TAPHONOMIC AND SEDIMENTOLOGICAL ASPECTS OF THE "PICOS II" PALEONTOLOGICAL SITE, MUNICIPALITY OF PIRANHAS, ALAGOAS, BRAZIL

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Abstract – The paleontological site "Picos II", located at Picos farm, municipality of Piranhas, it is a fossiliferous deposit with lagoon geomorphological features. The material found was in excellent condition, two Pleistocene mammalian taxa were identified: *Eremotherium laurillardi* and *Notiomastodon platensis*. The taphonomic analysis indicates that the deposited material suffered short transportation, in high-energy environment, taking form as a single depositional event covering the crystalline basement level, with disarticulation in situ, which explains the high degree of conservation of the material. The sedimentological analysis corroborate the information obtained in taphonomic analysis. The well preserved material found in SP Picos II demonstrated the great potencial of the lagoon type deposits, with less steep lateral than tanks, promotes a smoother transport and accommodation of skeletal elements.

Key-words: Fossil, Pleistocene, Megafauna, Taphonomy, Alagoas, Brazil

INTRODUCTION

The fossil record is rich in information related to the biology and ecology of species, but these data are often incomplete, as fossil is formed in a natural process of biased sampling (Behrensmeyer, 2000; Hart, 2012). Over the past 30 years, taphonomy has played a central role in the better understanding of these processes (Armstrong & Avery, 2014), so as data from the fossil record can be properly assessed, taking into account these tendencies (Behrensmeyer, 2000; Bissaro Júnior, 2008).

During the late Pleistocene occurred the accumulation of skeletal remains of animals, especially large mammals associated with other taxa in deposits of various dimensions as tanks, caves, lakes, riverbeds and gullies (Viana et al., 2007; Santos et al., 2002b; Bergqvist & Almeida, 2004; Porpino et al., 2004; Dantas et al., 2005; Ribeiro & Carvalho, 2009; Araújo-Júnior and Porpino, 2011). Most of these deposits are called fossil tanks, which are natural depressions formed on the surface of predominantly crystalline rocks of Precambrian age, being a very common occurrence in northeastern Brazil (Ximenes, 2008; Paula-Couto,1980; Rolim, 1981; Oliveira & Hackspacher, 1989; Santos, 2001).

The taxonomic and paleoecological aspects are the most studied in the Brazilian fossil vertebrates deposits (Araújo-Júnior et al, 2013a). Although several studies focusing on vertebrate taphonomic aspects have been published over the last decade (Silva, 2001; Silva, 2008; Santos et al., 2002a; Auler et al., 2006; Alves et al., 2007; Dantas and Tasso, 2007; Araújo-Júnior and Porpino, 2011; Araújo-Júnior et al., 2012, 2013c), tank taphonomy is still considered one of the most difficult and peculiar quaternary Brazilian fossil vertebrates accumulations (Araújo-Júnior et al, 2013b). One of the recognized standards in most of the previous studies is the predominance of bone fragments and poorly conserved skeleton elements in the tank deposits accumulation (Araújo-Júnior et al, 2013c).

In the State of Alagoas, it is very common the presence of tanks, with occurrences of fossil deposits reported in 24 municipalities and 16 identified vertebrates taxa (Silva et al, 2012; Silva, 2013). Only two studies of taphonomy (Silva, 2001; Silva, 2008) are registered to the tanks of the State of Alagoas.

The present study aimed analyze the taphonomic aspects of the fossil deposit in the Paleontological Site “Picos II”, Picos Farm, in the City of Piranhas, Alagoas, Brazil. Thus, the study aims to contribute to the expansion of knowledge about the bioestratinomical processes; investigating the deposit paleontological, sedimentological and taphonomic features.

STUDIED AREA

The municipality of Piranhas lies in the semiarid of Alagoas, 270 km from the state capital, Maceio. The municipality is predominantly inserted in the geoenvironmental unit Depressão Sertaneja (65%), which represents the typical landscape of the northeastern semiarid, characterized by a pediplan monotonous surface, predominantly slightly undulating relief, cut by narrow valleys, with dissected slopes. Residual elevations, ridges and/or hills punctuate the skyline. These isolates reliefs testify intense cycles of erosion that hit much of the northeastern backland. The rest of the municipal area (35%) is inserted in the geoenvironmental unit Planalto Borborema (Mascarenhas, Beltrão & Souza Júnior, 2005).

Geologically, it is inserted in the Província Borborema, a tectonic entity from the Neoproterozoic Era (Brasilian-Pan-African). In the region where the studied deposit lays, emerges the Shoshonitic Intrusive Suite Salgueiro/Terra Nova, consisting from quartz biotite-hornblende monzonite to granite. (Mascarenhas, Beltrão & Souza Júnior, 2005)

The fossiliferous deposit in the Picos Farm is located in the city of Piranhas, 10 km from the town of Piranhas and 26 km from the town center. The same was called Picos II Paleontological Site (SP Picos II), according to the naming standards established by the Division of Geology and Paleontology of the Natural History Museum of the Federal University of Alagoas. The deposit has a lagoon geomorphological feature (Fig 1), on the base of a small mountain range, formed by a depression dug by local inhabitants in a inselberg on the granitic rock.

Deposits with a lagoon geomorphological feature have the same characteristics and origin of the tanks, except the sides are not as steep, with an average slope of 25 degrees, between the border and the bottom, being even shallower than traditional tanks, providing better preservation of the organic remains due to its smooth entry and setting at the bottom of the depression.

The formation of vertebrates taphonomic processes relies heavily on sedimentary processes and depositional environments that control the accumulation, preservation and burial of the bones (Faux & Padian, 2007). Sedimentary processes influence the anatomic and taxonomic composition of fossil assemblies, necessary data for paleoecological interpretation (Alberdi et al, 2001; Casal et al, 2014).

These tanks were filled by lithoclasts deposited by streams of debris and/or mud through alluvial fans or runoff carrying large number of bioclasts, among which mammalian and other vertebrate groups that lived from the Late Pleistocene to the Early Holocene (Silva, 2001; Oliveira & Hackspacher, 1989; Oliveira et al., 1989).

In Picos Farm it is still found another paleontological site, called SP Picos I, a spring that was dug by the inhabitants, having as a witness only three small fragments of fossilized bones.

METODOLOGY

The material studied was listed and allocated in the Paleovertebrates Collection of the Paleontology Sector at the Museum of Natural History at the Federal University of Alagoas (SP-MHN-UFAL).

Field

As proposed by Badgley et al. (2010) to maximize the sample size and the targeted granulometric range, three types of sampling were performed: collects on the surface, excavation and sieving. Thus, it was possible to cover a larger number of skeletal elements from the orictocenosis (Fig 2).

A geological section was made to identify the area stratigraphic layers, collecting sediment from each layer for subsequent granulometric analysis in the laboratory.

Taphonomic data like bioestratinomy, paleoecological feature, orientation and position of the fossil were observed throughout the fieldwork and recorded for later analysis.

Laboratory

The specimens collected were taken to the laboratory for preparation, storage and registering (Fig 3). All specimens were subjected to macroscopic taphonomic analysis proposed by Shipman (1981), Behrensmeyer (1991), Rogers (1994), Holz and Simões (2002), and Simões et al. (2010). The following macroscopic aspects were considered: taxonomic composition and ontogenetic stage, articulation and fragmentation, teeth marks and color pattern.

The sediment collected from each of the three identified stratigraphic layers was subjected to particle size analysis in the Laboratory of Coastal and Environmental Geology (LGCA/UFAL).

TAXONOMIC COMPOSITION

Found Species

One hundred and thirty fossil specimens were found and registered between teeth, cranial and postcranial bones. From the total, one hundred and thirteen fossil specimens were considered anatomically and taxonomically identifiable. The remaining seventeen specimens are unidentified fragments. The taxonomic classification for this trial was based on the work of Hoffstetter (1958), Paula-Couto (1979) and Cartelle (1992).

Two individuals of ground sloth *Eremotherium laurillardi* Lund, 1842 belonging to different ontogenetic stages, an adult and a newborn, were identified. In addition to this specie, the probosciedean *Notiomastodon platensis* Ameghino, 1888 was also identified. Among the skeletal elements identified, eight were assigned to the *E. laurillardi* newborn due to clear difference in size and the presence of unclosed sutures (Fig 4).

Only one sample of a fragmented molariform from a young individual (0728-V) from *Notiomastodon platensis* was found, corresponding to a minimal fragment that provides no information beyond the occurrence confirmation of the species itself.

Fragments of bird bones were also found, but, due to its fragmentation, the material also provides no information beyond its own occurrence confirmation, which made it impossible to identify the taxa at a specific level.

The ground sloth is commonly found in fossil deposits nationwide, along with the fossils of mastodont and toxodont, the latter was not found in that deposit, the three are the best known representatives of the pleistocene megafauna.

TAPHONOMIC ANALYSIS

Death and Necrolysis

The investigation into the cause of death of the organisms that compose the fossiliferous concentration and the identification of the event that led to the death are important factors in taphonomy.

The causes of death of organisms are too numerous to be listed, especially when compared to the limited number of possibilities of the beginning of a new life. Lyman (1994) states that this is due to accidental factor in mortality. According to Holz & Simões (2002), basically two types of mortality are recognized: selective or natural death and non-selective or catastrophic death.

Berger (1991) suggests that animals with "normal lives" are rarely fossilized, therefore the preservation of the "unfortunate" is normal in paleontology. This happens because usually the animal that died by predation or disease was linked to an appropriate place to incorporate the geological record (Weigelt, 1989).

The investigated orictocenosis can be interpreted as having been generated by nonselective death through a stress situation justified by the presence of individuals with different age.

Vertebrates and several groups of invertebrates have a set of biomineralized tissues that are held together in life by "soft tissue". The term "soft tissue" is a colloquial description for various types of non-biomineralized tissues, including ligaments, tendons and muscles. The decay of these non-biomineralized "soft tissue" is made by two biological agents, autolysis and degradation by endogenous and exogenous microbes (Beardmore et al, 2012).

The necrolysis comprises the decomposition of connection soft tissues after death of the organism. This process can be caused by two different kinds of bacteria: 1) aerobic, that happens in the presence of free oxygen; and 2) anaerobic, occurs in the absence of oxygen (Holz & Simões, 2002; Weigelt, 1989)

The high concentration of pyrite in the collected sediment demonstrates the action of anaerobic bacteria, typical of reducing environments, being those bacteria responsible for the chemical decay process of the soft tissues, indicating that necrolysis occurred in the place where they were buried and then fossilized.

The formation of pyrite is often associated with the chemical processes resulting from the decomposition of organic matter by sulfate-reducing bacteria in the sediment. In the reducing environment, anaerobic bacteria need to reduce the sulfate to metabolize the available organic matter in the sediment forming hydrogen sulfide - which spreads through the sediment by diffusion - directly reacting with the iron in their reactive forms. Amorphous iron monosulfate originates from this reaction. Once released, if they remain in the reducing environment with high levels of elemental sulfur, the monosulfate can turn into pyrite (Berner, 1983; Berner & Raiswell, 1983).

Disarticulation, Transportation and Fractures

The transport, reorientation, disarticulation, fragmentation and corrosion compose the set of biostratinomic processes that must be evaluated in a fossiliferous aggregate.

When burial occurs before full necrolysis, virtually the entire skeleton is preserved and articulated. Otherwise, the body is subjected to biotic and abiotic processes that initiate disarticulation. The analysis of the disarticulation degree of the elements of taphocenosis is important as it provides data on the intensity of the transport and the period between death and burial. (Casal et al., 2014).

Semi articulated parts in SP Picos II, such as the left lower limb comprising the femur, tibia, fibula, austragalus and other bones concentrated in a $12m^2$ area suggest that the animal was carried still in its carcass, protected by ligament tissue and coating, in order that the final breakdown occurred in the deposit itself. This factor, along with a process of rapid burial and slightly steep lateral in the deposit, justifies the well-preserved and semi articulated fossil material found there.

For inferences concerning aspects of transport involving bone representativity analysis, the Groups of Voorhies (Voorhies, 1969) have been widely used (Bergqvistet al, 2011). Frison & Todd (1986) established another way of interpreting aspects of transport based on bone representativity. According to Araújo-Júnior et al (2012) using the Fluvial Transport Index of Frison & Todd (1986) allows to better achieve conclusions about the transport involved in the formation of brazilian pleistocene fossiliferous deposits generated by markedly hydraulic processes, due to the similarity between the size of animal used in experiments and mammals of the pleistocene megafauna.

For Frison & Todd (1986), skeletal elements with FTI less than 75 (sacrum, patella, astragalus, calcaneus and vertebrae) are equivalent to those found in Group I of Voorhies. Bones with FTI between 50 and 74 (rib, scapula, humerus, tibia and metacarpal) are similar to Group II, while skeletal elements with FTI below 50 (atlas, jaw, pelvis, radius-ulna and femur) are sent to Group III (Araújo Junior et al, 2012).

In the studied mammalian taphocenosis are the three Voorhies Groups and the three FTI transport groups are present. Relatively denser elements, such as pelvis and limb bones are present with the exception of complete skull, being present only the zygomatic arch. Lighter elements, and hence easier to be transported, are also found in abundance, such as vertebrae and phalanges.

Behrensmeyer (1991) proposed three differentiation stages of bone physical integrity: (1) complete (> 90% of preserved bone), (2) partial (50-90% of preserved bone), and (3) fragmented (<50 % of preserved bone). Of the 130 specimens, 52 specimens (40.7% of the total) are presented complete, 33 (25.3%) are partially intact and 44 (33.8%) were classified as fragmented.

Among 40.7% of the complete material, it's possible to mention elements such as ribs (Fig 5), which belong to Voorhies group II, and bones of the appendicular skeleton, belonging to the Voorhies group III. The presence of elements belonging to all Voorhies Groups and FTI, mainly of whole elements of groups II and III indicates a residual deposit formed by the action of a selective transport, resulting in a reduced degree of transport.

Since bones have suffered little weathering action, it can be stated that the permanence time in the surface was short (Bertoni-Machado & Fariña, 2006), and as well as little abrasion observed in the material (Fig 6) may not necessarily be related to the transportation and but to the time/intensity of interaction with the sediment (Behrensmeyer, 1991).

Macroscopic taphonomic features

In the stratigraphic analysis, a thick three-dimensional wedge-shaped fossilized concentration was identified, a densification with regular geometry tapering laterally in a complex manner. The deposit presents as paleoecological feature a polyspecific monotypic deposition, since only vertebrates have been found.

According to Simões, Rodrigues & Bertoni-Machado (2010), monotypic concentrations tend to have great taphonomic value, as they suggest that during diagenesis there was mass mortality, conditions of high environmental stress, intense hydrodynamic selection or differential preservation.

Evidence observed in the fossils in situ suggest a single depositional chaotic type event, with bones concentrated in basement rock level, experiencing a short-distance transport with high energy. This assumption is due to low degree of selection of lithoclastic and bioclastic sedimentary particles with grains and rock fragments in the size of angular pebble and boulder, and to the degree of packing shown by fossiliferous concentration from loose to dispersed (Fig 7). These factors suggest a disarticulation in situ.

SEDIMENTOLOGICAL ANALYSIS

The sediment results were obtained using percentage values of the textural classes (gravel, sand and mud) in the triangular diagram of clastic sediment rating - Shepard Diagram, indicating that the deposit was formed by gravelly sand. The granulometric analysis identified the following sedimentological features: very coarse to coarse sand (A1), gravel (A2) and very coarse sand with gravel (A3). The stratigraphic section is shown in Figure 8.

The sample one (A1) is refers to layer 1 of the deposit, which has 11 cm thick and exhibited quartz, feldspar, biotite and iron oxide in morphoscopic analysis. The sample two (A2) corresponds to layer 2, 15cm thick and exhibited minerals such as hematite, biotite, quartz and feldspar. This middle layer is the level where the fossils were deposited, presentind large amounts of carbonate, possibly originated from bone dissolution.

The third sample (A3) refers to the deposits layer 3, 22cm thick and exhibited feldspar, biotite, hematite, quartz and pyrite. The high concentration of pyrite found at this level was attributed to the decomposition of organic matter, making anoxid environment suitable for the formation of this mineral.

The data suggest an initial high energy depositional environment, moving to a low-energy environment with moderately selected particles and sub-rounded grains. As the deposit presents coarse gravelly sands, or even conglomerates, a little abrasion could be evidence of a short period of contact between bone and sediment, such as that happens in very strong and sudden flows (Bertoni-Machado & Fariña, 2006).

CONCLUSION

The work performed on the fossiliferous deposit of Picos II Paleontological site identified two species of Pleistocene mammals: *Eremotherium laurillardi,* a ground sloth and *Notiomastodon platensis,* a proboscidean. One hundred and thirty fossil specimens were collected, analyzed, identified and registered under the Paleovertebrates Collection of the Paleontology Sector at the Museum of Natural History at the Federal University of Alagoas.

The taphonomic analysis indicates that at least the carcass of *E. laurillardi* arrived at the deposit on necrolysis process, suffering little transport, but in a high energy environment, occurring in a single depositional event, with no reworking, which filled the depression, from the basement rock to the ground level, providing an in situ disarticulation.

The sedimentological analysis confirms the information obtained in taphonomic analysis, emphasizing the high energy transport over a short distance through the angularity of the grains and the variation in size of lithoclasts, ranging from pebbles to boulders.

The well preserved material found in SP Picos II demonstrated the great potencial of the lagoon type deposits, with less steep lateral than tanks, promotes a smoother transport and accommodation of skeletal elements.

The taphonomy of Pleistocene deposits of northeastern Brazil has been extensively studied in the last decade, but an effort in the differentiation of these deposits commonly known as tanks is still necessary, since there are variations such as lagoons that promote better preservation of the material.

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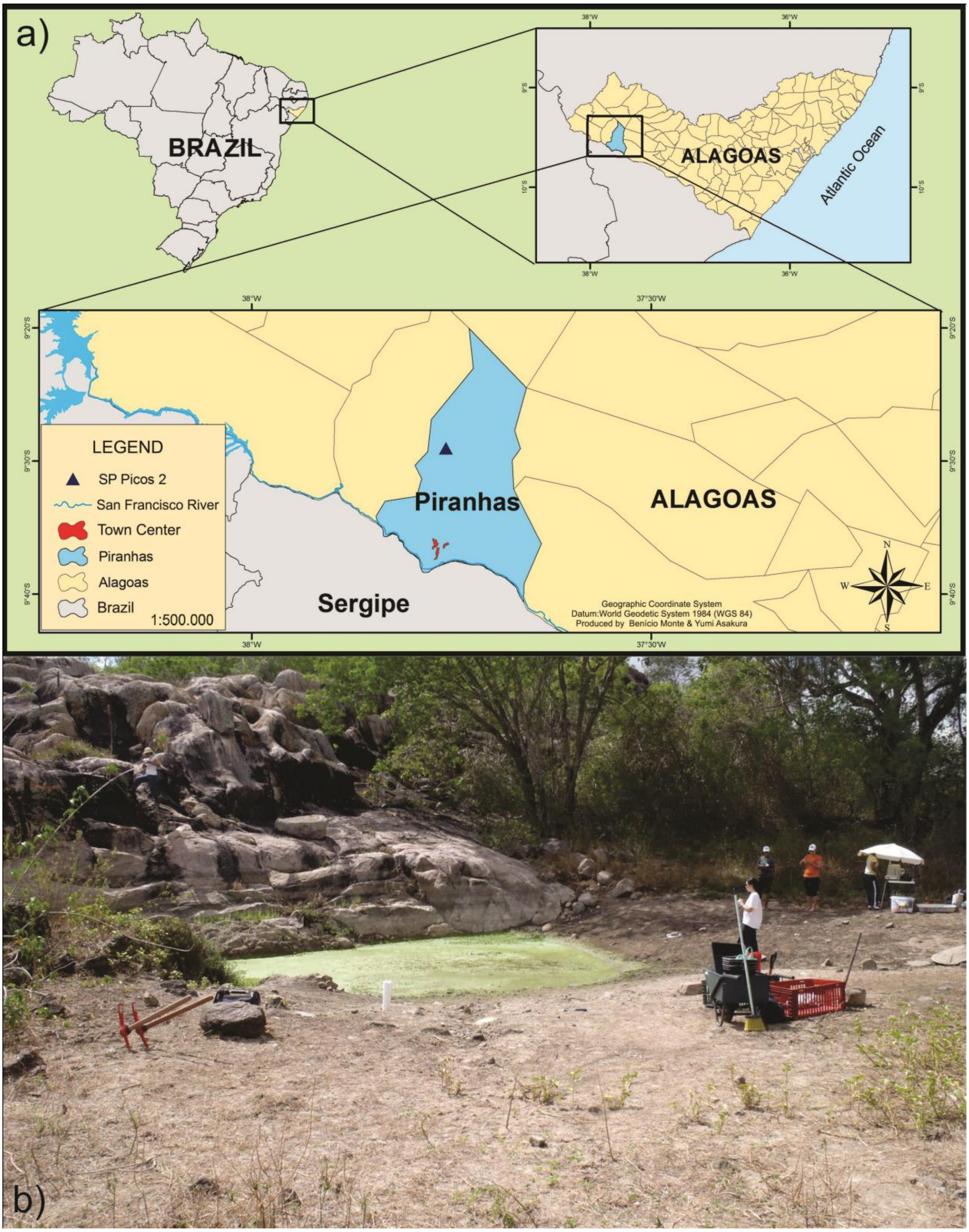

Figure 1 - A) Location map of the area of excavation and study. B) Overview of the Paleontological Site Picos II, deposit with lagoon geomorphological feature.

Figure 2 - Fossil material being excavated under the scale observe a femur of E. laurillardi.

Figure 3 - Preparation of the pelvis E. laurillardi, since the disassembly of the protective plaster (A), cleaning and bonding (B, C, D, E), until the finished piece (F), which was assembled using the adhesive epoxy resin and polyamino-amide.

Figure 4 - Left radius of adult (a) and young (b) E. laurillardi, both in lateral view.

Figure 5 - Ribs from the adult E. laurillardi, demonstrating the well preserved material.

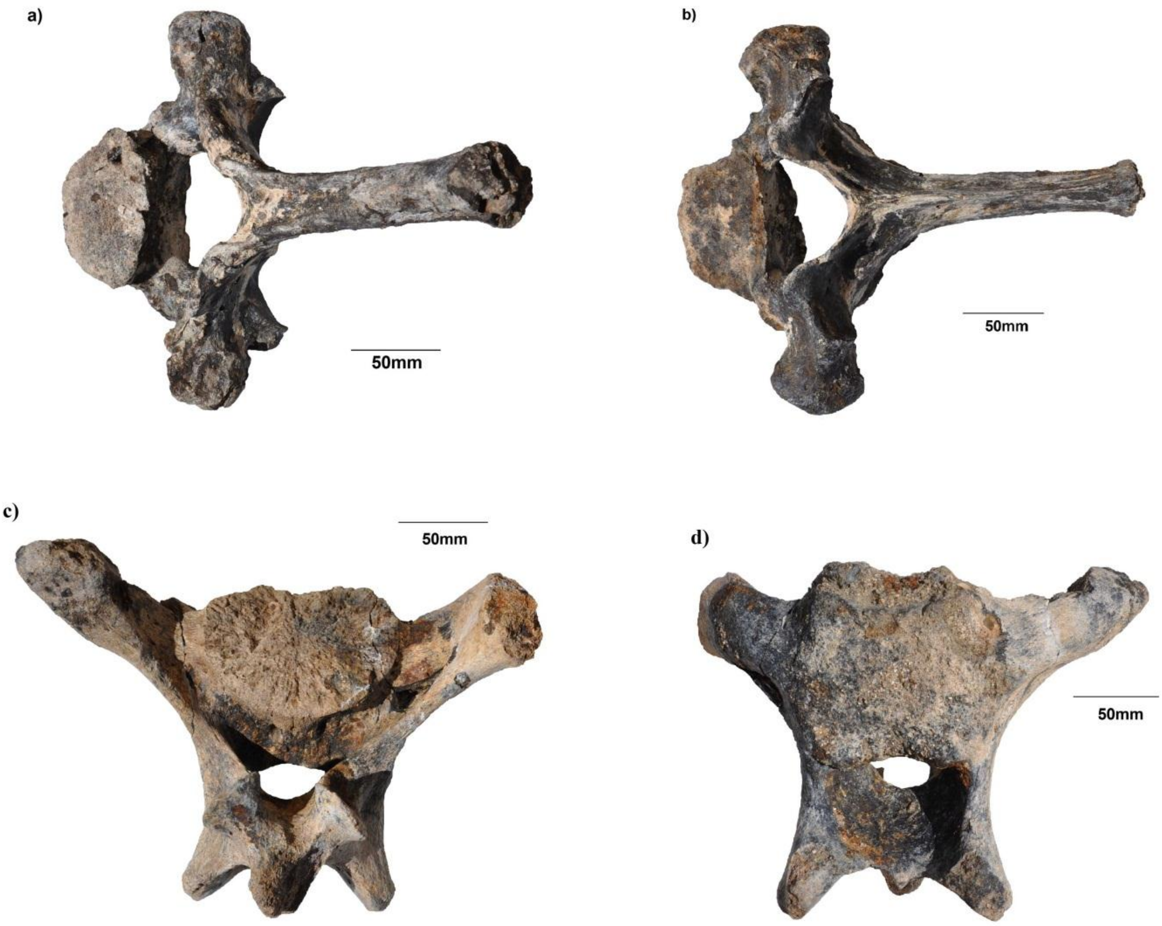

Figure 6 - Cervical vertebra (0742-V) of E. laurillardi: a) caudal view; b) cranial view; Caudal vertebra (V-0757) of E. laurillardi: c) caudal view; d) cranial view.

Figure 7 - Fossil in situ in the SP Picos II, where it is observed the degree of packing from loose to dispersed.

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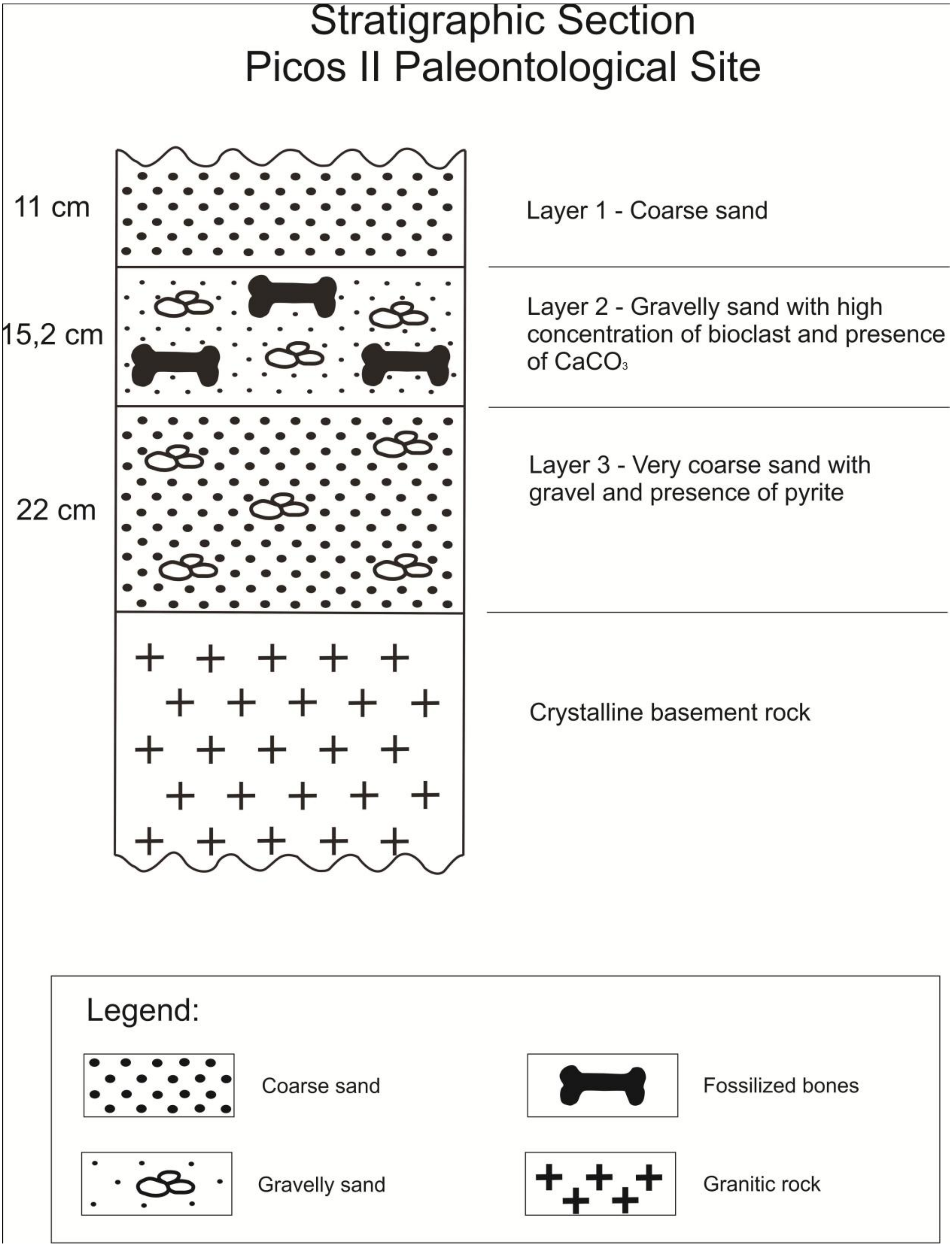

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511 Figure 8 - Stratigraphic section of the deposit fossil SP Picos II. Extracted symbolism of IN-03/94-SC
512 DEINFRA.