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Late Quaternary vegetational and climatic changes in cerrado and palm swamp from Central Brazil

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Abstract

Geochemical and palynological analyses of core CR1 from Cromínia, Goiás, provided information on the paleoenvironmental history of central Brazil. The records show that prior to 32,400 yr B.P. the vegetation of the Cromínia region was similar to the present one characterized locally by a complex of cerrado, gallery forest and palm swamp, indicating a semi-humid tropical climate. A palm swamp occupied the coring site. From 32,400 to about 20,000 yr B.P. a treeless grassland replaced the arboreal cerrado and the gallery forest suggesting that humidity increased but temperature probably decreased. The site was a shallow lake between ca. 27,000 and 20,000 yr B.P. Humidity started to decrease at ca. 18,500 yr B.P. and the period from ca. 18,500 to ca. 11,500 yr B.P. was very dry. A sparse vegetation was growing in the region during that time. The dry climate continued until 6500 yr B.P. and the core site probably dried out several times. At ca. 5000 yr B.P. humidity increased again, the palm swamp vegetation returned to the site and cerrado vegetation and gallery forest started to grow in the region. The abundant charcoal particles prior to 20,000 yr B.P. and from 10,500 to ca. 3500 yr B.P. document a long history of fires in the region. Results are compared with those from other sites in Central Brazil and with the climate sequence of the last glacial maximum and postglacial time in the tropical Andes.

Keywords: paleoecology; paleoclimatology; Central Brazil; savanna; Cerrado; vereda

1. Introduction

Geological and paleoecological studies from the high elevations of the tropical Andean mountains provide evidence for the occurrence of a glaciation at the end of the Pleistocene. Glaciers extended down to the present tree line and the montane vegetational belts were displaced to lower elevations (Van der Hammen, 1974, 1991; Hooghiemstra, 1984; Vogel, 1984; Schubert and Clapperton, 1990; Salgado-Labouriau, 1991, among others). Oscillations in temperature and humidity were detected during the period of deglaciation and into the Holocene indicating that climate has not been stable after the deglaciation. Changes in climate may have also occurred in the

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tropical warm lowlands of central Brazil, but very little is known until recently. Palynological records from the state of Minas Gerais were obtained from two locations in the westernmost section of the state, Salitre (Ledru, 1993) and Lagoa da Serra Negra (De Oliveira, 1992) and two locations in the center of this state, Lagoa dos Olhos (De Oliveira, 1992) and Lagoa Santa (Parizzi, 1994). They present a sequence of climatic and vegetational changes during the last 36,000 years.

In order to verify if changes in climate and vegetation at the different sites of central Brazil are simultaneous during the Late Quaternary and coeval to the Andean last glacial and the present interglacial, several other cores were taken from central Brazilian lakes and swamps. The results from the first of these cores are presented here.

2. The site

The studied area is located about 70 km south of Goiânia (State of Goiás, Brazil), within the Goiás crystalline highland in the municipality of Cromínia (17°15'–17°20'S and 49°20'–49°28'W; 710 m elev.). The terrain is locally dominated by pediments (Fig. 1).

The following morphological units are found in the area:

(a) a hogback represented by the Serra do Paraíso (ridge), with an altitude of 860–950 m, derived from a fault-line scarp;

(b) the abutted highland of Cromínia, characterized by a 730–750 m elevation intermontane pediplain, where the studied area is located;

(c) the depression zone of Mairipotaba (700 m a.s.l.), situated in the western part of Fig. 1, where a dense drainage network promotes an intensive dissection of the relief.

The coring site (Figs. 1 and 2) is a *Mauritia* palm swamp, locally known as "vereda", located upstream from the Água Limpa stream. At present the region around the swamp is covered by a savanna-like vegetation known commonly as "cerrado". It is crossed by many rivers and small streams with narrow gallery forests (Labouriau, 1966; Salgado-Labouriau, 1973, 1979; Novaes Pinto, 1990). It has a semi-humid tropical warm climate with an average temperature of about 30–32°C during the spring–summer (September–March); the average annual rainfall is 1750 mm and approximately 70% concentrates between November and March; the dry season, when little or no rain occurs, extends for about four to five months (May to September, Nimer, 1989).

3. Description and paleoecological interpretation of the core

A 281 cm long core was drilled with a vibrocorer (Martin and Flexor, 1989) at the palm swamp. A layer of sand prevented further coring (Fig. 3).

The radiocarbon dates from this core (Table 1) yielded three ages slightly older than 32,000 yr B.P. at the lower part of the section (281–154 cm depth) that are not statistically different. This implies that either the depositional rate was very fast and that the lowermost 127 cm was deposited very fast, or that there was a problem in the determination of these dates. The palynomorph assemblage of the lowermost section is different from level CR1-21 dated at 32,340±680 yr B.P. Therefore, sediments below 154 cm depth were considered being older than 32,400 yr B.P. and thus coeval to Pleniglacial times of the tropical Andean mountains.

At 63–65 cm depth an age of 13,150±50 yr B.P. was obtained which would correspond to the deglaciation in the Andean mountains. The Cromínia section ends at about 3500 yr B.P. (extrapolated age), thus including the last glaciation and most of the present interglacial time.

The preparation of the sediments for palynological analysis followed standard techniques (Faegri and Iversen, 1989; Salgado-Labouriau et al., 1977; Ferraz-Vicentini, 1993). The results of the palynomorph analysis are given in Figs. 3 and 4 (concentration of selected types; grains/cm^3) and Figs. 5 and 6 (percentage values including all pollen types). Pollen of *Kochia scoparia* was added prior to the chemical treatment, as an internal marker

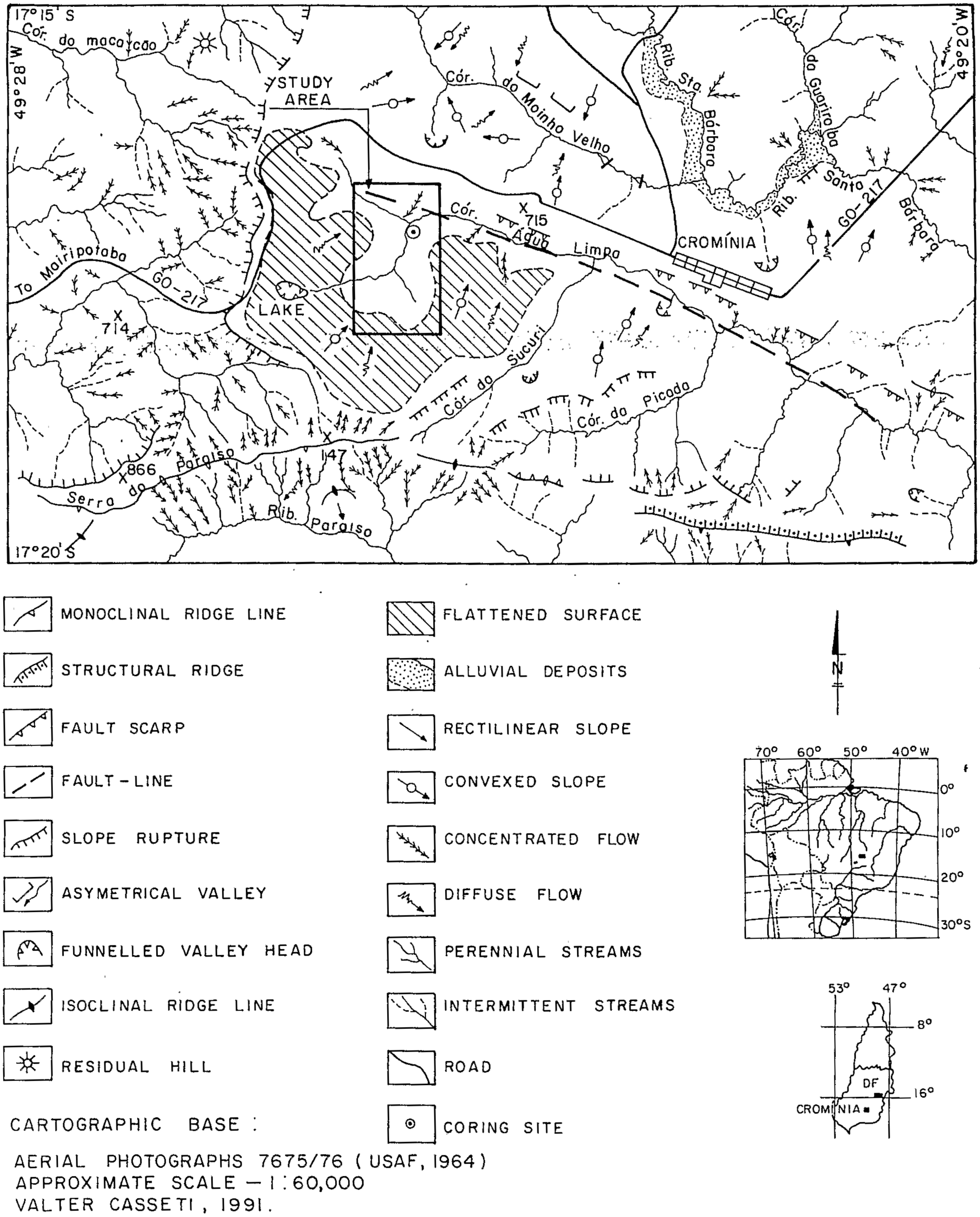


Fig. 1. Geomorphological map of the study area (after base map by V. Casseti).

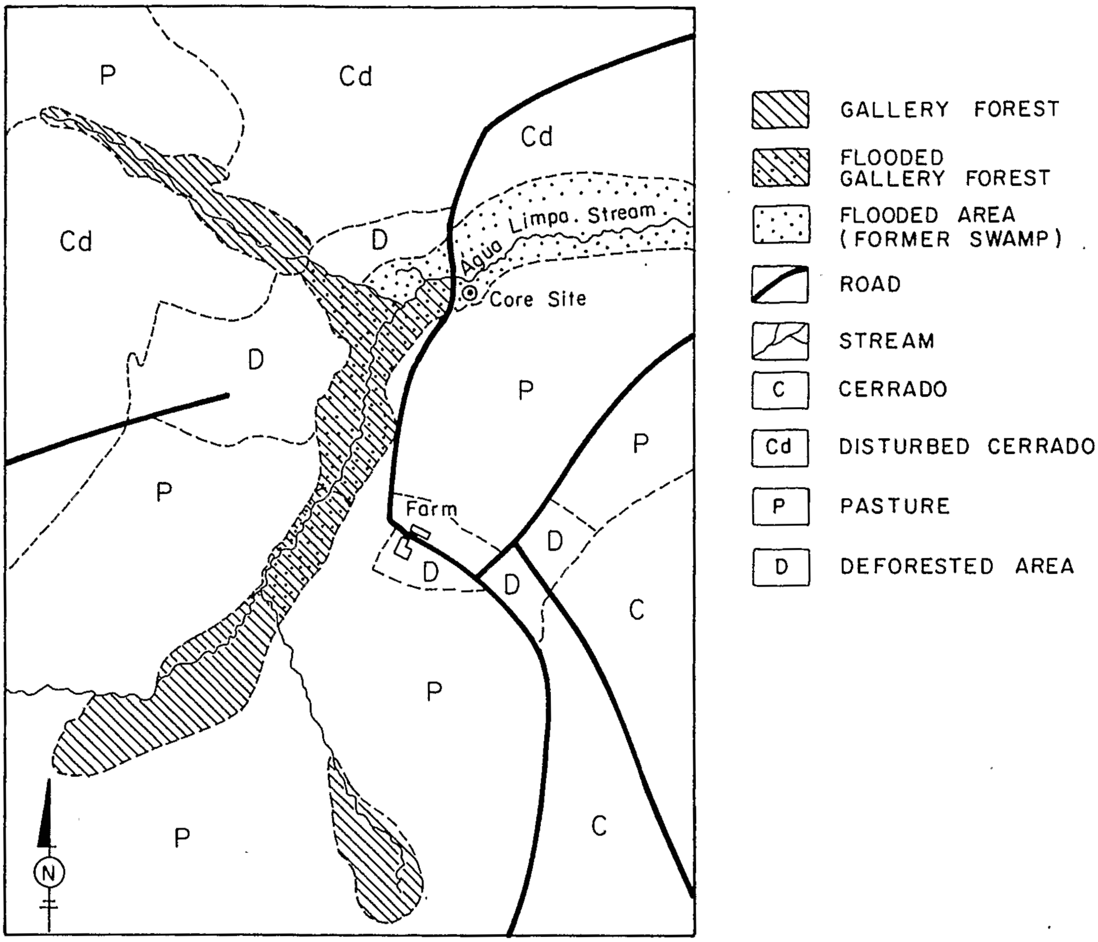


Fig. 2. Distribution of vegetation in the studied area (V. Casseti).

for concentration estimation (Salgado-Labouriau and Rull, 1986). A detailed analysis including all the palynomorphs is given elsewhere (Ferraz-Vicentini, 1993). The palynological record has shown six vegetational and climatic phases summarized in Figs. 3–5. The results of the chemical and physical analyses of the same sediments are given in Fig. 7. They will be discussed together with the palynological results.

3.1. Phase I—(280–167 cm depth), the lower part of the section, older than 32,400 yr B.P.

The lowermost part of the sediment consists of coarse to fine sand that gradually changes to sandy clay (Fig. 3). The sediment is characterized by high bulk density, low water and organic carbon content (Fig. 7). The sandy layer is devoid of palynomorphs and probably reflects alluvial deposition of an ancient stream. Pollen and spore concentration is high from 264 cm upward, in the sandy clay (Fig. 3), indicating the region was densily vegetated during the later part of the phase. The core site was a swamp dominated by the palm *Mauritia*, that is, a "vereda" (Figs. 4 and 5). Because the *Mauritia* palms do not grow in cold climates in which average winter temperatures are below 15°C, the climate therefore was warm during this phase. The vegetation distribution was similar to the present one with palm swamps in valleys,

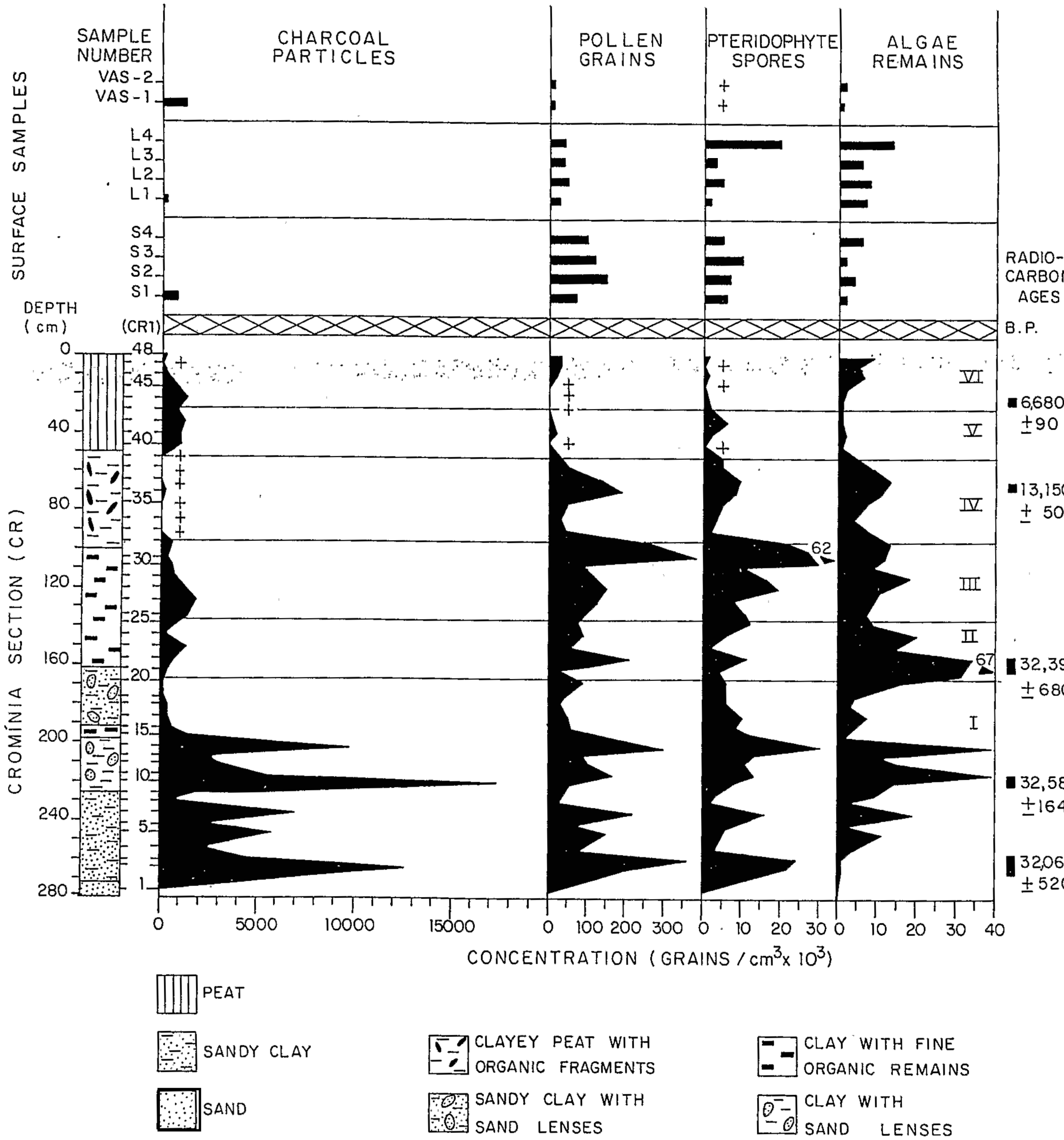


Fig. 3. Abundance of palynomorphs and charcoal particles in the Cromínia section; charcoal + = less than 200,000 particles/cm^3; pollen + = less than 10,000 grains/cm^3; spores and algae remains + = less than 1000 units/cm ^{3} (analysts: K.R. Ferraz-Vicentini and M.L. Salgado-Labouriau).

gallery forests along streams and arboreal cerrado in the surrounding area (Fig. 6).

Microscopic charcoal particles are abundant in the sediment during this time (Fig. 3), indicating frequent burning of the vegetation around the swamp.

Table 1
Radiocarbon dates from the vereda at Cromínia (GO), Brazil

Radiocarbon laboratory	Depth(cm)	Data(yr B.P.)	$\delta^{13}C$	^{13}C adjusted age	Sedimentation rate	
					cm/10^2 yr	yr/cm
Beta An.45715	19–23	6560±90	−17.6	6680±90		
					0.66	150.4
Bondy 00956	63–65	13,150±50	–	–		
					0.49	204.7
Beta An.45716	154–162	32,230±680	−15.4	32,390±680		
Beta An.64283	215–225	32,580±1640	–	–		
Beta An.45717	256–267	32,060±520	–	–		

Beta An. = Beta Analytics.

3.2. Phase II—(162–138 cm depth), from 32,390±680 yr B.P. to ca. 28,300 yr B.P. (interpolated age)

The sandy clay is replaced by clay with fine organic remains; the bulk density of the sediment decreases markedly in this phase, and water and carbon content increases (Fig. 7). The fine clay suggests that the site was a flood plain. The trees had almost disappeared, a grassland had replaced the arboreal vegetation and a marsh without palms occupied the core site (Figs. 3–5). Planktonic algae reach their maximum during this phase (Fig. 3) suggesting that the marsh remained moist the whole year round. These results suggest that during this time the climate was humid and probably cooler than at present in the region. Similar conditions are found at present at higher elevations of central Brazil, above treeline ("campos de altitude").

3.3. Phase III—(132–96 cm depth), from ca. 27,000 to ca. 20,000 yr B.P. (interpolated ages)

The sediment consists of clay with fine organic remains in the lower levels, and with macroscopic remains towards the top. Although oscillating, sediment bulk density is low; organic carbon reaches a maximum near the top of this interval. The high carbon to nitrogen ratio (C/N) is probably due to the good preservation of organic matter and the high concentration of algae. The presence of algae, *Isoëtes*, an aquatic fern, and other aquatic plants (Figs. 4 and 5) suggest the marsh had been replaced by a small shallow lake. Precipitation had probably increased in the region and the dry months were fewer than at present; the absence of trees suggests a cold climate as at present in the "alpine" regions of the central Brazilian mountains ("campos de altitude").

3.4. Phase IV—(90–52 cm depth), from ca. 18,500 to ca. 11,300 yr B.P. (interpolated ages); 63–65 cm depth dated 13,150±50 yr B.P.

The sediment consists of clay with macroscopic plant fragments (leaves, twigs and leafsheaths); bulk sediment density decreases and water content increases; organic carbon content oscillates but there is a steady decrease of the C/N ratio during this phase. The decrease in the concentration of pollen and spores (Fig. 4) and the absence of trees (Figs. 5 and 6) indicate a much more sparse vegetation than before in the region and a decline in humidity. However, pollen and spores indicate that the site was moist and probably was a marsh. This suggests that during the Upper Pleniglacial the Cromínia region had a climate drier and probably cooler than at present.

3.5. Phase V—(46–28 cm depth), from ca. 10,400 (interpolated age) to 6500±90 yr B.P.

The clay of the previous core interval is replaced by peat with macroscopic plant remains. The peat

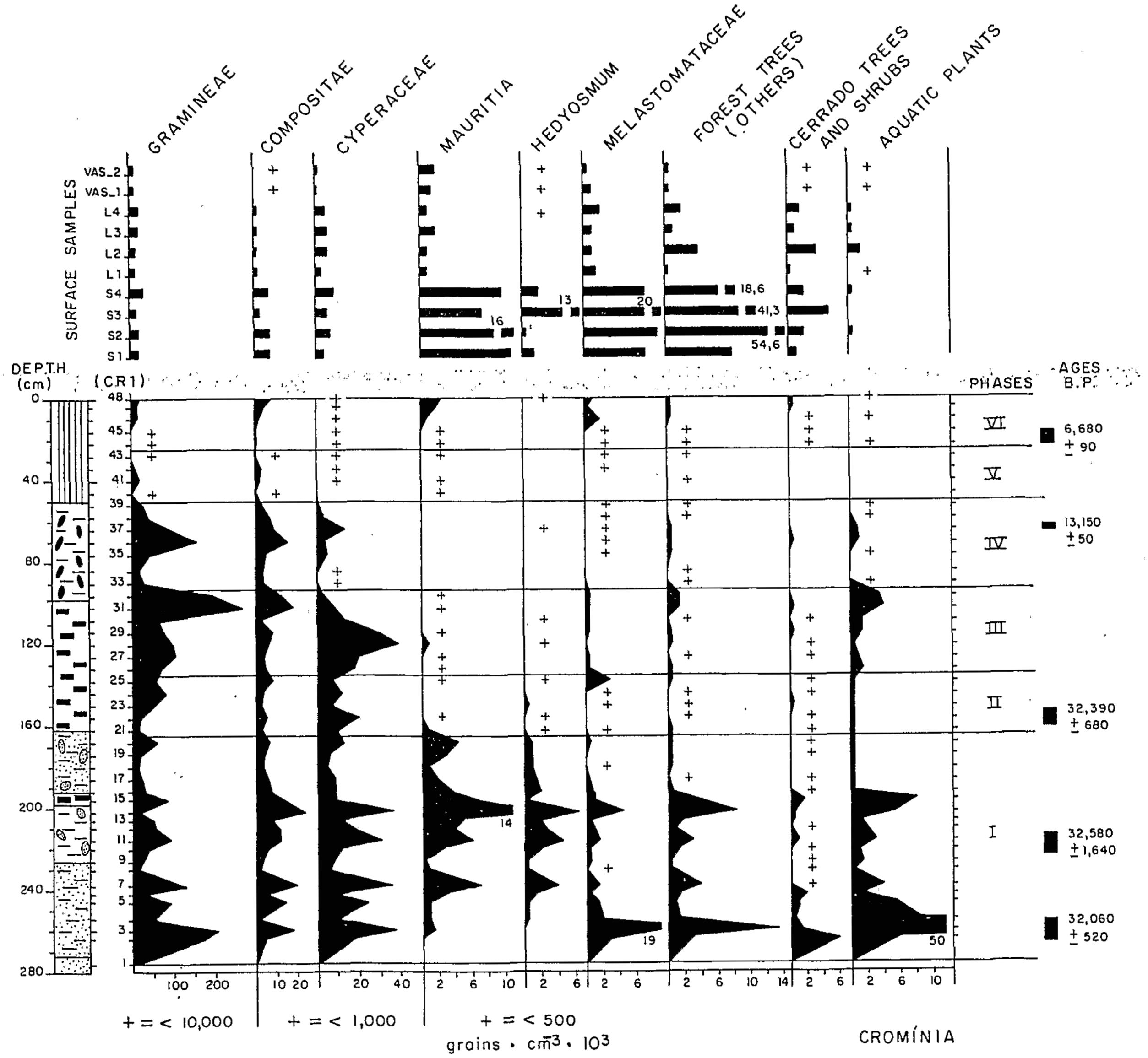
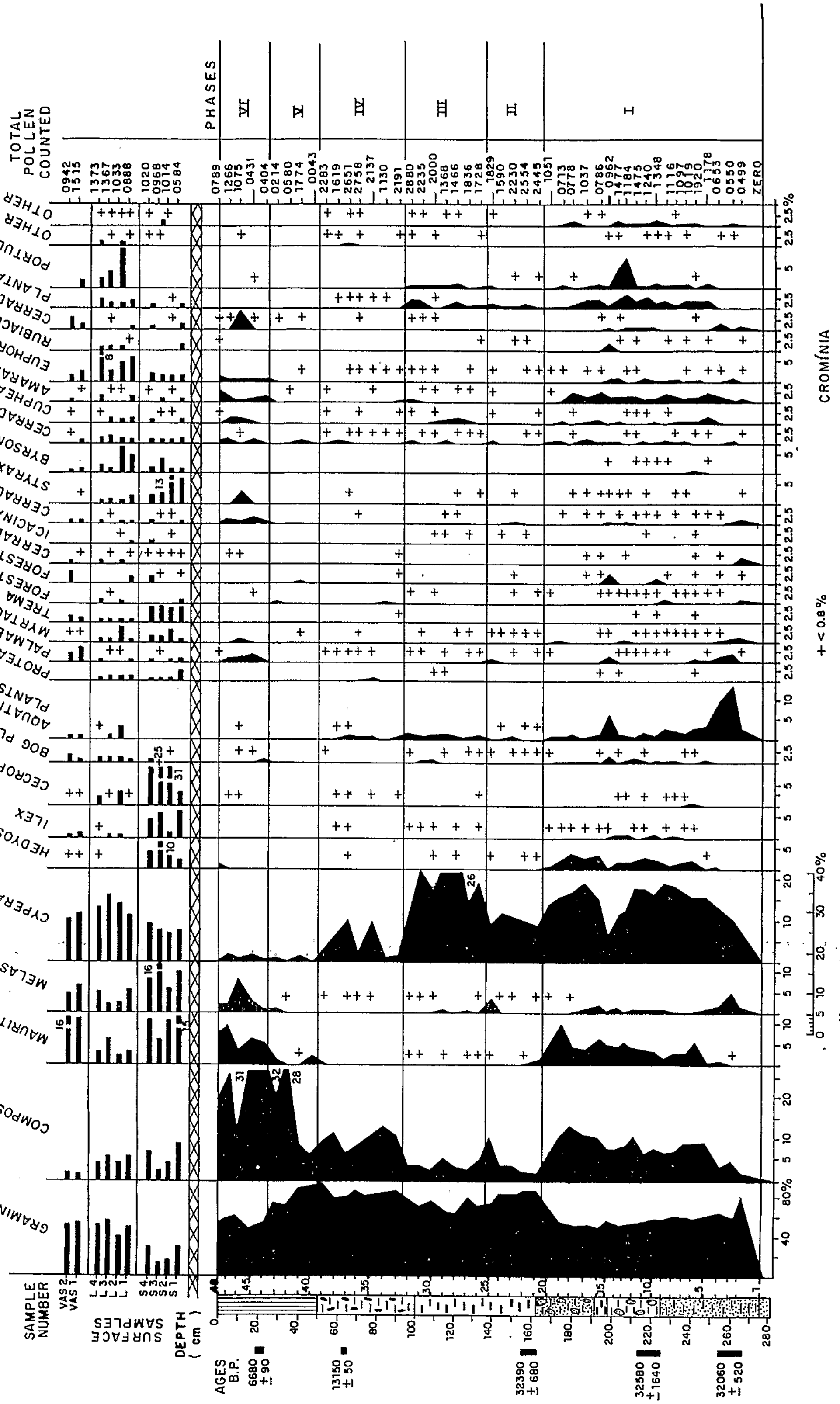


Fig. 4. Concentration diagram of selected pollen types in the Cromínia core (analysts: K.R. Ferraz-Vicentini and M.L. Salgado-Labouriau).

has low bulk density and high water content which continues to the top of the sequence; the organic carbon content is relatively constant but the C/N has lower values than before suggesting decomposition was high. Concentration values of all the palynomorphs is at their minimum (Figs. 3 and 4) but the presence of large charcoal particles and the poor preservation of pollen and spores does not suggest a reduction of vegetation cover in relation to the previous phase, but a destruction of the microfossils by fire. The core site was burned probably because it had dried out. It is not possible to reconstruct vegetation during this time due to the bad preservation of the palynomorphs. However, the climate during this phase was probably drier than at present. The marsh was desiccated



periodically, suggesting a long dry season of perhaps seven months (at present it is 4–5 months).

3.6. *Phase VI—(22–0 cm), from ca. 5000 to ca. 3500 yr B.P. (extrapolated ages)*

The interval consists of peat with the same chemical and physical characteristics described for phase V (Fig. 7). Pollen of the palm *Mauritia* and of aquatic plants (Cyperaceae, *Drosera, Ludwigia*, etc.) increases indicating the return of the *Mauritia* swamp to the site (Figs. 3–5). Other pollen types from the initial wet phase start at this phase. The pollen and spore assemblage is similar to the modern deposition in the region (top of Figs. 2–5) suggesting the vegetation assumed a modern aspect. Therefore, climate was probably similar to the present one, a semi-humid warm tropical climate. The Cromínia section (CR1) ends at about 3500 yr B.P. (extrapolated age) due to the removing of the top layers by farming.

4. Correlation with Late Quaternary events in tropical South America

The Cromínia humid cold phase was coeval with the humid Middle Pleniglacial that ended around 28,000 yr B.P. in the tropical Andes (Van Geel and Van der Hammen, 1973; Van der Hammen, 1991). It was also detected at Salitre (Ledru, 1993) further south in central Brazil. The Cromínia dry phase was also found in the cerrado of Minas Gerais (De Oliveira, 1992) and in Lake Valencia, Venezuela (Salgado-Labouriau, 1980; Bradbury et al., 1981). In Cromínia this long dry event (ca.18,500–6500 yr B.P.) ended much later than the Lake Valencia dry event (>13,000–10,000 yr B.P.) (Bradbury et al., 1981). The humidity increase in Cromínia at ca. 6500–5000 yr B.P. coincides with precipitation increase in other central Brazil sites, Lagoa dos Olhos (De Oliveira, 1992), and Lagoa Santa (Parizzi, 1994). From there onwards the climate became semi-humid in the cerrado region of Brazil suggesting that paleoclimatic conditions in the already studied regions were similar.

Charcoal particles were found throughout most of the Cromínia core (Fig. 1) indicating that the burning of the vegetation was common from 32,400 up to 3500 yr B.P. (Salgado-Labouriau and Ferraz-Vicentini, 1994).

Burned wood was found in cerrado soils of Brasília and Pirassununga (São Paulo) dated as old as 8600 radiocarbon yr B.P. (Coutinho, 1990); charcoal particles were found in the palynological analysis of a core from a small lake at the cerrado of Minas Gerais (De Oliveira, 1992) between 13,700 and 6800 yr B.P. However, the Cromínia record shows that fire has affected the cerrado ecosystem for a much longer period than was previously known.

The Cromínia record supports the proposed hypothesis for Lake Valencia (Salgado-Labouriau, 1980; Bradbury et al., 1981) that the climate in the tropical low lands below 1500 m elevation in South America was dry, probably semi-arid, at the close of the Pleistocene (13,000–10,500 yr B.P.). However, at Cromínia the beginning of the Holocene was also drier than at present, and only after 6500–7000 yr B.P. the present semi-humid climate with fluctuations in moisture levels started.

Fig. 5. Percentage diagram of total pollen in the Cromínia core (analysts: K.R. Ferraz-Vicentini and M.L. Salgado-Labouriau). *1* = *Drosera*, *Epilobium*, Umbelliferae, *Ludwigia*; *2* = *Typha*, *Potamogeton*, Pontederiaceae; *3* = *Euplassa*, *Roupala*; *4* = *Podocarpus*, *Trichilia*, *Cabralea*, *Clarisia*, *Ximenia*, Bignoniaceae, Moraceae, Sapindaceae; *5* = *Smilax*, *Fucsia*, *Serjania*; *6* = *Stryphnodendron*, *Aeschynomene*, *Andira*, *Sclerolobium*, *Cassia*, *Mimosa*, *Harpalyce*, *Zornia*, *Crotalaria*; *7* = *Emmotum*, *Vilaresia*; *8* = *Pseudobombax*, *Eriotheca*, *Laseguea*, *Tabernaemontana*, *Kilmeyera*, *Cochlospermum*, *Curatella*, *Antonia*, *Laplacea*, *Campomanesia*, *Cupanea*, *Vochysia*, *Helicteres*, *Ouratea*, *Agonandra*, *Solanum*; *9* = *Alternanthera*, *Gomphrena*, *Pfaffia*; *10* = *Acalypha*, *Alchornea*; *11* = *Borreria*, *Richardsonia*, *Tocoyena*; *12* = *Bernadia*, *Peixotoa*, *Didymopanax*, *Bredmeyera*, *Cestrum*, *Dickia*, *Ceratosanthes*, *Caryophyllacea*; *13* = *Dipladenia*, *Hyptis*, *Salvia*, *Neea*; *14* = *Rapanea*, *Symplocos*, *Diospyros*, *Salacia*; *15* = Rosaceae, Cunnoniaceae, Urticales, Malpighiaceae, Malvaceae.

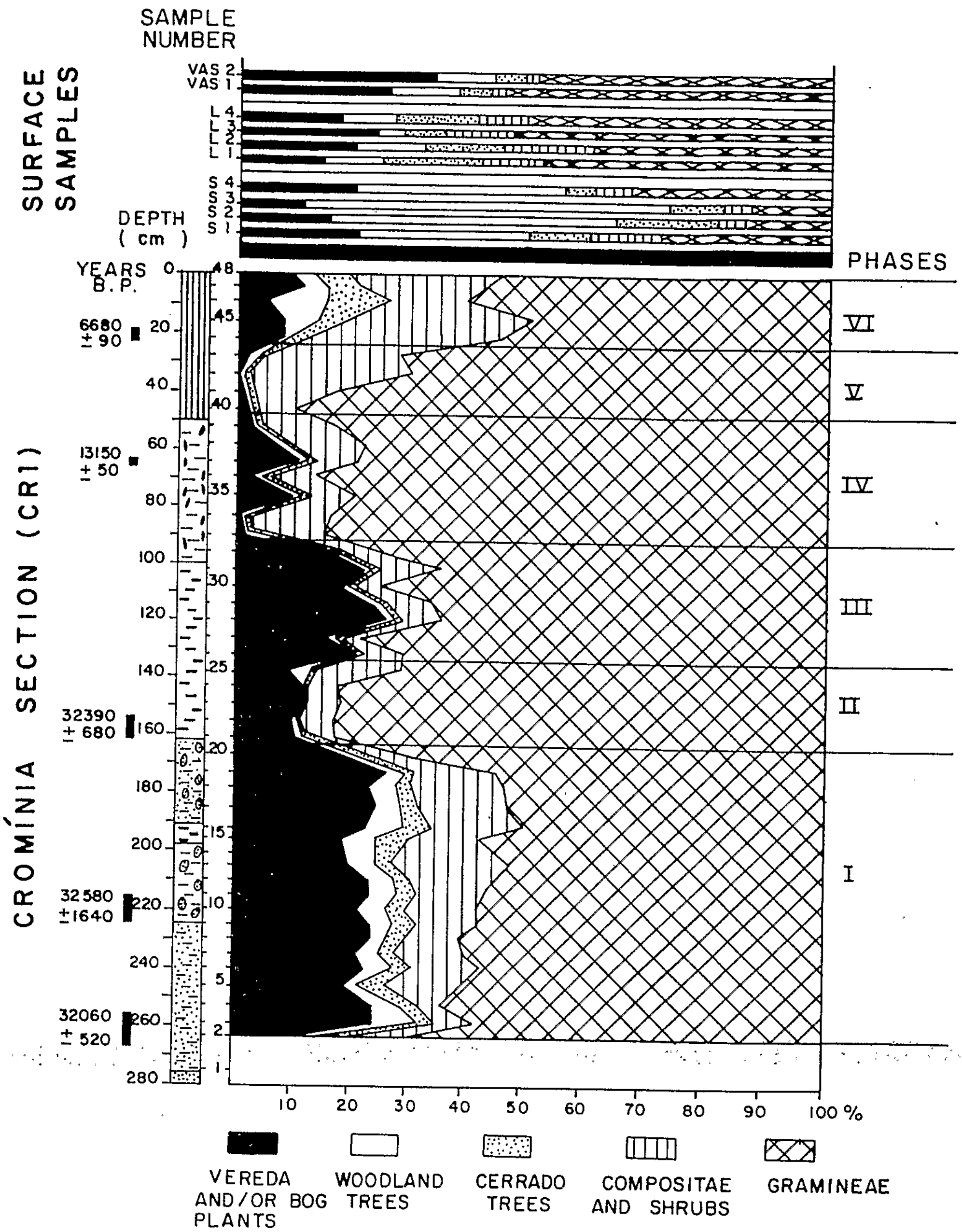


Fig. 6. Comparison of the percentage of different types of vegetation along the Cromínia section, based on data from Fig. 5 (analysts: K.R. Ferraz-Vicentini and M.L. Salgado-Labouriau).

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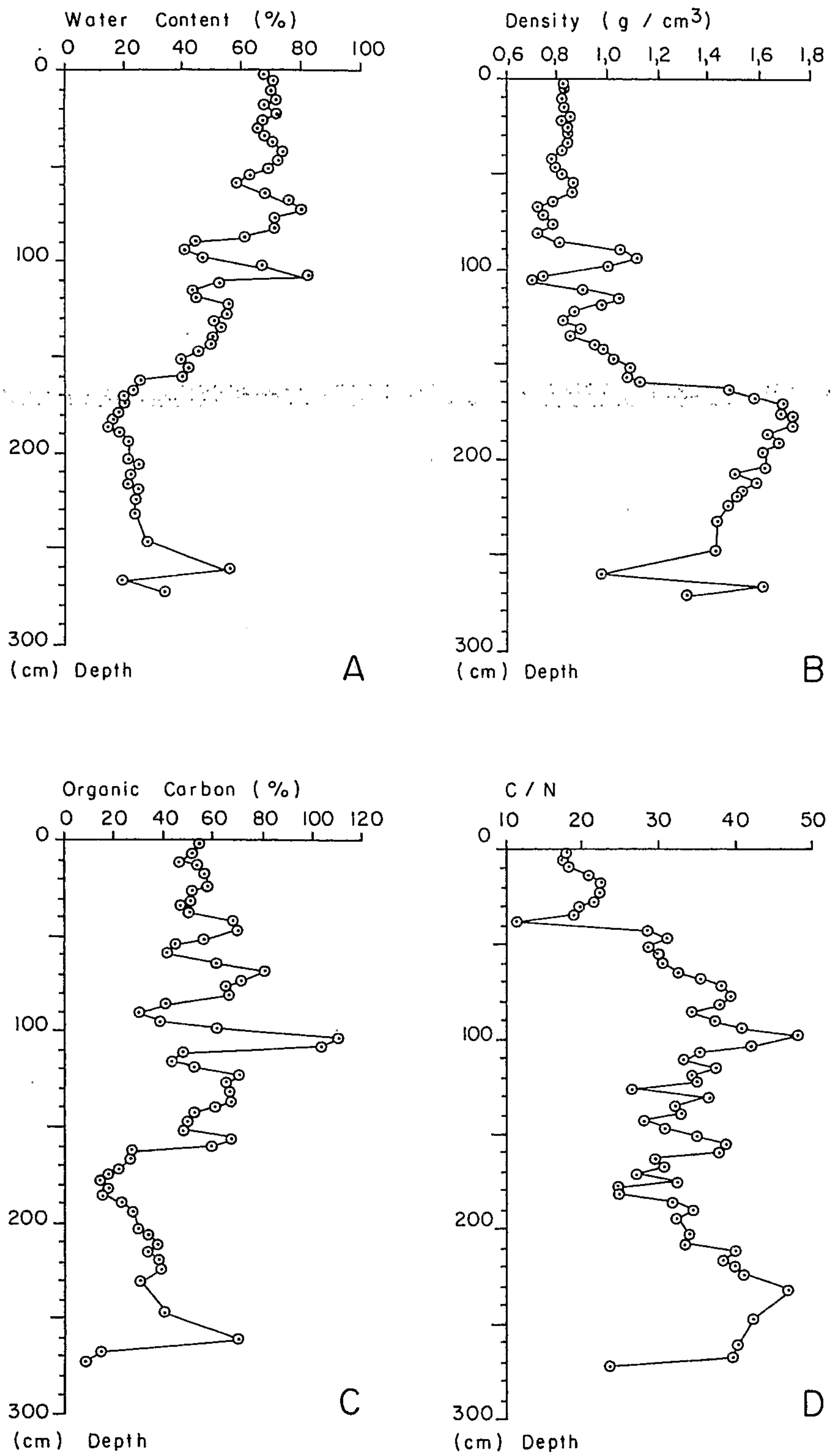

Fig. 7. Cromínia sediment, chemical and physical analyses (CR1). A. Water content in relation to dry weight. B. Density. C. Relative content of organic carbon. D. Ratio carbon/nitrogen (C/N) (analysts: ORSTOM, Centre de Bondy, under supervision of F. Sondag).

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