Geofísica Internacional (1996), Vol. 35, Num. 2, pp. 125-133

Initial results of the UNAM scientific drilling program on the Chicxulub impact structure: rock magnetic properties of UNAM-7 Tekax borehole

J. Urrutia Fucugauchi, Luis Marín and Alberto Trejo García
Instituto de Geofísica, UNAM, MEXICO

Received: October 3, 1995; accepted: March 11, 1996.

RESUMEN

Como parte de las investigaciones iniciales del Programa UNAM de Perforación de la Estructura de Impacto de Chicxulub se han realizado mediciones de propiedades magnéticas en el material colectado en el pozo exploratorio UNAM-7, que está localizado a 126 kilómetros del centro de la estructura, al sureste del Puerto de Chicxulub, en el municipio de Tekax (unos 2.5 km del centro de Tekax en dirección a Ticum). De la descripción inicial del material se ha identificado el contacto entre la secuencia carbonatada y las unidades de brecha a una profundidad de 222.2 m. En el intervalo adyacente al contacto, entre los 207 y los 215.2 m se observan horizontes de calizas arcillosas y entre los 215.2 y los 222.2 m se tiene la presencia de yesos y anhidritas. La unidad de brecha puede separarse en dos unidades mayores. La unidad superior se caracteriza por abundancia de clastos de rocas de basamento. La unidad inferior está caracterizada por abundantes clastos de anhidrita e intercalaciones de horizontes anisotrópicos de evaporitas. Los contrastes en susceptibilidad magnética permiten diferenciar y caracterizar las diferentes litologías. Los contrastes más marcados se encuentran asociados al contacto entre las calizas arcillosas y horizonte de evaporitas y la brecha polimíctica. La susceptibilidad es alrededor de -1 a 0×10^{-6} SI entre 210 y 222 m y se incrementa a valores entre 1 y 15×10^{-6} SI en el siguiente intervalo hasta 226 m. Después de este intervalo transicional se tienen valores que fluctuan alrededor de un nivel de alrededor de $50\text{-}100 \times 10^{-6}10$ SI, dentro de la unidad superior de brechas. El registro de susceptibilidad magnética permite identificar tres intervalos con valores mayores de susceptibilidad de hasta $550\text{-}1100 \times 10^{-6}$ SI, a los 244 m, 264 y 277 m y dos intervalos de anhidritas a los 237-239 m y 250 m. El registro de susceptibilidad refleja el porcentaje de clastos de basamento (o de carbonatos) presente en la brecha. El paso a la unidad de brecha con abundancia de clastos de evaporita está caracterizado por el cambio de valores de alrededor de 55×10^{-6} SI a valores entre -1 y 0×10^{-6} SI, el cual se presenta entre los 348.4 y 350.5 m. Debido a la naturaleza heterogénea de la brecha ha sido difícil estimar datos promedio de susceptibilidad magnética para el modelado de las anomalías magnéticas. Los datos para el UNAM-7 permiten un análisis estadístico de la susceptibilidad magnética. El espesor de la brecha con susceptibilidad de 55×10^{-6} SI es de 126.2 m.

PALABRAS CLAVE: Cráter Chicxulub, propiedades magnéticas, perforaciones, frontera Cretácico/Terciario, península de Yucatán.

ABSTRACT

As part of the initial studies of the UNAM scientific drilling program on the Chicxulub structure we have measured the magnetic susceptibility of cores recovered from the UNAM-7 exploratory borehole. The drilling site is located at 126 km from the center of the structure, south-southeast of Chicxulub Puerto, in Tekax County (2.5 km from downtown Tekax in the direction of Ticum). The contact between the Tertiary carbonate sequence and the impact breccia is observed at 222.2 m. Above this contact, there are marls (207 to 215.2 m) and evaporites (215.2 to 222.2 m). Low-field magnetic susceptibility measurements for the contact show a two-step increase from low -1 to 0×10^{-6} SI values in the carbonates and evaporites to intermediate values of 1 to 10×10^{-6} SI between 222.2 and 226 m, followed by an increase to values of about $50\text{-}100 \times 10^{-6}$ SI within the breccia. The polymict breccia can be divided into an upper unit of basement clasts and a lower unit of evaporite breccia. The contact between the two breccia units at 348.4 m is marked by a decrease in susceptibility from values around 55×10^{-6} SI to low values of -1 to 0×10^{-6} SI. The contrast in susceptibility between the carbonates, evaporites and the breccia and clasts is high enough to provide a simple means to diferentiate and characterize the different lithologies. Because of the heterogenous nature of the breccia, it is difficult to obtain data on bulk magnetic properties for magnetic anomaly modeling. Data obtained from well UNAM-7 allow estimation of statistically characteristic values for the magnetic susceptibility of the breccia, to be used in modeling of the magnetic anomalies. Thickness of the breccia with susceptibility values around 55×10^{-6} SI is 126.2 m.

KEY WORDS: Chicxulub crater, rock-magnetic properties, drilling, Cretaceous/Tertiary boundary, Yucatán peninsula.

1. INTRODUCTION

Gravity and magnetic studies carried out by Petróleos Mexicanos (PEMEX) allowed identification of some approximately circular large-amplitude anomalies over the northwestern sector of the Yucatán peninsula. The anomalies were associated with igneous bodies buried beneath a thick carbonate sequence. The igneous bodies were reached by deep drilling and showed to consist of volcanic and carbonate breccias and a massive igneous-textured unit of andesitic composition (e.g., Lopez Ramos, 1975). They were assigned a Late Cretaceous age and initially identified as part of the Circum-Gulf of Mexico Mesozoic igneous province. The anomalies were later interpreted in terms of an impact structure by Penfield and Camargo (1981). They attracted considerable attention because of the association of the structure to the impact that marked the end of the Cretaceous era (Alvarez *et al.*, 1980; Hildebrand *et al.*, 1991).

Subsequent studies provided evidence on the age, shock-diagnostic features, and isotopic, paleomagnetic, geochemical, mineralogical and geophysical data which strengthened the interpretation that the buried Chicxulub structure represents an impact crater at the Cretaceous/ Tertiary (K/T) boundary (e.g., Pope *et al.*, 1991; Sharpton *et al.*, 1992, 1993; Blum *et al.*, 1993; Krogh *et al.*, 1993; Pilkington *et al.*, 1994; Urrutia-Fucugauchi *et al.*, 1994; Schuraytz *et al.*, 1994). The bodies of igneous composition are impact breccias and the melt unit was produced by the high velocity impact of an extraterrestrial body.

Some workers have challenged the interpretation of the stratigraphy to retain the initial descriptions of Lopez Ramos (1975), who proposed that the igneous-textured units represent a Late Cretaceous volcanic sequence (Meyerhoff *et al.*, 1994). Others have objected that breccias in the south-southeastern sector of the structure were produced by the impact (Koeberl, 1993). The area is ideal for geophysical studies, and allows an excellent resolution which is hard to achieve in other regions. The topography is almost flat, with good access roads radiating out of Merida City (i.e., approximately normal to the crater structure). Tertiary carbonate units appear to be largely undeformed and are flatlying. There is a large contrast in physical properties (density, magnetic susceptibility, etc) between the carbonates and the breccias and melt unit. Despite the wealth of information available concerning the crater structure, several contrasting geophysical models were proposed. For example, crater diameter estimates range from some 170 km up to 300 km (Hildebrand *et al.*, 1991, 1995; Sharpton *et al.*, 1993; Pope *et al.*, 1991; Pilkington *et al.*, 1994; Espíndola *et al.*, 1995). A major problem with the geophysical models is the limited data available on physical properties for the source units, a common restriction in studies of impact basins (e.g., Pilkington and Grieve, 1992). As part of the project to investigate the Chicxulub impact structure, scientists from UNAM are currently conducting a scientific drilling program with continuous recovery of core material. Seven boreholes located in the southern sector of the structure have already been completed during 1994 and 1995 and studies on this material are underway (Marín and Sharpton, 1994, Marín *et al.*, 1995).

In this paper we report on initial results for the UNAM-7 borehole drilled near the town of Tekax, in the south-southeastern sector of the Chicxulub structure as defined by the potential field anomalies (Figure 1). The UNAM-7 borehole reached a depth of 702.4 meters and penetrated the carbonate sequence and the impact breccia. Here we provide on an initial description of the cores and of the rock magnetic study.

2. UNAM-7 BOREHOLE

The UNAM-7 borehole is located 2.5 km from downtown Tekax along federal highway 184 to Ticum. The site is in the recreational center of Tekax County, about 200 meters off the road (a concrete slab with a pipe marks the drill site), and about 126 km from the center of the crater structure near Chicxulub Puerto (Figure 1). It is located in the south-southeastern sector between rings 3 and 4 identified from the gravity study (Sharpton *et al.*, 1993), well beyond the cenote ring and to the east of Ticul range.

Drilling was carried out with a JKS Boyles BBS-37 equipment and was completed between May 24 and July 2, 1995. Maximum depth was 702.4 m (referred to the local ground surface). Three different diameters were used for drilling, corresponding to the intervals 3 to 114.7 m, 114.7 to 426.1 m and 426.1 to 702.4 m. Sample recovery was 99.01 %, 99.55% and 99.34%, for these three intervals.

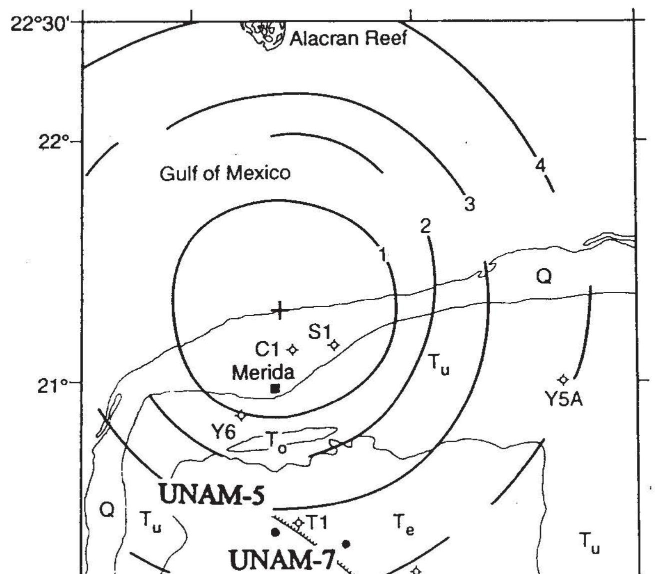


Fig. 1. Location of the UNAM-7 Tekax drill site. Note that UNAM-7 is located in the southern sector of the structure to the east of the Ticul range and fault system (marked by the hatchured lines). The site is located between rings 3 and 4 of the gravity model of Sharpton *et al.* (1993). Also shown are the PEMEX drill sites: C1, Chicxulub-1; S1, Sacapuc-1; T1, Ticul-1, Y1, Yucatán-1; Y2, Yucatán-2, Y5A, Yucatán-5A and Y6, Yucatán-6. Surface carbonate units are: Q, Quaternary (<2Ma); Tu, Upper Tertiary (2 to 35 Ma); Te, Eocene (35 to 55 Ma) and Tpal, Paleocene (55 to 65 Ma).

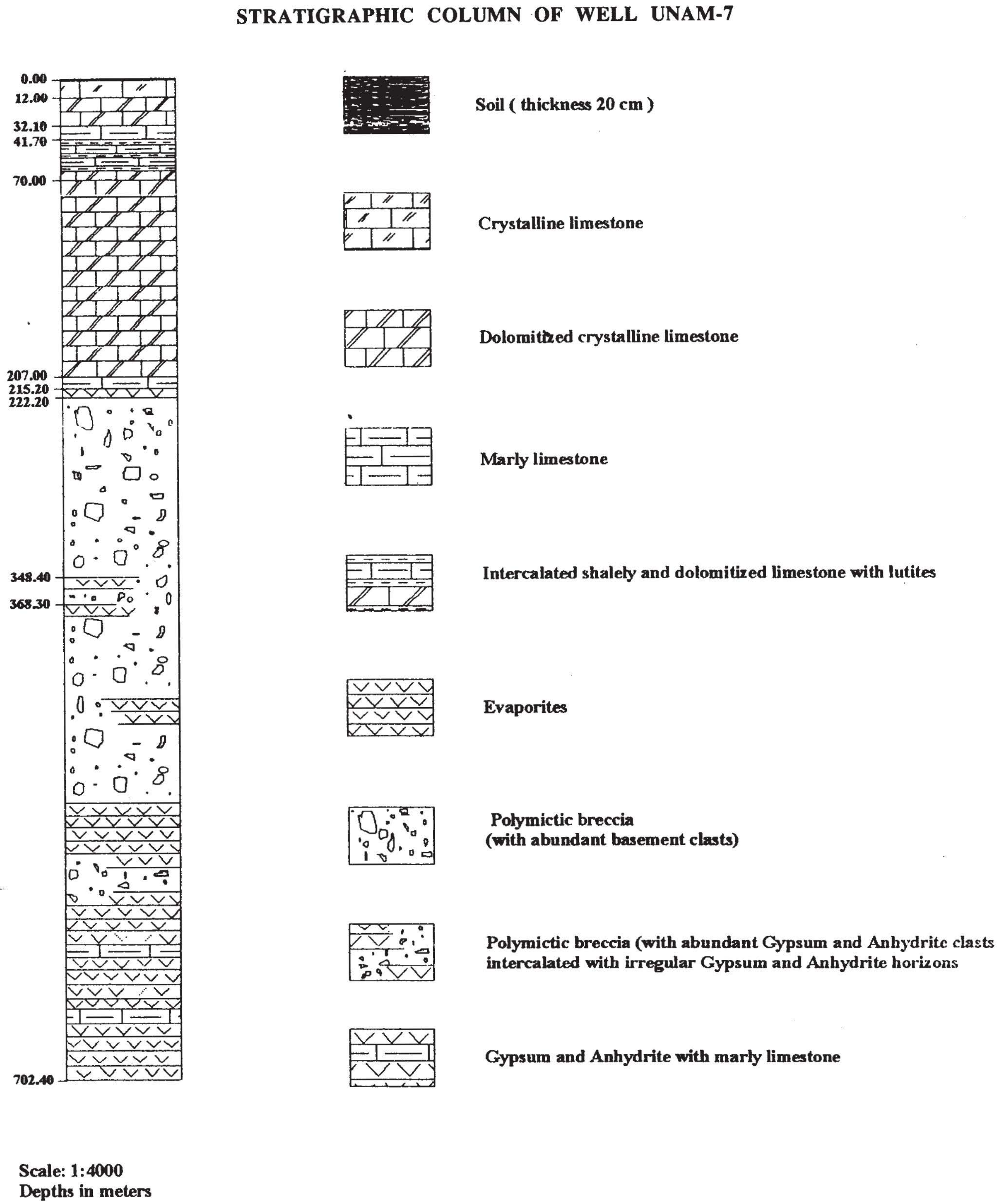


Fig. 2. Lithologic column of the UNAM-7 Tekax borehole. Stratigraphic position is in meters below ground level. Note that the Cretaceous/Tertiary boundary that is marked by the contact between the carbonate sequence and the breccia is at 222.2 m. The breccia is divided into an upper unit characterized by the occurrence of basement clasts and a lower unit characterized by evaporite clasts. Thickness of upper breccia unit is 126.2 m.

3. LITHOLOGY AND MAGNETIC PROPERTIES

A simplified lithological column is shown in Figure 2. From surface to bottom, the column consists of a thin soil cover (about 0.2 m), followed by a > 200 m thick Tertiary carbonate sequence and a 400-500 m thick breccia sequence on top of brecciated Cretaceous sediments or a megablock zone. The Tertiary carbonate sequence consists of dolomitized crystalline limestones and includes intercalations of clay-bearing dolomitized limestones and carbonaceous lutites, crystalline limestones and marls. The contact with the breccia occurs at about 222.2 m. Units above the contact include evaporites, between 215.2 and 222.2 m, and marls, between 207 and 215.2 m. The breccia unit can be divided into an upper unit characterized by the occurrence of basement clasts and a lower unit characterized by abundant anhydrite clasts intercalated with anisotropic horizons of evaporites (possibly representing large clasts). The boundary between the two breccia units occurs at about 348.4 m.The lower breccia unit grades into a sequence of anhydrite intercalated with marls.

The low-field magnetic susceptibility was measured along the column, with special emphasis on the breccia unit. Measurements were carried out with a Bartington MS2 system and a 60 mm diameter core-logging sensor. The system works at an operating frequency of 0.565 kHz and a calibration accuracy of 5%. Measurements were taken at different spacings, 5, 10 and 60 cm. Susceptibility shows a simple pattern, with low values in the carbonates, high values in the upper breccia unit and lower values within the lower breccia unit. The signal depends on the proportion of clasts and matrix components in the breccia; therefore, the susceptibility log is an indicator of breccia composition.

A semi-logarithmic plot of susceptibility as a function of stratigraphic position (Figure 3a) shows that the contact of the Tertiary carbonate sequence with the breccia is marked by a two-step increase of susceptibility from low values around -1 to 0×10^{-6} SI characteristic of limestones, to values between 1 and 10×10^{-6} SI over a 5 m interval, and then to values around $50\text{-}100 \times 10^{-6}$ SI that characterize the breccia. There is little variation across the marls and evaporitic units above the breccia, which mainly show negative susceptibilities indicating dominant diamagnetic effects or occasional small positive values of paramagnetic components. The first abrupt increase in susceptibility values is observed at 222.2 m and corresponds to intermediate values, which suggests that some smaller breccia fragments are mixed with the evaporites. The transitional zone marked by the intermediate values is observed up to about 226 m, which is followed by a sharp increase up to the values that characterize most of the breccia. Within the breccia, in the interval down to 280 m, there are two short intervals of limestone with no breccia fragments at about 238-239 m and 250 m, which show low -1 to 0×10^{-6} SI susceptibility values (Figure 3). There are also three discrete peaks located at about 242 m, 263-264 m and 276 m, with values above $650\text{-}1100 \times 10^{-6}$ SI, as well as several small amplitude fluctuations (Figure 3a and 3b). The peaks correlate with higher proportions of basement rock fragments in the breccia and the occurrence of fragments of a size comparable to the core diameter. The two short intervals of low susceptibility may correspond to large blocks of limestone.

Results for the interval between 330 m and 360 m signal the contact between the upper breccia unit and the lower breccia unit (Figure 4a). The low-field susceptibility decreases from the 55×10^{-6} SI values that characterize the lower portion of the ejecta breccia to low values around -1 to 0×10^{-6} SI. The susceptibility decrease is observed approximately between 348.4 m and 350.5 m (Figure 4a). In the interval 330-348 m above the contact, there is one peak above 300×10^{-6} SI and two smaller peaks above 170×10^{-6} SI (Figure 4a and 4b) that correspond to large breccia clasts.

4. DISCUSSION

The UNAM-7 borehole is located about 126 km from the center of the crater, to the south-southeast of Chicxulub Puerto (Figure 1). The site is between rings 3 and 4 identified in the gravity study of Sharpton *et al.* (1993). It is well outside of the inner central zone of strong magnetic anomalies delimited by ring 1 and outside of the cenote ring. The site is close to the outer limit of the structure. If the crater structure has a diameter < 240 km (Hildebrand *et al.*, 1991, 1995; Pope *et al.*, 1991; Espíndola *et al.*, 1995) then the well lies outside of the crater. Detailed stratigraphic information is important for the interpretation of the crater structure. Descriptions of core samples and well logs for PEMEX boreholes Yucatán-2 (Y-2) and Yucatán-5A (Y-5A) near ring 4 of the gravity model (Figure 1) documented the occurrence of a thick evaporite breccia, with clasts of anhydrite, dolomites and limestones. The breccia unit in Y-2 lies approximately between 220 and 900 m depth, and in Y-5A lies between 400 and 900 m depth. In the Yucatán-1 (Y-1) borehole outside ring 4, to the southeast of Y-2, the evaporite breccia presents a comparable thickness, between 300 and 900 m thick, comparable to that of UNAM-7 borehole. The evaporite breccia has been interpreted as ejecta (Hildebrand *et al.*, 1991, 1995). Koeberl (1993), however, has expressed doubts about this interpretation from geochemical and isotope analyses of samples from Y-2 breccias.

The high sample recovery rate achieved in the UNAM drilling program permits a detailed examination of the stratigraphy and characteristics of the different lithological units. The UNAM-7 borehole documents the presence of a polymict breccia that contains abundant basement and carbonate clasts, the breccia interpretation. From the magnetic susceptibility record, the depth to the top of the breccia unit in Tekax is 222.2 m and the thickness of the impact breccia is 126.2 m (Figure 2). The polymict breccia features abundant basement and limestone clasts. Beneath the depth of 348.4 m, the breccia is characterized by abundant

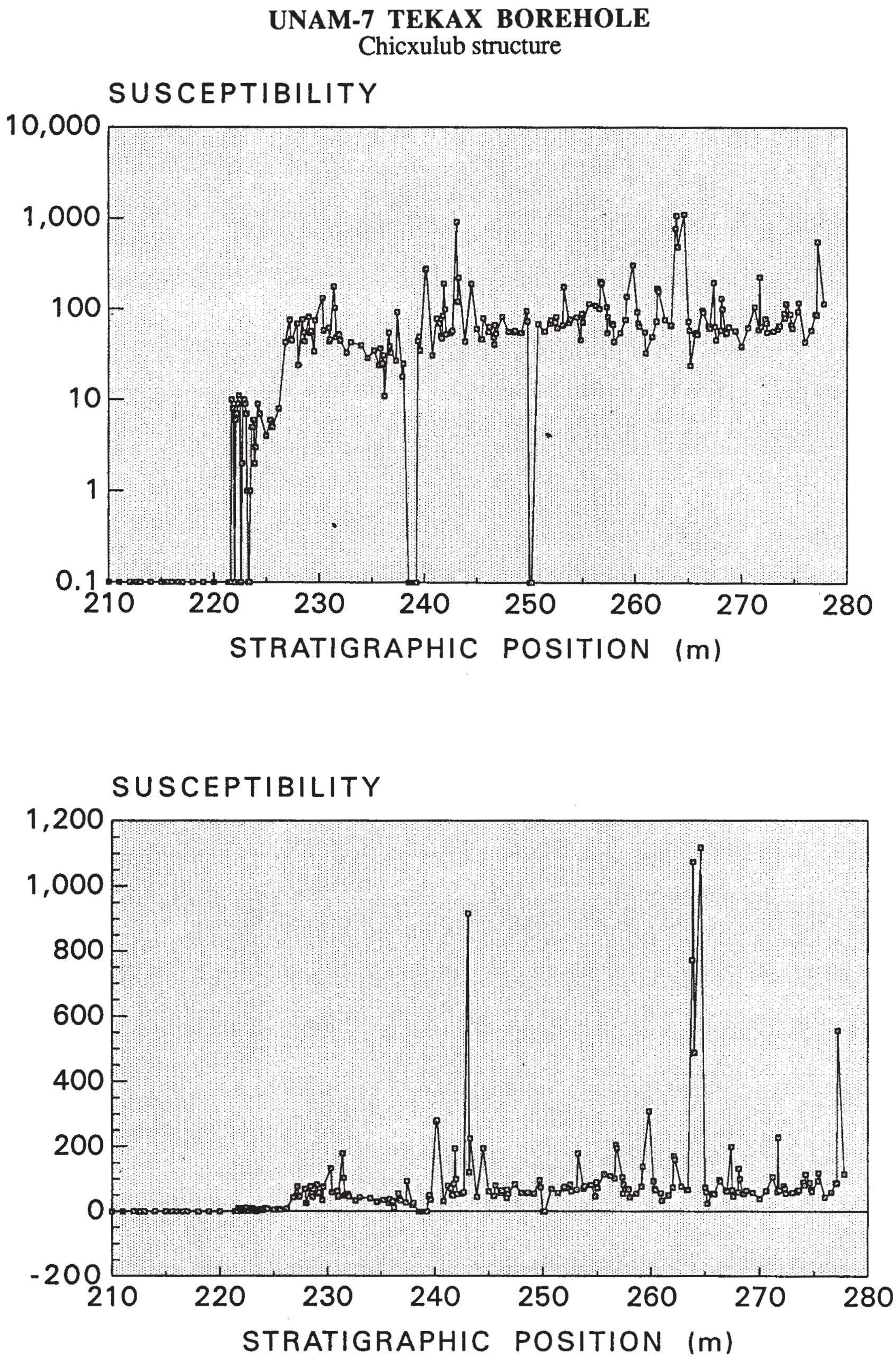


Fig. 3. Low-field magnetic susceptibility variations with stratigraphic position, for the interval 210 m to 280 m (below ground level). (a) Values plotted in a semilogarithmic graph. Note the low values that characterize the carbonate units, the increase to intermediate values between 222.2 and 225.5 m, and the increase to values between 50 and 100 10^{-6} SI that characterize the breccia unit. (b) Susceptibility plotted in a linear scale. Note the two minima at 237-239 and 250 m and the three maxima at 244, 264 and 277 m, as well as shorter amplitude fluctuations.

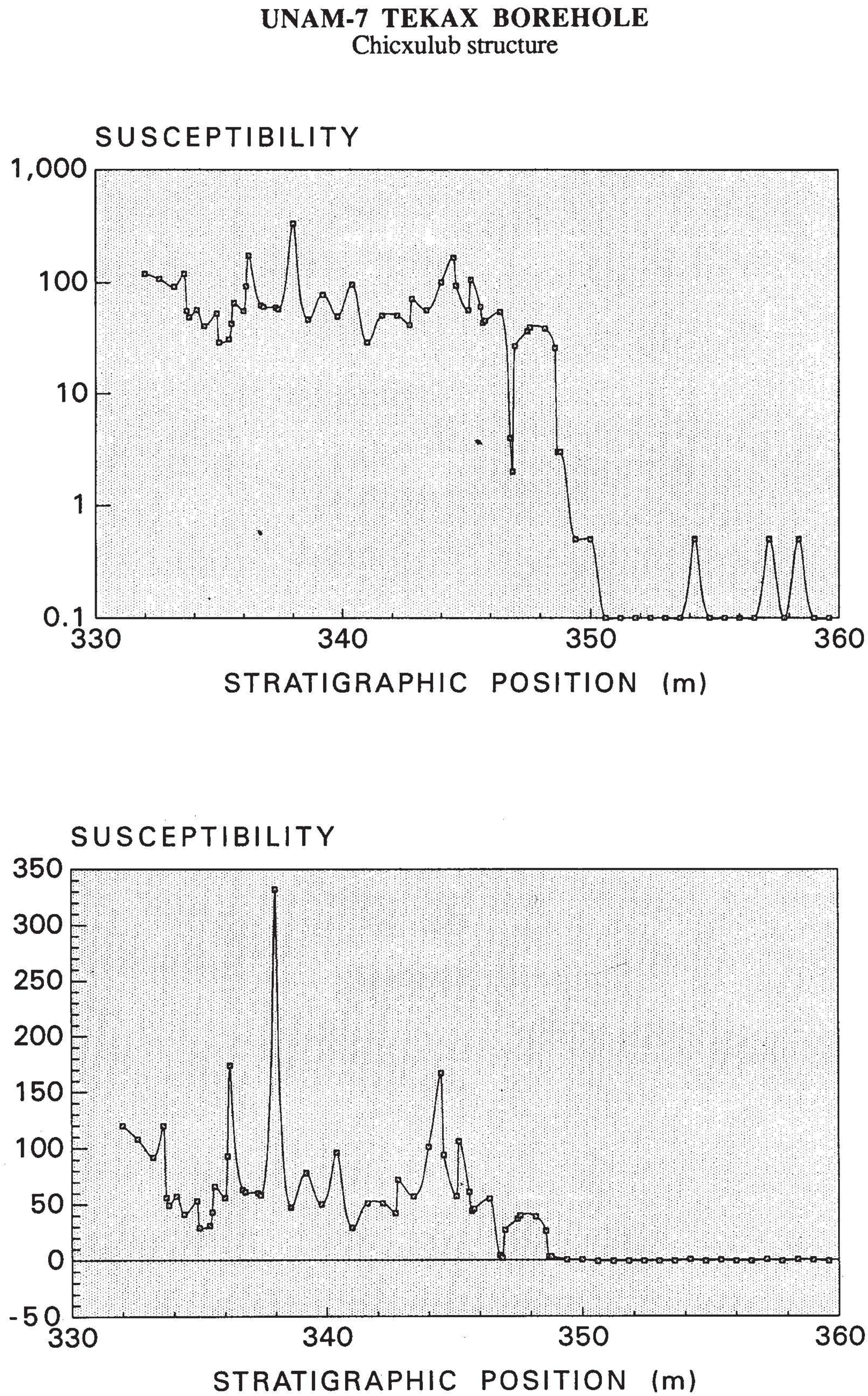


Fig. 4. Low-field magnetic susceptibility variations with stratigraphic position, for the interval 330 m and 360 m. (a) Values plotted in a semilogarithmic graph. Note the decrease at 348.4 to 350.5 m that marks the contact between the upper breccia with basement clasts and the lower breccia with anhydrite clasts. (b) Susceptibility plotted in a linear scale that shows the peaks and the short amplitude fluctuations. Note also the minimum at 348.4 m that corresponds to anhydrite clasts in the breccia.

clasts of anhydrite and carbonates, with intercalations of anisotropic horizons of evaporites. This evaporite breccia grades downward into a sequence of evaporites with horizons of marls. Comparison with the lithological sequence observed at other large impact craters such as the Ries crater suggest a correlation with the suevite/Bunte breccia sequence (Engelhardt, 1990). Furthermore, beneath the Bunte breccia at Ries crater there is a brecciated autochthonous country rock unit or megablock zone that may also be identified in the Chicxulub crater.

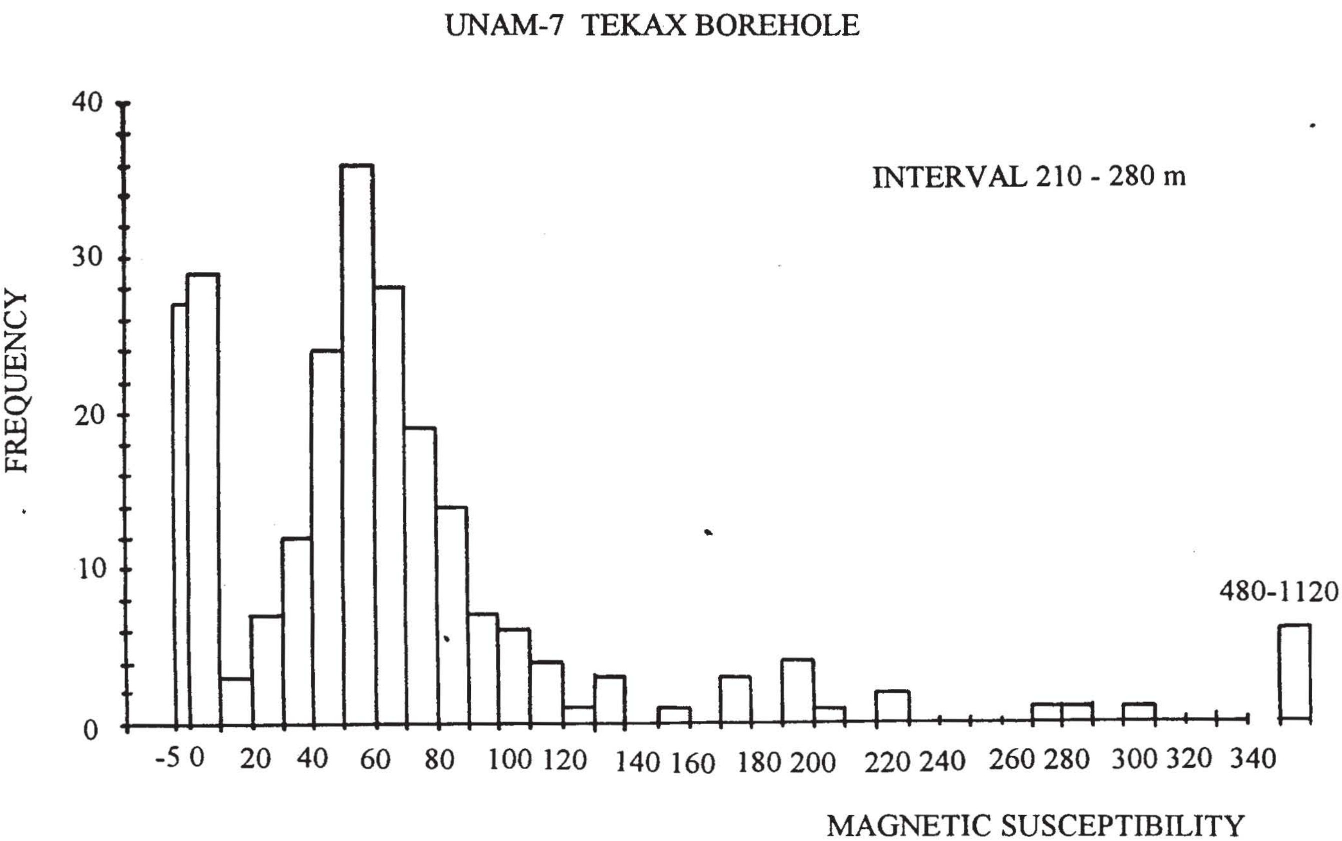
The depth to the top of the impact breccia observed in the UNAM-5 borehole was considerably deeper, at about 332 m (Marín *et al.*, 1995). The UNAM-5 is located near the town of Santa Elena, at about 110 km from the center of the crater structure, and to the northwest of the UNAM-7 borehole.

The magnetic anomalies observed over the Chicxulub area are most probably related to the breccia and assumed melt units which present a high contrast in magnetic properties compared with the carbonates. The aeromagnetic anomalies show three distinct major zones centered over the crater structure (Penfield and Camargo, 1981). The central anomaly zone is characterized by a large amplitude anomaly that extends over an area with a 20 km radius. This is surrounded by a zone of high-frequency, high-amplitude anomalies that extends radially over an additional 25 km. These two zones of high-amplitude magnetic anomalies show an elongated shape in a NNW-SSE direction. Analysis of a magnetic profile using Werner deconvolution gave source depths of about 1100 m, which correlate with the depth of the melt and suevitic breccias documented in the PEMEX boreholes (Penfield and Camargo, 1981). Magnetic anomalies outside the two central zones are characterized by low-amplitudes and high frequencies. Pilkington *et al.* (1994) have interpreted the central anomaly in terms of the effect of a central basement uplift. Magnetic parameters used for the modeling are inferred from the shape and magnitude of the anomaly itself, with a magnetization declination of 90° and an inclination of 0-30°. Magnetic anomalies in the intermediate zone present magnetic maxima and minima mainly located to the north and south, respectively. This suggests that remanent magnetization effects dominate, and source bodies have reverse polarity magnetizations. This is in agreement with the paleomagnetic observations for samples from the Yucatán-6 borehole (Urrutia-Fucugauchi *et al.*, 1994). The melt unit and suevitic breccias likely acquired a stable thermoremanent magnetization during cooling after the impact. In the outer zone, the low-amplitude high-frequency anomalies may be associated with the breccia unit that is distributed over an extensive area. Within this outer zone, remanent and induced magnetization effects may be important.

Modeling of magnetic anomalies has relied mainly on assumed values from the literature or from extrapolations of the limited data available (Penfield and Camargo, 1981; Pilkington *et al.*, 1994). The breccia, because of its heterogeneous composition, may likely present considerable variation in magnetic properties. Observations on breccia samples from one of the PEMEX boreholes, Yucatán-6, show that remanent magnetization directions and magnetic properties vary over short intervals (Urrutia-Fucugauchi *et al.*, 1994). The excellent sample recovery obtained in the UNAM-7 borehole offers the opportunity to obtain detailed rock magnetic data to document the vertical variations and analyse their statistical distribution. Histograms of the susceptibility measurements for the interval 210 m to 280 m (Figure 5a) and for the interval 330 m to 360 m (Figure 5b) enable us to distinguish three major groups. The group with negative susceptibilities, -1 to 0×10^{-6} SI, corresponds to carbonates and evaporites. The group with susceptibilities between 1 and 10×10^{-6} SI corresponds to anhydrites with breccia fragments. The impact breccia is characterized by a normal distribution with a mean of about 55 10^{-6} SI. The distribution is skewed and susceptibilities reach high values up to 1100×10^{-6} SI. The average value for the magnetic susceptibility of the impact breccia is 55 10^{-6} SI. Locally, higher values up to 550-1100 10^{-6} SI and 330 10^{-6} SI are observed at some levels in the upper and lower sections of the breccia, respectively, but there are no changes in mineralogical composition, as far as could be observed, and they may represent more abundant or larger basement clasts. The magnetic susceptibility of the impact breccia is orders of magnitude higher than the measurements taken on the carbonate and evaporite units. Furthermore, because the low-field magnetic susceptibility depends mainly on the type and content of clasts and any minerals present in the matrix, the data are useful for a non-destructive description of the breccia composition. This technique has allowed a precise identification of the Cretaceous/Tertiary boundary (marked by the impact breccia-carbonate sequence contact observed in the magnetic susceptibility record) at 222.2 m, and the contact between the upper impact breccia and the lower evaporite breccia at 348.4 m.

ACKNOWLEDGMENTS

This study is a part of the UNAM program for the Chicxulub impact structure. Financial support for the UNAM Chicxulub scientific drilling program has been generously provided by Servicios Corporativos Frisco, SA de CV. Assistance with the measurements of magnetic susceptibility by Luis Alva Valdívia, Martín Espinoza and Lorenzo Pérez is gratefully acknowledged. The facilities and assistance provided by the staff of the UNAM Museum of Geology and its director, Rodolfo Corona, have been valuable for the project. Critical comments by two anonymous reviewers have been helpful in the preparation of the manuscript.



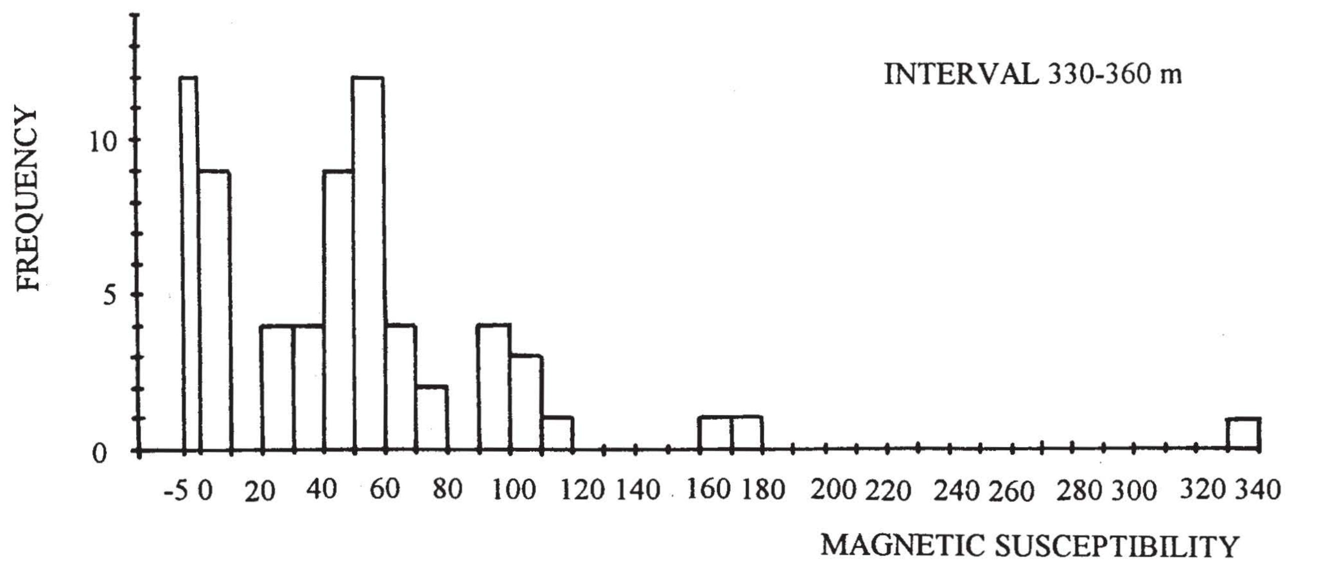


Fig. 5. Histograms of low-field magnetic susceptibility. (a) Data for the interval 210 to 280 m, and (b) data for the interval 330 to 360 m. Note that carbonates and anhydrites have negative values (-1 to $0x10^{-6}$ SI), and that susceptibility values in the upper breccia unit are normally distributed with a mean value of about $55x10^{-6}$ SI. The distribution is skewed and high values up to $1100x10^{-6}$ SI are present. Note also the peak at values between 1 and $10x10^{-6}$ SI that correspond to breccia components in the anhydrite and carbonate units.

BIBLIOGRAPHY

ALVAREZ, L. W., W. ALVAREZ, F. ASARO and H. V. MICHEL, 1980. Extraterrestrial cause for the Cretaceous-Tertiary extinction. *Science, 208*, 1095-1108.

BLUM, J.D., C.P. CHAMBERLAIN, M.P. HINGSTON, C. KOEBERL, L.E. MARIN, B.C. SCHURAYTZ and V.L. SHARPTON, 1993. Isotopic comparison of K/T boundary impact glass with melt rock from the Chicxulub and Manson impact structures. *Nature, 364*, 325-327.

ENGELHARDT, W.V., 1990. Distribution, petrography and shock metamorphism of the ejecta of the Ries crater in Germany - a review. *Tectonophysics, 171*, 259-273.

ESPINDOLA, J. M., M. MENA, M. DE LA FUENTE and J.O. CAMPOS-ENRIQUEZ, 1995. A model of the Chicxulub impact structure (Yucatán, Mexico) based on its gravity and magnetic signatures. *Phys. Earth Planet. Inter., 92*, 271-278.

HILDEBRAND, A.R., G.T. PENFIELD, D.A. KRING, M. PILKINGTON, A. CAMARGO, S.B. JACOBSEN and W.V. BOYNTON, 1991. Chicxulub crater: A possible Cretaceous/Tertiary boundary impact crater on the Yucatán peninsula, Mexico. *Geology, 19*, 867-871.

HILDEBRAND, A.R., M. PILKINGTON, M. CONNORS, C. ORTIZ-ALEMAN and R. E. CHAVEZ, 1995. Size and structure of the Chicxulub crater revealed by horizontal gravity gradients and cenotes. *Nature, 376*, 415-417.

KOEBERL, C., 1993. Chicxulub crater, Yucatán: Tektites, impact glasses, and the geochemistry of target rocks and breccias. *Geology, 21*, 211-214.

KROGH. T. E., S. L. KAMO, V. L. SHARPTON, L. MARIN and A. R. HILDEBRAND, 1993. U-Pb ages of single shocked zircons linking distal K/T ejecta to the Chicxulub crater. *Nature, 366*, 731-734.

LOPEZ RAMOS, E., 1975. Geological summary of the Yucatán peninsula. *In:* A. E. M. NARIN and F. G. STEHLI (Ed), The Ocean Basins and Margins, 3. The Gulf of Mexico and the Caribbean, Plenum, N.Y., 257-282.

MARIN, L.E. and V.L. SHARPTON, 1994. Recent drilling and core recovery within the Chicxulub impact structure, northern Yucatán, Mexico. *EOS Trans. Geophys. Union, Nov. Suppl.*, 408-409.

MARIN, L. E., L. E. FLORES and J. URRUTIA-FUCUGAUCHI, 1995. Perforaciones recientes en el cráter de Chicxulub, Yucatán, México. III Reunión Com. Geofís., Inst. Panamericano Geogr. Hist., México, junio 26-30, 1995.

MEYERHOFF, A. A., J. B. LYONS and C. B. OFFICER, 1994. Chicxulub structure: A volcanic sequence of Late Cretaceous age. *Geology, 22*, 3-4.

PENFIELD, G. T. and A. CAMARGO, 1981. Definition of a major igneous zone in the central Yucatán platform with aeromagnetics and gravity. Ann. Meeting, Soc. Expl. Geophys., Tech. Progr. Abstr., 51, 37 (abstr.).

PILKINGTON, M. and R. A. F. GRIEVE, 1992. The geophysical signature of terrestrial impact craters. *Rev. Geophys., 30*, 161-181.

PILKINGTON, M., A. R. HILDEBRAND and C. ORTIZ-ALEMAN, 1994. Gravity and magnetic field modeling and structure of the Chicxulub crater, Mexico. *J. Geophys. Res., 99*, 13,147-13,162.

POPE, K. O., A. OCAMPO and C. E. DULLER, 1991. Mexican site for K/T impact crater? *Nature, 351*, 105.

SCHURAYTZ, B. C., V. L. SHARPTON and L. MARIN, 1994. Petrology of impact-melt rocks at the Chicxulub multiring basin, Yucatán, Mexico. *Geology, 22*, 868-872.

SHARPTON, V. L., G. B. DALRYMPLE, L. E. MARIN, G. RYDER, B. C. SCHURAYTZ and J. URRUTIA-FUCUGAUCHI, 1992. New links between the Chicxulub impact structure and the Cretaceous/Tertiary boundary. *Nature, 359*, 819-821.

SHARPTON, V. L., K. BURKE, A. CAMARGO, S. A. HALL, D. S. LEE, L. E. MARIN, G. SUAREZ-REYNOSO, J. M. QUEZADA-MUNETON, P. D. SPUDIS and J. URRUTIA-FUCUGAUCHI, 1993. Chicxulub multiring impact basin: Size and other characteristics derived from gravity analysis. *Science, 261*, 1564-1567.

URRUTIA-FUCUGAUCHI, J., L. E. MARIN and V. L. SHARPTON, 1994. Reverse polarity magnetized melt-rocks from the Cretaceous/Tertiary Chicxulub structure, Yucatán peninsula, Mexico. *Tectonophysics, 237*, 105-112.

J. Urrutia Fucugauchi, Luis Marín and Alberto Trejo García

Instituto de Geofísica, UNAM, Coyoacán, 04510 México, D. F., MEXICO.