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Dark earths and the human built landscape in Amazonia: a widespread pattern of anthrosol formation

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ABSTRACT

Ancient anthrosols known as Amazonian dark earths or *terra preta* are part of the human built landscape and often represent valuable landscape capital for modern Amazonian populations in the form of fertile agricultural soils. The fertility, resilience, and large stocks of carbon in *terra preta* have inspired research on their possible role in soil fertility management and also serve as an example for a growing biochar industry it is claimed will sequester carbon for climate change mitigation. Although there is considerable scientific and public interest in *terra preta*, there is still much debate and little concrete knowledge of the specific processes and contexts of its formation. Research indicates that the formation of *terra preta* occurred mainly in midden deposits, themselves patterned around habitation areas, public areas, and routes of movement. Data from topographic mapping, soil analyses, and excavations in three regions of Amazonia demonstrate a widespread pattern of anthrosol formation in ring-shaped mounds surrounding flat terraces that extend across large areas of prehistoric settlements. It is hypothesized that there is a widespread type or types of occupation where the terraces were domestic areas (houses or yards) surrounded by refuse disposal areas in middens which built up into mounds over time, forming large deposits of *terra preta* and creating what could be called a 'middenscape'. Initial results support the hypotheses, showing the interrelationship of residential and public areas, anthrosols, routes of movement, and natural resources. The patterning of anthrosols in ancient settlements indicates the use of space and can therefore serve as a basis for comparison of community spatial organization between sites and regions.

1. Introduction

Anthrosols known as Amazonian dark earths (ADE) or *terra preta* are part of the ancient human built landscape that formed from repeated actions by individuals over time (Graham, 2006; Heckenberger, 2006; Neves and Petersen, 2006). For many modern and historic Amazonian farmers and possibly ancient ones as well, these soils represent(ed) valuable landscape capital in the form of fertile agricultural soils (Fraser and Clement, 2008; Glaser and Woods, 2004; Lehmann et al., 2003; Petersen et al., 2001; Smith, 1980; Woods et al., 2009). Their fertility and resilience not only attract local farmers but also scientists trying to learn how the rich soils were made and how knowledge about them might indicate management techniques for greater productivity and sustainability from tropical soils and ecosystems (German, 2001, 2003; Glaser, 2007). The large amount of carbon stored in *terra preta* in

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the form of charcoal and organic matter points to the potential of soil to act as a sink for atmospheric carbon, thus making it relevant to current debate on climate change (Glaser et al., 2000; Sombroek et al., 2003). Archaeological evidence, including the size and density of *terra preta* sites and other aspects of the built landscape such as extensive earthworks, is mounting that human landscapes were much more extensive and modified in Amazonia than once thought. This research is thus pertinent to the continuing debate over the extent of domesticated landscapes in Amazonia (Balée, 1989, 1994, 1998; Balée and Campbell, 1990; Balée and Erickson, 2006; Heckenberger et al., 1999, 2003; Levis et al., 2012; McMichael et al., 2012; Meggers, 1971, 2001, 2003; Roosevelt, 1991; Viveiros de Castro, 1996).

Archaeologists see *terra preta* not only as a matrix for material culture in prehistoric settlements but also as a key part of the archaeological record itself holding precious clues to past societies, environments, human landscapes, and resource management. These fertile soils formed in and around indigenous settlements from diverse actions such as the discard of organic and solid refuse, burning, and soil management for crop cultivation (Petersen et al., 2001; Schmidt, 2010a, 2010b, 2013; Schmidt and Heckenberger, 2009a, 2009b; Silva, 2003; Smith, 1980; Woods, 2003). *Terra preta* contains artifacts and features that archaeologists traditionally study along with organic remains including pollen, phytoliths, and starch grains. The soil chemistry is a legacy of the processes that formed it and a suite of laboratory analyses are able to show distinct properties of anthrosols in different contexts (Fraser et al., 2011; Kern, 1996; Rebellato et al., 2009; Schmidt, 2010a; Schmidt and Heckenberger, 2009a; Woods and McCann, 1999). Despite the importance of research on *terra preta*, we still lack a firm understanding of the specific formation processes that led to the diversity inherent in these anthrosols (Kern and Kämpf, 1989; Kern et al., 2003; Lehmann, 2009; Schmidt, 2010a, 2013; Smith, 1980).

Terra preta formed from the deposition of organic and solid materials that was patterned by the use of space within settlements (Petersen et al., 2001). The use of space and therefore the patterning of anthrosol formation may be similar or different for different cultures or groups (Erickson, 2003). Although there is evidence of terra preta of mid-Holocene age (Miller, 1992; Meggers and Miller, 2006), archaeological research indicates that there was a large increase in the development of *terra preta* in the mid 1st millennium B.C. in Amazonia (Neves et al., 2003, 2004). The deep temporality of many ancient sites led to complex archaeological records with multiple ceramic traditions and phases and complex patterns of archaeological deposits with stratigraphic layers, overlapping or intrusive features, transported sediment and artifacts, and inverted profiles. The complexity of the archaeological record challenges our ability to understand the development of anthrosols in prehistoric settlements. By examining a diversity of sites with anthrosols that formed in different contexts, including contemporary ones, we are able to understand more clearly the processes that led to their formation.

This article presents data from topographic mapping, soil analyses, and excavations to demonstrate a widespread pattern of *terra preta* formation documented in three regions. The pattern consists of curvilinear mounds of *terra preta* surrounding flat terraces that extend across large areas of prehistoric settlements. Curt Nimuendajú must have been referring to such features in the lower Tapajós region when he described over 60 years ago, "The surface of the aforementioned [*terra preta* sites] in general are not flat, but composed of a number of convex forms a few meters in diameter each, representing, probably, a number of house locations" (Nimuendajú, 1949: 104 translation). It is important to mention that this pattern of mounds does not necessarily apply to all mounds that have been studied in Amazonia. They are different, for instance, from mounds on Marajó Island that were built with sediment dug up from the surroundings along with occupational debris (Meggers and Evans, 1957; Roosevelt, 1980; Schaan, 2004, 2008). They are also different from some of the mounds documented in the Central Amazon such as the mounds that were constructed using sediment at the Antonio Galo site (Moraes, 2006, 2010; Moraes and Neves, 2012) or some of the mounds at Hatahara that appear to have been constructed with *terra preta* and layers of potsherds (Lima, 2008; Machado, 2005; Neves and Petersen, 2006; Rapp Py-Daniel, 2009).

This article describes results of research from the Upper Xingu and relates it with new data from the Central Amazon and lower Trombetas River (Fig. 1). The objective is to investigate the processes that formed archaeological sites with anthrosols and better understand the use of space and resources in ancient Amazonian settlements. The main questions are: A) How does the patterning of anthrosols reflect the use of space and how do anthrosols form in response to activity areas such as domestic areas and roads? B) Can we differentiate different types of occupation through the disposition of mounds and the formation of *terra preta*? This article aims to demonstrate the pattern and verify the following general hypotheses about the artificial topographic features: 1) the flat terraces were the locations of domestic structures or backyard activity areas, and 2) the curvilinear mounds were formed from the deposition of refuse in middens surrounding the domestic areas.

2. Material and methods

The research was carried out in the context of three existing archaeological projects in their respective study areas: 1) the Southern Amazon Ethnoarchaeology Project in the Upper Xingu directed by Michael Heckenberger of the University of Florida; 2) the Central Amazon Project directed by Eduardo Neves of the University of São Paulo; and 3) the Trombetas Project directed by Vera Guapindaia of the Museu Paraense Emílio Goeldi. Excavation methods followed those consistently used in each project (Guapindaia, 2008; Heckenberger, 2005; Neves, 2008). Excavations were carried out in 1 m^2 units with 5 or 10 cm artificial levels. The excavated sediment was dry screened for artifact and charcoal recovery. Ceramic fragments recovered from the excavations were washed, dried, counted, and weighed. Charcoal fragments were dried and weighed.

Topographic maps of archaeological sites were made using GPS and a total station. The relief was mapped over portions of several sites with data points at intervals from 50 cm to 3 m, depending on the terrain. This allowed the production of detailed contour and 3 dimensional maps of the topography. Additional mapping was carried out with handheld and precision GPS to map landscape features, to georeference maps, and to mark the locations of visible anthropic features.

Soil samples were collected by a variety of means depending on the context (see Schmidt, 2010a for detailed methods). For the results presented here, samples were collected with a trowel from the NE quadrant of each 1 m^2 unit or in a column sample collected in 5 or 10 cm levels from the profile (wall) of units. Additional samples were collected at 1 m intervals within or outside excavations using an 8 cm bucket auger to extract a core in 5 or 10 cm depth intervals up to 2 m deep. Samples were air dried and screened through 2 mm mesh in preparation for analyses that included measurements of pH in water, organic carbon (OC) using Walkley-Black modified (EMBRAPA 1997), and the elements Al, Ba, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, Sr, Ti, V, and Zn with ICP OES.

3. The Upper Xingu

Research in the Upper Xingu has revealed a complex ancient built landscape of diverse earthworks and extensive areas of

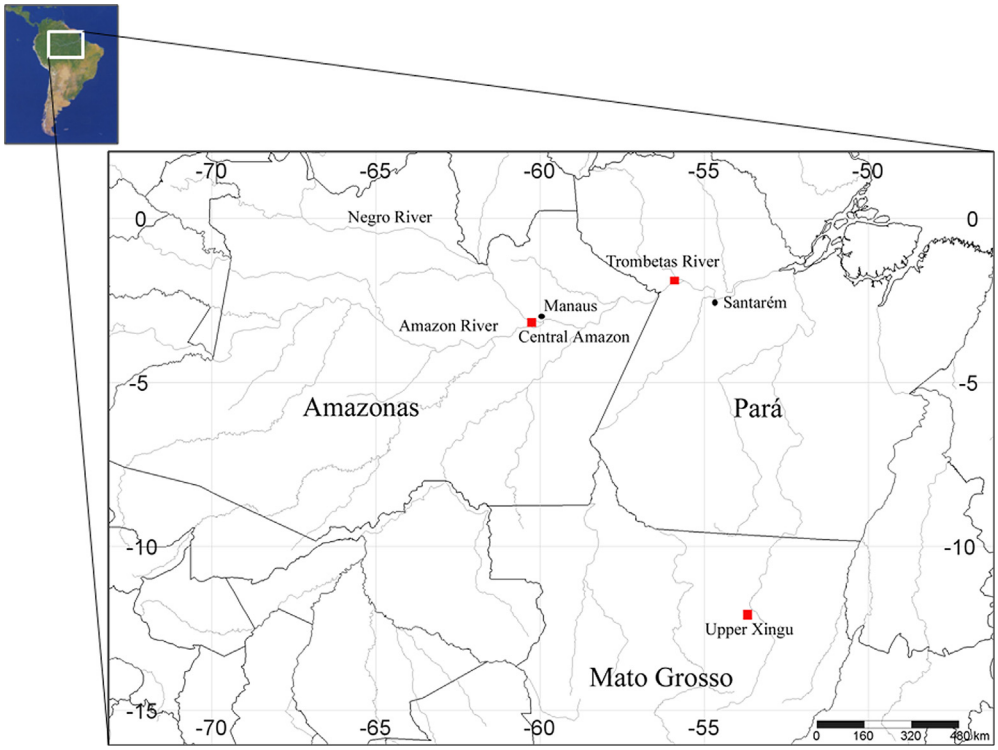

Fig. 1. Map of the Amazon Basin showing the locations of the three study areas: Upper Xingu, Central Amazon, and lower Trombetas River.

anthrosols (*terra preta*). The first archaeological studies in the region mentioned sites with large ditches, straight roads, and altered vegetation visible on aerial photos (Dole, 1961/62; Simões, 1967). Robert Carneiro mentioned these "striking archaeological remains" and hypothesized that the Upper Xingu once had "very sizable villages, strong political leadership, some degree of social stratification, considerable warfare, and extensive defensive works" (Carneiro, 1995: 64).

Research led by Michael Heckenberger incorporated archaeology, oral history, and ethnography to understand the history and pre-history of Upper Xingu society with an emphasis on basic resource use and material culture, community spatial organization, regional settlement patterns, and the ritual and political organization of the local "Xinguano" culture (Heckenberger, 1996, 1998, 2005; Heckenberger et al., 1999, 2001, 2003, 2007, 2008). This work confirmed large densely spaced settlements and showed that dense sedentary populations with complex societies existed in headwater regions such as the Upper Xingu. Heckenberger and his team mapped and characterized historic and prehistoric sites in the territory of the Kuikuro community, producing maps of roads, ditches, plazas, and other earthworks; excavations; and analyses of surface and subsurface ceramic distributions (Toney, 2012). A high-resolution GPS was used to refine settlement and regional maps as well as map a current Kuikuro village (Fig. 2).

Further research was carried out to investigate the formation of *terra preta* anthrosols in the Upper Xingu (Schmidt, 2010a, 2010b, 2013; Schmidt and Heckenberger, 2009a, 2009b). Results from the current village indicate that the darkest anthrosols, *terra preta*, are mainly formed in middens in backyard areas of dwellings. The middens typically form circular, linear, or ring-shaped mounds along backyard edges and trails. The degree of mounding follows a regular pattern that is dictated by the placement houses, backyard activity areas, and roads and trails, thinning out gradually with distance from these areas. Higher mounds form at locations between houses or at intersections of trails with backyards or with other trails. There is an absence or lowering of the mounds where trails cut through the refuse disposal area. This is shown in Fig. 2a where the black areas are trash middens and the gaps between them are trails leading out of the village.

In several prehistoric sites earthworks were mapped including ditches surrounding settlements and linear mounds around plazas and along road edges. This provided basic site configurations and transportation networks, showing relationships to natural resources and between settlements in the regional network. Other earthworks of the built landscape included raised causeways, bridges, levees, dams, reservoirs, ponds, and possible raised fields. Fig. 2b shows two of the prehistoric sites, Nokugu in the upper left and Hialugihïtï on the lower right, connected by an ancient road (Heckenberger et al., 2003). *Terra preta* is found in distinctive mounds formed from construction and maintenance activities and from refuse disposal in middens in locations that were dictated by the use of domestic and public space, much as in the current Kuikuro village (Fig. 3) (Schmidt, 2010a). Linear mounds define plazas and roads in prehistoric sites, dividing public space from residential areas. Refuse disposal in middens formed curvilinear or ring mounds surrounding houses and yards. Results of soil analyses show the distinctive characteristics of soils that underwent modifications in various activity areas (Table 1). Transects of soil samples clearly show the transition from domestic area to midden in the current village, historic village sites, and prehistoric sites (Figs. 4 and 5).

Transects across habitation areas show that soil pH, organic carbon, and a wide range of soil nutrients are elevated in domestic areas, increase on entering middens, and peak near the center or highest portion of middens. Results are presented for soil analyses along a 53 m transect in the historic Kuikuro I village (Fig. 4). From left to right the transect passes through the plaza edge, the domestic area, and finally into the mounded midden. Soil pH is lowest in the front of the house, higher in the rear, and is most elevated in the midden. Likewise, organic carbon is noticeably

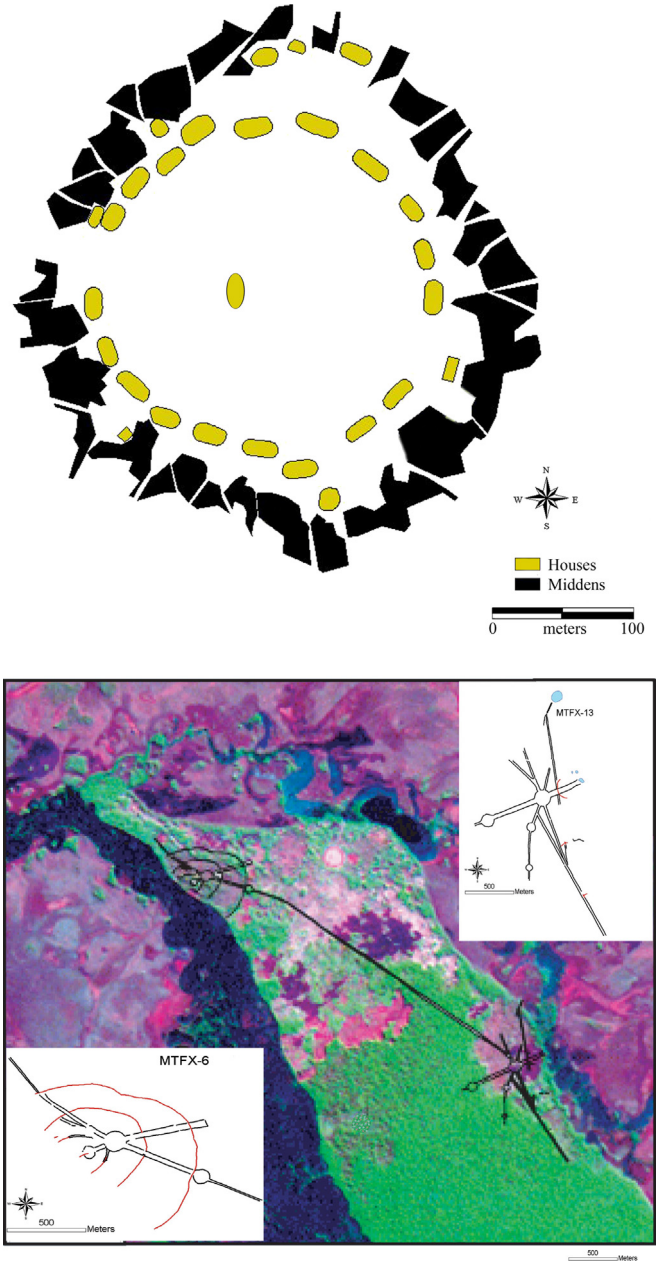

Fig. 2. Map of the current Kuikuro village (top) (adapted from Heckenberger, 2005) and Landsat image with overlying map of two prehistoric sites (MT-FX-06 Nokugu and MT-FX-13 Hialugihïtï) drawn from GPS data (bottom) (adapted from Heckenberger et al., 2003).

Fig. 3. Mounded midden at the intersection of a backyard and trail in the current Kuikuro village (top) and mound surrounding the plaza at prehistoric site Nokugu (bottom).

lower in the former house location, higher in the backyard area, and highest in the midden. Barium is slightly elevated in the backyard area and greatly elevated in the midden with other elements (Ca, Cu, Mg, Mn, P, Sr, and Zn) following the same pattern (Schmidt, 2010a). Exceptions are potassium and sodium. These two elements are elevated in the area of the house as well as in the midden.

In the prehistoric site Nokugu, a 164 m^2 block excavation was opened over the location of a hypothetical house that was likely facing the plaza in an area of level ground between the plaza mound and a mounded midden (Schmidt, 2010a; Toney, 2012). Excavations revealed a thin (~10 cm) layer of darkened soil with a few scattered artifacts except in features that probably represent a large hearth and several post molds. Excavation of the midden, on the other hand, revealed a much deeper layer of darkened soil (~40–50 cm) and an abundance of ceramic fragments. Results are presented for soil analyses along a 39 m transect that passes through a domestic area and into an adjacent midden, a context similar to that of the historic village and, in fact, results mirror those from the historic context (Fig. 5). A major difference from the historic context, however, is the presence of peaks on either side of the domestic area. The results for pH are particularly interesting with elevated values mainly in the surface level in the domestic area but in all three upper levels in the midden. Organic carbon displays a peak on the plaza side of the domestic area, lowest levels in the probable house location, and the highest peak in the mounded midden. Barium, likewise, shows this pattern with even more pronounced peaks on both the plaza side and the midden. Other elements (Ca, Cu, Mg, Mn, Na, P, and Sr) show similar patterns. These results indicate that organic refuse was disposed of around the front and rear of the house, although visible mounding was present only in the rear. This general pattern of anthrosol formation was also documented in sites in the Central Amazon and Lower Trombetas regions, i.e., flat domestic areas that have thin darkened soils with less concentrated artifacts and slightly elevated pH, organic matter and nutrient enrichment with associated mounded middens that have deeper darkened soil with more concentrated artifacts, a higher pH, and pronounced enrichment of organic matter and nutrients.

Table 1
Comparison of average soil results between activity areas in the Upper Xingu.

Area	*n*	pH	OC	Al	Ba	Ca	Cu	K	Mg	Mn	P	Sr	Zn
			g kg^{-1}		mg kg^{-1}								
Forest	26	4.0	35.0	39.1	3.9	194	3.8	147	53	117	1077	5.2	10.8
Fallow[a]	69	4.9	20.8	47.0	5.8	230	1.8	164	41	65	416	3.6	12.0
Mid-plaza[a]	44	4.6	8.2	39.6	4.0	221	1.5	105	30	41	401	2.3	13.2
Plaza[a]	59	4.8	9.0	40.5	5.1	361	5.4	137	43	60	608	3.8	16.9
House[a]	314	5.5	10.0	39.5	5.3	442	4.0	691	88	69	672	4.9	14.8
Hearth[a]	24	7.0	7.6	43.5	6.1	781	3.7	1805	196	87	707	7.3	14.7
Manioc[a]	39	6.1	11.8	31.5	5.1	403	5.1	467	105	73	700	7.5	11.6
Midden[a]	23	6.7	28.3	29.9	18.3	4197	7.0	855	455	244	3617	26.3	31.0
Midden[b]	29	5.9	27.6	36.4	20.5	2349	6.5	202	185	254	2814	20.6	21.3
Domestic[c]	232	5.7	12.4	33.3	9.3	323	4.5	107	61	126	830	8.6	10.1
Feature[c]	31	6.3	16.4	28.3	31.9	1145	10.4	79	108	139	1605	24.4	10.1
Midden[c]	42	5.9	19.3	28.8	10.7	657	5.5	191	106	204	1141	14.7	26.5

[a] Current Kuikuro Village. "Manioc" refers to a manioc processing area.
[b] Historical villages.
[c] Prehistoric site Nokugu.

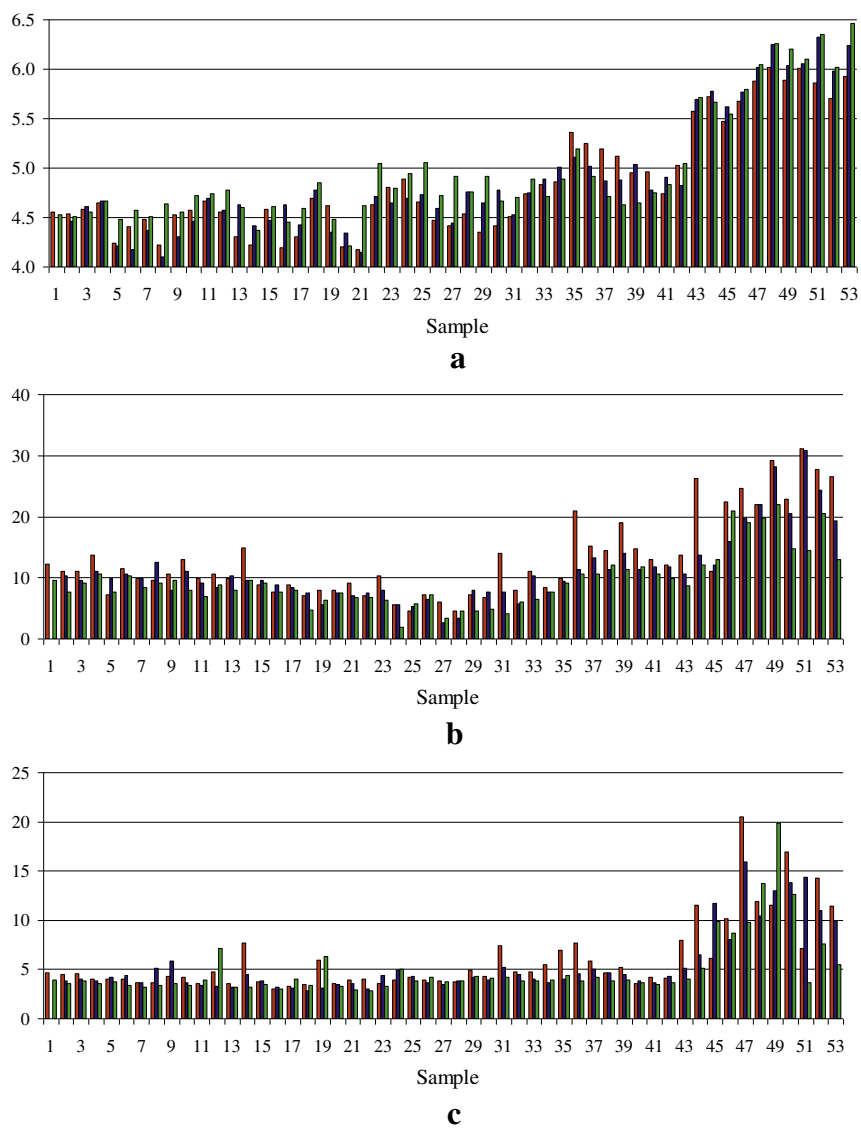

Fig. 4. Results for soil analyses from the upper 3 depth levels (0–5, 5–10, 10–20 cm) along a 53 m transect in the historic Kuikuro I village: (a) soil pH, (b) organic carbon (g kg^{-1}), (c) barium (mg kg^{-1}). The transect begins on the plaza edge (on left), passes through the house, backyard, and finally the midden (on right).

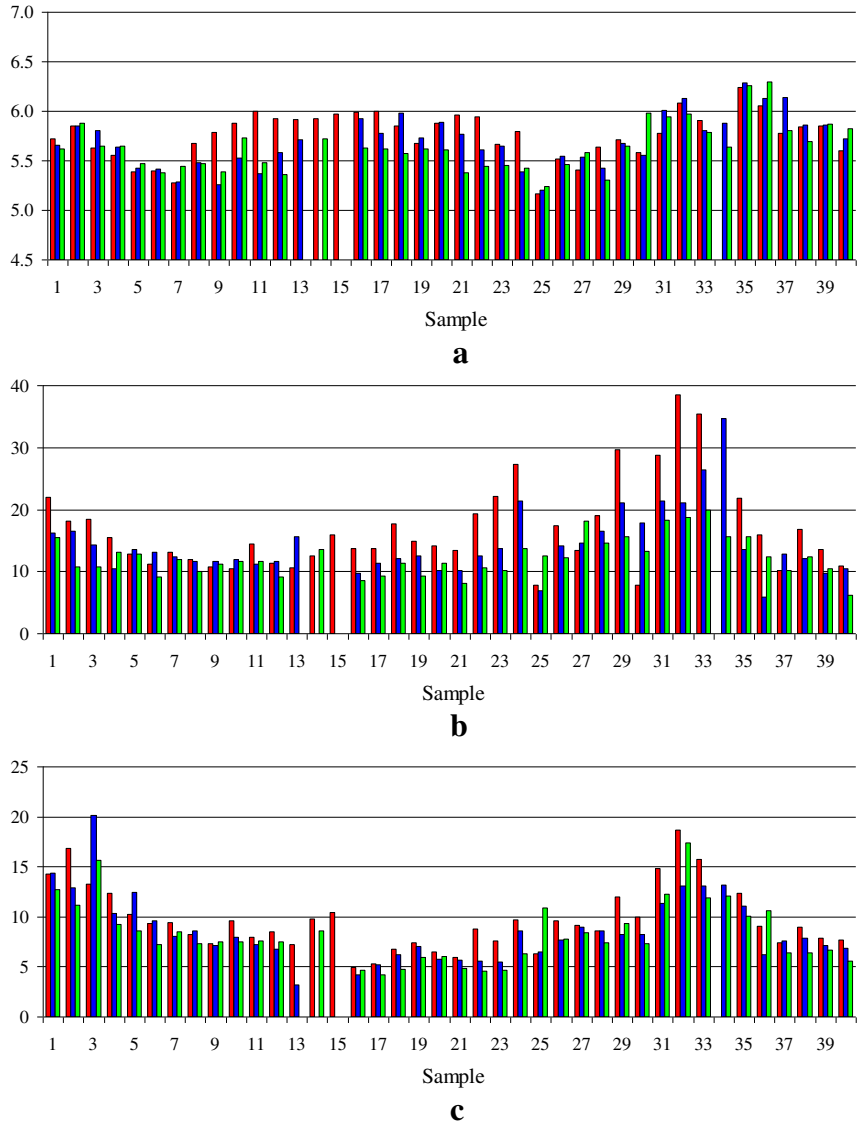

Fig. 5. Results of soil analyses from the upper 3 depth levels (0–5, 5–10, 10–20 cm) along a 39 m transect at Nokugu: (a) soil pH, (b) organic carbon (g kg^{-1}), (c) barium (mg kg^{-1}). The transect begins on the plaza side of the domestic area (on left) and passes through the probable house location and into the midden (on right).

4. The Central Amazon

The Central Amazon Project has located well over 100 archaeological sites in a study area approximately 900 km^2 near the confluence of the Solimões and Negro Rivers (Neves, 2008, 2010; Neves and Petersen, 2006). At least eight sites have been mapped and excavated. A ditch possibly for defensive purposes was located at the Açutuba archaeological site, along with mounds of *terra preta* anthrosols surrounding a possible rectangular plaza of large dimensions (approximately 450 × 100 m) (Heckenberger et al., 1999). Later studies have identified mounds of *terra preta* anthrosols in almost all of the sites that have been studied with some that show evidence of deliberate construction (Arroyo-Kalin, 2008; Castro, 2009; Donatti, 2003; Machado, 2005; Moraes, 2006, 2010; Neves et al., 2003, 2004; Petersen et al., 2001; Rapp Py-Daniel, 2009; Rebellato, 2007).

Fieldwork that focused on archaeological landscape features was initiated in 2006 at two sites investigated by the Central Amazon Project (Laguinho and Hatahara). Additional fieldwork was carried out at the nearby Caldeirão site in 2011. The three sites are located near one another on the northern bluff edge of the Solimões River floodplain or *várzea*, an ecosystem with immense aquatic resources including abundant fish and turtles. Several types of artificial landscape features have been identified and mapped including a pattern of ring-shaped mounds of *terra preta*, incised roads, and possible canals and ponds (Fig. 6) (Castro, 2009; Schmidt, 2010a, 2012a, 2012b; Schmidt et al., 2007). Possible wetland modifications observed at the three sites share similarities with artificial features documented in the Upper Xingu and likewise could have been utilized to manage aquatic resources (Heckenberger, 2005).

A recurring pattern of *terra preta* was discerned across the three sites consisting of mounds in the form of a ring or broken ring surrounding circular or semi-circular flat depressions or terraces of approximately 10–20 m in diameter. The pattern of mounds and terraces was partially mapped across large areas of the three sites using a total station and both a handheld and precision Global Positioning System (Figs. 7 and 8). The mounds separate and delineate flat circular terraces that lie, one next to another, along the crest of the bluff (for about 2 km at Laguinho and Caldeirão) and cover extensive areas of the sites further back from the bluff edge, behind the first row of terraces. While several

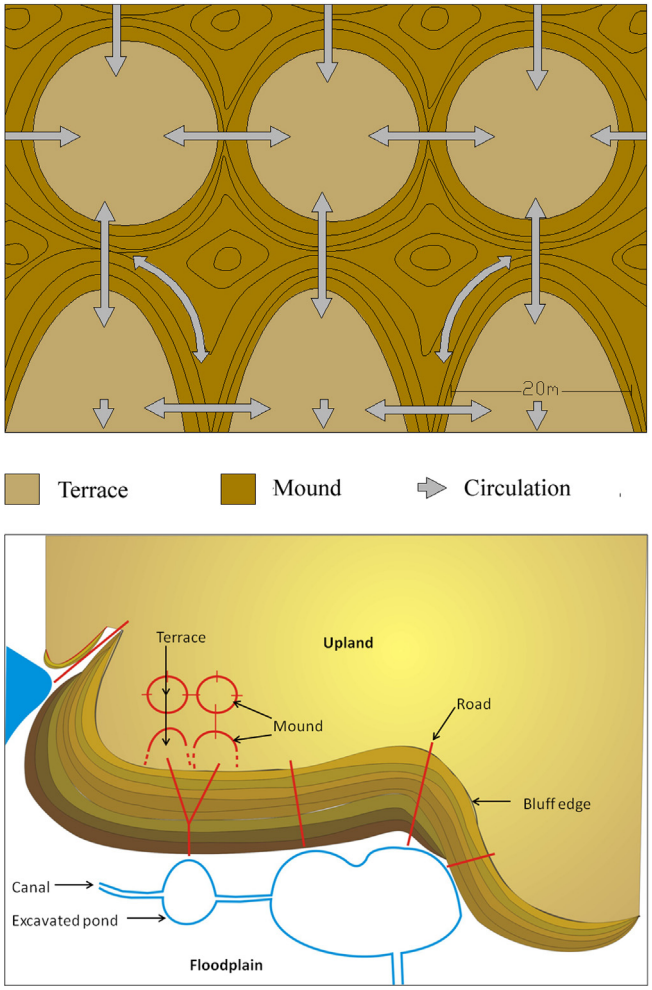

Fig. 6. Schematic representations of horseshoe and ring mounds and terraces (top) and interrelation between mounds, terraces, roads, and modified floodplain (bottom).

larger mounds that have been excavated previously at some of the sites appear to have been constructed with fill consisting of *terra preta* and layers of potsherds, the pattern of ring-shaped mounds appears to cover much of the remaining area of *terra preta* at the sites.

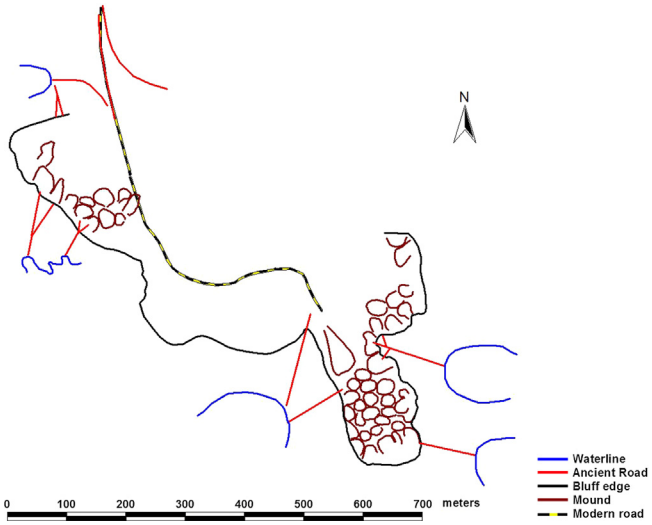

Fig. 7. Partial map of topographic features at Laguinho archaeological site.

When the terraces are on the bluff edge they are truncated by the edge and take on the aspect of terraces at different levels on the upper slope of the bluff with either an open or almost closed horseshoe-shaped mound defining the terraces. It appears that the residents dug and leveled some of terraces in sloping areas along the bluff edge. The open end of the horseshoe mound faces the bluff edge with the highest part of the mound to the inland side. Refuse was apparently thrown down slope at the bluff edge, thus not forming a mound, but forming darkened anthrosols down the length of the slope. In some cases the ring is complete, with a continuous mound along the top of the bluff edge and completely surrounding the circular terrace. The terraces are arranged side by side (with the mounds in between) along the entire length of the bluff's upper edge, with the terraces sharing the mounds in between them. This observed pattern of habitation fits with historical reports of settlements with houses lining the banks of rivers for distances of several kilometers.

The mounds regularly have depressions at the back of the terrace or the center of the "horseshoe". They also have depressions or level areas (absence or lowering of the mound) between adjacent terraces. These depressions in the mounds are interpreted to be circulation areas or trails where people passed from one terrace to another. Immediately behind or staggered behind the terraces on the bluff edge are additional rows of terraces. These are defined by ring-shaped mounds that are broken by depressions interpreted to

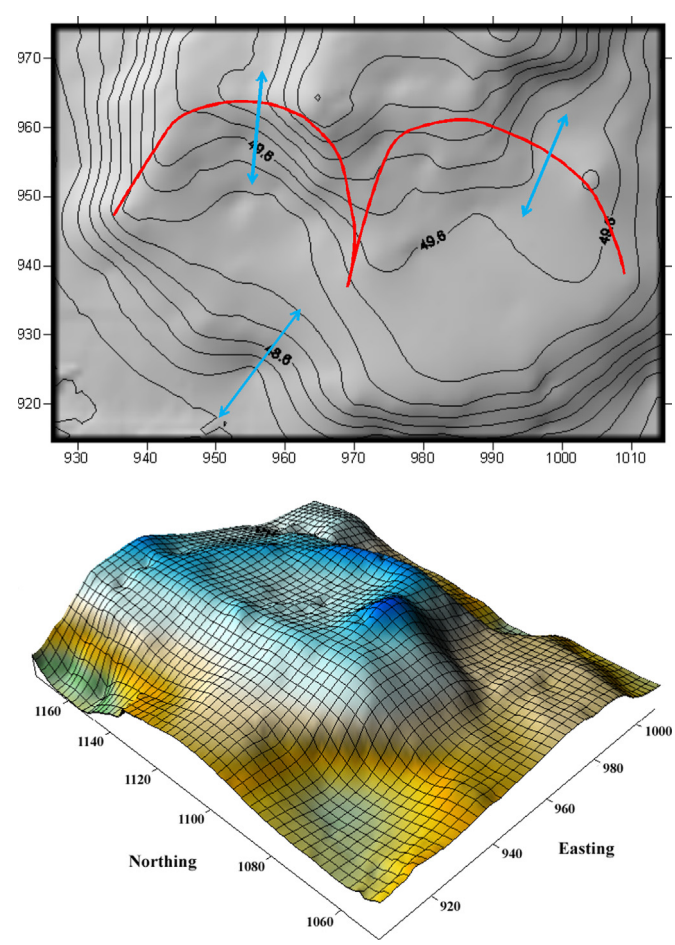

Fig. 8. Topographic map of two adjacent terrace and mound features at Laguinho (top) (thick lines are mounds, arrows are circulation areas, and thin lines are contours at 20 cm intervals) and topographic map of a large terrace and mound feature at Laguinho (bottom).

be exits or passage ways leading from one terrace to another. The terraces vary significantly in size with the ones along the bluff edge tending to be larger.

In addition to the ground elevation defining the ring-shaped mounds and the flat circular or oblong terraces, differences were also observed in the soil surface. The ring-shaped mounds have a rounded crest, darker color, more surface ceramics, visible surface erosion, an uneven or "bumpy" surface, more bioturbation, and less soil compaction. The soil surface in the terraces has a lighter color, less surface ceramics, less bioturbation, and is level and more compact.

Large linear incised depressions, interpreted to be roadways, were mapped in front of the terraces on the bluff edge that lead straight down to ports/bathing areas at the base of the bluff (Schmidt, 2012b). These incised roadways formed by rain water, wind, mechanical erosion, and mass wasting on the bare surface of a trail or road in sloping areas (DeGraff, 1980). Roads are usually found descending the bluff near the center of each terrace and sometimes exit from the center of two or three terraces and join with one another a short distance down the bluff. These features were documented at all three sites in the study and also at several other sites in the region including the Lago de Iranduba site across the lake from Laguinho, Açutuba on the Negro River as well as sites on the Urubu River. At Laguinho, the roads lead down to what appear to be circular ponds connected to one another and to the lake beyond by canals that have likely been constructed and the other two sites appear to have similar anthropogenic features. The canals and ponds extend along the base of the bluff back to the more inland areas of the site on both sides, giving canoe access from the floodplain lake to locations further from the river. Future research will document and map the wetland features and attempt to confirm their anthropogenic nature.

Hypotheses were generated for the possible use of space including living and activity areas, traffic areas, and refuse disposal areas based on the pattern of the mounds and roadways. It is proposed that the flat terraces were the locations of domestic activities in houses or yards. The mounds formed from refuse middens surrounding and between the terraces. The circulation areas are observed as depressions or flat passageways formed by foot paths connecting one terrace to another. The bluff edge is located at the open side of the horseshoe mounds with access ways in the form of linear depressions formed by paths leading down the bluff to water accesses, bathing areas, and ports on the floodplain below.

Excavations carried out at Caldeirão in 2011 gave similar results and seem to uphold the hypotheses. Namely, thin layers of darkened soil with markedly fewer artifacts and abundant features resembling hearths, post molds, and pits were found in the flat terraces while thick layers of *terra preta* with concentrated artifacts were found in the mounds surrounding the terraces (Fig. 9). Further analysis of the soil, topography, excavations, and artifacts at Caldeirão will allow a more rigorous evaluation of the hypotheses being tested.

Fig. 9. Caldeirão archaeological site showing excavations in a flat terrace (top) and a mound (bottom). The ground surface begins to rise at the far end of the block excavation (top) and reaches the crest of the mound about 10 m beyond.

5. The lower Trombetas River

The Trombetas Archaeological Project has been carried out by the Museu Paraense Emílio Goeldi in the lower Trombetas River region since 2001 (Guapindaia, 2008). Research initiated in 2006 aimed to detect anthropic landscape features in and around sites in the region. At a large site called "Terra Preta" on a floodplain lake of the lower Trombetas River, a detailed topographic survey was carried out with a total station to examine the micro-relief in three portions of the site about 1 ha each in size. The mapping detected a series of wide (10–15 m) flat terraces located (like steps) on the slope leading down to the lake's edge. Low mounds (<1 m) were observed in several points around the site and the topographic map showed that there is a circular flat area several 10's of meters in diameter surrounding each of the mounds. In the steepest portion of the bank leading down to the lake's edge, a wide (~10 m) linear depression was located that was once an access way to the beach.

Further research was carried out at three sites (Greig I, Greig II, Cipoal do Araticum) in the area of plateaus located between the Trombetas and Amazon Rivers (Guapindaia et al., 2008; Schmidt

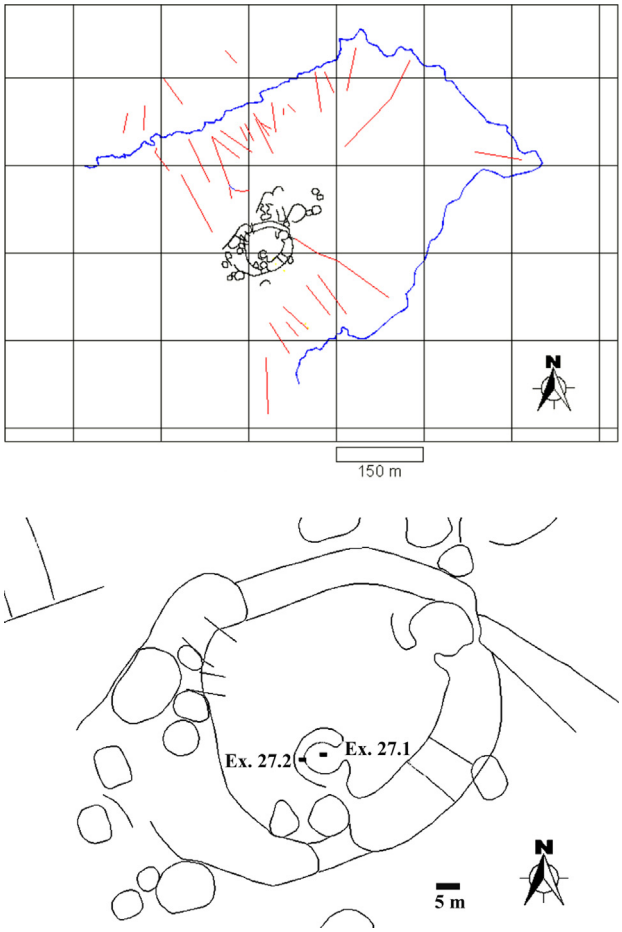

Fig. 10. Map of Cipoal do Araticum archaeological site showing mounds and incised depressions (top) (dark lines on three sides are streams) and map of topographic features in the central area of the site showing the location of Excavations 27.1 and 27.2 (bottom).

et al., 2008). Cipoal do Araticum and Greig I are large sites with deep *terra preta* (over 1 m in places) located between plateaus and adjacent to springs and streams, while Greig II is located on the top edge of a plateau. Cipoal do Araticum is located on a headland surrounded by three streams (Fig. 10). Large linear depressions, similar to those in the Central Amazon and Upper Xingu, were mapped going up and down slopes between the central area of the sites and the streams. The anthropic nature of the depressions is indicated by pairs on opposite sides of streams (crossings), depressions that traverse slopes diagonally, depressions along ridges, and depressions up and down plateaus on the straight line between two ancient sites. Furthermore, surveys were unable to locate similar features on slopes further away from ancient sites.

Shallow, flat depressions or terraces surrounded by low mounds (~40–50 cm) of *terra preta* were found at Cipoal do Araticum and Greig I that are similar to those in the Central Amazon and Upper Xingu. Several of these features were excavated to test the hypothesis that they were the locations of houses. One of these features at Greig I was located where the terrain begins a gentle slope down to a stream. The feature is an oval-shaped shallow depression like a terrace on the gentle slope. Another similar feature was located about 10 m from the first. The flat depression is surrounded by a mound approximately 20 cm high with dark soil and abundant ceramics on the surface. This contrasts with the flat center with lighter soil and few visible artifacts. A trench (26 × 2 m) was excavated bisecting the feature beginning in the center of the flat area and extending into the mound on the down slope side. A second trench (9 × 1 m) was excavated perpendicular to the first traversing the center of the terrace.

Excavations, carried out in 50 cm quadrants and 5 cm artificial levels, revealed an absence of *terra preta* soil in the flat center of the terrace. *Terra preta* began near the edge of the terrace and gradually deepened until reaching approximately 1 m depth past the edge of the terrace. Likewise, artifacts were scarce in the flat terrace and were abundant at its edge. The area of the terrace including its edge revealed frequent dark circular features (~10 cm diameter), at least some of which are likely post molds from a structure or, more likely, a palimpsest of structures. Preliminary results from soil analyses show greatly elevated levels of soil nutrients in the darker soil at the edge of the terrace. Ongoing research is being carried out with the objective to more fully understand this feature but it seems likely that an area was dug out and leveled on this gentle slope to create a terrace for a structure. During the use of this space, organic refuse along with ceramics and lithic artifacts were deposited around the structure especially on the downslope side where the deepest midden was formed.

At Cipoal do Araticum a number of these features were located and mapped. Again, excavations were carried out specifically to test the idea of the terrace/mound complexes as the locations of domestic structures and associated middens. Excavations were carried out in pairs in three locations with a unit in the terrace and on the adjacent mound. As predicted, the terraces again yielded shallow *terra preta* and fewer artifacts than the surrounding mounds. Artifacts and charcoal were much more abundant and concentrated in the mounds and artifacts, charcoal, and darkened soil extended significantly deeper. In addition, there were marked differences in soil properties with soil nutrients, organic carbon, and pH greatly elevated in mounds (Tables 2 and 3).

Excavation 27 was carried out in a circular terrace with a surrounding mound open on one end. The diameter of the inside edge of the mound is about 10 m and the diameter of the outside edge of the mound is about 20 m. Excavation 27.1 was dug near the center of the terrace and Ex. 27.2 was dug on the crest of the mound (Fig. 10, Table 2). Both units were 1 × 2 m excavated in 10 cm artificial levels. Soil samples were collected in a column from one wall of the units at 5 cm depth intervals. The difference in elevation between the two units was approximately 40 cm (this is about the same height as the mounded middens in the Kuikuro village).

Ceramics were present mainly in the surface level in Ex. 27.1 and none were found below 20 cm (Fig. 11). In Ex. 27.2, ceramics were present to 50 cm depth. The results for charcoal were similar with most fragments occurring in the 10–20 cm level and none below 40 cm in Ex. 27.1. In Ex. 27.2, charcoal fragments were most abundant in the 40–50 cm level but extended down to 1 m. Note that the ceramic distribution in the mound reaches a depth that is roughly equivalent to its height (~40 cm). Charcoal is therefore most concentrated near the base of the mound. The charcoal and dark soil extending deeper (under the mound) were likely carried downward by bioturbation and other soil forming processes. Tests of the terrace/mound features in two other locations yielded similar results, including Esc. 35 in a terrace and Esc. 36 in an adjacent mound (Table 3). Additionally, a 50-m transect across the central flat area of the site adjacent to Ex. 27 with test pits every 10 m showed a pattern of alternating high and low pH, and greater and lesser quantities of ceramics, indicating that this is a pattern that repeats itself across this area even where obvious mounded middens are not present (the last test pit was located in an obvious mound).

An extensive test pit survey of the site revealed a larger scale pattern in the distribution of *terra preta* with the deepest deposits

Table 2
Comparison of soil chemical data from excavations in a flat terrace (27.1) and an adjacent mound (27.2) at the Cipoal do Araticum site.

Depth cm	pH		OC		Ca		Cu		K		Mg		Mn		P	
	27.1	27.2	27.1	27.2	27.1	27.2	27.1	27.2	27.1	27.2	27.1	27.2	27.1	27.2	27.1	27.2
			g kg^{-1}		mg kg^{-1}											
0–5	5.1	6.0	16.4	32.9	1338	2362	nd	0.17	2.0	2.0	87.3	33.9	54.5	74.5	21.1	29.6
5–10	5.0	6.1	14.3	12.2	661	746	nd	0.29	1.3	1.0	32.0	57.7	48.7	60.4	16.1	21.4
10–15	4.9	5.7	7.1	7.9	417	670	nd	0.38	1.3	1.3	25.6	58.8	43.3	63.8	15.5	34.8
15–20	5.0	5.4	8.6	11.4	367	517	nd	0.35	1.0	0.7	21.0	57.2	44.0	51.9	13.4	33.2
20–25	5.2	5.5	10.7	14.3	353	497	0.04	0.26	1.0	0.7	15.5	56.4	35.9	65.0	15.2	38.4
25–30	4.9	5.6	7.1	17.9	158	447	nd	0.32	0.7	0.3	7.0	52.5	35.3	64.3	19.0	97.7
30–35	4.8	5.7	7.9	14.3	111	400	nd	0.43	0.3	0.3	3.5	48.9	31.4	67.9	22.3	111.7
35–40	4.8	5.8	4.3	10.7	91	203	0.05	0.44	0.3	0.3	0.0	32.5	15.7	45.0	15.6	181.5
40–45	4.8	5.7	4.3	6.4	75	171	nd	0.62	0.3	0.3	0.0	30.2	8.6	33.7	9.8	80.3
45–50	4.8	5.7	1.4	5.7	73	140	nd	0.49	0.3	0.3	0.7	25.3	5.8	21.0	6.9	66.3
50–55	5.0	5.7	2.9	5.0	80	94	nd	0.40	0.3	0.3	1.9	16.6	3.8	12.7	8.0	52.4
55–60	5.2	5.6	0.7	4.3	72	96	nd	0.70	0.3	0.3	2.3	14.4	3.6	11.0	8.4	59.3
60–65	5.2	5.5	1.4	4.3	76	86	nd	0.22	0.3	0.3	14.9	20.7	2.7	7.3	9.1	38.4
65–70	5.1	5.4	2.1	4.3	63	88	nd	0.46	0.3	0.3	4.5	15.9	2.2	5.1	9.1	55.8
70–75	5.2	5.5	0.7	4.3	55	79	nd	0.17	0.3	0.3	9.4	18.2	1.7	5.0	8.0	38.6
75–80	5.3	5.2	1.4	3.6	58	82	nd	0.17	0.3	0.3	11.3	24.9	1.1	5.7	6.2	36.3
80–85	5.3	5.1	1.4	3.6	50	64	nd	0.20	0.3	0.3	4.8	20.3	0.8	3.1	5.9	39.6
85–90	5.1	5.2	1.4	4.3	56	59	nd	0.05	0.3	0.3	8.4	17.8	0.8	1.7	6.0	31.7
90–95	5.0	5.3	1.4	1.4	46	62	nd	0.33	0.3	0.3	7.5	19.3	1.2	1.6	5.9	32.3
95–100	5.2	5.3	2.2	4.3	59	64	nd	0.19	0.3	0.3	12.5	0.0	0.7	1.1	7.4	27.7

nd = below detection limits.

occurring on the sloping ground surrounding the relatively flat terrain in the center of the site with deep deposits also occurring in the incised linear depressions believed to have been formed by roads and trails ascending and descending the slopes (Fig. 12) (Schmidt, 2012b). This indicates that the village structures were mainly located in the flat central area of the site and refuse disposal was especially intense on the surrounding slopes and in the incised depressions or roadways.

6. Discussion and conclusion

It appears that the initial hypotheses are sustained: A) the flat terraces are the locations of domestic activities (houses and yards) and B) the horseshoe and ring mounds were formed from refuse disposal in middens surrounding the terraces. These processes created a landscape of curvilinear mounds and terraces, or 'middenscape', when houses were located together within a settlement. This pattern of mounds of *terra preta* and terraces covers a large proportion of prehistoric sites in at least several regions of the Amazon Basin including the Upper Xingu, Central Amazon, and Lower Amazon. The results so far indicate that there are different types of occupations, mainly in the multi-occupational sites of the Central Amazon, but in the three areas studied and presented here there is a constant type of feature present – domestic terrace with surrounding middens – that suggests commonalities in the use of space within settlements and therefore, with further research, may indicate commonalities in cultural origins and/or interaction spheres.

Table 3
Comparison of soil chemical data from excavations in a flat terrace (35) and an adjacent mound (36) at the Cipoal do Araticum site.

Depth cm	pH		OC		Ca		Cu		K		Mg		Mn		P	
	35	36	35	36	35	36	35	36	35	36	35	36	35	36	35	36
			g kg^{-1}		mg kg^{-1}											
0–5	4.4	4.7	21.2	22.7	291	538	nd	nd	1.0	1.6	15.8	39.5	15.8	75.3	13.2	97.7
5–10	4.4	4.3	15.6	22.7	75	178	nd	nd	0.7	1.3	0.0	18.5	6.3	80.8	13.2	192.0
10–15	4.6	4.5	14.9	25.5	82	158	nd	nd	0.7	1.0	5.5	13.1	8.3	83.3	20.9	254.8
15–20	5.3	4.6	17.7	30.5	116	155	nd	nd	0.7	1.0	28.7	0.8	12.6	87.0	14.7	272.3
20–25	4.9	4.8	18.4	32.6	52	119	nd	nd	0.3	0.7	21.5	0.0	15.4	76.6	6.3	261.8
25–30	4.5	5.0	17.7	32.6	27	98	nd	nd	0.7	0.7	0.6	0.0	13.3	69.0	3.0	321.1
30–35	4.5	5.0	18.4	19.1	25	115	nd	nd	0.3	0.3	0.0	0.0	11.6	54.2	3.6	359.5
35–40	4.6	5.3	18.4	24.8	24	83	nd	0.21	0.3	0.7	0.0	0.0	8.1	41.0	7.2	394.4
40–45	4.8	5.3	15.6	26.2	29	69	nd	0.44	0.3	0.3	0.0	0.0	6.7	35.6	8.9	411.9
45–50	4.8	5.3	15.6	26.9	24	64	nd	0.66	0.3	0.3	0.0	0.0	4.7	30.1	9.1	390.9
50–55	4.8	5.2	17.0	24.1	24	54	nd	0.83	0.3	0.3	0.0	0.0	3.2	28.3	6.2	408.4
55–60	4.8	5.2	15.6	24.1	23	56	nd	0.85	0.3	0.3	0.0	0.0	2.8	30.2	5.1	464.2
60–65	4.7	5.2	15.6	22.0	20	37	nd	0.78	0.3	0.3	0.0	0.0	2.8	22.5	6.9	314.1
65–70	4.6	5.1	15.6	19.1	17	36	nd	0.56	0.3	0.3	0.0	0.0	3.0	18.4	5.6	237.4
70–75	4.7	5.2	15.6	18.4	16	34	nd	0.52	0.3	0.3	0.0	0.0	3.0	13.5	6.3	205.9
75–80	4.7	5.2	14.2	16.3	20	35	nd	0.42	0.3	0.3	0.0	0.0	1.5	13.2	4.5	181.5
80–85	4.8	5.3	14.2	17.0	18	32	nd	0.30	0.7	0.3	0.0	0.0	1.4	12.9	4.3	199.0
85–90	4.9	5.3	12.7	2.8	18	26	nd	0.14	0.3	0.3	0.0	0.0	1.4	9.6	4.4	160.6
90–95	4.9	5.2	13.5	3.0	16	26	nd	nd	0.3	0.3	0.0	0.0	1.2	8.1	3.8	122.2
95–100	4.9	5.2	9.9	2.3	16	24	nd	nd	0.3	0.3	0.0	0.0	1.3	7.1	4.9	129.1

nd = below detection limits.

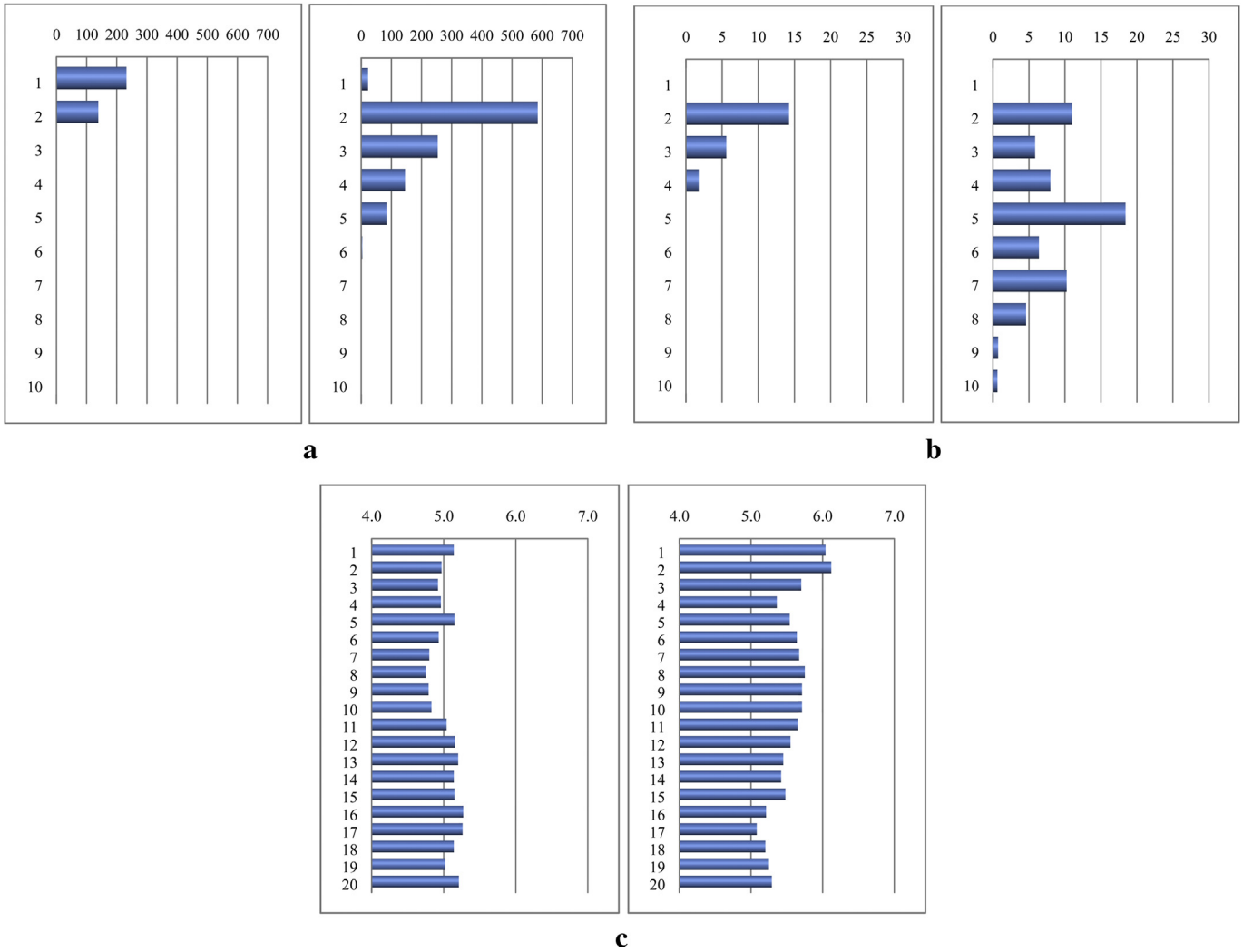

Fig. 11. Profiles from two adjacent excavation units (Ex. 27) in the flat terrace (left) and in the mound (right): (a) Ceramic fragments weight. (b) Charcoal weight. (c) Soil pH.

Domestic and public spaces, including roads and plazas, shaped (and continue to shape in the Upper Xingu) the patterns of anthrosol formation. The movement of people on roads and trails, in tandem with water and wind erosion, mechanical dislodgement of soil (from footsteps), mass wasting, and possibly maintenance activities created incised roads (large linear depressions), particularly on sloping areas in and around ancient settlements (Schmidt, 2012b). Some of the incised roads contain deep fill consisting of *terra preta* and ceramic and lithic artifacts. Thus, the eroding roadway may have served as a dumping location for refuse and/or this may have been used as a technique to ameliorate the effects of erosion (fill gullies) in the roadways in order to maintain a level surface.

The documentation and understanding of these anthropic landscape features offer a new level of detail on human use of space, movement, utilization of resources, and the formation of anthrosols in ancient Amazonian settlements and landscapes. The research presented here for three widely separated study areas indicates that this pattern of anthrosol formation is widespread in the Amazon region. Additional reports and observations from other areas of the Amazon indicate that the pattern of mounds and terraces can be found in many other areas as well. The pattern was observed at several sites near Silves where distinct terraces are found on sloping areas of sites (M. Schmidt, field notes, 2010) and on the Lower Urubu River (H.P. Lima, field notes, 2012), both in the Middle Amazon near the city of Itacoatiara in Amazonas State. The pattern was also observed at a site in Rondonia State in the southwestern Amazon (Dirse C. Kern, personal communication, 2012) as well as at Gurupá in the Lower Amazon near the mouth of the Xingu River (M. Schmidt, field notes, 2013).

More detailed studies of the terraces and routes of movement could delineate clusters of related terraces that might, for instance, represent family compounds, leading to a deeper understanding of past social organization. Careful excavations need to be carried out in different contexts to elucidate the pattern of mounds and terraces, study activity areas, and collect material for dating to determine if terraces in different areas of the sites are contemporaneous. This could conceivably allow for improved estimations of populations in ancient settlements.

Detailed studies could also refine knowledge on the formation processes and uses of anthrosols. For example, if the hypotheses are correct and if adjacent terraces were contemporaneously occupied, the space on the mounds/middens between the houses would have been limited, with implications for the activities that occurred on top of the middens. Both domestic activities and cultivation could have been carried out on top of middens within the settlement, as occur today in Xinguano villages (Schmidt, 2010a). A clue to the

Fig. 12. A linear incised roadway at the Caldeirão site (top) and an excavation on the edge of a roadway at the Cipoal do Araticum site (bottom).

possible use of middens for cultivation are the size of potsherds found in the sub-surface of mounds where large ceramic fragments indicate that they were deposited in middens that were not cultivated or, alternatively, incorporated into mounds that were constructed, likely using fill and potsherds from other middens. On the other hand, highly fragmented ceramic sherds found in the upper 20 cm of *terra preta* at some sites may be an indication of post-abandonment cultivation.

According to Tim Ingold's 'dwelling perspective', "the landscape is constituted as an enduring record of – and testimony to – the lives and works of past generations" (Ingold, 1993: 152). Landscapes are constructed by individuals and societies through their economic, social, and ritual activities. Each of us perceive the landscape according to our knowledge of places and events in that landscape as well as our cultural biases. As Ingold puts it, "the landscape tells – or rather is – a story". Thus, the dwelling perspective of a long-term resident imbues a landscape with greater meaning than it would for someone new to the area or just passing through. People who modified landscapes over time were also changed themselves by the landscape they modified, in other words, landscapes and cultures co-evolved (Neves and Petersen, 2006).

We propose that, like the conclusions drawn by Sheets (2009) that the incised roads uncovered in Costa Rica eventually assumed symbolic meaning or monumentality, the formation of anthropic landscape features at the sites studied were part of a landscape esthetic, in other words, a consistent idea of what was beautiful and orderly in the village environs or 'villagescape' (sensu Fowles, 2009; also see Heckenberger, 2005). Related to this idea is the idea that the mounds may have served a function of displaying social status with higher status families having larger mounds because of the greater amount of refuse they produced which reflected the larger available labor force they controlled (Heckenberger, 2005; Heckenberger et al., 1999; Toney, 2012). This esthetic of the villagescape consisted of circular or ovoid terraces that were the living spaces, divided or delineated by curvilinear mounds, connected to one another by paths, often forming depressions. Flat roads on level areas or incised roads on slopes led, in many cases, to landscaped streams and wetlands often consisting of artificial ponds and canals. The landscape became imbedded within the consciousness of the people who created and lived in it. Just as "material culture shapes the manner in which people act, perceive and think" (Malafouris and Renfrew, 2010: 1), the landscape shaped how people act, perceive and think. It is worth examining, in future research, how elements of the landscape might be depicted, consciously or unconsciously, in art and symbolism such as representations and motifs inscribed in ceramics or in the landscape itself as rock art.

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