TECHNOGENIC SEDIMENTS IN ALLUVIAL PLAIN IN PRESIDENTE PRUDENTE-SP[1]

SEDIMENTOS TECNOGÊNICOS EM PLANÍCIE ALUVIAL EM PRESIDENTE PRUDENTE-SP

SEDIMENTOS TECNOGÉNICOS EN LLANURA ALUVIAL EN PRESIDENTE PRUDENTE-SP

Érika Cristina Nesta Silva – Universidade Estadual Paulista Júlio de Mesquita Filho – Presidente Prudente – São Paulo – Brasil
erikanesta@yahoo.com.br

João Osvaldo Rodrigues Nunes – Universidade Estadual Paulista Júlio de Mesquita Filho – Presidente Prudente – São Paulo – Brasil
joaosvaldo@fct.unesp.br

Abstract

Technogenic depositions present different characteristics according to the places where they are formed. This article presents relevant contributions to interpretation of technogenic sedimentary materials, specifically in sand fraction (between 0,053mm and 2mm), studied in an alluvial plain in the city of Presidente Prudente-SP. Aiming to recognize the materials present in the depositions and relate them to their likely sources, it was accomplished sample collection, visual identification of the materials in the samplers, granulometric analysis, fractioning of the sand fraction and light microscopy. As a result, it was recognized the presence of fragments of burnings, plastic, building material and carbonate nodules. These materials were related to the track record of use and occupation of the land, and it was observed difficulties to recognize some of these materials as manufactured due to the visual similarity with fragments of the local rocky basis (sandstone of Adamantina Formation, Bauru Group). It was concluded that the presence of charcoal fragments in deep layers are related to burnings accomplished during the first phases of agricultural expansion in the region and the manufactured materials come from the allotment area and from the former domestic solid waste deposit.
Keywords: Technogenic deposits, manufactured materials, Adamantina Formation, use and occupation of land.

Resumo

As deposições tecnogênicas apresentam características diferentes conforme o local onde são formadas. Este artigo apresenta contribuições relevantes quanto à interpretação dos materiais sedimentares tecnogênicos, especialmente na fração areia (entre 0,053mm e 2mm), estudados numa área de planície aluvial de Presidente Prudente-SP. Com o objetivo de reconhecer os materiais presentes nas deposições e relacioná-los às prováveis fontes, realizou-se a coleta de amostras, identificação visual dos materiais nos amostradores, análises granulométricas, fracionamentos da fração areia e microscopia ótica. Conforme esses procedimentos, reconheceu-se a presença de fragmentos de queimadas, plásticos, materiais de construção e nódulo carbonático. Relacionou-se esses materiais com o histórico de uso e ocupação e observou-se as dificuldades de identificação de alguns desses materiais enquanto manufaturados, visto a semelhança visual com fragmentos do embasamento rochoso local (arenitos da Formação Adamantina, Grupo Bauru). Conclui-se que a presença de fragmentos de carvão em camadas profundas se relaciona às queimadas realizadas durante as primeiras fases de expansão agrícola na região e os materiais manufaturados originam-se da área

do loteamento e do antigo depósito de resíduos sólidos domésticos.
Palavras-chave: Depósitos tecnogênicos, materiais manufaturados, Formação Adamantina, uso e ocupação da terra.

Resumen

Las deposiciones tecnogénicas presentan características diferentes según el lugar donde se forman. Este artículo presenta contribuciones relevantes en cuanto a la interpretación de los materiales sedimentares tecnogénicos, especialmente en la fracción arena (entre 0,053mm y 2mm), estudiados en un área de llanura aluvial de Presidente Prudente-SP. Para reconocer los materiales presentes en las deposiciones y relacionarlos a las probables fuentes, se realizó la recolección de muestras, identificación visual de los materiales en los muestreadores, análisis granulométricos, fraccionamientos de la fracción arena y microscopía óptica. Con eso, se reconoció la presencia de fragmentos de quemas, plásticos, materiales de construcción y nódulo carbonatico. Se relacionó esos materiales con el histórico de uso y ocupación y se observaron las dificultades de reconocimiento de algunos de esos materiales en cuanto manufacturados, pese la semejanza visual con fragmentos del basamento rocoso local (arenisca de la Formación Adamantina, Grupo Bauru). Se concluye que la presencia de fragmentos de carbón en capas profundas se relaciona con las quemas realizadas durante las primeras fases de expansión agrícola en la región y los materiales manufacturados se originan del área de la asignación y del antiguo depósito de residuos sólidos domésticos.
Palabras clave: Depósitos tecnogénicos, materiales manufacturados, Formación Adamantina, uso y ocupación de la tierra.

Introduction

Technogenic depositions are found in urban and rural environments, defined as depositions formed from human action. Chemekov (1983) mentions the characteristics of these depositions, namely: diversity of means of formation; a variety of thickness and composition; high sedimentation rates and rapid changes in its characteristics. These depositions are increasingly frequent, due to the innumerable changes caused by society in the natural aspects of the landscapes, which allow direct and indirect depositions, located in overlapping and/or substitution to the soils, rocks, and sediments of natural origin.

It is recognized that in addition to the identification of the presence of technogenic depositions, an in-depth study of the materials present in these formations, even those not perceivable at first sight, is necessary. Thus, it is accepted that the highly fractioned technogenic materials, such as fragments of building materials, start to incorporate the sediments in granulometry corresponding to the sand fraction (between 0.053 mm and 2 mm), and that these materials can be related to the aspects of land use and occupation.

The recognition of the presence of technogenic depositions has occurred frequently in several works, such as those of Oliveira (1990),

Peloggia (1996), Nolasco (2002), Korb (2006), Silva (2009, 2012, 2017) and França Junior (2016). Peloggia et al. (2014), when approaching the technogenic theme, they present a classification proposal for the types of technogenic ground, dividing them into four categories: Aggraded Technogenic Ground; Degraded Technogenic Ground; Modified Technogenic Grounds and Mixed Technogenic Grounds. In the Aggraded and the Mixed Technogenic Grounds, there is the presence of technogenic deposits, altering aspects of the morphology and morphometry of the original landform, such as alluvial plains overlain with sediments of technogenic origin.

It should be noted that the changes caused by societies in the superficial structure of landscapes are mentioned before these works. In international literature, the works of Marsh (1867), Sherlock (1922) and Nir (1983), who consider the influences of society on the natural aspects of landscapes. Sherlock (1992) mentions the human being as geological agent and Nir (1983), as a geomorphological agent. Still in the perspective of the consideration of human actions as triggers of environmental changes, James (2013), works with Legancy Sediments, that is, sediments that bear evidence of these changes. Among the classifications of technogenic depositions most used in Brazil is that of Oliveira (1990). According to this researcher, these depositions can be: *constructed*, as in landfills and disposal areas; the *induced* ones, exemplified by the depositions resulting from silting and modern alluviums (exclusively for the cases in which society actions were deflagrant of the depositional process), and *modified*, in the case of the presence of natural deposits altered technogenically by effluents, fertilizers and others.With regard to induced depositions, it is worth mentioning that they arise from the alteration in the processes and the physical characteristics of areas upstream of deposition sites, such as the removal of vegetation cover, causing changes in hydrodynamic and erosive processes.

Peloggia (1996), on the other hand, classifies the technogenic depositions from the present material, adapting the proposal of Fanning and Fanning (1989): *urbic* materials, composed of earthly materials with artifacts manufactured by modern man (brick, nails, plastics, asphalt, glass and other), *garbic* materials, which correspond to debris rich in organic matter (such as organic waste), *spolic* materials, described as

excavated and redeposited earth materials, and *dredged* materials, which are the earth materials from dredging operations .

In the city of Presidente Prudente - SP, during the studies of Silva (2009, 2012, 2017) formations were identified of technogenic deposits located in the areas at the bottom of the valley, classified as constructed and induced, according to Oliveira (1990). These formations were related to the historical aspects of the use and occupation of the places, with consequent changes in factors and natural processes in the landscapes, resulting from the actions of the society.

The focus of the present article is the demonstration of the compositional characteristics of natural and social origins in samples of technogenic sedimentary depositions in the Vila Nova Prudente alluvial plain, in Presidente Prudente (Figure 1), regarding, in particular, the sand fraction fragments with granulometry between 0.053 mm and 2 mm). For the recognition of the technogenic materials present in the sediments, samples were collected in the plain area and physical and visual analysis of the materials present in the deposition layers were identified in these samples.The granulometric analysis followed the procedures described in EMBRAPA (1997), in addition to the sand fractionation with sieves referring to the Wentworth scale (1927, apud Suguio, 1973) and visualization of the materials in stereomicroscope (OPTON, model TIM - 30) and optical microscope (optical microscope Zeiss Discovery.V12 with AxioCam 5 camera; Zeiss AxioVision Software Rel. 4.8.2 - SP2.). The study of granulometry in samples of technogenic deposits is present in works such as Silva (2009, 2012) and the observation of materials present in the technogenic sediments in stereomicroscope, in the work of Dias (2015).

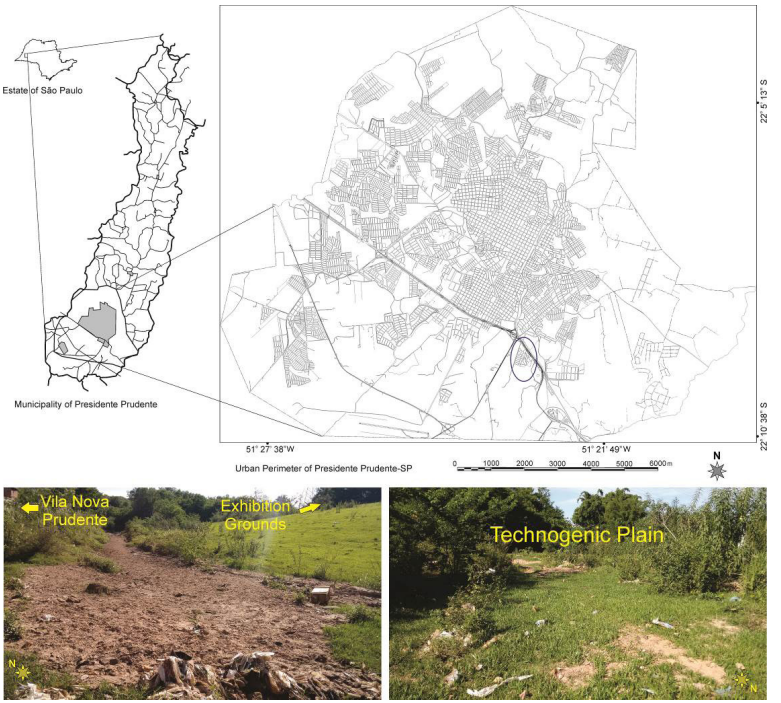


Figure 1 - Location of Vila Nova Prudente in Presidente Prudente, SP, Brazil, and photographs of the area of the Technogenic Plain in 2014.

Source: Adapted of Silva (2017).

Identification of physical characteristics in selected samples

Vila Nova Prudente is located in the southern sector of the urban perimeter of Presidente Prudente, in the watershed area of the Santo Anastácio river. Access to the district is via Raposo Tavares Highway (SP-270), through the hill-topped division where the main watershed of the city of Presidente Prudente is located, between the hydrographic basins of the rivers Rio Santo Anastácio and Rio do Peixe. Both basins are located in the Paraná Hydrographic Region, which covers most of the area of the states of São Paulo and Paraná, extending through the states of Mato Grosso do Sul, Minas Gerais, Goiás, Santa Catarina, and

the Federal District (Agência Nacional das Águas, 2015). The landform division identified as an alluvial plain in Vila Nova Prudente was named by Silva (2012, 2017) as a technogenic plain, a term first used by Peloggia (1996), because the present sedimentation processes are intensified by the action of society throughout the historical process of use and occupation in the area of the plain itself and its surroundings. According to the classification proposed by Peloggia et al. (2014), the area of the technogenic plain fits with the Aggraded Technogenic Ground, due to the presence of technogenic deposition.

As delivered by Silva (2012, 2017) through literature and by viewing aerial photographs of different periods, the neighborhood underwent changes in soil cover primarily related to the agricultural use and, from the 1960s, as a result of the installation of the subdivision (Sposito, 1990) in sloped sectors and tops of the broad hills, which characterize, in a general way, the geomorphology of the urban area of Presidente Prudente (Nunes; Freire; Perez, 2006).

In addition, the deposition of domestic solid waste (urbic and garbic materials) occurred in an area adjacent to the subdivision during the 1980s (Mazzini, 1997), in an area with erosive features near a spring whose watercourse is directed to the area of the studied technogenic plain. Figure 2 represents the landform of the site, as well as the location of the old solid waste disposal area, which was grounded and later, according to information from Mazzini (1997), on the site, was installed the parking lot of the Exhibition Grounds of the city.

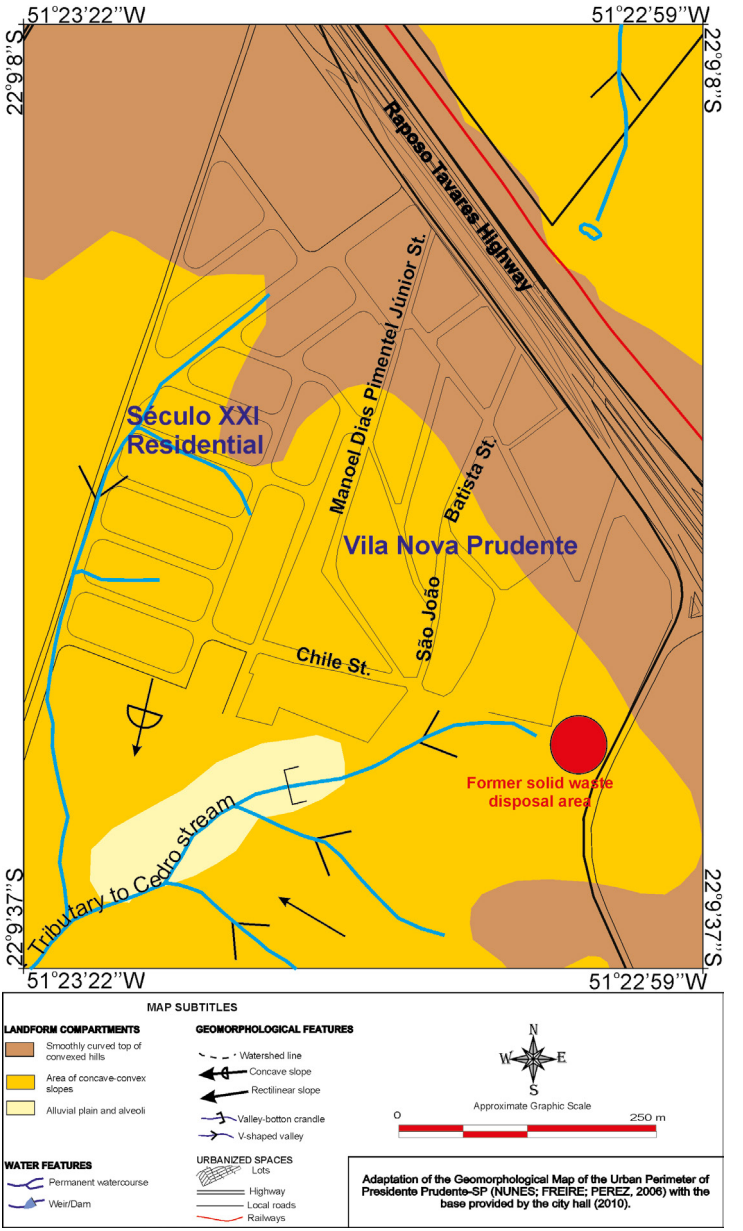


Figure 2 - Geomorphological map of Vila Nova Prudente and its surroundings

Source: Adapted of Silva (2017).

Collection of the technogenic deposition samples was performed for the purpose of recognizing the sedimentary layers and materials present, by visualizing the physical characteristics of the samples after opening the samplers in the annex "Júlio de Mesquita Filho" of the School of Technology and Sciences at the São Paulo State University (FCT / UNESP) in Presidente Prudente. In the laboratory, each of the 14 samples collected with three-inch iron tubes that percussively penetrated the surface underwent visual analysis for recognition of deposition layers and their general characteristics, such as color, apparent texture and present materials, manufactured and natural materials. After this initial stage, the sedimentary layers underwent granulometric analysis, according to EMBRAPA (1997), for the establishment of the percentages of the sand, silt, and clay fractions, whose values were transposed to the Soil Textural Triangle proposed by the United States Department of Agriculture (USDA, 1951), present in Lemos and Santos (1996), identifying corresponding textures.

Figures 3, 4 and 5 refer to three of the samples collected, respectively number 1 and 3 of the first fieldwork (09/06/2014) and number 3 of the second fieldwork (28/08/2014), and their respective textural classifications by layer and present materials. In order to facilitate the visualization of the color and material differences present in the sedimentary layers, the Figures present sketches of the collected samples, from the adaptation of the sketches presented by Korb (2006).

Profile 1: Sample number 1 (first collection) of Vila Nova Prudente Layers' textures

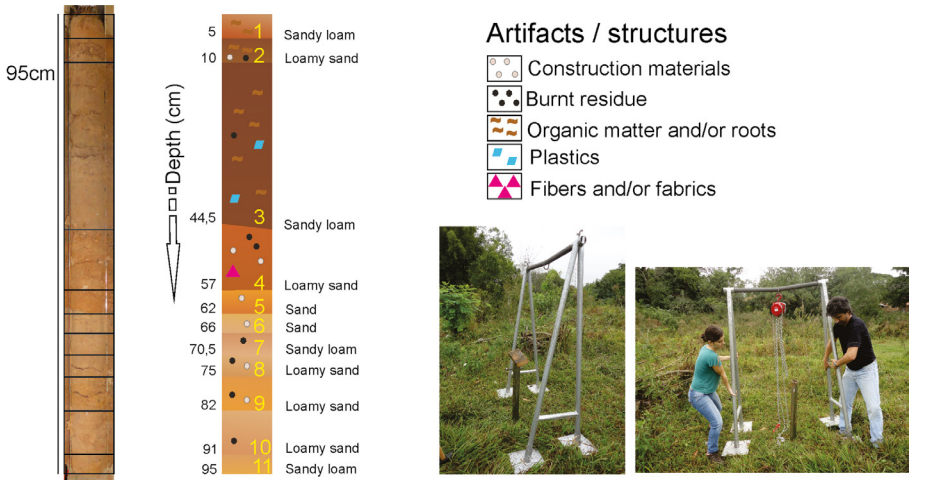


Figure 3 - Profile of the first sample of technogenic deposit collected in the Technogenic plain of Vila Nova Prudente, 58 meters away from the last street of the neighborhood (first fieldwork)

Source: Silva (2017).

Profile 3: Sample number 3 (first collection) of Vila Nova Prudente Layers' textures

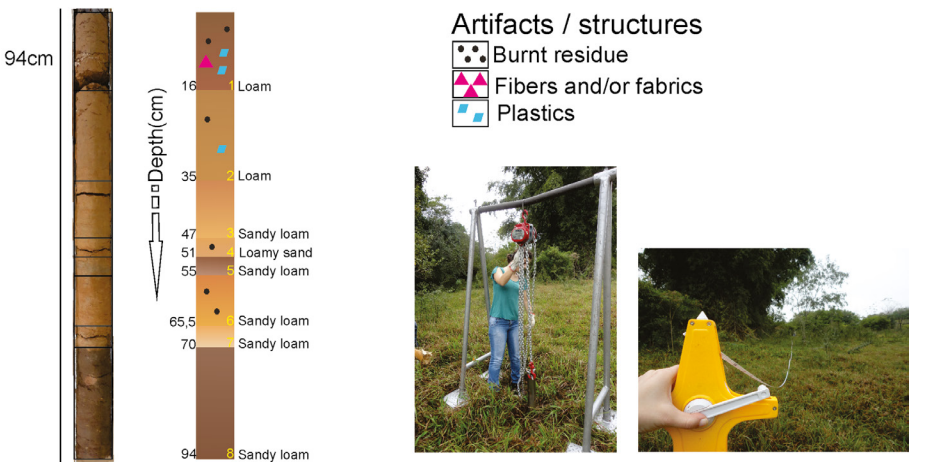


Figure 4 - Profile of the third sample of technogenic deposit collected in the Technogenic plain of Vila Nova Prudente, 172 meters away from the last street of the neighborhood (first fieldwork)

Source: Silva (2017)

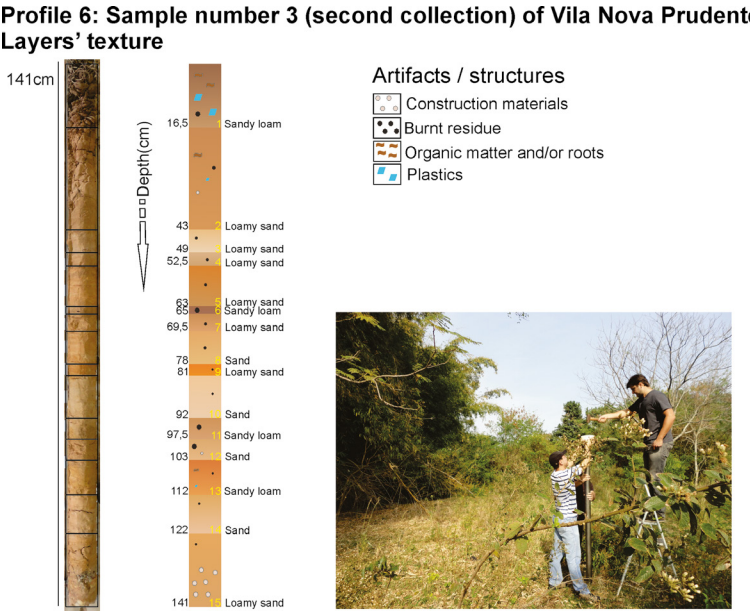
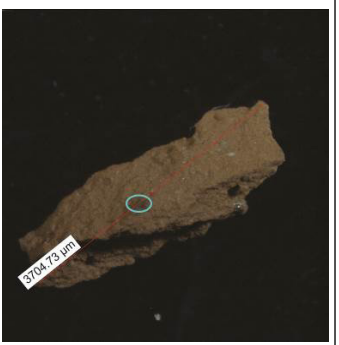
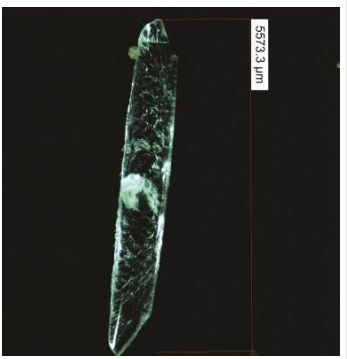
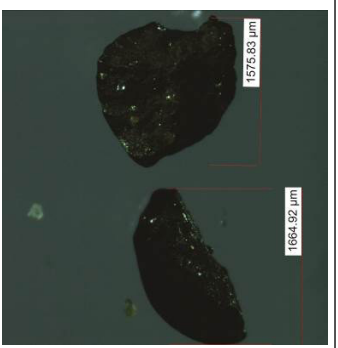


Figure 5 - Profile of the third sample of technogenic deposit collected in the Technogenic plain of Vila Nova Prudente, 100 meters away from the last street of the neighborhood (second fieldwork)

Source: Silva (2017).

The representative materials of the sand portions were stored after the granulometric analysis, underwent fractionation, according to the Wentworth scale (1927 apud Suguio, 1973), for the identification of representative values of the sand; very coarse (between 1 mm and 2 mm), coarse (between 0,500 mm and 1 mm), medium (between 0,250 mm and 0,500 mm), fine (between 0,125 mm e 0,250 mm) and very fine (between 0,053 mm and 0,125 mm).

After this procedure, some portions of the sand fraction were observed in a stereomicroscope, with a maximum magnification of four times, for initial observation of the materials. Among these, some samples were chosen for observation and image capture under an optical microscope with a maximum magnification of 100 times (Table 1).

Sample, number of the field work (F1 and F2) and layer	Image and interpretation of the material	Sample, number of the field work (F1 and F2) and layer	Image and interpretation of the material
1 (F1) Layer 4 (Photo 1)	 Interpretation: possibly granite / gneiss gravel. Approximately 2 mm. Note: near the neighborhood.	**1 (F1) Layer 4 (Photo 2)'**	 Interpretation: ceramic fragment (Brick or shingle). Marked in blue is a sign of possible burning. Approximately 3.7 mm.
1 (F1) Layer 5 (Photo 1)	 Interpretation: probable fragment of plastic. Approximately 5.5mm.	**1 (F1) Layer 9 (Photo 1)**	 Interpretation: probable fragment of basalt used for the production of gravel, with approximate sizes of 1.6mm.

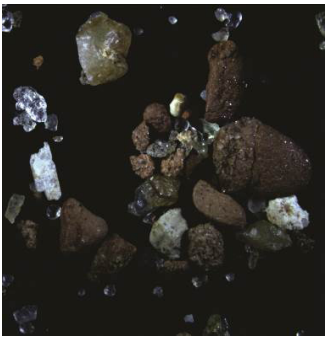
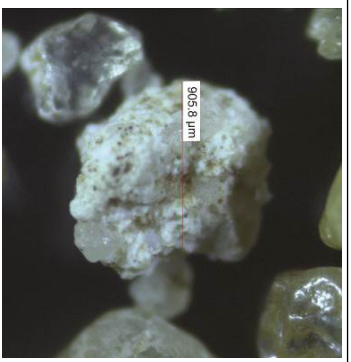
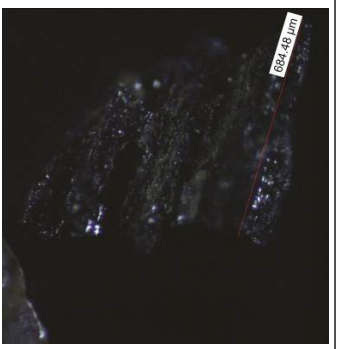
3 (F1) Layer 1 (Photo 1)	 Interpretation: probably plastic fiber. Approximately 3.1mm. Note: found at the end of the studied area.	**3 (F2) Layer 15 (Photo 1)**	 Interpretation: miscellany of materials and may contain building materials. Note: near the neighborhood.
3 (F2) Layer 15 (Photo 2)	 Interpretation: possible fragment of calcium carbonate. Approximately 0.9 mm.	**3 (F2) Layer 15 (Photo 3)**	 Interpretation: burnt Fragment. Approximately 0.6 mm.

Table 1 - Materials observed under an optical microscope with a magnification capacity of 100 times

Source: Silva (2017).

These procedures allowed for the collection of data about the materials present in the technogenic depositions of the studied area. It was possible, therefore, to establish hypotheses regarding the natural and artificial provenance of these materials from the relation with the history of local use and occupation and geological and pedological aspects raised through the consulted bibliographical reference.

Results and discussions

Because it is a technogenic plain area, mainly of induced origin, whose sediments and materials are transported from the landforms located upstream of the plain area, through surface runoff, the recognition of the material as natural or artificial, sometimes, is quite challenging. This difficulty is observed mainly when one recognizes that certain manufactured materials, when very fractioned, resemble sediments and fragments of rock naturally present in the city of Presidente Prudente.

Regarding the regional bedrock, Presidente Prudente is located in the area covered by the sandstones (sedimentary rocks) of the Adamantina Formation, belonging to the Bauru Group. According to Soares et al. (1980 apud IPT, 1981, p.73), the Adamantina Formation

> [...] includes "a set of facies whose main characteristic is the presence of sandstone banks from fine to very fine granulation, colors ranging from pink to brown, bearing cross stratification, with thicknesses ranging from 2 to 20 meters, alternating with layers of lamitic sandstones, from reddish brown to grayish-brown in color, solid or with coarse laminar-parallel bedding, often with crossed micro-stratification wave-marks".

It is common to occur in the Adamantina Formation "pebbles of argillite from itself, cement and carbonate nodules" (IPT, 1981, p.73). According to Godoy et al. (2006), calcium carbonate, present in this formation, is characterized as a cementing agent. Godoy (1999) mentions the presence of ferruginous cement in a sample of collected rock, in addition to the presence of ferruginous nodules in a soil sample, during a research carried out in the premises of FCT/UNESP in Presidente Prudente.

Fragments of sedimentary rock and fractured manufactured materials, such as those used in civil construction, can be quite similar visually. An example is the fragments that resemble both the ceramics used in construction and small fragments of sandstone and/or lamitic sandstone found in the sand fraction. It is observed that the production of red ceramic uses clay in its composition[2] and the Adamantina Formation contains deposits of lamitic sandstone and argillite rock, that makes these manufactured and natural materials visually similar.

Microscopy is a procedure that helps in the identification of technogenic materials, such as construction aggregates and ceramics. As an example, shown in Table 1, the fragment photographed in sample number 1 (F1[3]), in layer number 4 (Photo 2), probably refers to a ceramic fragment with a burn mark highlighted in the middle.

However, it is possible that certain fragments originate from the local bedrock, considered in this way as an indication of the erosion process happening upstream of the deposition area, or even removal of fragments by direct action of society (in the process of earthwork, for example), in the rock or in the C horizon in the soil profile. Examples of these types of materials, present in Table 1, are shown in photograph 1, layer 15 of sample 3 (F2), showing miscellany of materials which may be of natural or artificial origin, related to construction.

In relation to sand, which is widely used in construction, it is one of the mineral components of aggregates, together with crushed stone and grit, present in the production of concrete, asphalt, and mortars (Brasil, 2009a). Some aggregates used in civil construction appear to be fragments of the sandstone from the Adamantina Formation. According to Fushimi (2012), the region of Presidente Prudente has sand quarries from alluvial sediments. Thus, the identification of the sand is compromised meaning it is hard to determine if the sands are from a local place (sediments and local soils) or of the used ones in the civil construction (possibly coming from sand quarries located in the region).

Other materials found in the sample layers were the charcoal fragments. Through the understanding of the history of land use and occupation in the region of Presidente Prudente, it is verified that the burning of primary vegetation was a technique widely used for the preparation of the land for the development of agricultural activities and, later, livestock. However, although this practice is considered inadequate nowadays, it is still observed, mainly in the peripheral sectors of the city, the burning of domestic solid waste in the bottoms of valleys.The main residues of the fires are in the forms of ashes and charcoals. Although the possibility of natural fires is recognized, especially in periods of lower rainfall, most of the charcoal fragments found indicate action by society.

Because of the negligible mechanical resistance (Figueroa; Moraes, 2009), it is concluded that the charcoal fragments found in the samples

originate from places very close to where the samples were collected, and the transportation and deposition occurred together with sediments.

Madari et al. (2006), when citing different studies, mention that charcoal, in general, is a type of material that is poorly reactive and hydrophobic, and these characteristics depend on factors such as temperature and time of burning, source material, etc. Therefore, the biodegradation of this material is usually slow (from decades to hundreds of years). According to the history of the city of Presidente Prudente, whose foundation dates back to 1917, with agricultural activity in the vicinity, and the implantation of the Vila Nova Prudente subdivision in the 1960s, it is considered that these charcoal fragments can be very old, related to the beginning of agricultural activities in the region, given the relative slowness of biodegradation. This statement is likely to be true mainly because the charcoal fragments are found in deeper layers, in the middle of the sediments and without the presence of manufactured materials that denote the phase after the beginning of the construction of the dwellings in Vila Nova Prudente. Photo 3 referring to layer 15 of sample 3 (second field work) shows an example of a charcoal fragment found in the area (Table 1).

Small dark fragments attracted by magnet were also found. These may be related to the crushed stone fragments used in various sizes in construction. According to the Ministry of Mines and Energy (Brasil, 2009b), crushed stone is the product of the fragmentation of several types of rocks, such as granite and gneiss (85% of Brazilian production), followed by limestone/dolomite (10%) and basalt/diabase (5%).

The attraction to magnets is due to the presence of ferromagnesian minerals. In relation to the crushed stone, in the cases originating from the crushing of basalt, magnet attraction occurs due to the presence of minerals of the pyroxene family, rich in ferromagnesian metasilicates, as well as olivine (magnesium silicate and iron) (Guerra; Guerra, 2009).

In relation to granite, the presence of iron occurs, for example, in the case of mica being ferromagnesian, as the biotite (Guerra, Guerra, 2009). Photo number 1 of layer 4, belonging to sample number 1 of the first fieldwork, shows materials that resemble small fragments of granite. In the same sample, in the deeper layer (layer 9), fragments were found that can be related to the fractionation of basalt (Table 1). However, considering the presence of ferruginous nodules in the soils in the region (Godoy, 1999),

it is necessary, in future works, the application of other procedures and techniques to be certain as to be crushed stone or fragment from natural materials of the ferruginous nodules mentioned by Godoy (1999).

It is observed that the fragments that resemble manufactured materials related to the civil construction, such as crushed stone and ceramics found in the sand fractions mentioned above, were recognized in layers that presented larger building materials, as observed in the sketches (Figures 3 and 5).

Other materials observed in samples is related to fragments similar to the carbonate nodules, common in the Adamantina Formation. Photograph 2 of layer 15, present in sample number 3 (second fieldwork), refers to a possible calcium carbonate nodule, the size of the coarse sand present in a layer with coarse fragments of building materials.

Despite the presence of well-fragmented materials in the sand layer, whose identification as a natural bedrock and the region's soils or manufactured materials from the construction industry is still challenging, given the procedures used, there are fragments of materials that are no doubt manufactured. It is the example of the photographed materials belonging to layer 5 of sample number 1, and layer 1 of sample number 3, both collected in the first fieldwork.

In the case of sample number 1 (layer 5), it is observed that at first glance, no plastic fragments were identified, but civil construction materials were observed, as shown in Figure 3. It should be noted that these plastics fragments are larger than a fraction of course sand, i.e. larger than 2mm. These materials are possibly related to the period of construction of the subdivision and even to the period subsequent to the deposition of domestic solid waste since the area is currently in the process of erosion and consequent transport of materials into the studied technogenic plain.

Final Considerations

The area of the studied technogenic plain has received a high quantity of sediments and manufactured materials of different sizes. The erosive processes that occurred in the sectors of the nearby slopes, many of which were accelerated by the action of the society when removing the primary vegetation cover, are responsible for much of the sediment

supply that has been deposited in the technogenic plain, containing charcoal fragments related to the fires, a technique widely used during the occupation by farmers in the region of Presidente Prudente.

The manufactured materials, however, refer to the most recent phases, beginning in the 1960s, with the implantation of the neighborhood, and 1980s, with the deposition of domestic solid waste in an area susceptible to erosion, which lead to the consequent transportation and deposition of sediments and other materials in the direction of the studied plain. The plastic fragments are quickly recognized by the procedures adopted and considered as one of the main manufactured materials to be used as a criterion for the identification of technogenic sedimentary layers.

However, the construction materials, such as fragments of red ceramics, are difficult to distinguish when compared to the bedrock of the region, composed of sandstones of fine to very fine granulation, as well as banks of lamitic sandstones and the presence of argillite pebbles (IPT, 1981).

In spite of this difficulty, the procedures used were essential for a more detailed observation of the materials, through the recognition of the textural characteristics of the layers of technogenic deposition and obtaining images of diverse materials such as plastics, charcoals and possible construction materials. With this, it is demonstrated that the action of the society interferes in the compositional characteristics of the sediments, especially in an urban area, with the presence of materials in the sand layer that are not necessarily coming from the weathering of the rocks that make up the bedrock of the area.

Notes

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2 Available at: <http://abceram.org.br/materias-primas-naturais/>. Acessed on: 17 Aug. 2016.

3 F1 is regarding the first fieldwork and F2 is related to the second fieldwork.

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Érika Cristina Nesta Silva – Possesses Undergraduate, Master's, and Doctorate Degrees in Geography from the School of Technology and Sciences at the São Paulo State University (FCT/UNESP) in Presidente Prudente. ORCID: https://orcid.org/0000-0001-8383-8236.

João Osvaldo Rodrigues Nunes – Obtained an undergraduate degree in Geography at the Federal University of Rio Grande do Sul, Doctorate degree and "Livre Docência" in Physical Geography from the School of Technology and Sciences at the São Paulo State University (FCT/UNESP) in Presidente Prudente. Currently an adjunct professor of the Department of Geography at the School of Technology and Sciences at the São Paulo State University (FCT/UNESP) in Presidente Prudente. ORCID: https://orcid.org/0000-0003-3924-4056.

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