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

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A B S T R A C T

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