Chapter 6
An Assessment of the Cultural Practices Behind the Formation (or Not) of Amazonian Dark Earths in Marajo Island Archaeological Sites

DP Schaan, DC Kern, and FJL Frazão

6.1 Introduction

For many decades, archaeologists working in Amazonia have looked for *terra preta* (black soil) areas in their search for ancient settlements. The typical Amazonian archaeological site is comprised of a combination of black soil, ceramic sherds and some distinct vegetation species, which William Balée calls "cultural forests" (Balée 1989). Sites are usually located in elevated terrains or riverine bluffs, protected from the annual floods when along the major rivers floodplains. Archaeologists also know that there is some correlation between soil color and density of ceramic sherds, both being a sensor for ancient demography patterns.

Ever since Sombroek (1966) and Smith and Nigel (1980) reported the existence of the anthropogenic *terra preta* soils, and especially after several research projects carried out by soil scientists and archaeologists during the last 20 years, research on ADE (Amazonian Dark Earth) sites has drawn much scientific interest. Analysis of ADE samples have demonstrated that such soils present higher levels of chemical nutrients such as C (carbon), P (phosphorus), Ca (calcium), Mg (magnesium), Zn (zinc) and Mn (manganese) when compared to original, background soils, besides presenting superior pH, as well as higher amounts of organic material, which make them particularly fertile (Kern and Kampf 1989; Kern et al. 1999; McCann et al. 2000). Such elements were possibly added to the soils during degradation of organic debris related to human occupation and discarding activities (Eidt 1985; Kern, et al. 1999; Woods and McCann 1999; McCann et al. 2000).

High values of P, Ca and Mg on ADEs can be attributed in part to animal residues, since bones, blood, carapaces and feces are rich in these elements. Zn and Mn might occur as residues of palm trees, whose leaves are commonly employed as construction material for house walls and roofs, beds, hammocks, and basketry (Kern et al. 1999).

Soil chemistry studies directed to solve archaeological problems have increased in number in the last three decades. While physical modifications caused by anthropic factors, such as sediment compression and texture changes can be perceived by an experienced archaeologist, chemistry, although less evident to the naked eye, can contribute to determine boundaries of activity areas, and help to define stratigraphy and function of an archaeological site (Woods 1984). Chemical anomalies coupled to

WI Woods et al. (eds.), *Amazonian Dark Earths: Wim Sombroek's Vision*,

ethnographic data can inform on ancient settlement patterns (Ball and Kelsay 1992; Manzanilla and Barba 1990; Sokoloff and Carter 1952). P can be used to estimate population size, duration and intensity of occupation, determine basic subsistence patterns, define garbage dumps areas and establish relative chronology (Collins and Shapiro 1987; Griffith 1980; Sjoberg 1976). Other authors use chemical analysis in the field in order to obtain quick responses for the differentiation of post molds and rodent holes, and define stratigraphy (Deetz and Dethlefsen 1963; Verwe and Stein 1972). Hence, geochemical studies have demonstrated that chemical signatures caused by anthropogenic activity vary within a site or even residence, and these variations tell us something about human behavior.

ADE sites have a wide-ranging distribution in Amazonia. Some of the largest ADE sites (e.g. in Manaus, Oriximiná, Juruti, Santarém, and Belterra), containing remains of ancestor cult (elaborate ceramics and funerary vessels) and prestige goods were the *loci* of ancient chiefdoms, regional societies that emerged at the end of the first millennium. At the same time, small ADE sites representing autonomous villages dated to the last two millennia are found in diverse ecological settings

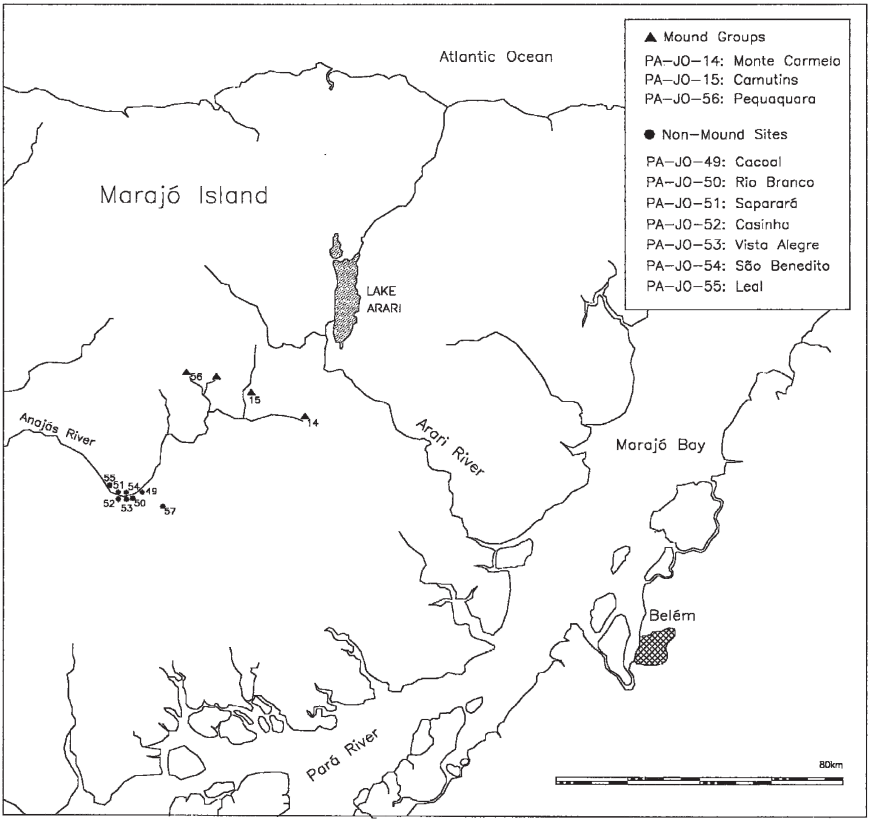

Fig. 6.1 Research area

(Kern et al. 2004). So wherever ADE sites exist, they belong to roughly the same time period, and speak about the emergence of a new way of life. Since ADEs were formed as remains of human activities were incorporated to the soils, the sudden appearance of such soils signals changes in consumption and discard practices.

This chapter discusses the results of geoarchaeological research carried out in three archaeological sites, belonging to different time periods: (1) Rio Branco site, *c*.3500–3000 BP; (2) Camutins site, *c*. AD 700–1100; and (3) Leal site, *c*. AD 1200–1600) (Fig. 6.1). At the Rio Branco and Leal sites it was observed a negative correlation between soil color, ceramic density and chemical content. On the basis of such findings, the presence or not of ADE and its characteristic chemical signatures is explained as caused by diverse spatial organization. Cultural practices, subsistence patterns, as well as certain post-depositional processes might have been responsible for the formation or not of ADE on the Marajó Island sites.

6.2 Pre-Columbian Settlers

Marajó Island is one of the best known archaeological areas in Amazonia. Research there started in the late nineteenth century, due to the special attraction that monumental mounds and exquisite funerary pottery exerted over scientists and the general public. Since then, looting has destroyed many of the most prominent large mounds, but there are still many sites in fair state of preservation.

In the late 1940s, Betty Meggers and Clifford Evans studied several sites located in the center and north of the island, identifying other occupations besides the mound builder culture called Marajoara (Meggers and Evans 1957). The cultural sequence they described, later refined by radiocarbon dates (Meggers and Danon 1988; Roosevelt 1991; Simões 1969), included three ceramic phases that preceded the Marajoara phase (dated to *c*. AD 400–1300), Ananatuba (*c*.3500–*c*.3000 BP), Mangueiras (*c*.3000–*c*.2800 BP), and Formiga (*c*. AD 0–800); and one later ceramic phase: Aruã (*c*. AD 1300–1600), contemporary to European presence during the sixteenth and seventeenth centuries.

Meggers and Evans interpreted Ananatuba, Mangueiras, Formiga, and Aruã as the typical tropical forest phases: semi-sedentary people living on slash-and-burn cultivation, hunting, fishing, and collecting (Meggers and Evans 1957; Steward 1948). In the Marajoara phase, however, they recognized all the characteristic traits of chiefdoms: stratification, occupational division of labor, control of labor, organization, and leadership, “features more closely resembling those of Circum-Caribbean or Sub-Andean cultures than those of the Tropical Forest” (Meggers and Evans 1957:404).

Before the advent of radiocarbon dating, Meggers thought Marajoara was short-lived on the island, attributing its existence to migration from the Andean foothills. Arriving to the Amazon delta, migrants were not able to reproduce intensive agriculture in poor soils, and their fate was to decline and vanish. After radiocarbon dating was available, however, the long endurance of Marajoara culture (*c*.900

years) emerged as a problem, and Meggers was never able to adequately explain it within her theoretical framework.

In disagreement with Meggers' interpretations of the Marajoara culture, Anna Roosevelt carried out, in the 1980s, a comprehensive study of a single Marajoara phase mound, Teso dos Bichos, finding there evidence for sedentary habitation. According to her assessment of human osteology, faunal and botanical remains, she found out that the Marajoara subsistence "was based on annual cropping of seed crops, plant collection, and intensive seasonal fishing" (Roosevelt 1991:405). However, Roosevelt did not really find any evidence for maize consumption and cultivation (Roosevelt 1999).

Disagreeing with both Meggers' theory of foreign origin of Marajoara peoples, and Roosevelt's insistence on intensive agriculture as the basis for social complexity, and aiming to investigate Marajoara social organization and subsistence patterns, the first author carried out, between 1998 and 2002, a research project in the Anajás River basin (central Marajó). Six sites located in the middle Anajás River were mapped and excavated. Seventy five kilometers up river, the largest known mound group on the island, the Camutins site, was surveyed, mapped, and two of the elite mounds were excavated (Schaan 2004).

The Anajás Project made it possible to study sites belonging to different time periods, revealing a long history of cultural change. The chronology of cultural change shows initial occupation by cultivators with a generalized economy living in small autonomous villages. By AD 400, people moved to the headwaters and lakes in order to establish permanent villages and intensively exploit the abundant fish resources. In a few decades, cooperation and competition in such bountiful areas led to the emergence of chiefdoms (Schaan 2004). There is archaeological evidence for water management, with the construction of dams, ponds, and elevated causeways between adjacent mounds. Mound building was in fact a side effect of earthmoving activities aiming to control aquatic fauna. By AD 1100 chiefdoms spread throughout the savannas, and non-mound settlements replicating Marajoara culture also emerge along the major rivers. By AD 1300, chiefdoms collapsed, mounds and water systems were abandoned, and population returned to the autonomous village type of social organization. However, the typical Marajoara material culture still persisted in post-chiefdom villages along rivers.

6.3 The Archaeological Study

Two of the six sites excavated during the Anajás Project were selected in order to conduct geochemical studies: PA-JO-50, the Rio Branco site and PA-JO-55, the Leal site. The Rio Branco site was first investigated by soil coring at regular intervals, in order to assess the depth of archaeological strata. Anthropogenic soils and ceramics spread over a 4,000 m^2 elliptical area, next to the Rio Branco stream, 150 m before its mouth at the Anajás River (Fig. 6.2). The area was previously used for manioc cultivation, but at the time of our research it was occupied by secondary

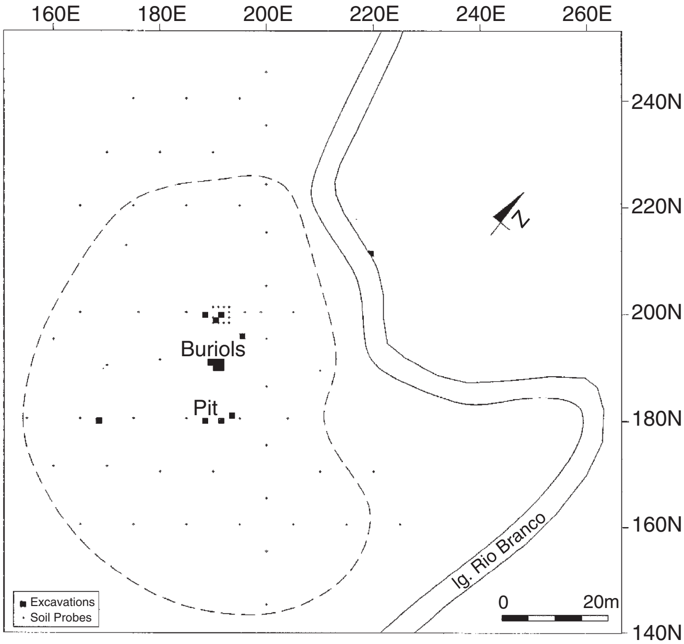

Fig. 6.2 Rio Branco site map

vegetation, including banana trees. The archaeological deposits were buried under 10–20 cm layer of sediment, which was visible in a profile at the eroded stream banks. After mapping, the site was surveyed by geophysical methods, using a proton precession magnetometer and a GPR on a 4 m grid, covering a 6,400 m^2 area. A sample of the anomalous areas was investigated through stratigraphic excavations, resulting in 18.25 m^2 of excavations. The depth of archaeological strata varied from 50 to 80 cm. The investigation of anomalies revealed features such as: (1) clusters of ceramic sherds over ancient surfaces, indicating areas to which the sherds were swept (e.g. DeBoer and Lathrap 1979) (Pits 4, 5, 6 and 7); (2) a hummus and ceramics filled pit, which was interpreted as a garbage dump (Pit 2); (3) two buried broken vessels, covered by a thick layer of sherds (Pit 5). Some 26,000 ceramics sherds belonging to Ananatuba phase were recovered. This phase was dated to 3500–3500 BP in other sites of the island (Meggers and Danon 1988; Simões 1969). The only two radiocarbon dates obtained from the site were too recent to be trusted, probably the result of intrusive recent charcoal, so they were disregarded.

The Leal site occupied a 2,000 m^2 elliptical area (Fig. 6.3). The site was located 5 km downriver from Rio Branco, on the Anajás River right bank. The area was once cultivated, but it was then covered by cocoa trees and secondary vegetation. Geophysical mapping did not reveal any outstanding anomalies. A total of 13 m^2 of non-continuous area was excavated, including 1 × 1 m pits and a trench. The depth

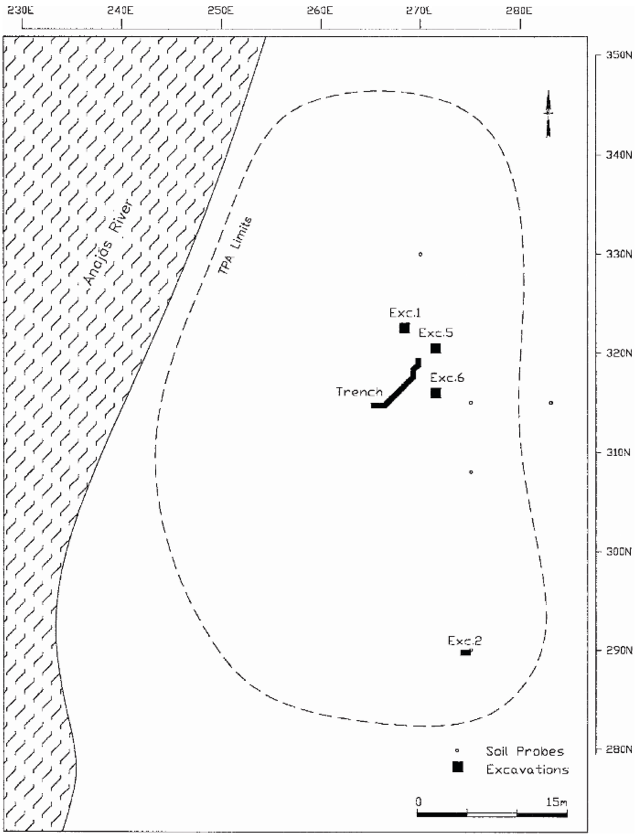

Fig. 6.3 Leal site map

of archaeological strata was about 40 cm. Cultural features consisted of small clusters of ceramic sherds and charcoal, one of which, located 30–40 cm below surface in trench 1, was dated to 730 ± 80 BP (c. AD 1170 to 1400, calibrated, Beta 146,221), which was assumed to represent the initial occupation. Some 7,000 ceramic sherds were recovered from all excavations. There are important changes in ceramic technology as observed for other post-marajoara period sites (Schaan 1999, 2004). Decorated sherds comprise 6.75% of the total, and no burials were found.

The Camutins site was excavated in 2001 (Mound 1) and 2002 (Mound 17) (Fig. 6.4). No chemical studies were performed, but dark earths were observed as a result of post-depositional processes in cemeteries, as well as littering.

P, Ca, Mg, Zn, and Mn were chosen for analysis, because these are chemical elements that better characterize ADE archaeological sites (Kern 1988, 1996). Soil samples were collected from pit walls after archaeological excavations were completed, and the profiles recorded. Lemos and Santos (1984) methodology was employed for soil sampling and description, separating the pedological horizons, and collecting samples every 20 cm. Since excavations were conducted only to the archaeological sterile layer, soil samples

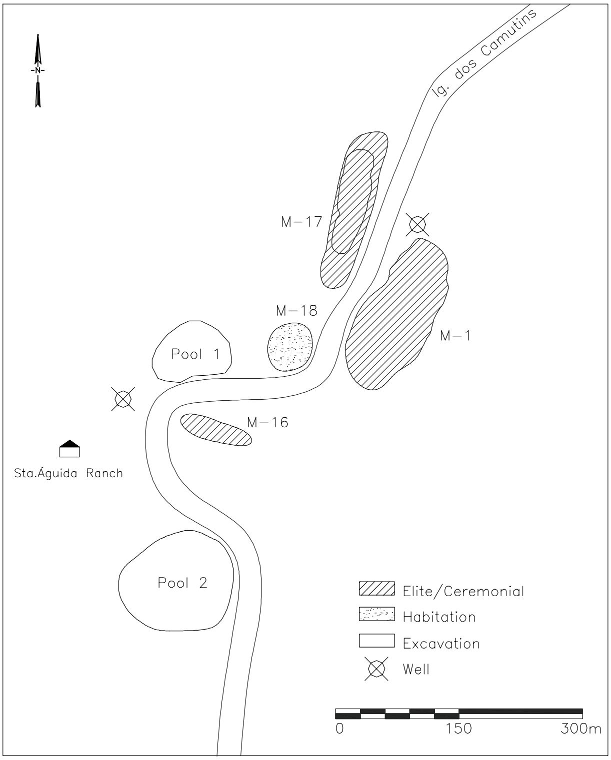

Fig. 6.4 Camutins lower course mounds

were collected even further down, to reach the B horizon, some 50cm deeper. In each site, one of the pits was excavated one more meter below cultural strata. Control samples of background soil were collected outside both sites (thereafter AA – adjacent areas).

6.4 Results and Discussion

In the Leal and Rio Branco sites horizontal and vertical variation in physical, morphological, and chemical characteristics of the soils was observed. Both sites presented a sequence of horizons A_1, A_2, A_3, AB, BA, and B, for in-site profiles, and A_1, AB, BA, and B, for background soils' (AA) profiles. In-site A horizon was thicker, reaching up to 56cm in Rio Branco and 30cm in Leal, while in AA soils they average 10cm. P_2O_5, Mn, and Zn levels markedly diverge between in-site and AA soils (Figs. 6.5–6.7).

The two sites presented similar data for AA soil samples, which allows for direct comparison. This similarity compensates a possible influence that differences in soil texture must have caused in the retention of chemical nutrients, because Leal soils were much sandier than the clay-rich Rio Branco soils.

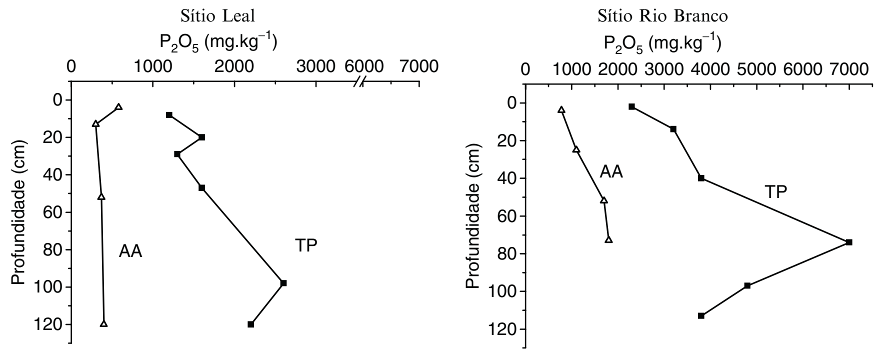

Fig. 6.5 Variation of phosphate according to depth in ADE/*terra preta* (TP) and adjacent area (AA), in Leal and Rio Branco

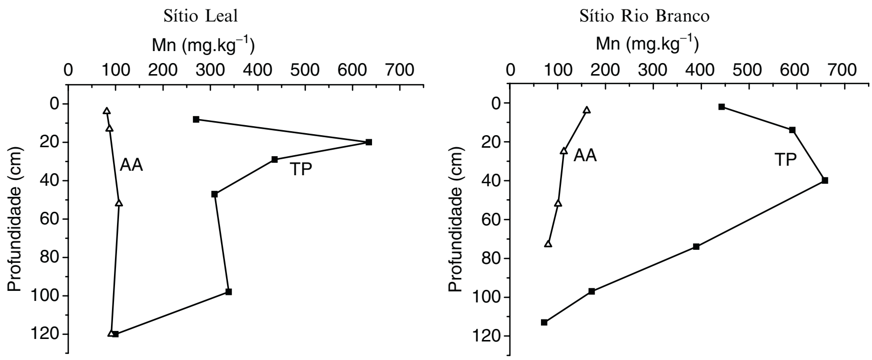

Fig. 6.6 Variation of Mn according to depth in ADE/*terra preta* (TP) and adjacent area (AA), in Leal and Rio Branco

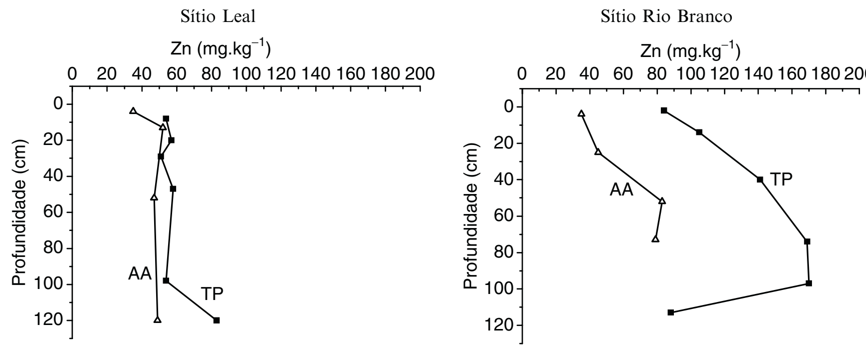

Fig. 6.7 Variation of Zn according to depth in ADE/*terra preta* (TP) and adjacent area (AA), in Leal and Rio Branco

In the Rio Branco site, P_2O_5 levels in horizon A vary from 780 to 7,500 mg/kg^{-1} in the anthropogenic soil and from 410 to 600 mg/kg^{-1} in background soil. This element also presented meaningful horizontal variation. In the Pit 2, horizon AB (56–91 cm deep), P_2O_5 levels (7,000 mg/kg^{-1}) were exceedingly high (Fig. 6.5). Examining a soil sample in a Scanning Electron Microscope, bone fragments were detected. In this excavation, the profile reveals a humus and ceramics filled pit, likely a garbage dump.

Evaluating proportions of ceramic sherds and P_2O_5 levels by layer, it was noticed that there is no correspondence between these two variables. That, in part, may be due to the watering of P to lower levels. However, if Pit 6, where there was a cluster of sherds in horizons BA and B (a total of 3,743 fragments), with P_2O_5 level of 1,800 mg/kg^{-1}, is compared to Pit 3, where sherds are in smaller amount (223 fragments), with P_2O_5 level of 2,800 mg/kg^{-1}, it is clear that these two variable do not co-vary.

Zinc and manganese levels in Rio Branco show different behavior when compared to P_2O_5. For example, in Pits 1, 2, and 5, manganese and P_2O_5 have similar behavior by horizon, with contrary trends in excavations 3, 4, and 6. Since zinc and manganese are elements related to the decomposition of plant matter, higher levels of manganese in Pit 4 and zinc in Pit 3 might mean a higher amount of palms and materials used in the construction of houses at the periphery of the site, while phosphorus predominate in the center, where there would be higher incidence of animal matter (burial, food residues, etc.).

In the Leal site, P_2O_5 levels in A horizons vary from 1,200 to 2,500 mg/kg^{-1} in the anthropogenic soils, but from 300 to 580 mg/kg^{-1} in AA. There is also important in-site horizontal and vertical variation. From horizon A3 to horizon A2, P_2O_5 levels decrease from 2,500 to 1,400 mg/kg^{-1} in Pit 6 and from 2,400 to 1,700 mg/kg^{-1} in the trench, while they increase from 1,300 to 1,600 mg/kg^{-1} in Pit 1. There is an increase in the amount of ceramics of 3.3% in these horizons, at the same time that occurs a dramatic increase in the proportions of caraipé tempered ceramics, which goes from 49% to 62% of the total. The typical Marajoara phase ceramics (grog tempered) decreases 9%. From horizon A2 to A1, soil color gets lighter and P_2O_5 values decrease considerably. At the same time that ceramic proportions decrease around 10%, caraipé tempered ceramics again increases, from 62% to 74% of the total. Comparing geochemical data to the results of ceramic analysis, one sees that important changes were in place. The decrease of P_2O_5 levels from A3 to A2 horizons do not seem to be relate solely to demographic decrease, since ceramics do not decrease as much; therefore chemistry signatures must indicate changes in human behavior.

Although Ca and Mg are important markers for ADE sites, these elements did not provide good results for the Anajás River sites. This is likely due to the seasonal flooding to which many areas are subjected; besides that, some areas are affected by the inversion of the Atlantic Ocean currents that penetrate the island during the dry season, carrying salt water. Normally, Ca levels in soils are higher than Mg, since these are more easily watered. For soils under study, higher levels of Mg indicate influence of salts. The geological, morphological and pedological characteristics of Marajó soils, then, could have affected the absorption of Mg and Ca.

In both sites, P levels in B horizon were also observed to be too high for non-cultural strata, especially when compared to AA soils. That is due to the leaching phosphate, together with the pedological characteristics of both sites. Even though, considering that phosphate might migrate in the whole site, it is still possible to compare between horizons. The correlation between cultural features and phosphate content, for example, is significant in Pit 2, Rio Branco site, so chemical analysis likely confirm that it was a garbage dump. In the same way, high P_2O_5 levels associated to clusters of ceramic sherds on ancient surfaces indicate sweeping of both sherds and biological debris to non-circulation areas.

Data showed a more intense and differentiated occupation at Rio Branco site, where organic matter was disposed in discrete areas, compatible with well-organized social and domestic activities, following cultural patterned behavior. It is possible that houses were disposed in a circle or semi-circle around a central plaza. In Pit 3, for example, P_2O_5 levels are higher than in AA, but lower than in the center of the site; there zinc levels were high, an element associated to degradation of construction materials of organic origin, such as palms, which suggests that was the locus of a house. In Pit 6, lower levels of all elements indicate it was a peripheral area.

Comparing both sites, it is possible to affirm that: (1) Leal is smaller in area and demography than Rio Branco. (2) Activities carried out in Rio Branco involved a greater amount of organic materials, which, contrary to the expectations, did not lead to the formation of the typical ADE, although soil is darker in areas where there are more ceramics and nutrient levels are higher. (3) Geophysical, geochemical, and ceramic analyses suggest that in Rio Branco houses were disposed around a central plaza. (4) The fact that Leal is located next to the river suggests fishing as a primary subsistence activity. Its houses would be aligned along the river, as it has been suggested for other Marajoara phase sites (Schaan 2004). Discarding activities were less organized; garbage would be thrown around the habitation.

In the Camutins site both mounds were artificially build by the accretion of silt brought from adjacent areas. After a layer of silt was added, a period of occupation took place. During the occupation, human debris was consistently swept, so only a thin layer of dark soil was formed (Fig. 6.8). Such layers were comprised of charcoal and a few sherds. After a period of occupation (a year or a couple of years) another layer of silt was added. Silt was constantly being removed from the adjacent lake in order to improve hydraulic works (e.g. Schaan 2004).

Since Mound 1 was largely looted, the frontal part of the mound was covered with dark earth and amazing amounts of broken sherds (Fig. 6.9). These included parts of funerary vessels. Although no bones were found, it is a fact that looters frequently discard bones and broken pottery, taking with them only the best preserved pieces.

In the better preserved Mound 17, ADE was found in the cemetery area and in the back of a house. In the cemetery area it was associated with broken funerary pottery and bones. In excavation 4, it was associated to kitchen dump (charcoal, broken pots, pot stands) and human bones (Fig. 6.10).

Fig. 6.8 Camutins stratigraphy

6.5 Final Remarks

As this paper have tried to demonstrate, diverse lines of evidence (soil cores, excavations, geophysics, and geochemical analysis) can help interpreting pre-Columbian human behavior and settlement patterns. In the Rio Branco site, the study of cultural features and soil analysis permitted to understand spatial organization. In the Leal site, the lower levels of P_2O_5, if compared to Rio Branco, was interpreted as the result of a smaller population, something also supported by the amount of artifacts recovered.

It is important to emphasize that soil color in A horizon at the Leal site is darker than in A horizons of the Rio Branco site. While in the Leal site A horizons present soil colors of 10YR3/2, 3/3 and 2/2, in the Rio Branco A horizon with more intense occupation (A2 and A3) display 10YR4/3 and 4/4 colors. Darker soil in the Rio Branco site is restricted to the A1 superficial layer (3 to 7 cm thick), 10YR 2/1 at Pit 3, but 10YR 4/2 and 4/1 in other pits. An exception is Pit 5, where A2 color is 10YR3/3. Although, the Leal site soil has a typical ADE color, P_2O_5 levels are higher for Rio Branco. It might mean that the formation of ADE was not associated to the intensity of human activities and demographic increase, but to a particular cultural practices, such as a higher dependence on riverine fauna. Future studies,

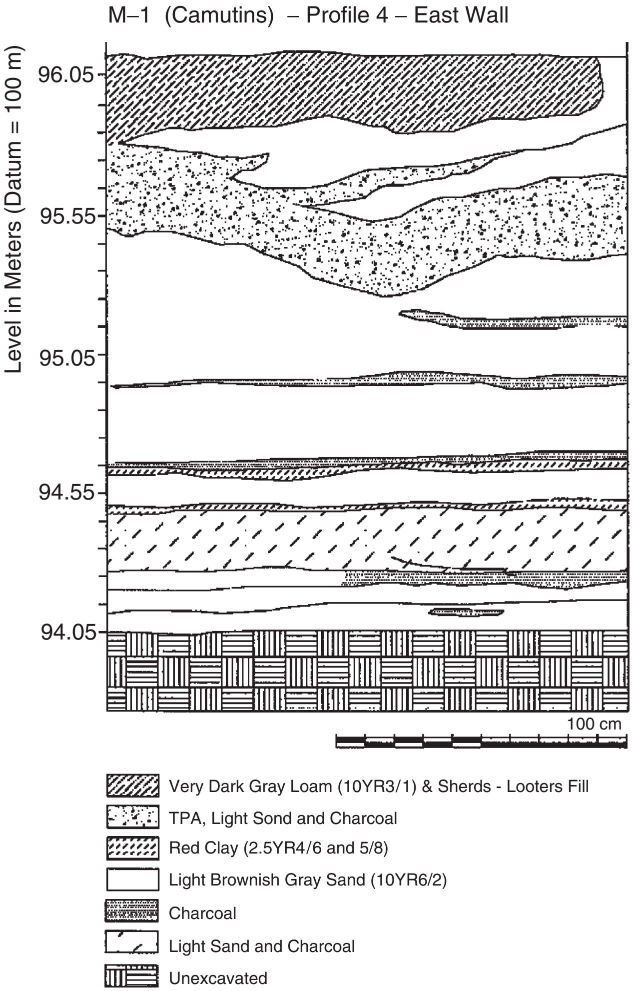

Fig. 6.9 M-1 Excavation 4 showing looters fill

combining studies of faunal and botanical remains associated with soil studies could certainly contribute significantly to our understanding of ADE formation. By now, it is suggested that the solely presence of dark earths, without investigation of archaeological structures, artifact remains, and soil chemistry is not a safe measure for demography and settlement patterns.

Given the special characteristics of Marajó Island hydromorphic soils, subjected to tide regimes and seasonal floods, analysis of Ca and Mg were handicapped. P_2O_5, however, together with manganese and zinc showed to be good indicators of human activity. Their values in both sites seem to be directly proportional to settlement size and quantity of artifacts, despite the fact that artifact amount may exhibit more variation. In the Rio Branco site, P_2O_5 levels indicate the location of garbage pit (clearly seen in the stratigraphy), while at the Leal site there seems to be a disagreement between cultural features (remains of charcoal and ceramics in excavation 6 and trench) and P_2O_5 levels; in Pit 1, where no significant features were found, P_2O_5

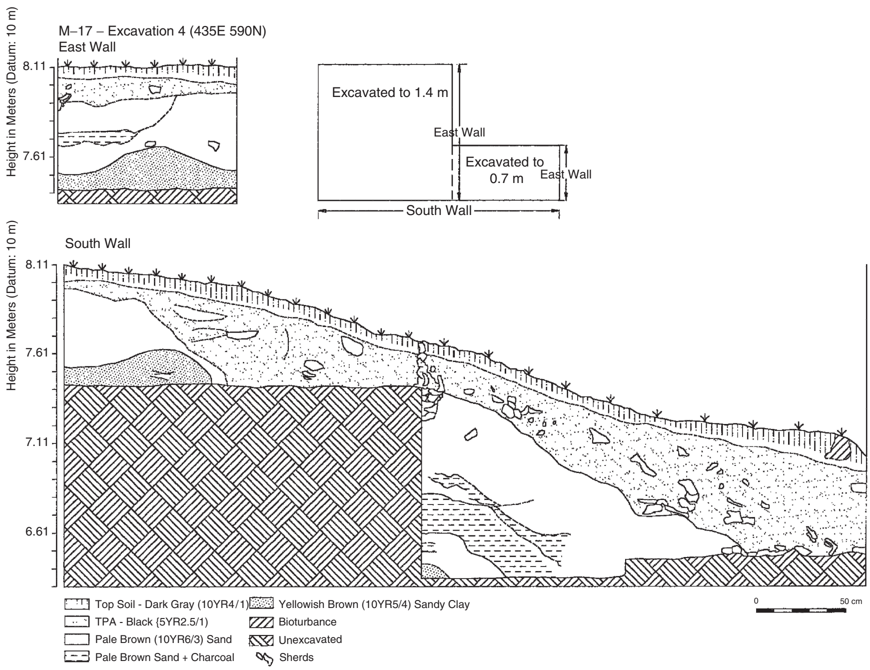

Fig. 6.10 Belém kitchen dump

levels are as high as in other areas of the site. It is likely that the population that lived at the Leal site was less integrated socially, smaller in number and more variable in terms of their discarding behavior. On the contrary, at the Rio Branco site, a larger and socially bounded population developed more intense, constant and ritualized activities.

Finally, populations that inhabited the ceremonial mounds were very concerned with cleaning their living platforms, so dark soils are only found associated to garbage dumps. Post depositional process related to disruption of burials produced very dark sediments, where human bones are assumed to have provided the organic content necessary for soil modification.

It is hoped that this research could, in some way, encourage other archaeologists to carry out geochemical studies in Amazonian archaeological sites, especially if integrated to studies of biological remains. In this way researchers could all have access to more data for comparative studies, in order to refine their methodologies and improve geochemical studies of ancient settlements.

Acknowledgements The Anajás project received financial support from several institutions during its 5 years of duration. We would like to thank to CDP-AHIMOR (Cia. Das Docas do Pará and Administração das Hidrovias da Amazônia Oriental), NSF – National Science Foundation (Grant No. 0233788), Department of Anthropology and Center for Latin American Studies, from the University of Pittsburgh, CNPq – Conselho Nacional de Desenvolvimento Científico e Tecnológico and Museu Paraense Emílio Goeldi. We wish also to thank all the participants and the technicians of the Coordenação de Ciências Humanas and Coordenação de Ecologia of the Museu Paraense Emílio Goeldi for their help and support. Chemical analysis in soil samples were performed by the Lakefield Geosol Ltd. Laboratory, in Belo Horizonte, Brasil.

References

Balée W (1989) The culture of Amazonian forests. In: Posey DA, Balée W (eds) Resource management in Amazonia: indigenous and folk strategies. Advances in Economic Botany, New York Botanical Garden, New York, 7:1–21

Ball JW, Kelsay RG (1992) Prehistoric intrasettlement land use and residual soil P levels in the upper Belize Valley, Central America. In: Killion TW (ed) Gardens of Prehistory: The Archaeology of Settlement Agriculture in Greater Mesoamerica, University of Alabama Press, Tuscaloosa, AL/London

Collins ME, Shapiro G (1987) Comparison of human influenced and natural soils at the San Luis Archaeological site, Florida. Soil Science Society of America Journal 51:171–176

DeBoer WR and Donald W. Lathrap (1979) The making and breaking of Shipibo-Conibo ceramics. In: Kramer C (ed) Ethnoarchaeology: The Implications of Ethnology for Archaeology, Columbia University Press, New York, pp 102–138

Deetz J, Dethlefsen E (1963) Soil pH as a toll in archaeological site interpretation. American Antiquity 29:242–43

Eidt RC (1985) Theoretical and practical considerations in the analysis of anthrosols. In: Archaeological Geology. Yale University Press, New Haven/London

Griffith M (1980) A pedological investigation of an archaeological site in Ontario, Canada: use of chemical data to discriminate features of the Benson site. Geoderma 25:27–34

Kern DC (1988) Caracterização pedológica de solos com Terra Preta Arqueológica na Região de Oriximiná, Pará. Dissertação de Mestrado, Universidade Federal do Rio Grande do Sul, Brazil

Kern DC (1996) Geoquímica e pedogeoquímica em sítios arqueológicos com terra preta na Floresta Nacional de Caxiuanã (Portel/PA). Tese de Doutorado, Universidade Federal do Pará

Kern DC, Kampf N (1989) Antigos assentamentos indígenas na formação de solos com Terra Preta Arqueológica na Região de Oriximiná, Pará. Revista Brasileira de Ciência do Solo 13:219–25

Kern DC, Marcondes LC, Juvenal LF, Jardim M (1999) A influência das palmeiras como fonte de elementos químicos em sítios arqueológicos com Terra Preta. Paper presented at the VI Simpósio de Geologia da Amazônia, Belém

Kern DC, d'Aquino G, Rodrigues TE, Frazão FJ, Sombroek W, Myers T, Neves E (2004) Distribution of Amazonian Dark Earths in the Brazilian Amazon. In: Glaser B, Woods WI (eds) Amazonian Dark Earths: Explorations in Space and Time. Springer, Berlin, pp 51–75

Lemos A, Santos PB (1984) Manual de descrição e coleta de solos em campo. SBCS/SNLCS, Campinhas

Manzanilla L, Barba L (1990) The study of activities in classic households. Two case studies from Coba and Teotiahuacan. Ancient Mesoamerica 1:41–49

McCann JM, Woods WI, Meyer DW (2000) Organic matter and anthrosols in Amazonia: Interpreting the amerindian legacy. Paper presented at the British Society of Soil Science Proceedings, London

Meggers BJ Danon J (1988) Identification and implications of a hiatus in the archeological sequence on Marajo Island, Brazil. Journal of Washington Academy of Sciences 78(3):245–53

Meggers BJ, Evans C (1957) Archeological Investigations at the Mouth of the Amazon Bulletin 167. U.S. Govt. Print. Off., Washington, DC, Smithsonian Institution Bureau of American Ethnology

Roosevelt AC (1991) Moundbuilders of the Amazon: Geophysical Archaeology on Marajo Island, Brazil. Academic, San Diego, CA

Roosevelt AC (1999) The development of prehistoric complex societies: Amazonia: a tropical forest. In: Bacus EA, Lecero LJ (eds) Complex Polities in the Ancient Tropical World, pp 13–33

Schaan DP (1999) Evidências para a permanência da Cultura Marajoara à época do contato europeu. Revista de Arqueologia 12–13:23–42

Schaan DP (2004) The Camutins Chiefdom: Rise and Development of Complex Societies on Marajó Island, Brazilian Amazon. Ph.D. Dissertation, University of Pittsburgh

Simões MF (1969) The Castanheira site: new evidence on the antiquity and history of the Ananatuba phase (Marajó Island, Brazil). American Antiquity 34(4):402–410

Sjoberg A (1976) P analysis of anthropic soil. Journal of Field Archaeology 3:448–454

Smith, Nigel (1980) Anthrosols and human carrying capacity in Amazonia. Annals of the American Association of Geographers 70(4):553–566

Sokoloff VP, Carter GF (1952) Time and trace metals in archaeological sites. Science 116:1–5

Sombroek WG (1966) Amazon Soils. A Reconnaissance of the Soils of the Brazilian Amazon Region. Centre for Agricultural Publication and Documentation, Wageningen

Steward JH (1948) The tropical forest tribes. In: Steward J (ed) Handbook of South American Indians. Smithsonian Institution. Bureau of American Ethnology. Bulletin 143, Washington, DC, v 3

Verwe N, Stein PH (1972) Soil chemistry of post molds and rodent burrows: identification without excavation. American Antiquity 37:245–254

Woods WI (1984) Soil Chemical Investigations in Illinois Archaeology: Two Example Studies. American Chemical Society (Advances in Chemistry Series), Washington, DC, pp 67–77

Woods WI, McCann JM (1999) The Anthropogenic Origin and Persistence of Amazonian Dark Earths. Yearbook, Conference of Latin Americanist Geographers 25:7–14