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Research paper

Fertility and desorption capacity of Anthrosols (Archaeological Dark Earth - ADE) in the Amazon: The role of the ceramic fragments (sherds)

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A B S T R A C T

Numerous patches of black soil can be found throughout the Amazon basin, primarily along the margins of rivers. This type of soil is known as Archaeological Dark Earth (ADE) and is formed as a result of prehistoric human occupation and classified as Anthrosols. The chemical characteristics of ADE are distinct from those of the region's predominant soils, making them popular with local subsistence farmers. The patches of ADE are characterized by an abundance of ceramic fragments (sherds) (CF) both on the surface of the patches and within their inner depths. Considering that these sherds are generally composed of quartz, metakaolinite, feldspars, non-plastic materials, often with high levels of aluminum phosphates, the present study focused on their potential contribution to maintenance to the fertility of ADE soils, under the conditions of tropical weathering. With this aim, the mineralogical composition of the sherds was obtained using X-ray diffraction with the support of SEM-EDS readings. In addition, some parameters of fertility were measured as well as phosphates dissolution in the presence of citric acid as a function of time. The nutrients and micronutrients were determined by atomic absorption spectrometry and the molybdenum blue method. The results showed that the fragments analyzed were composed of quartz, feldspars, metakaolinite, micas/illites, and anatase, but differ in the presence/absence of chlorites, talc, cristobalite, and calcites. This study characterized the sherds as highly fertile and provides experimental confirmation that the sherds release phosphor under conditions approximating the natural weathering environment, which indicates that they are an important potential source of nutrients.

1. Introduction

Ceramic fragments (sherds) in general abundant in the horizons of soils of the Archaeological Dark Earth (ADE) are the principal evidence that these soils are related to the prehistoric and pre-colonial occupation of the Amazon basin by Amerindians (Birk et al., 2011; Costa et al., 2004b, 2011a; Glaser and Birk, 2012; Grossman et al., 2010; Novotny et al., 2009) and were classified as Arqueo-Anthrosols (Kämpf and Kern, 2005). The ADE soils were formed following the dumping of ceramic utensils, which either arrived as fragments, or were broken on site. The sherds represent parts of domestic utensils produced in clay with subsequent calcinations, and used primarily for the processing, cooking, and storing of food (Allegretta et al., 2014; Bernedo and Latini, 2013; Machado, 2006). Until recently, studies of these sherds concentrated on their technical and morphological aspects, with the principal aim of identifying technological traits through which the manufacturing culture could be interpreted.

Mineralogical and geochemical studies have provided increasingly important contributions to the field of archaeology and these studies have been successfully applied for investigation of the sherds found in the ADE soils (Cano et al., 2014; Costa et al., 2004b, 2011a,b; Nunes et al., 2013). The data available on the mineralogy and chemical composition of these sherds reveal a predominance of SiO_2 and Al_2O_3, besides the low contents of Fe_2O_3 and TiO_2 which are consistent with high concentrations of metakaolinite and quartz, and hematite/goethite and anatase, as accessory minerals; additionally low variable contents of K, Mg and Ca, among others, may represent feldspars, micas, feldspars, etc. (Costa et al., 2004b, 2011a,b). In general the most prominent characteristic of these sherds from ADE sites is the presence of P_2O_5 at levels of between 0.5% and 12% (Costa et al., 2004b, 2011a,b). However, this P_2O_5 signature is not homogeneous, and only the sherds from the coast of the Brazilian state of Pará examined by (Costa et al., 2004b, 2011a,b) presented micro- and crypto-crystals of crandallite-goyazite, whereas all other samples phosphor should be X-ray diffraction (XRD)-amorphous aluminum phosphates, and, more rarely, variscite, variscite-strengite and crandallite (Costa et al., 2004b, 2011a,b; Rodrigues et al., 2015).

The ADE soils are renowned for its relatively high fertility, which contrasts considerably with the typically poor soils found throughout

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most of the Amazon basin. This makes ADE an important resource for local agriculture, which is normally of the subsistence type in this region. The nutrient charge of these soils apparently remains unaffected, even after continuous cultivation, which demands an uninterrupted source of nutrients to replace those eliminated by continuous crops and the organisms growing on the soil and erosion/leaching. The identification of this source of nutrients is obviously of the highest priority since it will contribute to understand how we can improve the poor fertility of the Amazon soils. From the geological and pedological viewpoint, the rocks that are the principal source of these nutrients are absent from the A horizons of ADE soils; the ceramic fragments (CF) are the only material that can compared to rock or weathering rocks which are generally present in large quantities in the ADE soil profiles. Since these CF could play an important role in the chemistry and mineralogy of these soils the present study will experimentally demonstrate the potential capacity of the CF to release some of the essential nutrient for the plants, like phosphorus.

2. Materials and methods

2.1. Materials

The sherds analyzed (44 samples) in the present study were obtained from four distinct archaeological sites in the Amazon: Barcarena (1° 33′ 56″ S/48° 44′ 28″ O), Raimundo at Caxiuanã (1° 45′ 36″ S/51° 26′ 34.3″ O), Juruti (Terra Preta 1: 2° 10′ 1.68″ S/56° 5′ 57.58″ O and Terra Preta 2: 2° 10′ 36.86″ S/56° 6′ 17.05″ O), in Brazil, and Quebrada Tacana at Letícia (4° 7′ 9.1″ S/69° 55′ 16.1″ O), in Colombia (Fig. 1). The sherds correspond to the horizon (0–60 cm) of an ADE. Some characteristics of the sherds are listed in Table 1.

2.2. Methods

2.2.1. Mineralogical analysis

The mineralogical composition of the sherds was determined using a PANalytical X'PERT PROMPD (PW 3040/60) X-ray diffractometer (XRD) with a PW3050/60 (θ/θ) goniometer, ceramic X-ray tube, and a cobalt anode ($\lambda CoK\alpha 1 = 1.79026$ Å), except for the sherds from the Raimundo site, for which a copper anode ($\lambda CuK\alpha 1 = 1.54060$ Å) was used. The instrumental conditions used were: scan of 5–75° at 2θ, voltage of 40 kV and current of 40 mA, pass of 0.0170 at 2θ, and 10.3377 s per pass. These analyses were conducted in the UFPA Mineral Characterization Laboratory. The mineralogical studies were also supported by scanning electron microscopy (SEM), using a LEO VP 1450 microscope, with an energy-dispersive X-ray spectrometry system (SED) for chemical microanalyses in the UFPA MEV Laboratory. The images and chemical analyses obtained here contributed to the finalization of the identification of the minerals by XRD, as well as improving the identification of amorphous phases, such as the phosphates. The samples were metalized with Au at a pressure of 3×10^{-1} bar and current of 25 mA.

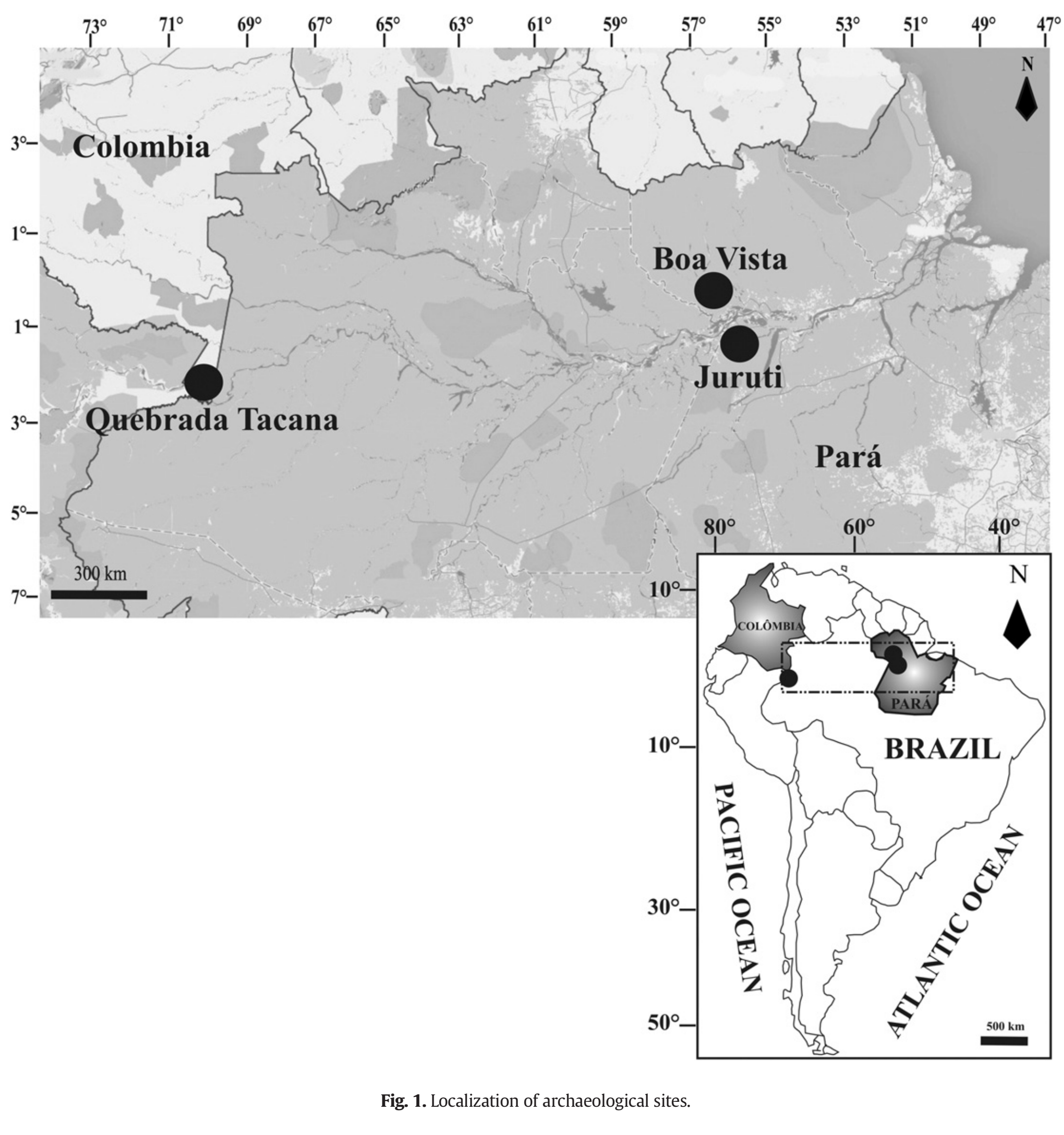

Fig. 1. Localization of archaeological sites.