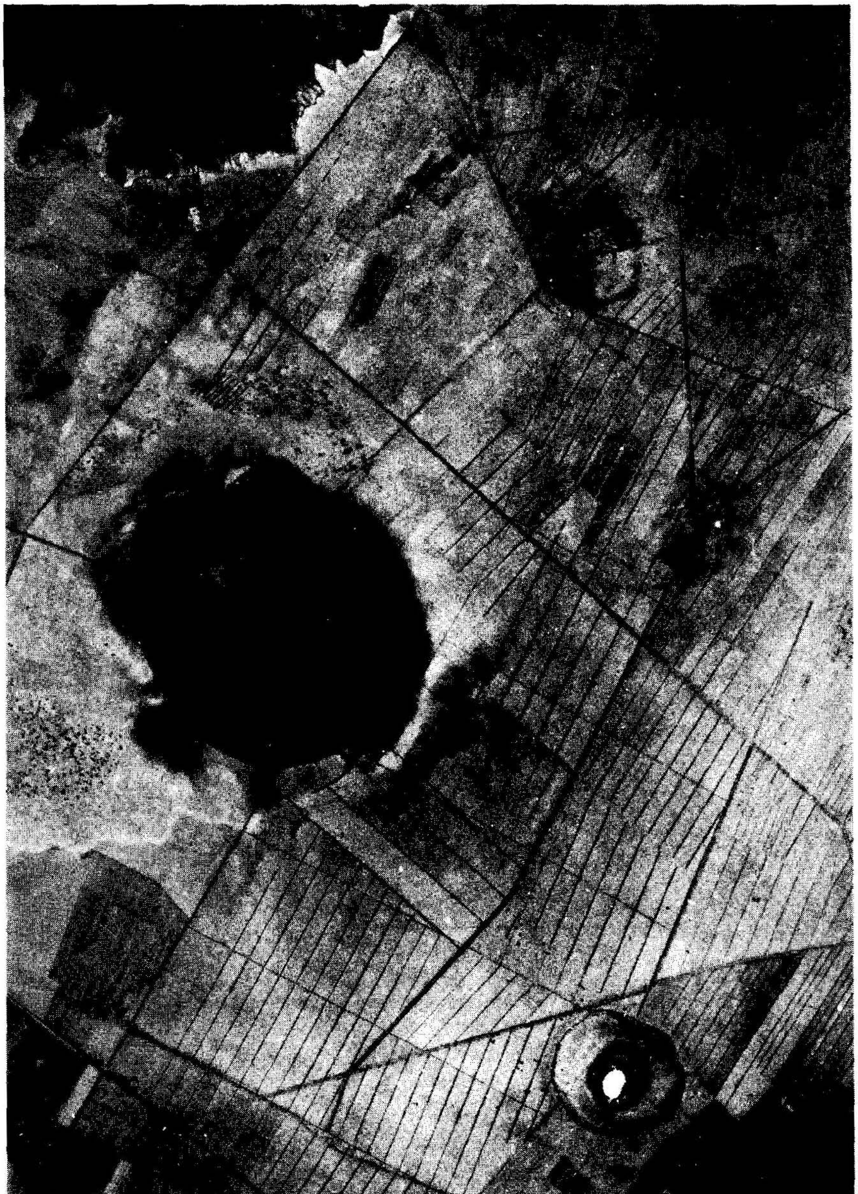

Fig. 7. Aerial view of Volcán, Buenavista and Xalapasquillo de la Hacienda. The former is at the center and the last two to the east and west respectively.

Fig. 11 (a). Aerial view of Tecuitlapa. The shallow lake, lava dome, and craters are clearly discernible. The Malpaís lava flows are close to the NW limits of Tecuitlapa.

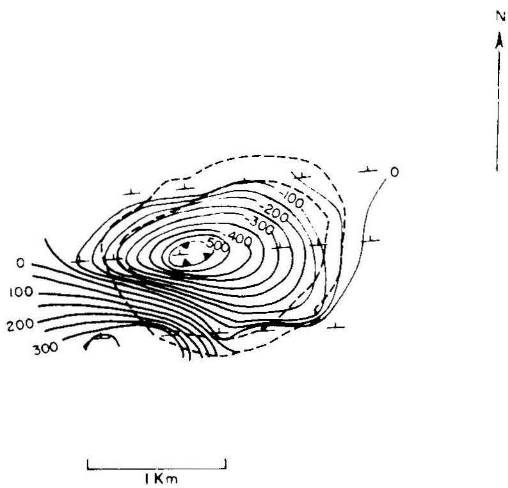

Fig. 11 (b). Total field intensity map for Tecuitlapa. Contour interval is 50 gammas. Total field values are obtained adding 43 360 gammas. Dashed lines delimit the rim of the structure.

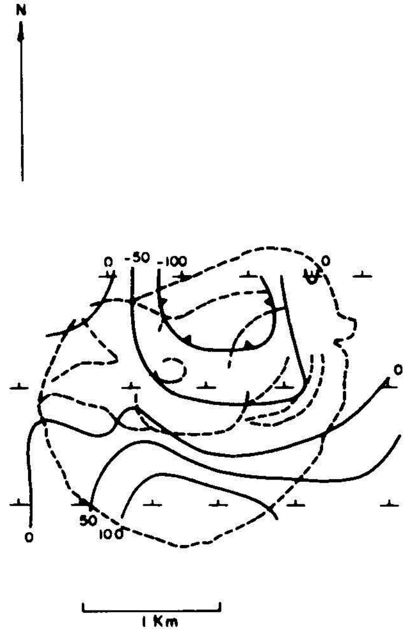

Fig. 9. Total intensity map for Volcán. Contour interval is 50 gammas. Total field values are obtained adding 43 560 gammas. The dashed lines within the structure denote surface features visible on Figure 7.

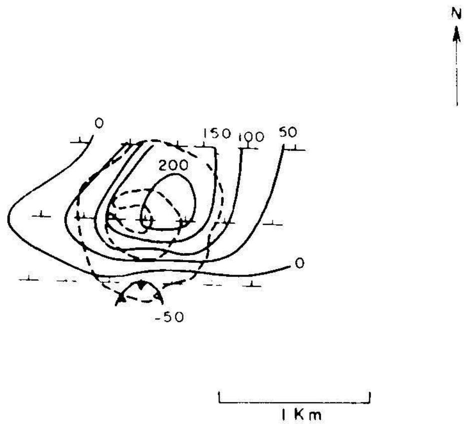

Fig. 10. Total intensity map for Xalapasquillo de la Hacienda. Contour interval is 50 gammas. Total field values are obtained adding 43 560 gammas.

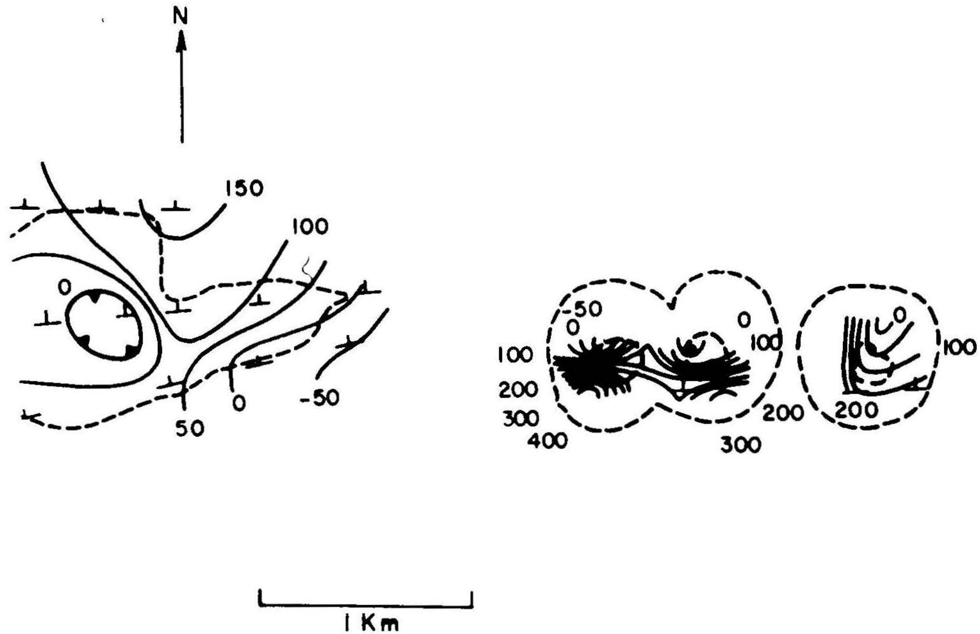

Fig. 12 (b).Total field intensity map for Aljojuca and the Zotoltepec cones. Contour interval is 50 gammas. Total field values are obtained adding 43 360 gammas. Dashed lines delimit the structures. Only two lines were flown across the cones; they indicate strong gradients associated to these structures.

Fig. 12 (a). Aerial view of Aljojuca and the Zotoltepec cones. An asymmetry appears in the western edge of the crater; it may be that an intrusive, different from the one that apparently created the crater, is responsible for such a feature. However, Ordóñez (1906), favors a purely erosional origin for the asymmetrical portion of the structure.

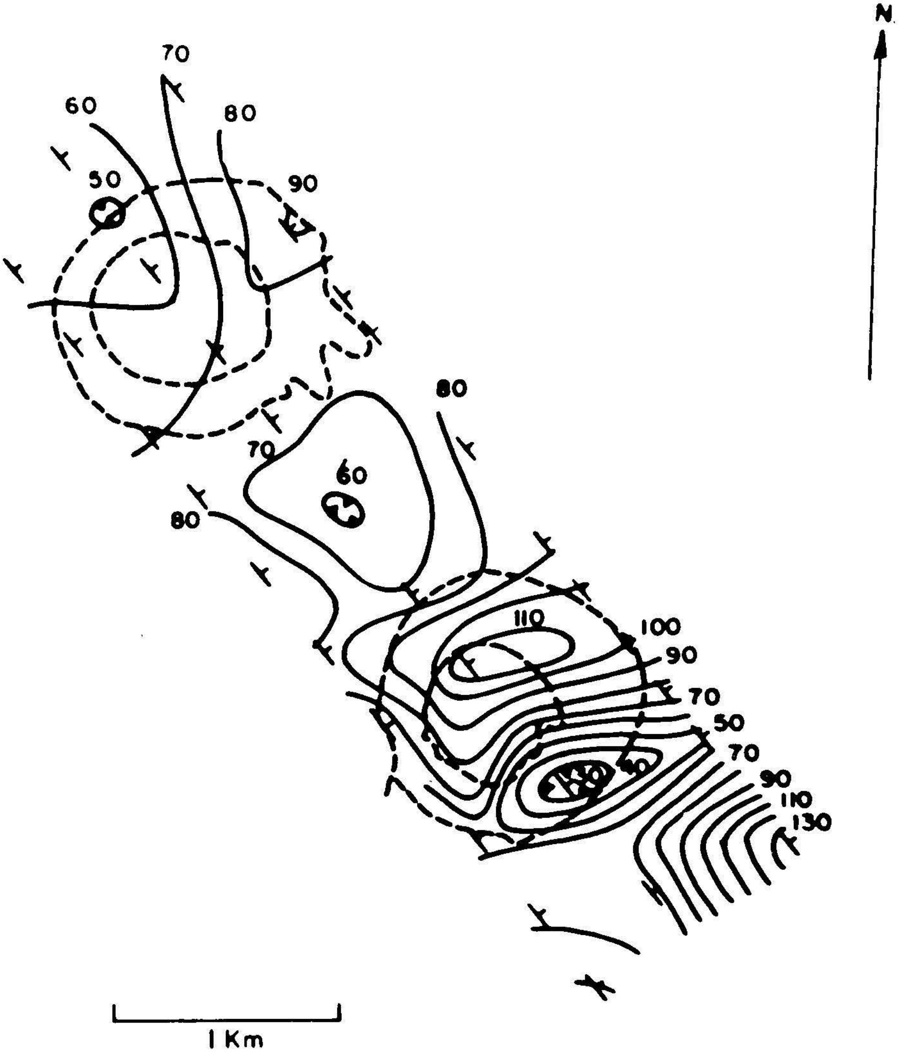

Fig. 13 (b).Total field intensity map for the Xalapazcos. Contour interval is 10 gammas. Total field values are obtained adding 43 360 gammas. Dashed lines represent top and bottom perimeters of these structures. A considerable difference in response is observed between the two Xalapazcos.

Fig. 13 (a). Aerial view of the Xalapazcos; the Xalapazco Grande is located NW of the Xalapazco Chico. Their respective diameters are 700 and 600 m.

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