THE QUATERNARY LACUSTRINE DEPOSITS OF THE SERRA DOS CARAJÁS (STATE OF PARÁ, BRAZIL) - AGES AND OTHER PRELIMINARY RESULTS*

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INTRODUCTION

The Quaternary deposits of the Amazon basin in Brazil are still now very imperfectly known. The difficulties of penetration within a huge tropical forest and a poor human occupation are probably the most important factors. Though very scarce, the published papers especially during the last fifteen years, allowed us to reach the conclusion that this area was also subjected to fluctuation in paleoclimate which was worldwide active during the Quaternary. This certainty is based on ecological (SIMPSON & HAFFER, 1978; COLINVAUX, 1979; OCHSENIUS, 1985 and VANZOLINI, 1986), palynological (VAN DER HAMMEN, 1974 and ABSY, 1985), pedological (SOMBROEK, 1966; SOUBIES, 1980, and SANFORD et al., 1985), geomorphological (TRICART, 1974, 1977, and AB'SABER, 1977), and

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sedimentological (DAMUTH & FAIRBRIDGE, 1970; BAKER, 1978; SERVANT et al., 1981, and SHOWERS & BEVIS, 1988), rarely studied but well concordant arguments. Arid paleoclimates probably dominated some areas of the Amazon basin during the Quaternary, introducing a savanna-type vegetation frequently burned in driest seasons and consequently inducing soil erosion. At that time the humid evergreen forest was probably reduced to some "refuges". However, very few age determinations and more criterious researches have been done in this area, and some chronologically established paleoclimate crisis is limited to the Holocene epoch.

Until the end of 1985, french and brazilian scientists composed a team of participants mainly from ORSTOM (Institut de Recherche Scientifique pour le Développment en Cooperation) and USP (University of São Paulo), with a financial support of ORSTOM, CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) and a local help during the field work of DOCEGEO (Geologia e Mineração) in the solution of this problem. The Serra dos Carajás (State of Pará), within Brazilian Amazon has been chosen by this team. The researches being developed in this area integrate a multidisciplinary project of ORSTOM, named GEOCIT, whose main objective is to make the paleoenvironmental, mostly paleoclimatic reconstitution of intertropical areas (low latitude) from 30,000 years B.P. until today. Here are presented the first radiochronological ages in Amazon Pleistocene deposits, and some other preliminary informations.

THE LAKES OF THE SERRA DOS CARAJÁS

The Serra dos Carajás, situated in a straight line about 500 km southward of Belém (Fig. 1), presents the worldwide famous big iron ore deposits (18 billion tons. of 66%Fe_2O_3), and important manganese, gold and copper ore deposits, discovered by DOCEGEO in 1967. Extensive lateritic plateaus (about 5 x 30 km), developed upon "banded-iron formation", constitute the 700 to 890 m high Northern and Southern Serra dos Carajás "emerging" from a dense evergreen forest.

The surface of the plateaus, representing a pre-Cretaceous erosional plane covered by savanna-type vegetation, exhibits numerous small lakes (some hundreds of meters to less than two kilometers long). These lakes are situated within partially interconnected and semi-closed depressions, whose form looks like dolines in a karstic landscape, and their waters apparently were originated from pluvial waters running through surrounding lateritic slopes. They are relatively shallow (maximum depth of about 18 m), and show several stages of silting by fine to very fine sediments, very rich in organic carbon and small carbonized woods. As they are located in the headwaters of small rivers forming the regional hydrographic net, free of erosional processes and receiving the "pollen rains" precipitated within the area, possibly they represent the ideal records of changes in paleoclimate and past vegetations of the area.
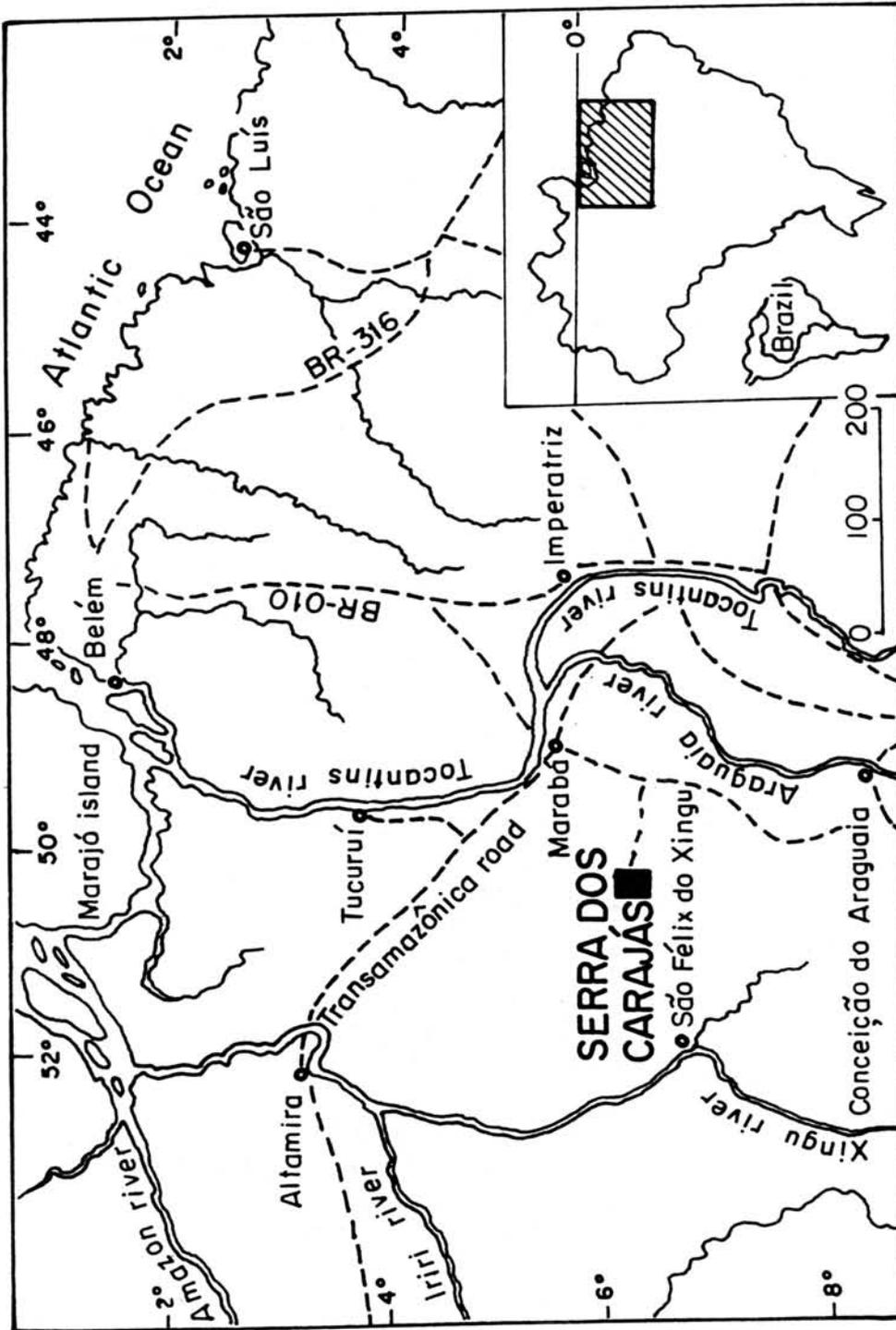
Figure 1 - Location map of the studied area (State of Pará, Brazil).

SEDIMENTARY SEQUENCE AND SOME RADIOCARBON AGES

The Figure 2 shows the lithology and radiocarbon ages of the first sample obtained by a vibro-corer, which is now being submitted to a detailed study. This drill core was collected from one of the lakes , situated in Southern Serra dos Carajás, practically fulfilled by sediments and now almost entirely invaded by aquatic grasses. In a fine to very fine, dominantly clayey-silty deposit, it is possible to recognize three successive sedimentary cycles. Each of them begins with a yellowish to light-brownish layers, very rich in siderite and poor in organic carbon (less than 5%). These sediments are followed by a brownish-black argillaceous sediments, almost exempt of siderite but very rich in organic carbon (40 to 50%), locally containing concentrated carbonized wood fragments. This succession is suggestive of, at least, two phases of abrupt paleoenvironmental change in the area. The last change, observed between 20,000 years and 10,000 years B.P. (uppermost siderite layers) could be contemporaneous with the last worldwide glacial stage (Würm or Wisconsin), and the older limit of the lower siderite layer may be situated between 40,000 and 50,000 years B.P., near the maximum limit of the ^{14}C conventional dating method.

Then these deposits cover a quite long time interval of the Quaternary period, and certainly they represent the oldest records of paleoenvironmental changes up to that time studied in the area.

OTHER ANALYTICAL RESULTS

The preliminary results of physical, chemical and mineralogical analyses are presented in the Figures 3 and 4, and in the Table I. Although incomplete, striking differences are shown between organic matter and siderite layers, and their possible significances in terms of paleoenvironmental changes reconstitution are here considered.

Physical analyses

Water contents and densities - changes in these parameters are directly related to the composition of the sediments (Fig. 3). Siderite-rich layers are characterized by lower water contents and higher densities while the organic matter-rich layers are represented by higher water contents and lower densities. These parameters have been measured after drying the samples within an oven at 105°C during 48 h.

Grain size analyses - organic matter-rich layers are particularly difficult to be dispersed, then it is very problematical to interpret the grain size distribution along the core. These sediments exhibited
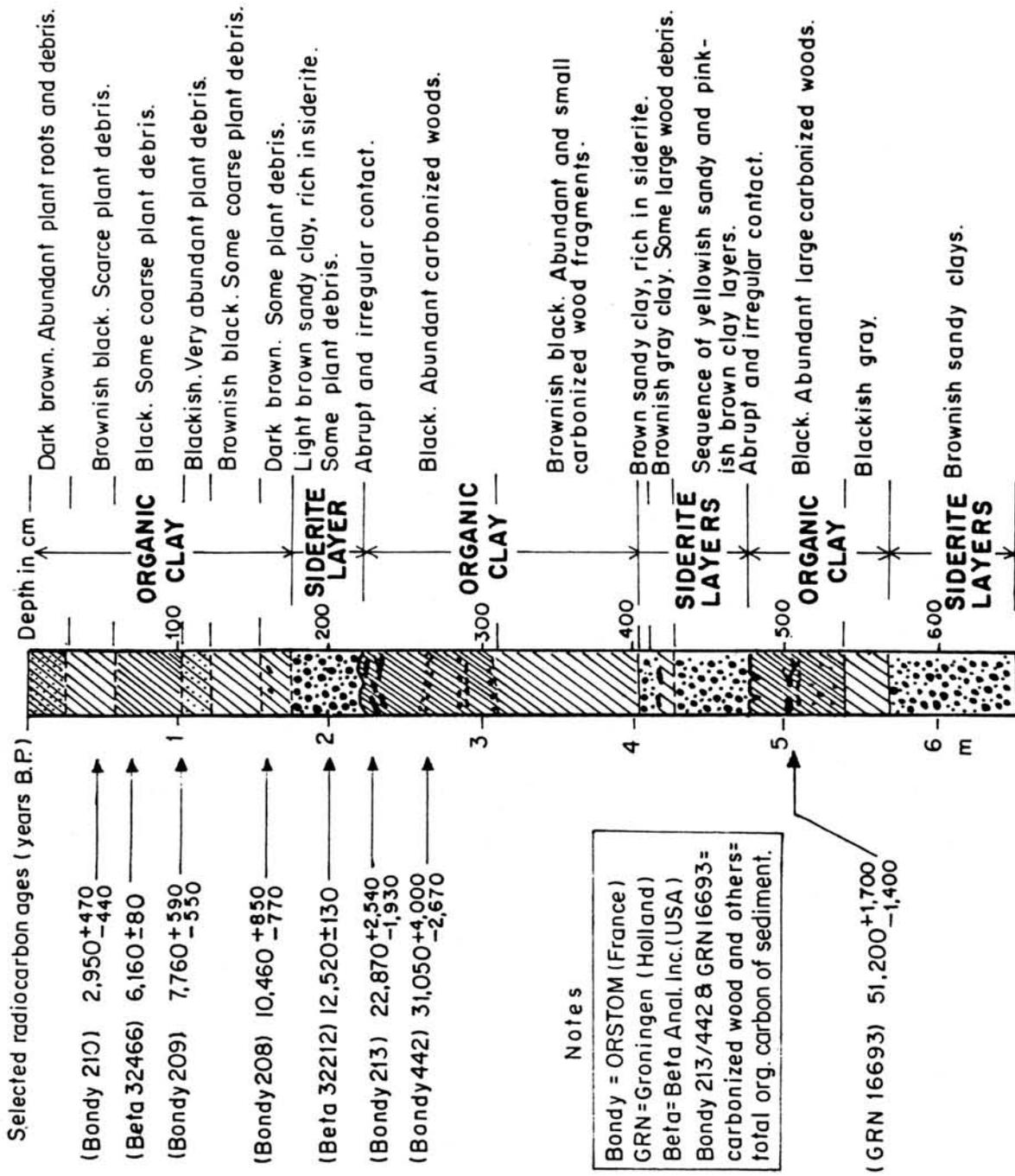
Figure 2 - Lithologic log of the core CSS-2 ("Carajás Serra Sul").

Depth in cm

ORGANIC CLAY
- Dark brown. Abundant plant roots and debris.
- Brownish black. Scarce plant debris.
- Black. Some coarse plant debris.
- Blackish. Very abundant plant debris.
- Brownish black. Some coarse plant debris.
- Dark brown. Some plant debris.

SIDERITE LAYER
- Light brown sandy clay, rich in siderite. Some plant debris.
- Abrupt and irregular contact.

- Black. Abundant carbonized woods.

ORGANIC CLAY
- Brownish black. Abundant and small carbonized wood fragments.

SIDERITE LAYERS
- Brown sandy clay, rich in siderite.
- Brownish gray clay. Some large wood debris.
- Sequence of yellowish sandy and pinkish brown clay layers.
- Abrupt and irregular contact.

ORGANIC CLAY
- Black. Abundant large carbonized woods.
- Blackish gray.

SIDERITE LAYERS
- Brownish sandy clays.

Selected radiocarbon ages (years B.P.)

(Bondy 210) 2,950 +470 −440

(Beta 32466) 6,160 ±80

(Bondy 209) 7,760 +590 −550

(Bondy 208) 10,460 +850 −770

(Beta 32212) 12,520 ±130

(Bondy 213) 22,870 +2,540 −1,930

(Bondy 442) 31,050 +4,000 −2,670

(GRN 16693) 51,200 +1,700 −1,400

Notes

Bondy = ORSTOM (France)
GRN = Groningen (Holland)
Beta = Beta Anal. Inc. (USA)
Bondy 213/442 & GRN 16693 = carbonized wood and others = total org. carbon of sediment.

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Figure 3 - Densities and water, organic carbon and nitrogen contents of the CSS-2.

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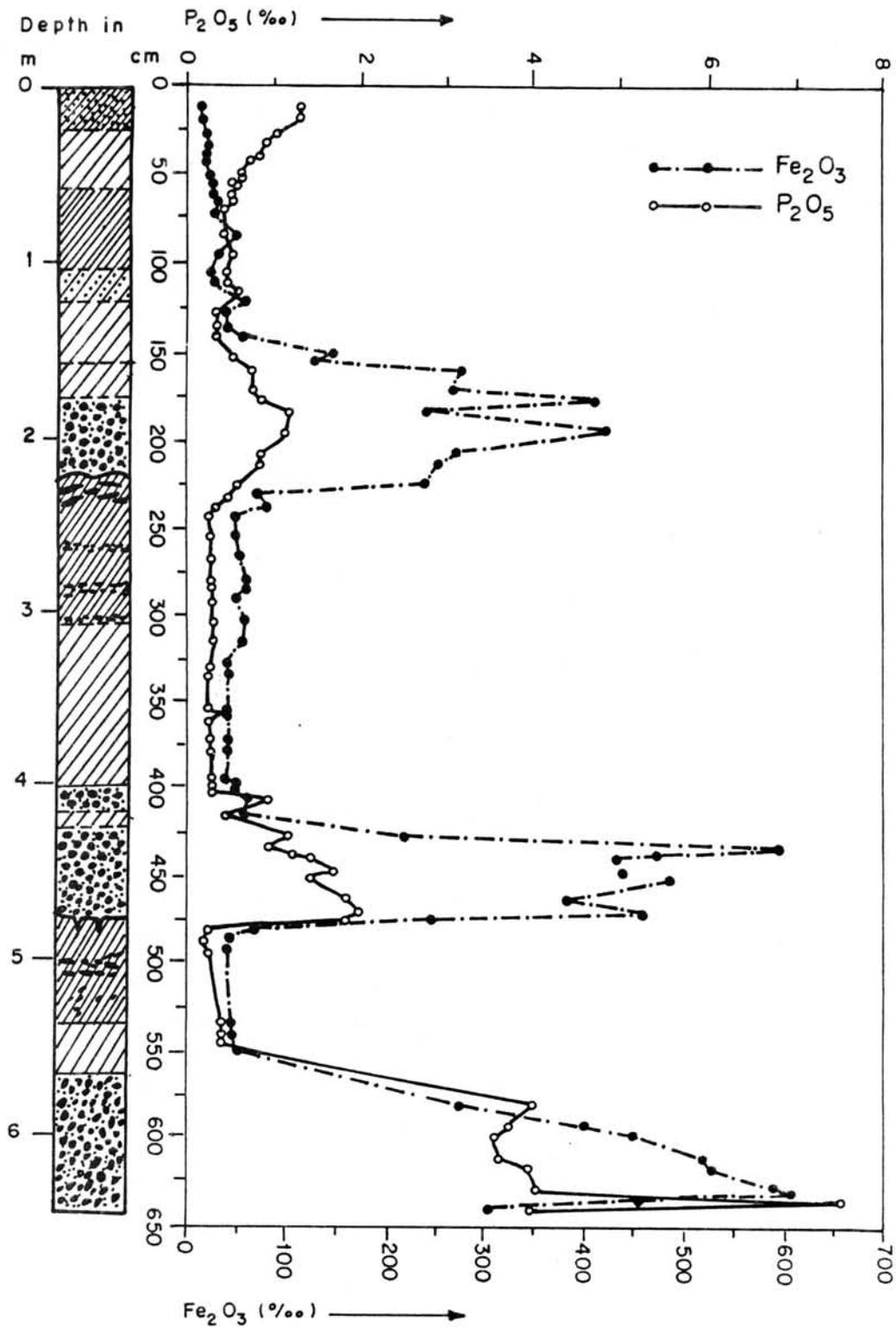
Figure 4 - Fe$_2$O$_3$ and P$_2$O$_5$ contents of the core CSS-2

dominantly a clayey-silty size with very scarce sand size fraction. The organic matter was previously eliminated by H_2O_2, while the ferruginous cement was attacked by HCl, and afterwards a wet sieving allowed us to separate the fractions = <50 μm from 50 μm - 2 mm.

Chemical analyses

Hydrogen ion concentration (pH) - in general, the measured values were very little changeable being situated between 5 and 6. The first upper 100 cm, as well as the siderite-rich layers, were characterized by systematically lower pH (in average 5.5). This parameter was measured by index paper for pH.

Organic carbon and nitrogen - the contents of both elements diminish in siderite-rich layers, and the curves representing their frequencies are almost parallel (Fig. 3). Walkley & Black method and Kjedahl method have been used, respectively for determinations of organic carbon and total nitrogen contents. The samples have been previously dried in the open air.

Fe_2O_3 and P_2O_5 - there are tremendous increasing of Fe_2O_3 content, followed by less important growth of P_2O_5 values, in siderite-rich layers in relation to other portions of the core. This fact is suggesting that probably some environmental conditions changed more-or-less abruptly during the formation of these layers. Total phosphorus and total iron contents have been determined, respectively by colorimetric and atomic absorption methods. The samples have been previously dried in the open air.

Mineralogical compositions

The preliminary results are shown in Table I. Semi-quantitative evaluations contained in this table correspond to organic carbon free estimations and in some cases the percentages by weight of this material were between 60 and 95%. The mineralogical specimens identified in this paper can be grouped into two classes: inherited (detrital) and authigenic (neoformed) fractions.

Inherited fraction

Quartz - very fine to fine sand fraction, limpid and very angular grains , which are scattered along the core and especially concentrated within siderite-rich layers.

Ferruginous nodules - micro-agglomerates of goethite or very fine quartz grains cemented by goethite, with rounded-to-irregular shapes (sometimes placoidal) smooth surfaces (sometimes scoriaceous and vacuolar), exhibiting reddish to brownish colours. At first glance, the great resemblance of these micro-nodules and some fine-grained products presently derived from superficial degradation of

Table 1 - Semi-quantitative frequencies of inherited and authigenic minerals along the core CSS-2.

	Fraction ≤50 µm								Fraction 50 µm – 2 mm					
Depth (cm)	Strengite	Kaolinite	Illite	Goethite	Anatase	Rutile	Amorphous SiO₂	Quartz	Quartz	Siderite	Ferruginous nodules	Silico-phosphatic nodules	Siliceous spicules
0	–	–	–	–	–	–	+	+	tr	+	–	–	+++
50	++	+	tr	–	–	–	–	+	+				
80	++						–			tr	–	++/++	–
112	–	+	+	–	tr	tr	+	++/+	++/+	+/+	–	+++	–
160	–	+	+	+/+	tr	tr	–	+/+++/+	++/+	+/+	+/+	–	–
220													
310	+ / –	+	tr	–	+	+	tr	+/+/+	+/+/+	tr	–	+/++/+	–
350													
400	–	+	+	+	+	tr	–	+/+	++/++/+	tr	–	+/++/+	–
430	–	tr	+	+/+	+	tr	–	+/++	+/++	+/+	+/++/+	–	–
489	–	tr	tr	–	–	–	+/+++/+	tr	tr	–	–	+++	–
573	–	+	tr	+/+++/+	+	+	–	+	+	+/+	+/+++/+	–	–

– (0%) = absent; tr (some %) = traces; ◆ (10-20%) = present; ◆◆ (20-40%) = many; ◆◆◆ (>40%) = dominant.

adjacent ferruginous cuirasses suggests that probably their provenance is related to erosion of these duricrusts. These ferruginous cuirasses, originated by chemical weathering of "banded-iron formations" (jaspilite), are essentially composed of aluminous goethite accompanied by few quartz, kaolinite, hematite, magnetite, etc. and their average chemical composition, according to BEISIEGEL (1982) and COELHO (1986) is: Fe_2O_3 = 81,17%; FeO = 0,70%; Al_2O_3 = 8,10%; SiO_2 = 0,70%; P_2O_5 = 0,48%; TiO_2 = 0,38%; MnO_2 = 0,28%; ignition loss = 9,10%. The phosphorus content of this material is sufficiently high, which could explain the high content of this element in siderite-rich layers (Fig. 4).

Other inherited components - in almost entire core, here analysed, there are small quantities of fine grained minerals, like kaolinite, illite (sensu latu), anatase and rutile, which were probably inherited from the ferruginous cuirasses, where already have been identified. Occasionally, some other minerals, like zircon, tourmaline, sillimanite, kyanite, staurolite, epidote, and hornblende have been identified, however the provenance of this mineralogical suite is more problematic and could be eventually related to the metasedimentary and metavolcanic rocks intercalated within "iron-banded formation".

Authigenic fraction

Phosphates - rounded or irregular fine sandy grains, with whitish or brownish colours of phosphate composition, are locally abundant within organic clays. They are amorphous to X-ray diffraction analysis and under electron microprobe analyser they exhibited changeable contents of P, Si and Al. Sporadically they are accompanied by a well crystallized phosphate, which has been identified by X-ray diffraction analysis as strengite ($FePO_4 \cdot 2H_2O$).

Amorphous silica - siliceous sponge spicules, occurring as very thin tubes (50-80 μm long and some μm of diameter), transparent and colourless, have been abundantly found in the uppermost part of the most recent organic clay, although they have been encountered much more scarcely in other portions of the core. On the older hand, within the organic matter-rich layers and only there, occurs an amorphous silica identified through a "dome shaped" curve outlined by X-ray diffraction analysis, whose peak is centered approximately at 3,34 Å.

Siderite crystals - they have been found as well-formed monocrystal (Fig. 5A and Fig. 5B) 100-200 μm long or as sea-urchin like aggregates, when the crystals are bigger than in the first case. They are reddish brown, yellowish to greenish coloured and their faces are always characterized by conspicuous corrosion figures.

Other authigenic components - some framboidal pyrite granules have been identified during field works when testing the vibro-corer. Possibly, in some organic clay layers manganese micro-concretions could occur in mixture with quartzose sand.
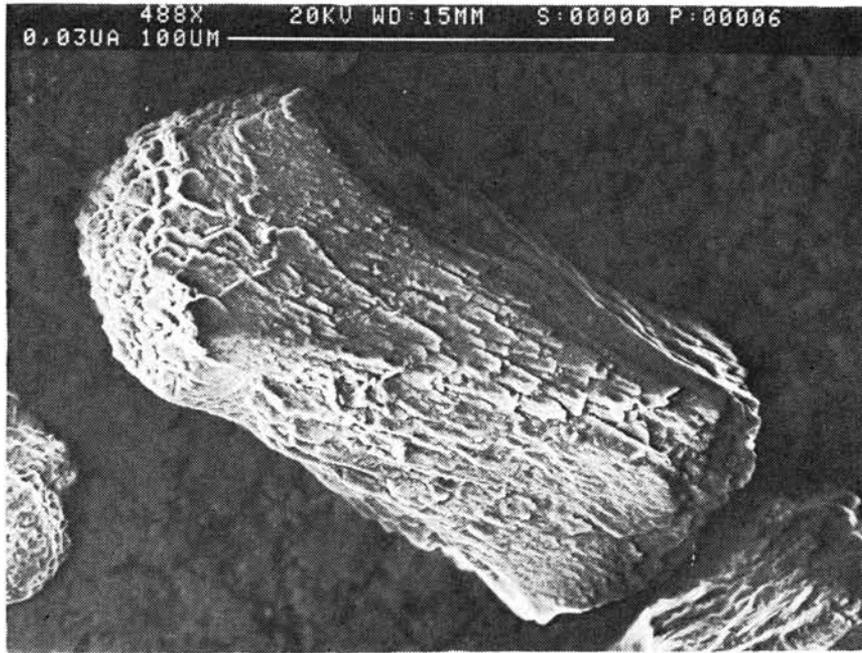
Figure 5A - A well-developed siderite crystal of the core CSS-2 as seen under SEM. Observe the conspicuous corrosion figures on the surface.
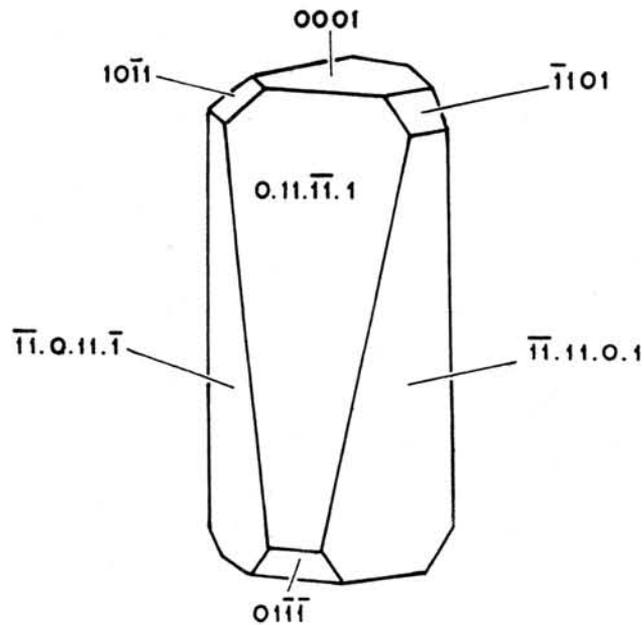
Figure 5B - Morphology of siderite crystals from the core CSS-2 with indexation of faces after SEM photography.

GENERAL DISCUSSIONS

The analytical results ratified, with more certainty, which was suggested by the macroscopic examination of the sedimentary sequence, i.e., that the nature of sedimentation within the studied lake changed cyclically through the time. Is it possible, as we suggested in the beginning of this paper, to assume a climatic cause for this cyclic phenomenom and, then, which would be the climates that prevailed during that time? We would try to answer these two questions based on the available analytical results.

A climatic cause ?

The studied lake, from which core CSS-2 was obtained, is situated in Southern Serra dos Carajás at latitude 06°15'S and longitude 50°30'W occupying an elongated depression (100-200 m wide and 600-700 m long), entirely circumscribed, except toward an outlet where a very compact lateritic pavement close the culvert, by small hills with generally changeable gentle slopes, but sometimes more abrupt (Fig. 6A). The hills dominate the landscape from 10 to 100 m (Fig. 6B), and their cuirassed slopes, disseminated by ferruginous blocks (lithosols) and some termite constructions, are covered by a savanna-type vegetation. The dense tropical evergreen forest appears only as far as about 1 km from here, at the foot of the scarp bordering the cuirassed plateau (Fig. 6B). Any evidence of underground drainage (water table or other) has been observed, then apparently there are not other water source for the lake, except for direct arrival from pluvial precipitations running as very little disorganized streams across its slopes.

Subjected to these conditions it is possible to visualize only the following three possible sources for the organomineral sediments which fulfilled the lacustrine basin: hydrological, mechanical and chemical slope washing, aquatic biological (plants and animals) activities and aerial supplying. These three sources were directly or indirectly controlled by climatic conditions. For example, the lake water depth and, consequently, the type of life susceptible to develop there are dependent of pluviosity and evaporation rates, which are in turn related to the temperature, wind, etc.; similarly, the slope erosion is controlled by vegetal cover whose nature is primarily dependent of the climate, etc.

Then, is it possible to attribute a climatic significance for the cyclic sedimentation observed in the studied deposits? This is not absolutely correct because some non-climatic events could play a role as important as the climate modifying the sedimentary environment. However, the probability of non-climatic event looks to be very low. It is possible to imagine a falling down (collapse) of the cuirassed topography, followed by an active internal erosion (LEPRUN, 1979); however, this mechanism could cause, for example, a tremendous evacuation of the lake or, contrarily the lake level rising. If this kind of event have played a role to originate the depression, we have not observed any recent evidence of its intervention in the present geomorphology.

It is also possible to imagine some tectonic perturbation which could similarly modify the
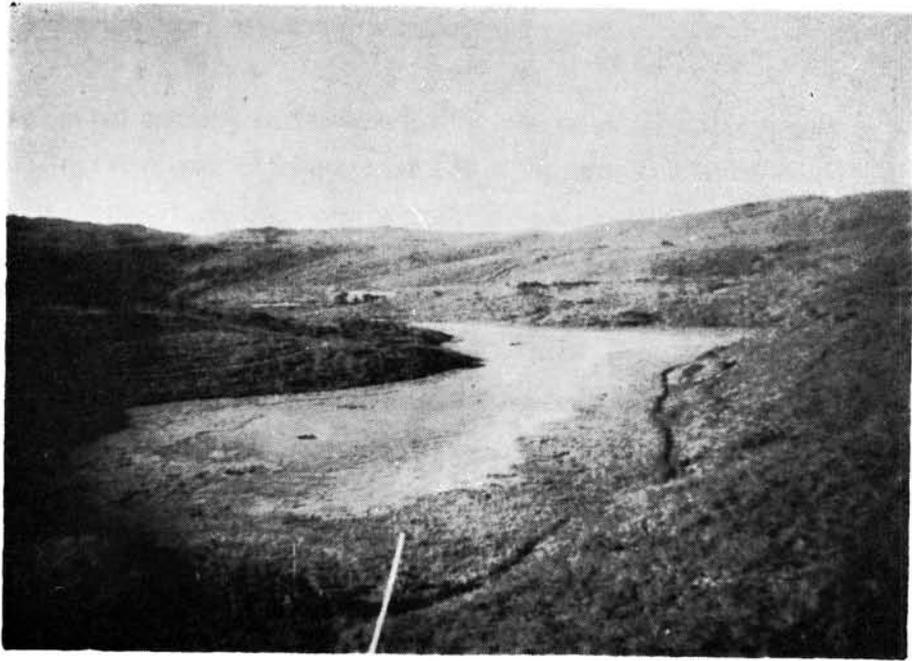
Figure 6A - Lake studied in the southern Serra dos Carajás surrounded by gentle slope relief and banded superficial vegetation.

Figure 6B - Oblique aerial view of the Southern Serra dos Carajás highland covered by a savanna-type vegetation and the surrounding lowland with an evergreen rainforest.

water level of the lake; however, there are not any evidence of this, and the evolutionary history of the Serra dos Carajás, as it is known presently, does not indicates any important tectonic activity in this area after the Precambrian times.

Finally, it is possible to think to human activities affecting the area which, for example, could modify by fire the nature of vegetal cover. But the presence of man in this area is not considered to be older than 8,000 years B.P. ("Gruta do Gavião", Serra Norte - Folha de São Paulo, 01/06/1987), and then it is not possible to attribute for this eventual participation, except for the uppermost portion of the sedimentary sequence!

Consequently, there is a high probability that the cyclic sedimentation composed of alternated siderite-rich and organic matter-rich layers, studied in CSS-2 core, is in fact translating paleoclimatic changes which occurred in this Amazon area during the last 50,000 years.

Which climate ?

For each of the most important sedimentary facies (siderite-rich and organic matter-rich), is possible to look for their possible significance studying the genetic conditions of the associated authigenic minerals, as well as the relative frequence of the inherited minerals.

Siderite-rich layers - several authors studied elsewhere genesis of siderite (GARRELS & CHRIST, 1967; CURTIS & SPEARS, 1968; BERNER, 1971; STUMM & MORGAN, 1981; POSTMA, 1981, 1982, 1983, and BERNARD & SYMONDS, in press) emphasizing the fact related to thermodynamic stability domain of this mineral which is very restrict. It could be precipitated only within very uncommon situation, characterized by reducing environment with high CO_2 partial pressure, low sulphate content and moderate calcium/iron ratio (Ca/Fe<20); a medium pH is also necessary to avoid its dissolution (pH>5). These conditions allow us to understand why siderite is much less frequent in sedimentary sequences than other carbonate minerals. In general, richness in SO_4^{-2} and Ca^{+2} of interstitial waters in marine environments propitiate the formation of pyrite and/or calcite instead of siderite, except if sedimentation rate is very high (BERNER, 1971; CURTIS et al., 1975; PYE, 1981, and POSTMA, 1982).

Siderite is much more frequent within continental domains where waters impoverished in sulphates are more favorable to its formation, being common in confined and organic matter-rich environments such as sediments and hydromorphic soils in deltaic environments (TANCREDI et al., 1975; POSTMA, 1981, 1982, and SIEFFERMANN, 1988), anoxic lacustrine deposits (GIRESSE, 1987; MALEY et al., 1987; BERNARD & SYMONDS, in press, and BAHRIG, 1989), etc. Within these anaerobic environments, the required CO_2 and Fe^{+2} for precipitation of siderite will be directly produced by enzymatic activities of some bacterias using fresh organic matter as electron donor (oxidation) and the ferric compounds as electron receiver (reduction) (OTTOW & MUNCH, 1981; MUNCH & OTTOW, 1983). On the other hand, BERNARD & SYMONDS (in press) considered the possibility of participation of extra-sedimentary CO_2, as of volcanic origin.

The environmental conditions of Carajás siderite-rich layers, characterized by confinement, production or supply of biodegradable organic matter, waters with a low content of SO_4^{-2} and Ca^{+2} and richness in Fe, are in perfect agreement with the above mentioned previous papers, and these conditions probably have been always assured, particularly nowadays. A sample of peaty water collected beside the boring site showed the following composition (ppm): SO_4^{-2} = 25,0; NO_3^- = 2,1; NH_4^+ = 0,9; Cl = 21,0; P = 0,3; Ca = 3,2; Fe = 93,4; Si = 5,1; Na = 0,8; K = 1,7; Mg = 0,6; Al = 0,5, and pH = 6,3.

The reason why siderite production was sometimes tremendously intensified and otherwhile almost null is not, then, perfectly understood. Possibly, some siderite could be dissolved during diagenesis, based on which is suggested by corrosion figures; however, this hypothesis is in disagreement with the measured pH values (BERNARD & SYMONDS, in press). It seems more probable, like suggested by BAHRIG (1989) and also by certain characteristics of the Carajás deposits, that other factors, besides those already mentioned, might have controlled the genesis of the siderite-rich layers. BAHRIG (op. cit.) studied Eocene lacustrine deposits bearing occasional siderite-rich layers in Germany. The $\delta^{13}C$ and $\delta^{18}O$ of siderite layers and associated sediments, as well as their petrographic studies, induced the author to reach the conclusion that they are probably related to changes in the paleoclimate, especially an increase of the, precipitation/evaporation ratio within the drainage basin, which propitiated an additional supply of allochtonous organic matter and other detrital particles toward the lake. An intensification of the bacterial activity (methanogenesis) in the water/sediment interface is also noted. At least two evidence observed in the Carajás siderite layers suggest that this interpretation could be correct:

a) Only the siderite-rich layers present considerable amount of ferruginous micro-nodules which are undoubtedly of detrital origin (Table I). It is possible to think that they have been equally supplied for the organic matter-rich layers, being laterly dissolved, but this hypothesis is in disagreement with their low Fe_2O_3 content (Fig. 4), as well as with their pH values. The siderite-rich layers are also richer in quartz fragments, which are of detrital origin too. Plainly, it is necessary to do more precise calculations, particularly of detrital inflow (weight of the deposited carbon/weight of inorganic detrital fraction = per unit surface per unit time interval) for the entire sedimentary column to confirm these higher clasticity ratios of the siderite-rich layers.

b) At the base of the first two siderite layers, in contact with organic matter-rich materials, there are two levels of abrupt contact (220 and 480 cm, Fig. 2) with indentations interpretable as a level of desiccation cracks. Moreover, there is an important difference of age between the base of the first siderite layer (12,520 years B.P.) and underlying organic clays (22,870 years B.P.), which is suggestive of a sedimentation hiatus.

There are many similarities between the case studied, in detail, by BAHRIG (op. cit.) and that of Carajás. Here the siderite-rich layer could be also explained by a tremendous increase in organomineral detrital influx sometimes during the past. After a long period of hydraulic deficit

(precipitation<< evapotranspiration) the lake became completely dry, propitiating the development of savanna-type vegetation in its slopes, and an abrupt increase in rainfall could promoted some erosion of lacustrine sediments, and the lake again filled by water developed a good condition for massive precipitation of siderite, with high terrestrial organic matter and ferruginous detrital particles inflow, suitable microbial fauna, etc.

Organic matter-rich layers - these deposits succeed systematically the siderite-rich layers and, apparently are a consequence of a landscape evolving mostly by dissolution processes. In fact, the detrital fraction is much less important than in siderite layers, and simultaneously authigenic fractions, like phosphates, silicophosphates, opale, etc. (Table I) are indicating that dissolution processes prevailed upon transportation of detrital materials.

In the same way, the low iron content and the absence of ferruginous micro-nodules in the organic matter-rich layers suggest that the iron dynamics was quite different during these events; probably the iron supply to the lake was mainly in the form of hydrosoluble or colloidal organic complexes which have been only partially retained within the basin due to the continuous lake water flowing off. Sometimes occurred the strengite authigenesis suggesting phases of better oxigenized water (NRIAGU, 1972; NRIAGU & DELL, 1974, and WARRY & KRAMER, 1976). The organic matter-rich layers are then indicative of phases when occurred well developed vegetation cover with intensive hydrolisation of the substrates. Possibly, the vegetation was of forest-type with many trees (there are some levels with concentration of carbonized woods) which, at that latitude and altitude, suggest humid tropical climate, possibly more humid than today (annual precipitation of 1,500 to 2,000mm and mean annual temperature of 24 to 26°C).

On the other hand, the organic matter-rich layers corresponding to 8,000 years B.P. to present (80 cm to O) are different from others in some characteristics: abundance of siliceous sponge spicules and small charcoal fragments and absence of phosphate nodules and quartz. The absence of quartz could be explained by the fact that the lake is presently almost fulfilled by sediments and detrital fragments could not reach the central portion of the depression, but the feasible meaning of the other characteristics remains questionable. The association between sponge proliferation and charcoal fragments could be not fortuitous. In fact, it is possible that important burning devastated eastern Amazon during that time (SOUBIES, 1980, and SERVANT et al., 1989). The abundant charcoal fragments could record these fires and the proliferation of siliceous fauna could be a consequence of massive production of phytolithes supplied to lake sediments through winds and/or slope running waters.

CONCLUSIONS

The preliminary results of physical, chemical and mineralogical analyses of a sedimentary column sampled in a Southern Serra dos Carajás (State of Pará, Brazil) lake suggested very clearly that this Amazon area has been submitted to important alternate paleoclimate change during the last 50,000 years. This conclusion is in perfect agreement with palynological studies developed on the same sample (ABSY et al., 1989). Moreover, additional age determinations and other analyses, including petrology and isotope geochemistry (δ^{13}C and δ^{18}O) of organic matter are presently being done by A. Sifeddine at ORSTOM (Paris), which could allow, in near future, to reconstruct better than presently the evolutionary history of changes in the recent paleoclimate in this portion of Amazon area.

ACKNOWLEDGEMENTS

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