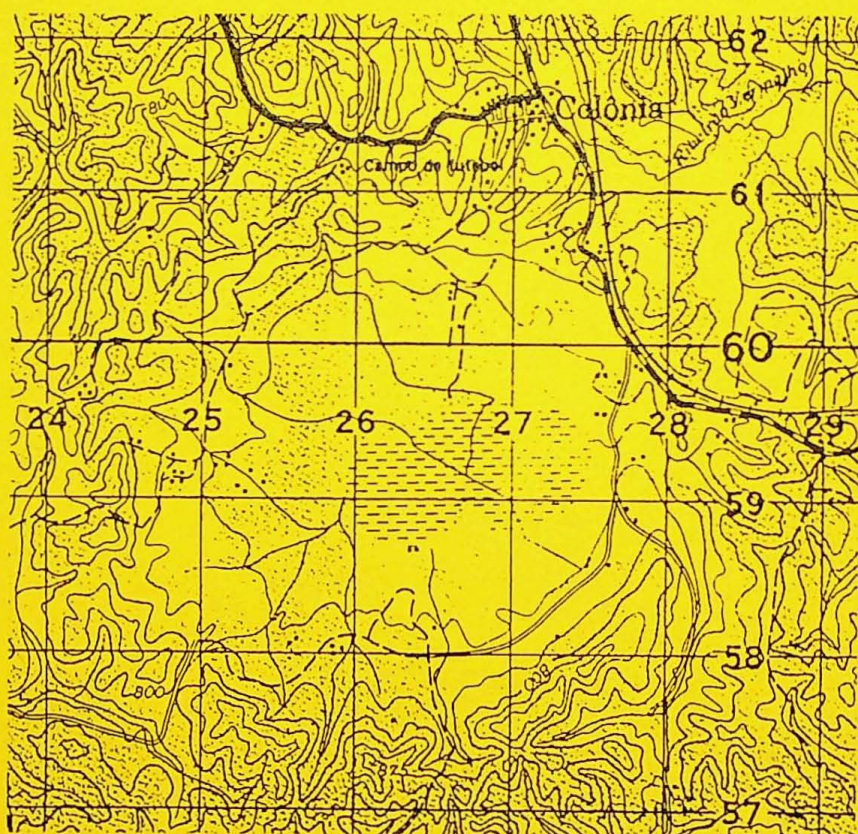


INTERNATIONAL SYMPOSIUM ON
GLOBAL CHANGES IN SOUTH AMERICA
DURING THE QUATERNARY

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THE COLONIA ASTROBLEME
Excursion field guide

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INTRODUCTION

Fewer than 150 impact structures of celestial or interplanetary bodies at the Earth's surface, the so-called astroblemes, are recognized over our planet (GRIEVE & ROBERTSON, 1979, 1987). The study of astroblemes has recently increased because impact cratering was a fundamental process in the evolution of all the terrestrial planets (SHOEMAKER, 1977), hence its importance in comparative planetology.

About 35 km from Sao Paulo, near C lonia (fig.1), there is a conspicuous ring feature, 3.64 km in diameter, centered at 23°52'S, 46°42'20"W, within Precambrian crystalline basement rocks, and defined by a hilly circular outer rim up to 125 m (figs. 2, 3) higher than an inner alluvial plain presently occupied by a large swamp, where the present-day water level may be, in part, controlled by the Billings reservoir just to the east.

The structure is located in the border of the Serra do Mar, a coastal mountain chain originally covered by the "Mata Atl ntica" tropical rain forest with localized occurrences of Araucaria angustifolia (Bertol.) Kuntze.

The hypothesis that this feature is a probable impact structure has long been postulated, ever since the first studies carried out in the area (KOLLERT et al., 1961).

In this field-guide, the regional geology is briefly explained, different hypotheses as to the origin of the structure are discussed, and morphological parameters pertinent to an understanding of this feature are given. Preliminary vibrocore data are also presented. A second vibrocore, next to the site of the 878-cm-long core described below, will be drilled and examined during the one-day field trip.

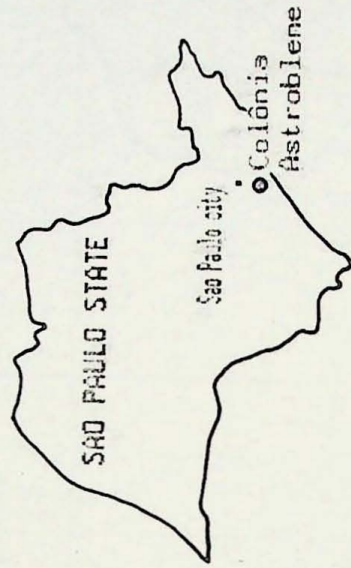
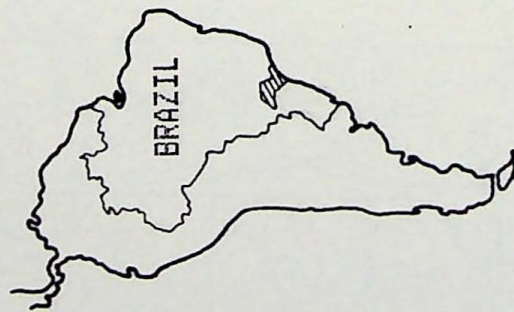


Figure 1: Location of the Colônia Astrolene.

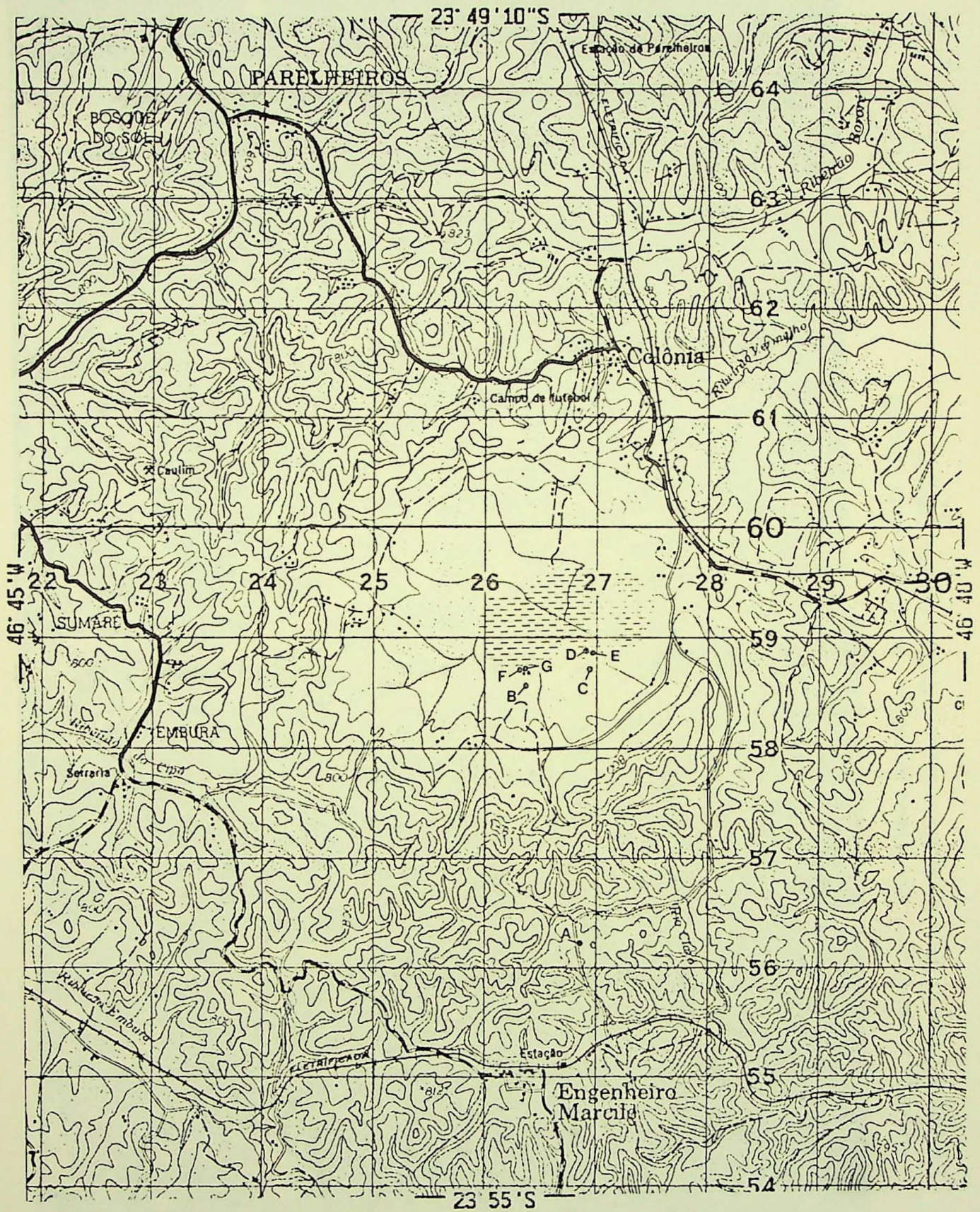


Figure 2: Topographic map of the Colônia Astrobleme with location (A-G) of sites mentioned in the text. Scale 1:50,000, contour interval 20 meters. Source: Instituto Geografico e Geologico de Sao Paulo, 1971.

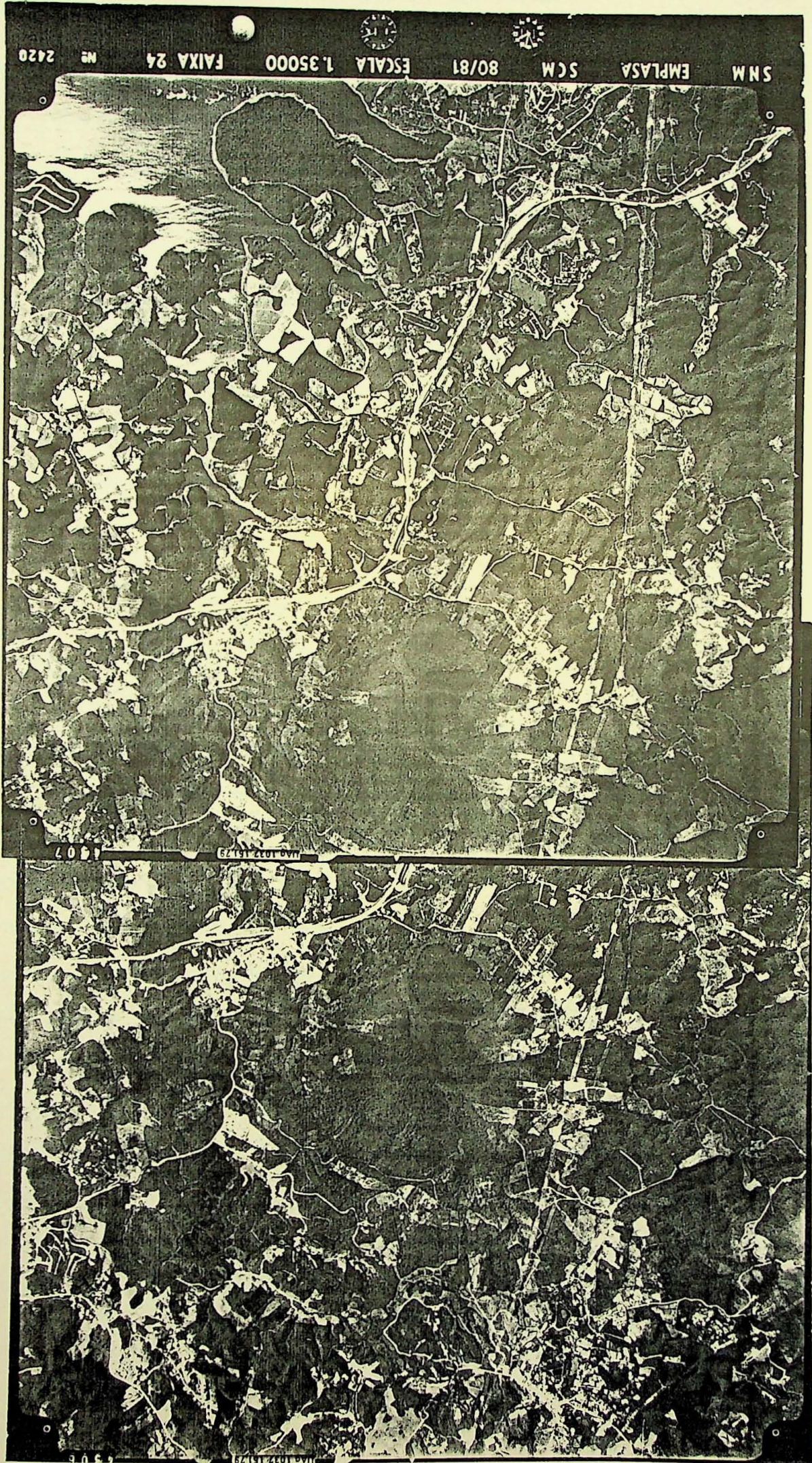


Figure 3: Stereo-pair of the Colônia Ástroblene. Approximate scale 1:53,000 (original scale of photos 1:35,000). Source TERRAFOTO/EMLASA, 1980-81.

REGIONAL GEOLOGICAL SETTING

The Colônia structure is located within the domain of the Ribeira Fold Belt (HASUI *et al.*, 1975). According to SADOWSKI (1974) and COUTINHO (1980) the main rock types of the region are gneisses, migmatites, diorites, mica schists, quartzites, mylonites, amphibolites, metabasites, granites and granodiorites (fig.4). The general structural trend of the basement rocks is ENE.

Sedimentary rocks are exposed along the southern and southeastern borders of the structure and are probably related to the Middle Eocene/Early Oligocene (MELO *et al.*, 1986) or, more precisely Oligocene (RICCOMINI *et al.*, 1987) deposition of the Sao Paulo Formation, prominent in the Sao Paulo Basin located just to the north.

All the rock types have been very intensely weathered, which makes geological observations difficult. Colluvial and alluvial deposits of probable Quaternary age are also present in the region.

THE COLÔNIA STRUCTURE: HYPOTHESES AS TO ITS ORIGIN

As mentioned above, ever since the first studies of this structure, the hypothesis of a probable impact structure has been popular (KOLLERT *et al.* 1961). Further studies, mainly those by COSTA (1982, 1986), based on morphological parameters, have reinforced this idea. The presence of higher altitudes in the southwestern part of the rim has led COUTINHO (1987, oral communication) to suppose a body trajectory from northeast before the shock.

Alternative hypothesis, such as (1) sinkhole, (2) structural interference pattern, (3) intrusion and (4) crypto-explosion (phreato-magmatic structure related to a kimberlite), among others, may be rejected, respectively, by (1) the absence of carbonate rocks in the region, (2) the persistence of the ENE structural trend of the basement, (3 and 4) the lack of structures and/or minor intrusives bodies (dikes, sills, etc.) that should be associated with such

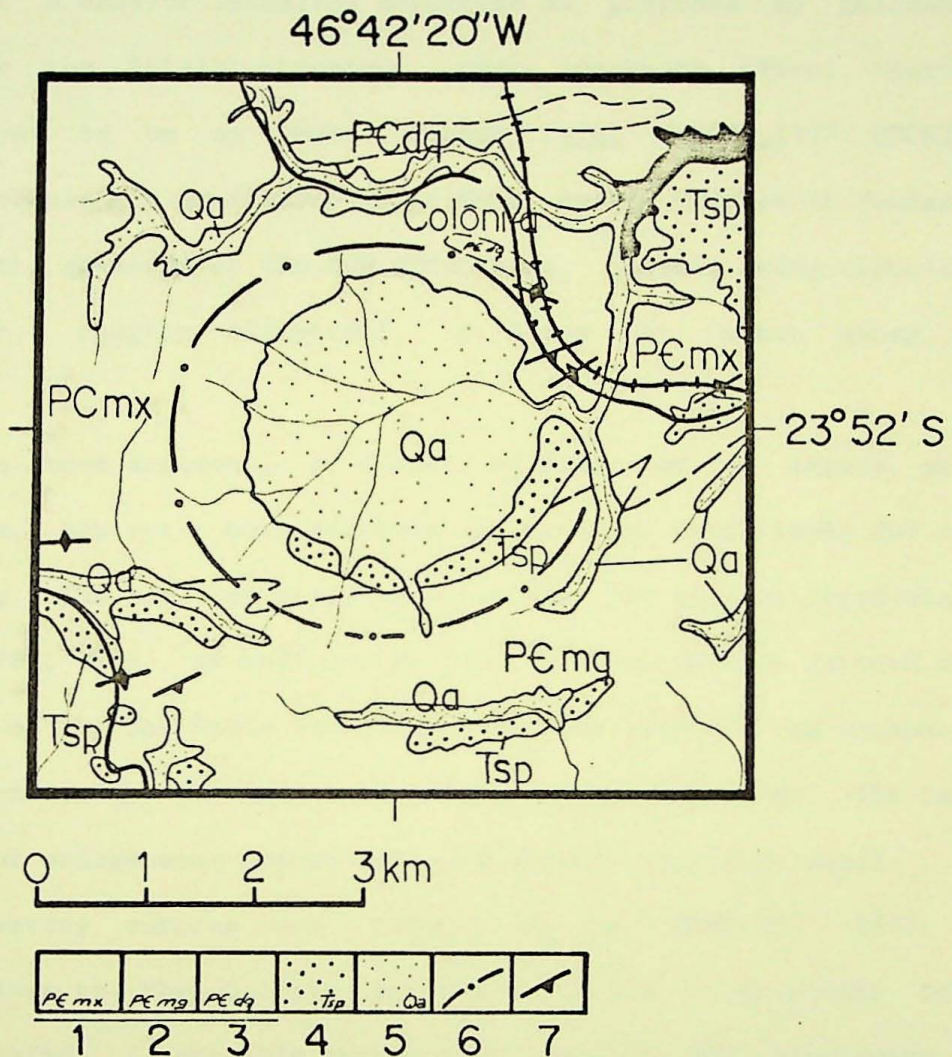


Figure 4: Geology of the Colônia area, after COUTINHO (1980), simplified. 1: mica schists, quartzites, locally mylonites; 2: gneisses, migmatites, also locally nylonites; 3: diorites and quartz diorites; 4: Sao Paulo Fm. 5: Quaternary alluvial deposits; 6: crater rim; 7: structural trend of the Precambrian basenent.

intrusions, and the excessively unusually large dimension for a kimberlite pipe. The hypothesis of a massive landslide structure as proposed by ERISMANN et al. (1977) for the Köfels structure, near Innsbruck (Tirol, Austria), previously believed to be an impact crater (e.g. SUESS, 1937; STORZER et al., 1971), is probably not applicable to Colônia, mainly because of fundamental differences in the geometry of the two structures, Colônia being circular and Köfels irregular, roughly elliptical, a shape not common among known astroblemes.

Despite the above argument, no direct evidence of an impact, such as shock metamorphism, has yet been observed in the area, most likely due to the intense weathering. The peculiar circular shape and the typical depth/diameter ratio (CROSTA, 1982, 1986), as well as the semi-circular outcrop pattern of the sedimentary rocks of the Sao Paulo Formation along the southern and southeastern inner part of the rim, are the main indicators of an astrobleme. The lack of convincing proof of endogeneous process also reinforces this hypothesis.

An interesting outcrop was referred to by COUTINHO (1979, oral communication) close to the Colônia structure. Field observations for the present study revealed a probable thrust zone, striking WNW and dipping ENE. This outcrop is relatively well exposed one kilometer southward from the structure, along the secondary road to Engenheiro Marsillac (site A, fig.2). Sandy to pebbly mudstones, probably of the Sao Paulo Formation, are tectonically imbricated within Precambrian gneisses of the basement. An ENE subvertical family of joints is well developed in these sediments, leading to the assumption of an ENE compression axis (σ_1) and a NNW extension axis (σ_3). This situation could represent a part of the overturned rim. Nevertheless, this deformation pattern is not completely incongruous with the transpressive event of post-Oligocene to Pleistocene age observed in the Serra do Mar Rift System (RICCOMINI et al., 1989).

All of the above considerations concerning the pattern of Tertiary sedimentation point to an Oligocene or younger geologic age for the impact event.

ANALYSIS OF THE MORPHOLOGICAL PARAMETERS OF THE STRUCTURE

DENCE (1972) has classified terrestrial impact craters in seven different levels or degrees of preservation: 1: ejecta largely preserved; 2: ejecta partly preserved; 3: ejecta removed and rim partly preserved; 4: rim largely eroded and crater-fill products preserved; 5: crater-fill products partly preserved; 6: only remnants of crater-fill products preserved, with crater floor exposed; 7: crater floor removed, substrate exposed.

GRIEVE & ROBERTSON (1979), studying the morphology of the 140, proven, probable and possible, impact structures known throughout the world, have verified a 600 Ma recognizable life for craters less than 20 km in diameter, according to DENCE's seven-stage scale. The Colônia structure lies between preservational degrees 3 and 4, i.e., a structure with ejecta removed, rim partly preserved, although deeply eroded, and crater-fill products preserved. GRIEVE & ROBERTSON (1979) have established an empirical relationship between diameter, age and preservational degree of impact structures, in order to estimate the maximum age of structures with a given dimension. The observed preservation degree is plotted against a preservation index defined by the ratio between the diameter in kilometers and the age in Ma. Given the 3.64 km diameter and the preservational degree between 3 and 4 of the Colônia Astrobleme, the maximum impact age would range between 36.4 Ma (Eocene-Oligocene boundary) and 5.2 Ma (Miocene-Pliocene boundary), dates well in agreement with the maximum age of Oligocene postulated on other grounds.

Also according to GRIEVE & ROBERTSON (1979) the depth-diameter relationships for simple craters with diameters less than 3.8 km in crystalline targets are described by the functions:

$$P_t = 0.326 D^{0.786},$$

$$P_a = 0.159 D^{0.829},$$

where P_t and P_a are, respectively, the true and apparent depths in kilometers and D is the rim diameter also in kilometers. The true depth corresponds to the altitude difference between the top of the rim and the base of the crater-fill, whereas the apparent depth is the difference between the top of the rim and the top of the crater-fill. Using these relationships, the P_t and P_a parameters for the Colônia structure are respectively 900 and 464 meters. Theoretically, therefore, the crater-fill should be 436 meters thick.

The present vertical distance from the top of the rim to the top of the crater-fill is around 125 m. The difference with respect to the calculated P_a may be explained by the action of intense weathering and erosion.

There is no available data on the maximum crater-fill thickness. Geophysical (gravimetry and resistivity) surveys indicated 300-400 m for the depth to the crystalline substratum within the crater. A water-well, originally 190 m in depth (site B, fig.2), was drilled in the southern part of the structure, about 650 m from its center, and does not reach the basement (CEPAS, 1989). Later this well was continued down to 263 m depth, where it was reported that the drilling had reached the basement. It is possible, however, that this level, 263 m below the alluvial plain, could merely represent the top of the initial, coarse, crystalline fill eroded from the slopes of inner part of the rim.

Drilling has revealed essentially organic-rich clayey material. No palynological analysis of this material is available yet. As shown in Fig.5,

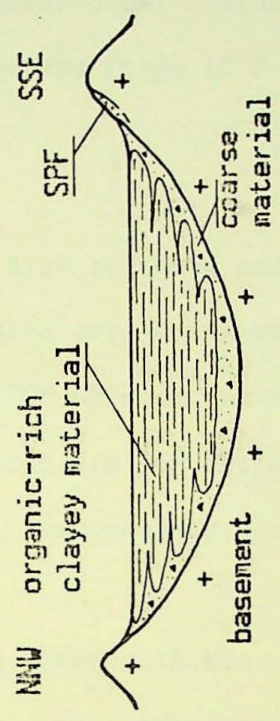
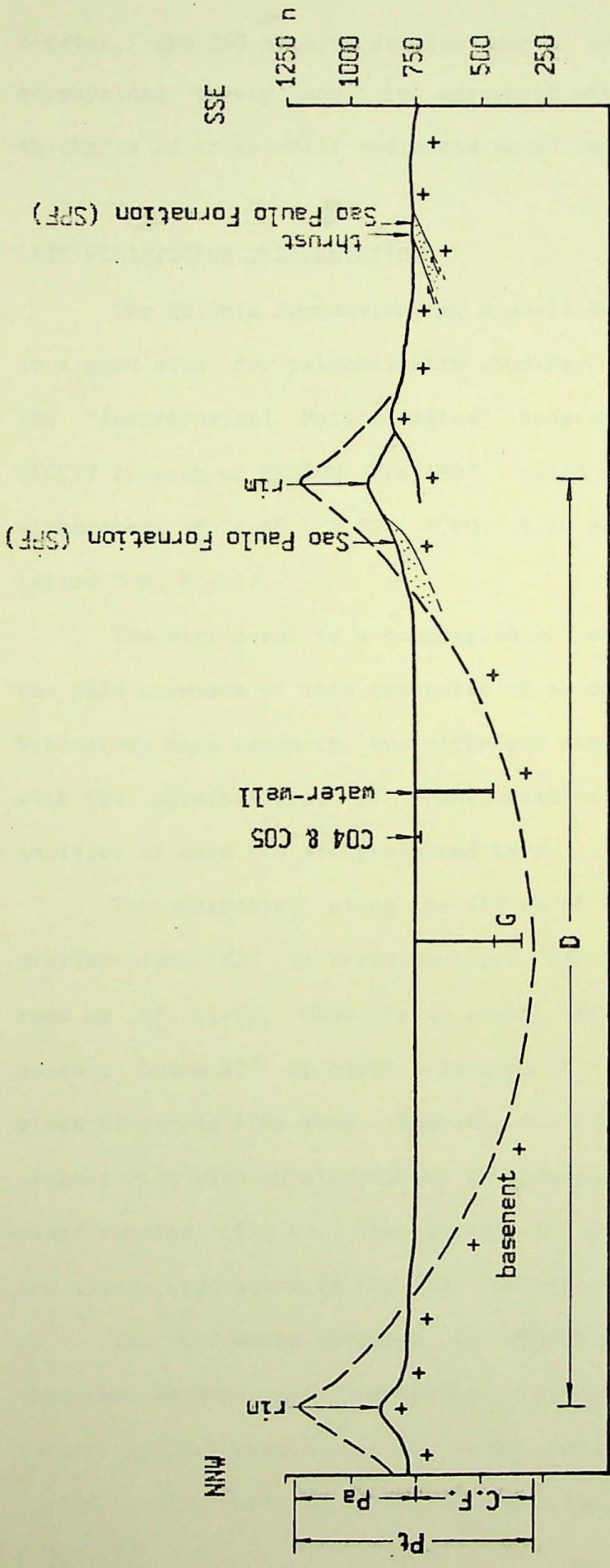


Figure 5: Upper - Idealized section across Colônia Astrobleme, showing available data (heavy lines), and theoretical parameters after GRIEVE & ROBERTSON (1979, dashed line). Pa: apparent depth; Pt: true depth; D: diameter; C.F.: crater-fill thickness; G: depths according to geophysical data. Right - Interpretation of sedimentary deposition.

however, the 263 meters drilled depth and the 300-400 meters obtained by geophysical survey are in agreement with the theoretical values for the thickness of crater-fill sediments based on the parameters P_t-P_a (C.F.).

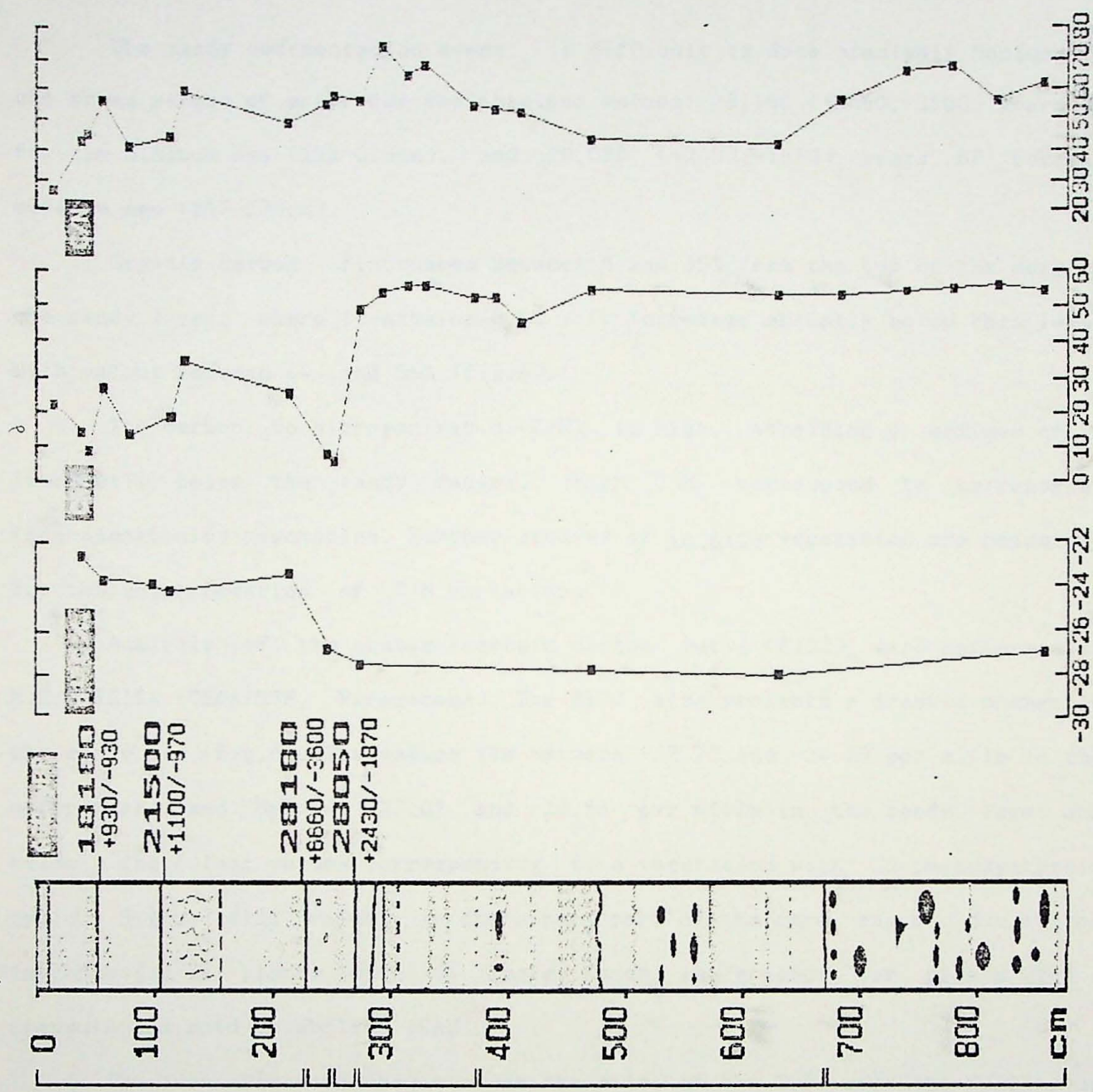
LATE PLEISTOCENE SEDIMENTATION

The Colônia depression, as a small basin with high sediment accumulation, is a good site for paleoclimatic studies. Such studies are being supported by the "Intertropical Paleoclimates" program of ORSTOM-CNPq accord and by the GEOCIT program of ORSTOM. In 1987 field work resulted in the collection of 5 vibrocores of 4.65, 7.52, 7.80, 5.60 and 8.78 m, respectively cores C01-C05 (sites C-G, fig.2).

The vibrocorer is a conception of one of the authors (L.M.) and one of the main purposes of this excursion is to demonstrate this sampling technique. Vibrocores were taken in two different zones of the depression, in accordance with the possibilities of transportation. Only the preliminary results of analyses of core C05 are presented here.

The sediments, along the 878 cm of core C05, are organic rich, with a greyish-black (N2) to brownish-black (5YR 2/1) color (fig.6). They are mainly made up of clays. Some fresh quartz grains, with diameters of 1 to 3 mm, appears below 227 cm depth. Between 253 and 265 cm the facies is a greyish black micaceous fine sand. Beneath this limit the sediments continue clayey and organic rich with an alternation of fine-laminated plant fragments and larger plant remains (fig.6). The quantity of large plant remains, including fruits and spines, increases in the last two meters at the base of the core.

The ^{14}C dates obtained in ORSTOM laboratories in Bondy (France) shows that the sediments are Pleistocenic, almost all the core being older than the latest glacial maximum: at 54-57 cm depth the radiocarbon age-data is 18,180 \pm 930 years BP. The sedimentation rate between 54 and 225 cm is about 0.02 cm/y.



Greyish black (N2) clay, locally rich in fine plant remains; between 36 and 40 cm the colour becomes blackish brown (SYR 2/1)

Locally rich in fresh quartz grains
Locally rich in fine micaceous sand

Greyish black (N2) clay, locally rich in fine plant remains

Greyish black clay with horizontal laminations of fine plant remains, some coarse (>1cm) plant remains

Greyish black (N2) clay with coarse (> 1 cm) plant remains

Figure 6: Core C05, description, d¹³C ‰, C ‰, C/N.

The sandy sedimentation event is difficult to date precisely because of the broad margin of error for the obtained values: 28,180 (+6660,-3600) years BP for the minimum age (222-225cm), and 28,050 (+2430,-1870) years BP for the maximum age (267-270cm).

Organic carbon fluctuates between 8 and 35% from the top of the core to the sandy layer, where it attains 5.6%. It increases abruptly below this level with values between 44 and 56% (fig.6).

The carbon to nitrogen ratio (C/N) is high, attaining a maximum of 74 immediately below the sandy facies. High C/N correspond to terrestrial (non-planktonic) vegetation. Further studies of in_situ vegetation are necessary for the interpretation of C/N variations.

Analysis of the stable isotopic carbon ratio ($\delta^{13}C$) were performed by M.Z.MOREIRA (CENA/USP, Piracicaba). The $\delta^{13}C$ also presents a drastic change in the sandy bed (fig.6). The values lie between -22.72 and -24.29 per mille in the upper part, and between -27.02 and -28.56 per mille in the sandy layer and below, these last values corresponding to a vegetation with C3 photosynthetic cycle. Higher $\delta^{13}C$ values in the upper part of the core may be due to the introduction of plants with C4 cycle, such as grasses, or plants with a crassulacean acid metabolism (CAM).

The available data show that at the site of the CO5 core the filling-up of the depression nearly stopped after the glacial maximum of 18,000 years BP. The Late Pleistocene sedimentation occurred in a humid environment as evidenced by the high content in organic carbon. Sandy deposition at about 28,000 years BP may have be associated with heavy rainstorms in a basin with a low density of vegetation. Palynological studies presently being conducted by M.L. LORSCHETER (UFRGS, Porto Alegre) should allow a better comprehension of the past environments.

FINAL CONSIDERATIONS

In spite of the lack of direct evidence, the Colônia structure is probably an astrobleme. Preliminary studies of the Quaternary sedimentation are promising and further studies should be undertaken, such as (1) study of present sedimentary environments and the ecology of this particular swamp, (2) a second set of vibrocorings in order to sample the Holocene period, and, mainly, (3) the realization of a deep core through the complete crater-fill in order to obtain a continuous record of Quaternary and earlier deposits.

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REFERENCES

- CENTRO DE PESQUISAS DE AGUAS SUBTERRANEAS (CEPAS), 1989. Atividades 1984-1988. Instituto de Geociências, Universidade de Sao Paulo, 433p.
- COUTINHO, J.M.V., 1980. Mapa geologico da Grande Sao Paulo, 1:100.000. Sao Paulo EMPLASA, 2 sheets.
- CROSTA, A.P., 1982. Estruturas de impacto no Brasil: uma sintese do conhecimento atual. 32° Congresso Brasileiro de Geologia, SBG, v.4, p.1372-1377.
- CROSTA, A.P., 1987. Impact structures in Brazil. In: POHL, J., ed., Research in terrestrial impact structures. Friedr. Vieweg & Son, Braunschweig/Wiesbaden, p.30-38.
- DENCE, M.R., 1972. The nature and significance of terrestrial impact structures. 24th International Geological Congress, Section 15, p.77-89.
- ERISMAN, Th., HEUBERGER, H. & PREUSS, E., 1977. Der Bimsstein von Köfels (Tirol), ein Bergsturz-"Friktionit". TPM, 24, p.67-119.
- GRIEVE, R.A.F. & ROBERTSON, P.B., 1979. The terrestrial cratering record, I. current status of observations. Icarus, 38, p.212-219.
- GRIEVE, R.A.F. & ROBERTSON, P.B., 1987. Terrestrial impact structures. Geol. Soc. Canada, map 1658 A, scale 1:63,000,000.
- HASUI, Y., CARNEIRO, C.D.R. & COIMBRA, A.M., 1975. The Ribeira Folded Belt. Rev. Bras Geoc., 5, p.257-266.

- KOLLERT, R., BJÖRNBERG, A. & DAVINO, A., 1961. Estudos preliminares de uma depressão circular na região de Colônia: Sto Amaro, Sao Paulo. Bol. Soc. Bras. Geol., 10, 57-77.
- MELO, M.S., CAETANO, S.L.V. & COIMBRA, A.M., 1986. Tectônica e sedimentação na área das bacias de Sao Paulo e Taubaté. 34° Congresso Brasileiro de Geologia, SBG, V.1, p.321-336.
- RICCOMINI, C., APPI, C.J., FREITAS, E.L. & ARAI, M., 1987. Tectônica e sedimentação no Sistema de Rift Continentais da Serra do Mar (bacias de Volta Redonda, Rosende, Taubaté e Sao Paulo). 1° Simposio de Geologia Rio de Janeiro - Espirito Santo, SBG, p.252-298.
- RICCOMINI, C., FIGUEIRA, R.M., KOHNKE, M.W., SALONI, J.C.L. & PELOGGIA, A.U.G., 1989. Neotectonic activity in the Serra do Mar Rift System. J. South Am. Earth Sciences, 2, (in press).
- SADOWSKI, G.R., 1974. Tectônica da Serra de Cubatao, SP. Dr. Sci. Thesis, Instituto de Geociências, Universidade de Sao Paulo. 159p.
- SHOEMAKER, E.M., 1977. Why study impact craters?. In: RODDY, D.J., PEPIN, R.O. & MERRIL, R.B., eds., Impact and implosion cratering. Pergamon, Elmsford, NY, p.1-10.
- STORZER, D, HORN, P. & KLEINMANN, B., 1971. The age and origin of Köfels structure, Austria. Earth Planet Sci. Lett., 12, p.238-244.
- SUESS, F.E., 1937. Der Meteor-Krater von Köfels bei Umhausen im Oetzale. Tirol. N. Jb. Min., Geol. und Paläont., Abh. 72, Beilage-Bd. Abt. A, p.98-155.

