

Itaboraí Basin, State of Rio de Janeiro*The cradle of mammals in Brazil*

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© Bergqvist,L.P.; Mansur,K.; Rodrigues.M.A.; Rodrigues-Francisco,B.H.;Perez,R.A.R.; Beltrão,M.C.M.C. 2008. Itaboraí Basin, State of Rio de Janeiro - The cradle of mammals in Brazil. *In*: Winge,M.; Schobbenhaus,C.; Souza,C.R.G.; Fernandes,A.C.S.; Berbert-Born,M.; Queiroz,E.T.; (*Edit.*) Sítios Geológicos e Paleontológicos do Brasil. Available on line 25/04/2008 at the address: <http://www.unb.br/ig/sigep/sitio123/sitio123english.pdf> [Actually <https://sigep.eco.br/sitio123/sitio123english.pdf>]

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SIGEP 123

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The Itaboraí Basin, of late Paleocene age, is one of the smallest basins in Brazil (*ca.* 1 km²). In spite of its small size, it is extremely fossiliferous. It is located in the district of São José, in the town of Itaboraí, about 60 km far from the city of Rio de Janeiro. The basin was filled with a sequence of clastic and chemically deposited (travertine) limestones that were vertically cut by fissures where most of the fossils were found. The Itaboraí Basin limestone was economically explored for approximately 50 years and it was the source for the production of cement used in the construction of the Maracanã stadium and the Rio-Niterói Bridge, for example. The Itaboraí Basin contains the oldest continental biota in Brazil ever since the extinction of the dinosaurs. The biota consists of mammals (the most diverse and abundant ones), reptiles, birds, amphibians, plants, gastropods, palynomorphs and ostracods (one occurrence of each). The name for the Itaboraian South American Mammal Age was proposed based on the rich assemblage of fossil mammals from the Itaboraí site. A continuous technological sequence of artifacts (burins, knives, large scrapers, among other artifacts), at least one million years old (middle Pleistocene), has been discovered at the archaeological site of Dynamite hill, with the advent of *Homo ergaster*.

Key-words: Itaboraí Basin; Paleocene; Itaboraian; mammals; Rio de Janeiro, Archaeology

INTRODUCTION

The paleontological site of São José de Itaboraí (Fig. 01) is the only known Brazilian deposit which registers the first dispersal of mammals after the extinction of the dinosaurs. Since it contains fossils from the first groups of mammals of the modern lineage (Metatheria and Eutheria), it is also known as “cradle of mammals”, a metaphor that alludes to the primitive condition of the mammal fossils preserved at that site. The São José de Itaboraí Basin or Itaboraí Basin, as it is frequently known in the literature, belongs to the late Paleocene. Despite its small size, it is extremely rich in vertebrate and gastropod fossils. Among such fossils, the mammals are the more abundant and important ones, and due to their existence, the basin is recognized in the international scientific community. Due to the abundance, quality and diversity of the mammal fossils found at the basin and to their importance for the understanding of the evolution of the South American mammals, one of the ages of the South American Land Mammals (SALMA) was termed Itaboraian by Marshall (1985) after the Itaboraí Basin (Fig. 02).

The Itaboraí Basin was discovered in 1928 by Carlos Euler. He was an engineer who analyzed presumed samples of kaolin found at the Fazenda São José by its owner, Mr. Ernesto Coube. Mr. Euler

proved that it was limestone. Some researchers were sent to the site and during the prospecting work carried out there they found a large quantity of continental gastropod fossils, a fact that called the attention of scientists to the region (Oliveira & Leonardos, 1978). On the other hand, the preliminary field studies along with the chemical analyses evidenced good perspectives for exploiting the limestone for the production of Portland cement.

For more than 50 years (from 1933 to 1984) the Companhia Nacional de Cimento Portland Mauá (CNCPM), a Brazilian company, explored the quarry, and the cement produced from such limestone was used to build the Mario Filho Stadium (Maracanã) and the President Costa e Silva Bridge (Rio-Niterói), among other great engineering works. The exploration was also responsible for the discovery of an abundant fauna of land mammals and gastropods as well as amphibians, reptiles, birds, some plants and ostracodes which has greatly contributed to a better understanding of the important dispersal of the mammals occurred at the beginning of the Cenozoic Era.

The interruption of the mining activities at the site also stopped the draining of the water and due to the deep digging work the groundwater started to accumulate at the bottom of the basin. As time went by, a lake approximately 70 m deep was formed at the

depression created by the extraction of the limestone (Fig. 03) therefore hindering new collecting of materials and geologic studies. This lake is currently used as a water supply by the community of the São José district and it is managed by Cooperágua, a concession service of the Municipality of Itaboraí. Since its discovery up to our days several researchers have contributed for the geopaleontological knowledge of Itaboraí. Due to the importance of their contributions, two researchers, among others, distinguished themselves: Geologist Victor Leinz, who first correctly described the sediments of the basin in the decade of the 1930's. The basin was detailed by

the subsequent authors. The other researcher was Carlos de Paula Couto, a paleontologist who identified the majority of the mammal species from Itaboraí (Bergqvist, *et al.*, 2006) from the middle of the decade of the 1940's up to the end of the decade of the 1970's.

The Itaboraí Basin constitutes an important Brazilian paleontological site due to its paleontological abundance as well as for giving name to one of the SALMAS and, also, for contributing to the social development of the Rio de Janeiro State with its limestone exploration.



Figure 1 - View of the Itaboraí Basin in 1957. The São José fault is visible on the left. Photographer unknown.

LOCATION

The Itaboraí paleontological site is situated at São José, a district of Itaboraí located in the Metropolitan Region of Rio de Janeiro (Fig. 04). The geographical coordinates of the center of the area are 22°50'20"S e 42°52'30"W.

The best way to the district of São José starting from the city of Rio de Janeiro is to take the Rio-Niterói Bridge and, then, the BR-101 highway up to the section which connects Manilha to Duques. On this same road, approximately 4 km after the

interchange there is a road sign indicating the localization of the São José de Itaboraí Paleontological Park (Fig. 05) and it points out the entrance to the municipal road Ademar Ferreira Torres (formerly Cabuçu road). On this municipal road, about than 7,7km, at the village of Cabuçu, there is another road sign. From this point on, 3 km further on a dirt road there is the village of São José where the park is located. The entrance of the park is 1 km further (Fig. 06). The distance covered from the tollhouse on President Costa e Silva Bridge (Rio-Niterói Bridge) up to the park is 46km.

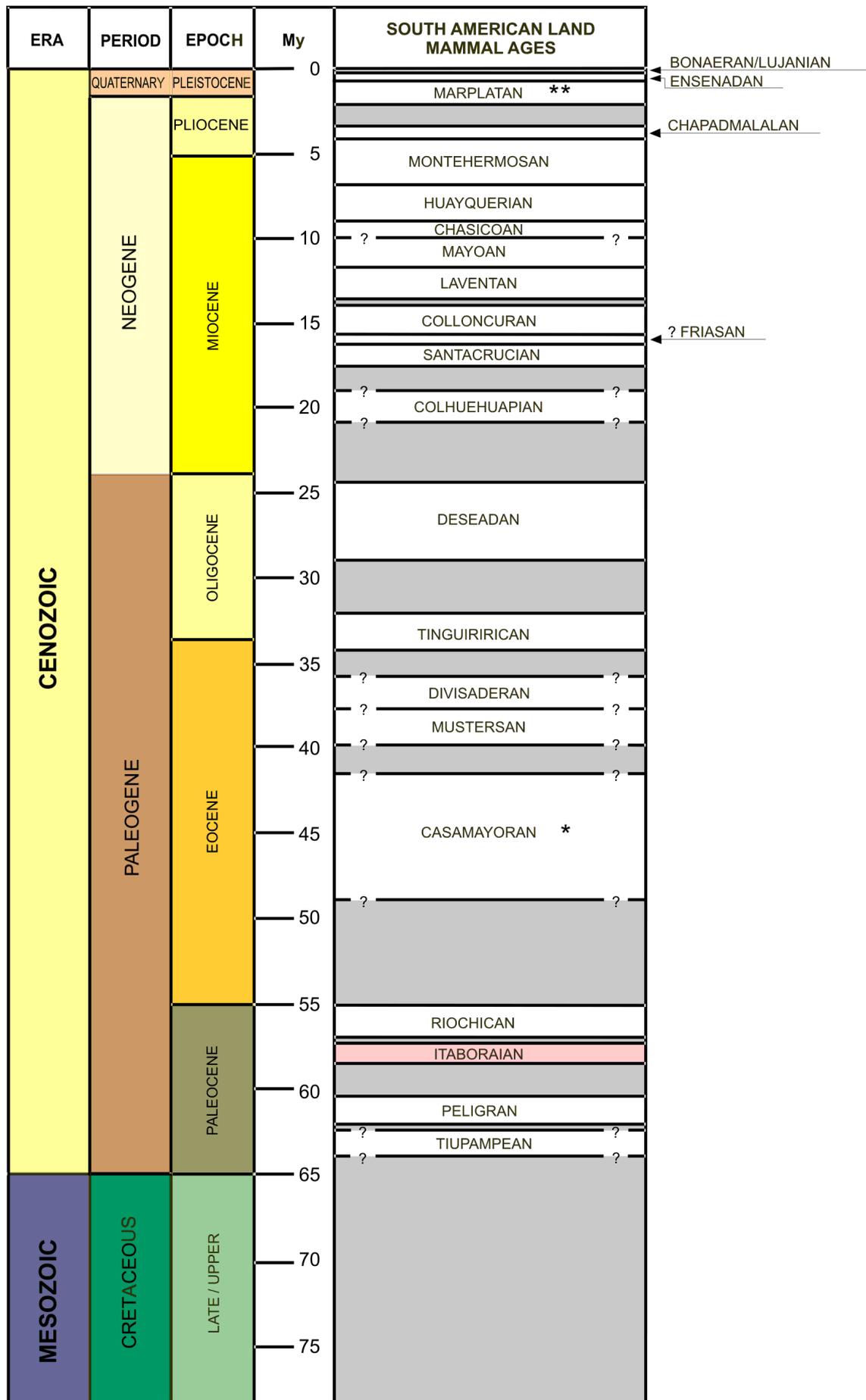


Figure 2 - Geochronologic table showing the various South American land-mammal ages; Itaboraian age highlighted. From Bergqvist *et al.* (2006).

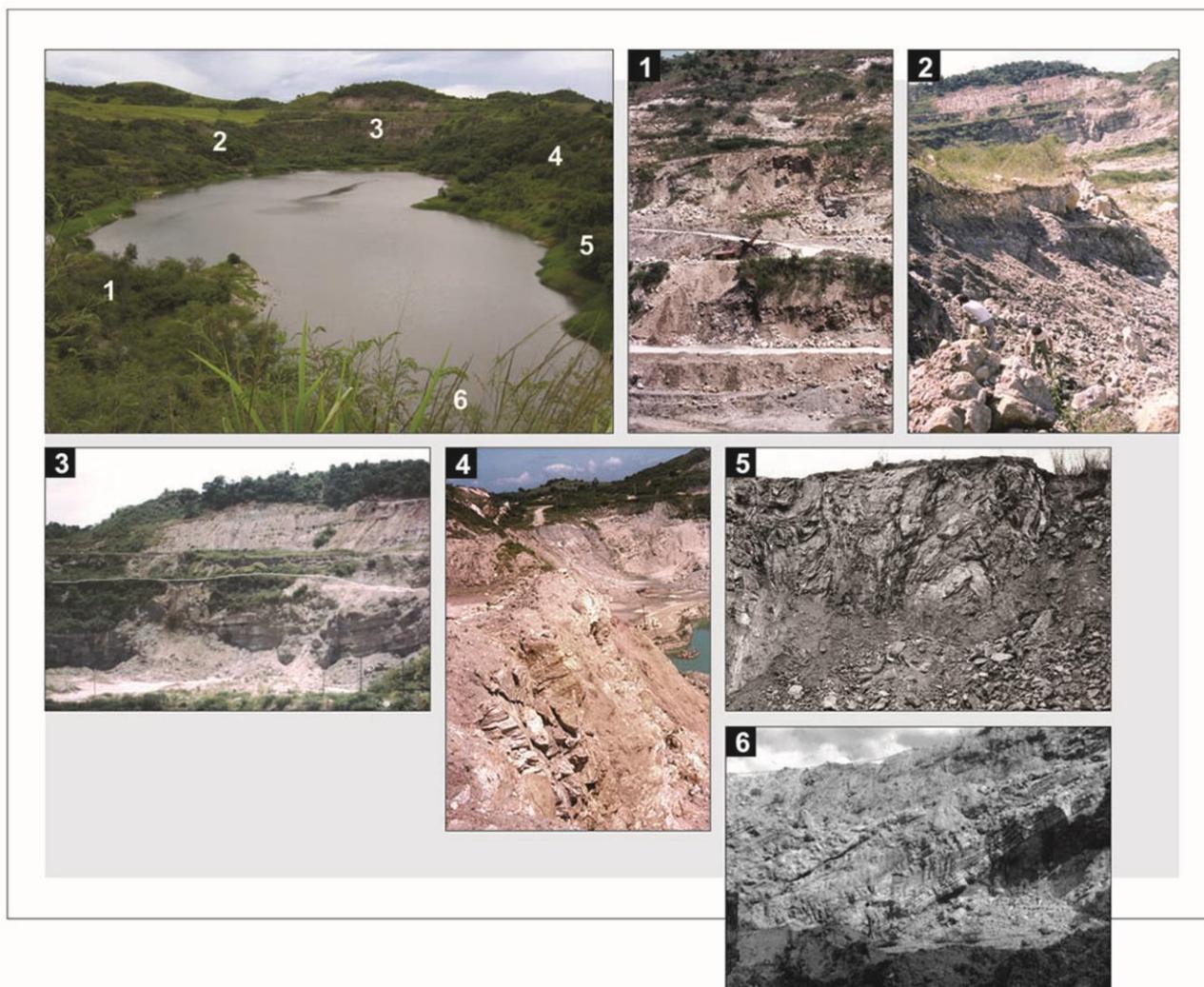


Figure 3 - Current status of the Itaboraí Basin and images of the area during the exploration period (70's and 80's decades). (1, 2) Northern border of the basin; (3) Eastern border of the basin where the limestone layers are distinctly horizontal; Dinamite hill is situated above such layers. (4, 5) São José Fault; (6) Western border, where the limestone layers are markedly oblique in relation to the direction of the São José Fault. Photos: L.P. Bergqvist, F. Cunha and unknown photographer.

SITE DESCRIPTION

Geology

The difference in level between the Serra do Mar and the Itaboraí lowlands is greater than 2,000m. The origin of this relief is related to the tectonic movements occurred approximately 80 million years ago, which caused an ample elevation of the border of the South American continent, in the area that currently corresponds to the portion of land extending from Paraná to Espírito Santo States (Ferrari, 2001). The increasing elevation on one side of such border provoked a rupture and the consequent lowering of the adjacent crustal blocks. The high areas correspond to the ranges of Serra do Mar and Mantiqueira and

also to the coastal massifs constituted generally of late Paleo-proterozoic to paleozoic gneisses, migmatites and granites of the Ribeira Belt (Fig. 07). Also calcosilicated rocks and crystalline limestone (marble) occur in the form of lenses locally in the gneisses (Rodrigues-Francisco & Souza-Cunha, 1978). The dissolution of such marble lenses permitted the deposition of carbonates on the São José de Itaboraí basin during the Paleocene.

Small sedimentary basins such as the São José de Itaboraí basin were formed in the deepened areas. This depression was called Continental Rift of Southeast Brazil (CRSB) by Sant'anna & Riccomini (2001). It is a depressed and elongated strip of ENE general direction, approximately 900 km long, comprising more than ten sedimentary basins.

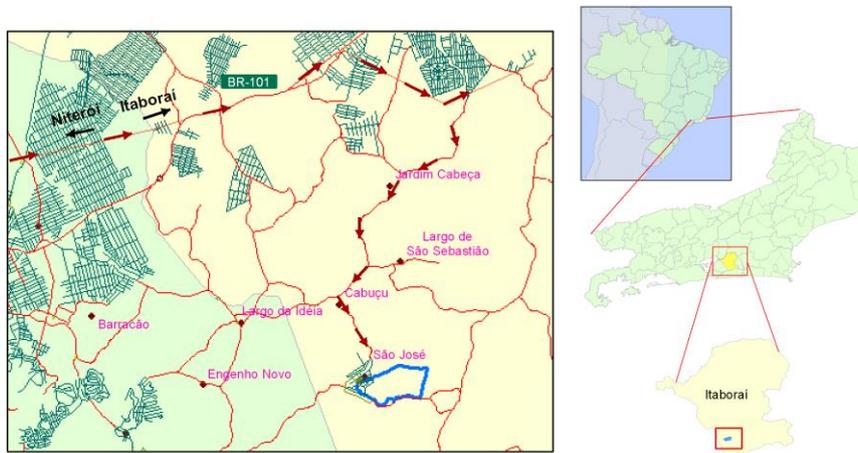


Figure 4 - Location of the Paleontological site of São José de Itaboraí. Photo: Information and Data Center of Rio de Janeiro State.



Figure 5 - Road Sign near the entrance to the road to Cabuçu. Photo: K. Mansur.



Figure 6 - Signboard of the Geological Pathways Project (*Projeto Caminhos Geológicos*) at the entrance of the São José de Itaboraí Paleontological Park headquarters. Photo: K. Mansur.

The evolution of the CRSB (Continental Rift of Southeast Brazil) has been related to the latest phase of the tectonic activation of the South American Platform, an event associated to the fragmentation of the Gondwana and to the formation of the South Atlantic Ocean. According to Ferrari (2001), this event would be responsible for the Juro-Cretaceous basaltic flows of the Serra Geral Formation, for the implantation of the marginal basins as well as for the formation of the Rio Paraíba do Sul antecline and its middle graben (Ferrari, 2001: 30). Almeida (1976) included the associated taphrogenic basins of Curitiba, São Paulo, Taubaté, Resende and the Guanabara Graben in the Serra do Mar Rift Systems. Schobbenhaus *et al.* (1984) called “South Atlantian Event” to the tectonomagmatic activities that followed the separation of the African and South American continents.

According to Rodrigues-Francisco & Souza-Cunha (1978) and to Rodrigues-Francisco *et al.* (1985) the Itaboraí Basin presents a rhomboedric shape with the largest axis in the NE-SW direction, measuring about 1,400m, the smaller axis in the NW-SE direction is approximately 500 m long, and a maximum depth of about 125 m which was observed near the São José Fault, which is its southern limit. Considering the

maximum depth of 125m, about 70m of the total are composed of limestone and such thickness diminishes progressively in the direction of the borders of the basin. The upper level of the deposit was positioned at 93 m above sea level and the lower level was positioned 9 m below sea level (Paula-Couto, 1949).

The first description and the first geological profile of Itaboraí were made by Leinz (1938), who distinguished three distinct packages in the filling up of the basin: (a) travertine limestone, which occurs in irregular and lens shaped banks, tens of meters long, and some meters thick, afossiliferous, which, in some points becomes (b) oolitic limestone. Leinz was the first researcher to suggest a hydrothermal origin for the limestone. The travertine limestone presented an irregular contact with a gray massive, brecciated and fossiliferous limestone originated in a lacustrine system. (c) Covering the sequence and locally interfingering with the limestone, occur thick eluvial sediments, poorly stratified, 10 m to 20 m thick, with many fragments, some fresh and some intemperized.

Oliveira (1956) called Itaboraí Formation the package of limestone layers which fill up the Itaboraí Basin. However, such lithostratigraphic name was not used by the majority of the authors who preferred to call the deposit just as Itaboraí Basin.

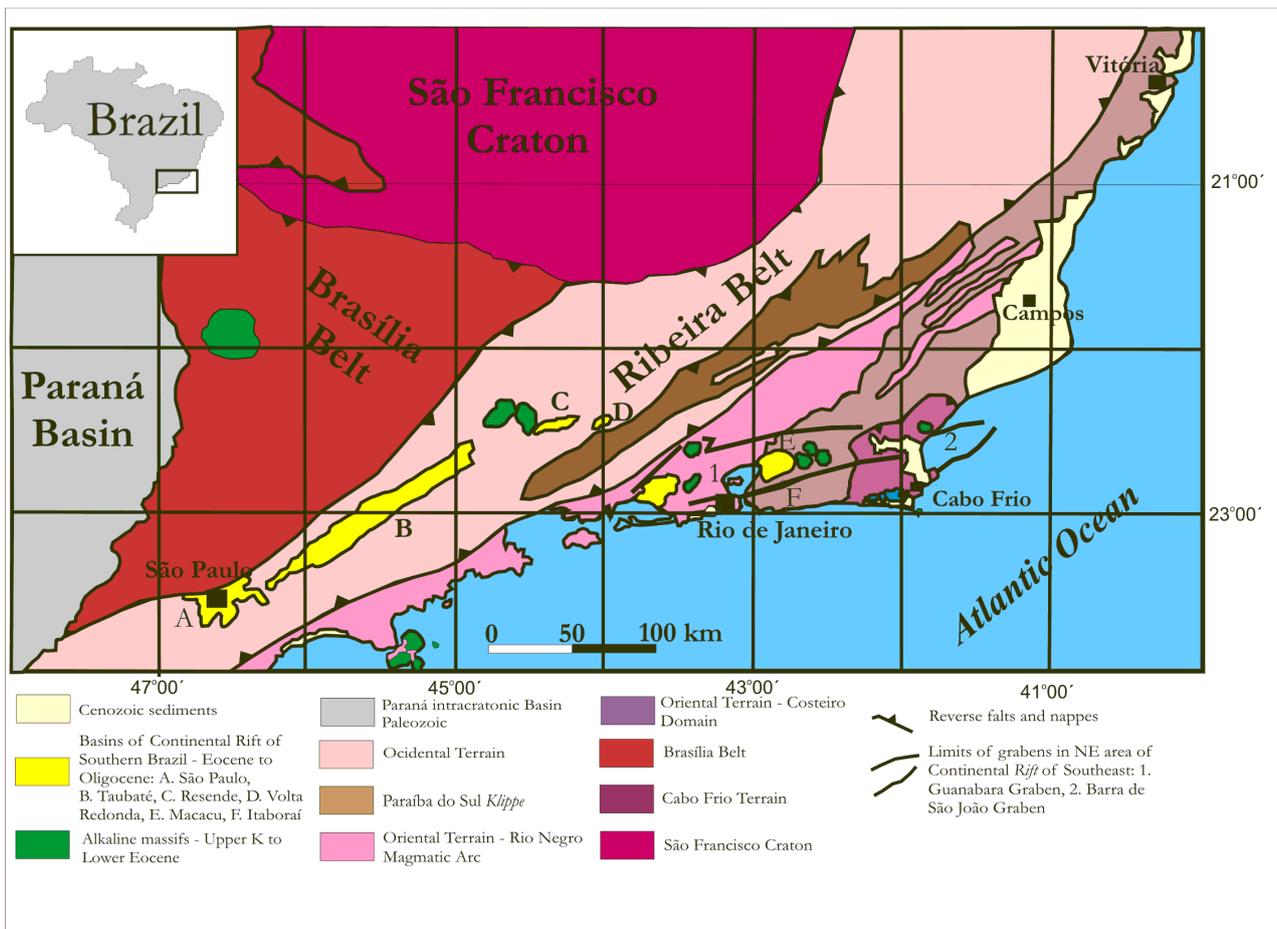


Figure 7 - Tectonic map of Southeastern Brazil. Modified from Ferrari (2001)

As a consequence of the flooding and accumulation of rejects, new direct geologic studies were not possible. The most recent interpretations on the evolution of the basin (Medeiros & Bergqvist, 1999; Ferrari, 2001) were based on old observations data carried out in the area by other researchers, on the analysis of the few outcrops not submerged or covered by vegetation or rejects, on the transversal and longitudinal profiles of the former Cia. de Cimento Portland Mauá, and also on the available literature.

Medeiros & Bergqvist (1999) grouped the facies associations present at the Itaboraí Basin in three stratigraphic sequences which correspond, in part, to the three sedimentary packages as indicated by Leinz (1938) (Fig. 08). According to those authors, the lower sequence S1 (packages "a" and "b" of Leinz, 1938) occurs over the precambrian bedrocks. In this sequence predominates chemical and clastic carbonates interfingered, the last bearing a great amount and diversity of fossil mollusks, remains of plants and some reptiles and mammals. Three main litofacies were recognized in this sequence: travertine, gray limestone and oolitic-pisolitic limestone. The travertine limestone facies is of inorganic origin, presenting a banded arrangement resembling stromatolitic structures and a variety of colors. It is thicker near the São José Fault where the tectonic

subsidence was greater. The oolitic-pisolitic limestone facies occurs in association with the travertine limestone and it is composed of grains of 1,0 mm to 10,0 mm usually with an ellipsoidal shape and a nucleus constituted by mineral grains and, very rarely, by small gastropods. This facies occurs more frequently near the São José Fault and it suggests an association with a hydrothermal spring. The gray limestone facies is an association of facies which grades laterally from calcirudites, calcarenites into sandy and silty limestones. The bedding is usually massive, however locally occurs normal or inverse grading. This association of facies is intercalated with the travertine limestone and forms the floor of the basin (Medeiros & Bergqvist, 1999). The fossiliferous content of late Paleocene age includes mainly mollusks but also, plants and some mammals.

The origin of sequence S1 would be related to hydrodynamic and gravitational flows within a shallow tectonic lake. The chemical carbonates originated predominantly in thermal springs located along the southern border, which was tectonic and sismically active. The existence of marble lenses in the gneisses (Rodrigues-Francisco & Souza-Cunha, 1978) reinforces such hypothesis. The interfinger of the travertine limestone with the clastic carbonates increases progressively upward suggesting an increase in the arid conditions and a decrease in the

gravitational and hydrodynamic flows. The sporadic occurrence of carbonatic shales and lignites in this sequence reveals periods in which carbonatic solutions did not flow into the lake (Ferrari, 2001).

After the deposition of the carbonates related to sequence S1, a process of dissolution and opening of the fissures was started, thus creating the karstic topography of the intermediary sequence (S2). Remains of plants, amphibians, reptiles, birds and abundant late Paleocene mammals are found in this sequence. The sediments that fill up the fissures correspond to a sole facies characterized by marls and collapse breccias whose composition is similar to the gray limestone facies although poorly consolidated, and transported into these cavities by heavy rains and gravitational flows.

On the northern border, over the sequences S1/S2, approximately 90 meters above the basin floor, occurs a flow of ankaramite with approximately 52.6 ± 2.4 my (Riccomini & Rodrigues-Francisco, 1992). Such flow was fed by a tabular sub-vertical dike, about ten meters thick and 150 meters long which cuts the bedrocks, the basal calcirudites and the limestone sequence (Klein & Valença, 1984). This flow is very intemperized and most part of its thickness, according to these authors, would have been eroded during the interval which preceded the deposition of sequence S3. At the discordance contact with the sequence S1 layer, which constitutes the floor of the basin (called Basal Conglomerate by the authors), the flow affected the sediments and therefore carbonized the then existing plants (Barros *et al.*, 2007) and locally silicified the limestones.

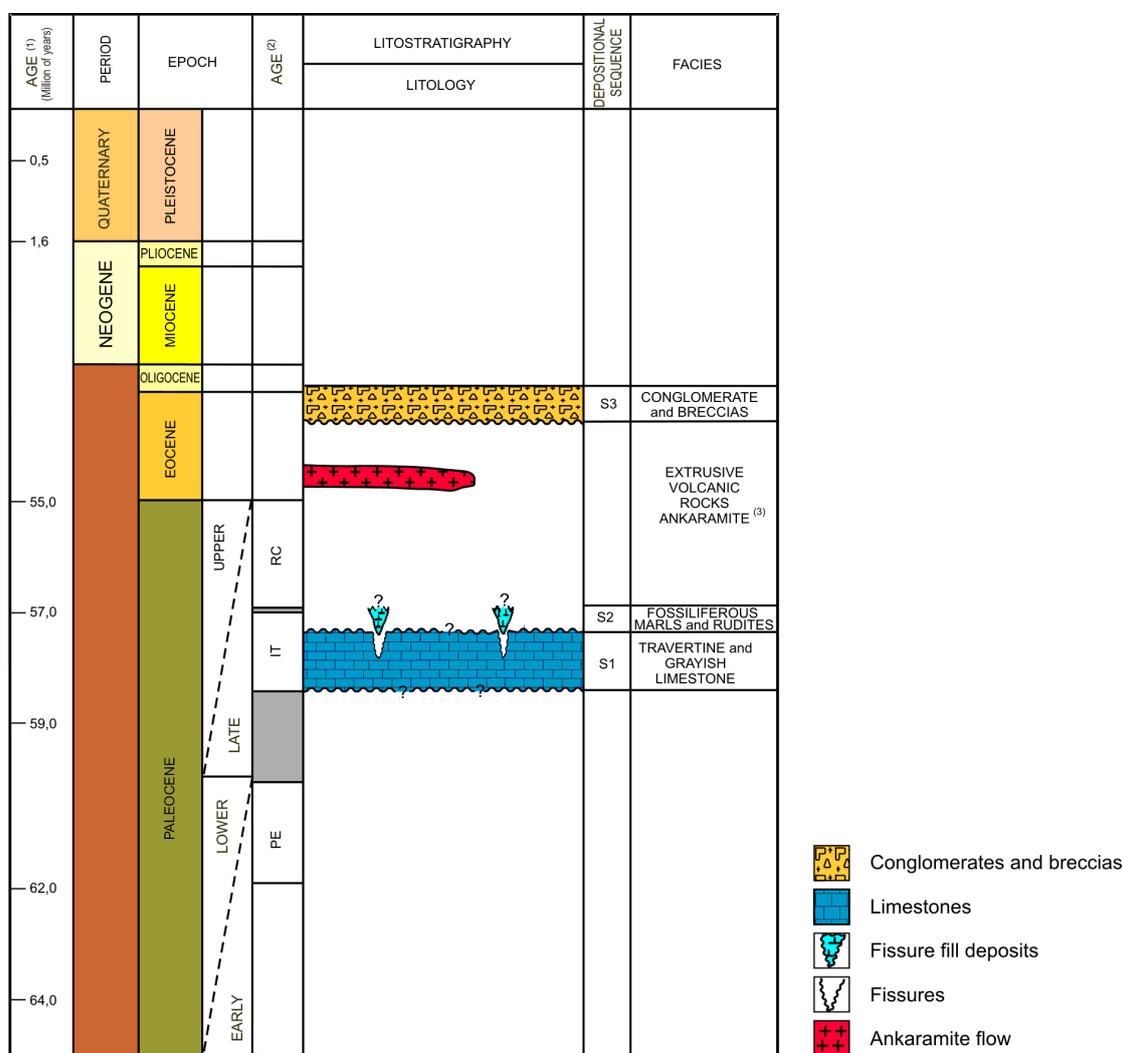


Figure 8 – Chronostratigraphic section of the Itaboraí Basin. Limestones are related to the Itaboraí Formation

The last sequence (S3; package (c), Leinz, 1938) was deposited after the closing of the tectonic cycle which formed sequence S1 and after the erosive processes that formed sequence S2. The sole facies of this sequence is constituted by thick terrigenous sediments (rudites) prograding over the paleocenic

strata, covering the basin. The Pleistocenic age formally attributed to this sequence was based on its sedimentological similarity with a deposit of gravel located over the bedrocks, south of the São José Fault (Price & Campos, 1970), where remains of the pleistocenic megafauna were found. Ferrari (2001)

questioned the use of these fossils for dating sequence S3, since they were found about 100 m south of the southernmost limit of the basin (São José Fault). This author also emphasized the existence of some differences between these two ortoconglomerates and the fact that the terrigenous sediments of sequence S3, at the southeastern portion of the basin, showed a dipping towards the São José Fault, revealing that its deposition was also controlled by the fault.

Sant'Anna (1999) observed the presence of smectitic clays in the matrix of the rudaceous sediments of sequence S3, and he also recognized the similarities between this sequence and the conglomeratic mudstones of the Resende Formation. Therefore, he attributed an eocenico-oligocenoic age to sequence S3. These sediments were called Macacu Formation by Sant'Anna *et al.* (2000), comparing them to those sediments that occur at the homonymous basin in Rio de Janeiro State. According to Ferrari (2000), the presence of mudstones of the sequence S3 in the Macacu Formation presupposes that a link between the Itaboraí and Macacu basins had occurred, a fact the author doubts. Therefore, the author suggests an informal subdivision of the Itaboraí Formation into two members: the Basal Member, including sequences S1 and S2, and the Superior Member, constituted by sequence S3. In this work, however, the authors follow the traditional designation of Itaboraí Formation for all its sequences.

According to Klein & Rodrigues-Francisco (1981) the floor of the basin is constituted by layers displaying gastropods and, at the south border, such layers continue down to level zero, thus contesting the conclusions of Brito *et al.*, (1972) who suggested that the gray limestones rich in gastropods were overlying the travertine limestone. These authors also observed the presence of sole marks in some spots and a gradational structure in almost the gray limestone as a consequence of turbid flows caused by sporadic heavy rains. The authors also observed several structural features such as thrust folds, reverse faults, chevron folds and a brecciated zone. Those authors concluded that the São José Fault is a directional fault and the transverse fault is a reverse fault. These tectonic movements occurred in the southwestern third portion of the basin. In the remaining two-third portions of the basin, the limestones became more porous therefore favoring the formation of the karstic processes.

Paleontology

The first fossils found in Itaboraí were remains of incomplete internal casts of gastropods. They were of little significance and their exact classification could not be determined (Maury, 1929). A new collection

was then organized by Alberto Ribeiro Lamego, in 1934, in which Maury (1935) identified the presence of new genera and species of gastropods in the Itaboraí Basin. This collection also contained the first vertebrate fossils found in the basin – an incomplete crocodile jaw so far not studied yet. Even though the most diversified collection of Paleogene mammals of Brazil came from Itaboraí, the first indications of the presence of this group in the basin was only found in 1944, approximately fifteen years after the discovery of the first gastropods. These remains were referred to as "...scarce and inexpressive fragments" (Price & Paula-Couto, 1946:2), later detailed as "...a premolar of an animal of good load, a phalange of an animal of small size and other less expressive fragments." (Price & Paula-Couto, 1950:152). After these first few discoveries, tens of thousands of fossils were found during the explorations at the quarry. Such fossils are presently in the collections of mammal (M) and invertebrate (I) fossils housed at the Museu de Ciências da Terra ("*Earth Sciences Museum*"), (former Section of Paleontology of the Divisão de Geologia e Mineralogia / DGM) ("*Division of Geology and Mineralogy*") of the Departamento Nacional da Produção Mineral ("*National Department of the Mineral Production*"), in Rio de Janeiro, in the Departamento de Geologia e Paleontologia do Museu Nacional/UFRJ ("*Department of Geology and Paleontology of the National Museum / UFRJ*"), as well as in the collection of mammal fossils of the Departamento de Geologia da Universidade Federal do Rio de Janeiro (UFRJ-DG) ("*Department of Geology of the Federal University of Rio de Janeiro (UFRJ-DG)*") and in the Fundação Zoobotânica do Rio Grande do Sul (Zoobotanic Foundation of Rio Grande do Sul).

Of the several fossil groups collected in the basin, the gastropods are the only ones that come from the clayish limestone layer (sequence S1) that covers the bottom of the basin (Klein and Rodrigues-Francisco 1981). Vertebrates were also occasionally found in this layer, but the great majority of them came from sedimentary deposits that filled up the cracks and channels (sequence S2) (Paula-Couto, 1949; Souza-Cunha, 1982).

The bone and dental remains of the different groups of vertebrates registered in the basin were found mixed, disjointed and dissociated (Fig. 09). Many of them were fractured and some of them showed marks of weathering, but the great majority is in excellent state of preservation. There is little information on the location of the cracks and fissures existing in the basin, and none on the positioning of the fossils inside them. The fossils were collected in the years of 1948, 1949, 1950, 1953, 1961, 1967, 1968 and 1976, as new cracks were found in the limestone and also as the field works advanced.

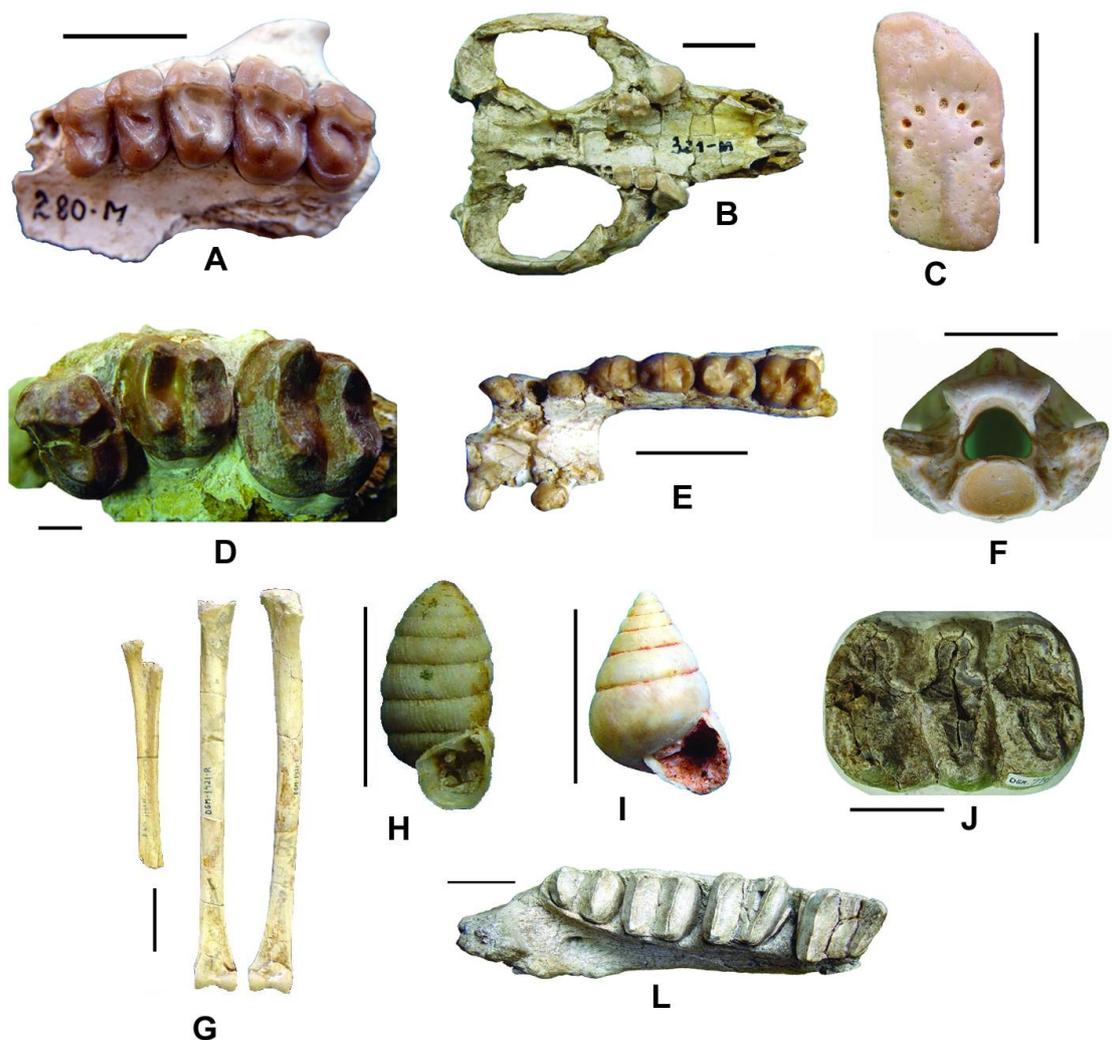


Figure 9 - Fossils of the Itaboraí Basin. A, fragment of upper jaw with teeth of *Colbertia magellanica* (DGM 280-M); B, skull of *Epidolops ameghinoi* (DGM 321-M) in occlusal view; C, osteoderm of *Riostegotherium yanei* (UFRJ-DG 317-M) in dorsal view; D, fragment of upper jaw with P4-M2 of *Carodnia vieirai*; E, fragment of lower jaw with teeth of *Miguelsoria parayirunbor* (DGM 330-M); F, vertebra of *Coniophis* cf. *C. precedens* (UFRJ-DG, class collection) in anterior view; G, leg bones of *Diogenornis fragilis* (DGM 421-M); H, shell of *Brasilennea minor* (DGM 4999-I); I, shell of *Bulimulus fazendicus* (DGM 4993-I); J, molar of *Stegomastodon* sp. (DGM 716-M); L, fragment of lower jaw with teeth of *Eremotherium* sp. (DGM 732-M). A-E, G, H scale bar equals 10 mm; F, I, J equals 50 mm.

Some fossils of pleistocenic age (Fig. 09) were also found in the surroundings of the basin (inside the geographical area of the São José de Itaboraí Paleontological Park), in a bed of gravel deposited on the irregularities of the gneiss, south of the São José fault (Price & Campos 1970), and therefore out of the limits of the basin. Fragmented and friable bones of chelonians, mastodons and giant sloths were collected in a small area of 9m², with 1,3m deep, filled up by boulders, pebbles and angular pebbles predominantly of quartz.

Among all paleocenic macrofossils recovered in the Itaboraí Basin, the mammals constitute the more abundant and diversified group, representing 39% of the total of families present in the basin (Fig. 10). Among these, the Marsupialia are the more diversified ones, and they are represented by 25 genera

distributed into eight families. Although more abundant, the ungulates are less diversified than the marsupials, and they are currently represented by 12 genera distributed in eight families belonging to the extinct orders “Condylarthra”, Litopterna, Notoungulata, Astrapotheria and Xenungulata. Postcranial bones and osteoderms confirm the presence of a genus and those bones suggest the existence of another genus of Xenarthra-Cingulata. The gastropods constitute the second more frequent group of families (21%) in the basin. There are ten genera, distributed in nine families. The reptiles constitute the third more frequent group (19%), and they are distributed in eight families of Squamata, Serpents, Crocodylia and Chelonia. Of these eight families, two are uncertain and only five genera were defined. Among birds diversity (7%), only postcranial

remains of three genera, belonging to three families, are known. Each family belongs to a distinct taxon: Rheiformes, Gruiformes and Cuculiformes. The amphibians, the rarest vertebrates found in Itaboraí (5%), and are known by only two genera belonging to two families of the orders Gymnophiona and Anura. Three genera and four families of plants were defined based on trunks, leaves and seed found in Itaboraí, and they represent 9% of the total of families present in the basin. These families belong to the orders Urticales, Malvales, Myrtales and Rosales.

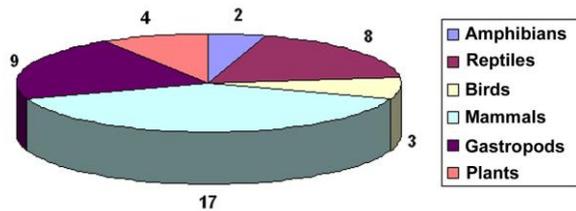


Figure 10 – Comparative diagram of the amount of animal and plant macrofossil families from the Itaboraí Basin.

Microfossils are very rare in Itaboraí and there is a single record of ostracodes (Macedo, 1975) and palynomorphs (Lima & Souza-Cunha, 1986) in the basin.

Recent studies revealed the existence of coprolites associated with the vertebrate fossils found in the cracks (Souto, 2001; 2007). Histological sections made in one of the coprolites revealed the presence of grass cuticles, suggesting the existence of these plants in the basin or in its surrounds (Santos *et al.*, 2007).

No fish remains or of any benthic animal were found in the basin. This is probably related to the water that filled out the lake formed in the original tectonic depression, which was probably very hot thermal water, and/or is due to the high concentration of calcium carbonate dissolved in this water.

The diversity of the above mentioned biota is conditioned not only by the amount of recovered fossils, but it is also influenced by the studies carried out on the different groups. The studies carried on marsupials, part of the ungulates, of snakes and lizards were revised in the last 15 years, which resulted in the recognition of new species and families in the basin. However, turtles and crocodiles have yet not been studied and their presences in the basin were just mentioned by some authors (e.g. Paula-Couto, 1949; Melo & Schwanke, 2006). Detailed information and images of the Itaboraí Basin biota can be found in Bergqvist *et al.* (2006).

Archeology

The Itaboraí Basin is richly fossiliferous and keeps the most important record of the human occupation in America. The main archeological site of Itaboraí was discovered at the beginning of the 70's

decade (Beltrão *et al.*, 1982), at the hillside of Morro da Dinamite (“Dinamite Hill”, eastern portion of the basin) as a consequence of its displacement that started at the top of the elevation (Beltrão, 2000). This site, composed of sedimentary layers whose source area does not exist anymore, with 600 m of extension and 70 m deep, has relatively steep hillsides associated to the morphology of “Ramps”. The most recent occupation of the site took place about 8.100 ± 75 BP. This age was obtained with the Carbon-14 dating method in coals of a bonfire located on the top of the elevation, associated with lithic artifacts (Beltrão, 2000 and Beltrão *et al.* 1982). All the sediment layers and the lines of pebbles show artifacts.

The most recent prospecting carried out in the Itaboraí Paleontological Park area led to the identification of three other sectors of relevant archaeological occurrence, named as “Silix Site”, on the northern border; “Paleontological Site”, on the southern border and “Morro Verde”, also on the northern border.

The Morro da Dinamite site is of exceptional importance because it was possible to identify, through the artifacts found there, a continuous technological sequence. This sequence started, at least, 1 my (middle Pleistocene). Even without absolute dating, it was possible to identify its age on the basis of: a) the evolution of the chipped lithic material that includes choppers, bifaces, hand axes, Levallois type artifacts, lateral rasps, burins, etc (typological method); b) the study of the climatic stains which were deposited on the artifacts during middle Pleistocene, revealing the possibility of an older age, that is, lower Pleistocene; c) the use of two techniques of maturation of the sediments firstly developed in Africa and later applied in Brazil: the ratio of free iron / crystallized iron and the ratio silt-clay; d) and, finally, the application of the stratigraphical method, due to its great depth (Beltrão *et al.*, 2001).

The archeological sites existing in the Itaboraí Basin area integrate the group of sites that constitute the Archeological area of Manguinhos. Those sites, especially the Itaboraí one (Morro da Dinamite), are shore sites. Due to the variation of the sea level in the Pleistocene, the Itaboraí site was located much closer to the shore line. The shore sites are strategically located on elevations and this fact demonstrates that the prehistoric man avoided confrontation with the pleistocenic megafauna in the plains, since caves are rare in the area. Some of such sites, as Cobras and Boa Viagem, are presently located in islands in the Guanabara Bay.

In Itaboraí, the Prehistoric Man used raw materials from the region, and the minerals and rocks used were, in order of preference: quartz (62.2%), silice (18%), limestone (16.6%), quartzite (1.8%) and other hard materials, including gneiss and chalcedony (1.4%). The lowest layer reveals the largest percentage

of white quartz, which is almost colorless. The artifacts found there were used to beat (chisels), to scrape, to cut (backed knives), to cut and to bore (knife-perforator) and to engrave (burins) (Fig. 11).

Several observations can be made regarding the artifacts of Itaboraí, taking in consideration the lithic industry at the site:

1. As already mentioned, the prehistoric occupants of Itaboraí showed a preference for quartz (62.2%) as well as for raw materials with greater homogeneity – because it might have favored the manufacturing of objects. The man of Itaboraí discarded the heterogeneous pieces and/or those pieces showing natural fractures or with fractures derived from chipping accidents when making artifacts, or obtaining a support to produce such artifacts. The reason for this was that using fractured or chipped material would produce unexpected or unwanted artifacts due to the quality of the material.
2. It was also possible to observe a difference in the choice of the raw material according to the local distribution of the sites. The mining activity imposed alterations to the area and the discontinuity of the research did not permit, up to now, that more exact deductions were made regarding the variation in the usage of raw materials observed in the various sectors.
3. The artifacts made from pieces of quartz were not submitted to many finishing touches probably due to the fact that this type of material did not require finishing touches to show cutting edges.
4. As for the artifacts removed during the excavations at the Morro da Dinamite site, it was possible to observe, according to the stratigraphical distribution, a change in the choice of the type of quartz used. In the lower layer it was observed a greater percentage of the white type of quartz, almost hyaline. In the upper layer, however, there were a greater number of artifacts made of quartz with saccharoidal texture.
5. The artifacts found in the beds of gravel on top of the colluvial ramp, as well as in several points of the ramp cut by the road, are: choppers, bifaces, flake axe (hachereau), intense percussion flakes, big rasps (rauloir), back knives.
6. The artifacts from Itaboraí, identified as burins, have remarkable characteristics in relation to the classic definitions of burin. For Laplace (1964), the burin is an artifact whose beveled point is usually perpendicular to the chipped face, and the bevel is constituted by one or several canter.

However, for Tixier (1960), burin is defined as the striking of the burin technique (an expression that apparently designates the action of manufacturing the faces of a burin) which consists in the production of a burin plan by removing a flake, by the means of using a single movement of percussion or pressure, starting from a worked surface or a surface naturally ready to serve as a percussion plan.

In Africa, the typical artifacts of *Homo habilis*, who lived there 2.5 Ma, are the choppers. In the same way, the typical artifacts of the first *Homo erectus* (presently called *Homo ergaster*), who lived in Africa 2 Ma, are equally choppers, although the most characteristic artifact of the *Homo ergaster* is the biface. The wide distribution of biface in Africa, Asia and Europe resulted in the assumption that the *Homo ergaster* was exogamic, this is, that he would marry out of his nuclear group. Other artifacts found in Africa may be attributed to different species of the human evolution, as to the *Man of Neandertal* (formerly called *Homo sapiens neanderthalense* and nowadays known as *Homo neanderthalense*), who lived 300 thousand years ago, until the current man, *Homo sapiens sapiens*, only 45 thousand years old.

Surprisingly, the Itaboraí site presents a technological sequence of chipped stone corresponding to several species of *Homo* in a same site, this is, having choppers and bifaces in its basis, as in Africa. Up to the present, another similar site is not known in the world, even in Africa, that would present such an assemblage of artifacts in a same site. Beltrão & Sarcia (1987) proposed that the *Homo erectus*, who lived 1 Ma, could have arrived in America (not excluding the possibility that the *Homo ergaster* have also arrived in America) since the *Homo erectus* had spread out through regions of different temperatures. The authors call the attention to the fact that, even before the advent of man in the world, animals passed through the Strait of Bering in both directions, as Repenning (1967) had already mentioned. Therefore, the oldest "candidate" to have arrived in America would have been the *Homo erectus* or his older version, this is, the *Homo ergaster*. That assumption was also defended by Henri de Lumley, President of the International Association of Human Paleontology of UNESCO and Director of the Museum of Natural History of Paris (Lumley *et al.*; 1987 1988), based on the discoveries of Beltrão in the Toca da Esperança site, in Bahia, Brazil. Surprisingly, this site revealed choppers in its base and a minimum age of 300 Ky obtained with the uranium-thorium dating method.

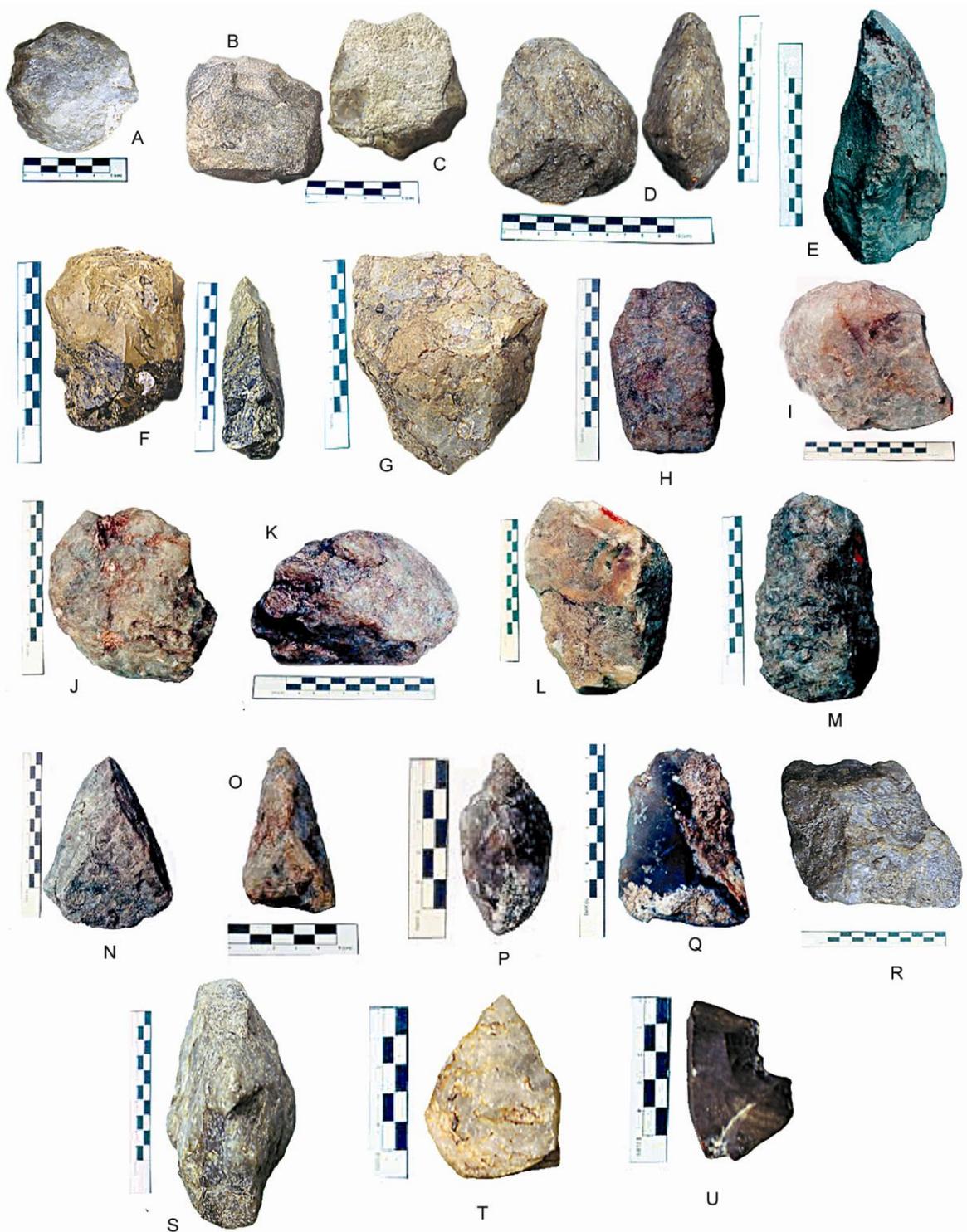


Figure 11 - Artifacts used by prehistoric man, recovered at morro da Dinamite (Dinamite hill), in the Itaboraí Basin. A) discoidal chopper; B) chopper; C) double chopper; D) heart-shaped biface; E) pic-biface with rectilinear edge; F) square bifaces with rectilinear edge; G) ax over flake; H) intense percussion flake; I-K) large scrapers; L) backed knife; M) pre-Levallois flakes; N-O) Levallois flakes; P) perforator; Q) knife; R-S) large and solid scrapers in lateral (R) and upper views (S); T-U) burins. Modified from Beltrão (2000).

SYNOPSIS ON THE ORIGIN, GEOLOGICAL EVOLUTION AND IMPORTANCE OF THE SITE

The Itaboraí Basin is approximately 60 my old and it is one of the smallest sedimentary Brazilian

basins (with approximately 1 km²). A sedimentary basin is a depression where sediments are accumulated and produced by the weathering and erosion of rocks, the action of rivers, oceans, winds, glaciers, etc., or by chemical precipitation processes. In the Itaboraí Basin the sediments have a predominantly chemical origin,

and they are represented by limestone rocks. The formation of the basin is related to the geological phenomena which uplifted the Serra do Mar range and formed the depressions in which the sediments were accumulated.

The origin of the limestone seems to be related to the dissolution of preexisting marbles in the region (more than 500 my). Such marbles were dissolved by subterranean waters and were brought up to the surface by thermal springs. The limestones were formed in the depression when the water evaporated. Sediments originated from the borders of the basin mixed into the limestone and therefore formed a package of clayish limestone (sometimes with a coarse texture) interfingered with pure limestone of chemical origin. The limestone sequence was covered, approximately 50 my, by coarse terrigenous sediments.

The existence of geologic faults delimiting and cutting the basin are of special importance to the basin because such faults reveal movements of rocky blocks after the formation of the basin. Klein & Valença (1984) mentioned the existence of ankramitic lavas (very rare rocks), of approximately 50 my, demonstrating the occurrence of volcanism in the basin.

The limestone deposit which filled up the basin was vertically cut by dissolution cracks (limestone is easily dissolved in water) and the great majority of the fossils were found in those cracks. The remains or vestiges of ancient animals or plants, such as teeth, bones, impressions of leaves or tracks are called fossils.

The Itaboraí Basin is the only Brazilian deposit which registered the first dispersal of the continental mammals after the extinction of the dinosaurs about 65 my. The basin is best known in the international scientific community for its mammal fossils. Due to the abundance, quality and diversity of the mammal fossils found at the basin and to their importance for the understanding of the evolution of the South American mammals, one of the South American Land Mammals (SALMA) ages was named "Itaboraiense" in homage to the basin. It is the sole Brazilian paleontological site whose name was used in an international scale of time. Among Paleocene macrofossils recovered in the Itaboraí Basin, the mammals constitute the most abundant and diversified group. Amid these mammals, the marsupials (mammals that carry their young in pouches, as the skunks) are the most diversified ones. Although they are more abundant, the ungulates (mammals having hooves, as the horses) are less diversified than the marsupials. All ungulate orders registered at the basin were extinct before modern times. The oldest known armadillo fossil was found in Itaboraí. The gastropods (snails) constitute the second more diversified group, followed by the reptiles,

(lizards, snakes, crocodiles and turtles). Fossils of birds and amphibians are also present in the basin but the amount and diversity of such fossils is really small. Among the birds, the species resemble the casuar, the seriema and the cuckoo, and among the amphibians, some species resemble the extant *Caecilian* (blind snake) and toad. The few fragments of trunks and leaves, but abundant seeds of plants recovered in Itaboraí, resemble relatives of the hackberry, the inajarana (*Quararibea*) and the guava tree (Fig. 12).

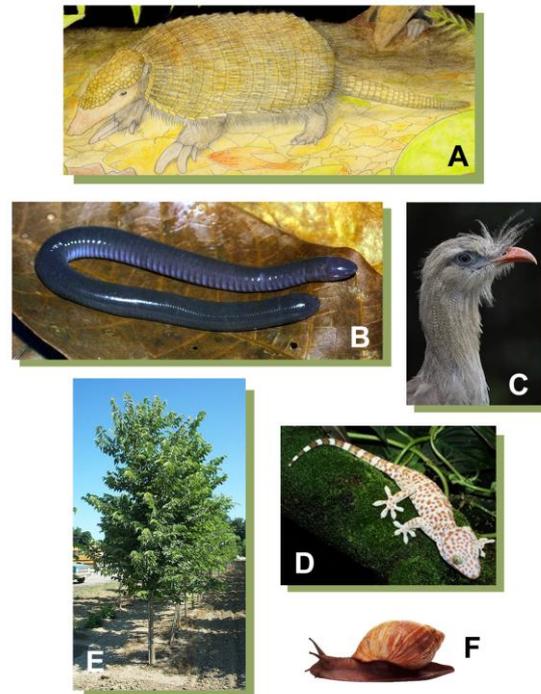


Figure 12 - Reconstitution and extant relatives of Itaboraí species. A, drawing of the armadillo discovered in the basin; B, a caecelian C, a seriema; D, a lizard; E, hackberry; F, a snail.

No fish remains or of any benthic animal were found in the basin. This is probably related to the water that filled out the lake formed in the original tectonic depression, which was probably very hot thermal water, and/or is due to the high concentration of calcium carbonate dissolved in this water.

Microfossils are also present in Itaboraí, but they are very rare. There are single records of ostracodes (small arthropod with two shells) and palynomorphs (pollens) in the basin. Younger fossils (of pleistocenic age) were also found in the surroundings of the basin, in a bed of gravel, revealing that the mastodont and the giant sloth lived in Itaboraí some time ago (Fig. 13).

The Itaboraí Basin is richly fossiliferous and it also keeps the most important record of human occupation in America. The main archeological site of Itaboraí was discovered at the beginning of the decade of the 1970's (Beltrão *et al.*, 1982), at the hillside of Morro da Dinamite (eastern portion of the basin). This site is the oldest one in the Americas (1 Mya – middle Pleistocene) and it would have been initially

inhabited by *Homo ergaster* (formerly known as *Homo erectus*). Although this age has been suggested without an absolute dating, the analysis of the lithic material present at the site and the application of different sedimentologic and stratigraphic techniques support this proposal.

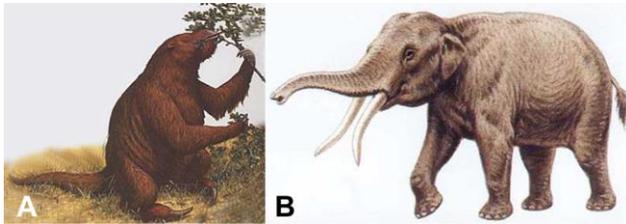


Figure 13- Reconstruction of a giant sloth (A) and a mastodont (B).

The most recent occupation of the archeological site of Itaboraí by *Homo sapiens* dates about 8.100 ± 75 BP, an age obtained by the Carbon-14 dating method in coals of a bonfire located on the top of the elevation, associated with lithic artifacts (Beltrão, 2000 and Beltrão *et al.*, 1982). All the sediment layers and the lines of pebbles (beds of gravel) reveal artifacts. The raw material used by man in Itaboraí comes from the same area.

The Itaboraí sites are part of the Archeological Area of Manguinhos. They are strategically located on elevations and this fact demonstrates that the prehistoric man avoided confrontation with the pleistocenic megafauna in the plains since caves are rare in the area.

SITE PROTECTION

Due to the economic exploration, most of the limestone was removed from of the basin and part of the depression which resulted from the exploration is presently filled out with water. Although most of the original sediments that formed the basin are not preserved, they can still be observed in the borders of the basin, as testimony of the geo-paleontological importance of Itaboraí. The area that was originally owned by Companhia de Cimento Mauá now belongs to the Municipality of Itaboraí which created the "São José de Itaboraí Paleontological Park" (Law 1.346, of December 12, 1995), with the goal of preserving its physical area, the testimonies of the original geology and the fossils remaining in these rocks as well as to make known the geo-paleontological importance of the Itaboraí Basin.

Underground water and rains filled up the mine pit forming the lake which currently supplies the whole town of São José through a cooperative named Cooperágua. The water lamina which in more humid periods may reach approximately 50 m of depth is also a leisure attraction for the local population, such as fishing. Therefore, Cooperágua and the local population also care for the Paleontological Park.

Since 2003, the importance of the São José de Itaboraí Paleontological Park has been strengthened. The Carlos Chagas Filho Foundation for Research Support of the State of Rio de Janeiro - FAPERJ (*"Fundação Carlos Chagas Filho de Apoio à Pesquisa do Estado do Rio de Janeiro - FAPERJ"*), through its Paleontology Virtual Institute (*"Instituto Virtual de Paleontologia"*) offered twenty scholarships to local students. These scholarships are part of the Young Talents Program (*"Programa Jovens Talentos"*) aimed to teenager highschool students of the Francesca Carrey State School (*"Escola Estadual Francesca Carrey"*), located in the surroundings of the Park. Six new scholarships were also obtained for the Visconde de Itaboraí State School – CEVI (*"Colégio Estadual de Visconde de Itaboraí"* - CEVI). All these students have been trained in Geology, Paleontology, Archeology and Environmental Education by teachers from several educational and research institutions of Rio de Janeiro State to prepare them to become guides and guardians of the park. Since then, scientific pre-initiation scholarships have been renewed annually and scientific orientation activities are developed in the Park.

In 2006, an agreement celebrated between Petrobras (Brazilian Petroleum Company) and Instituto Walden (a non-governmental organization) played an important role in the enclosing of the park with a fence (Fig. 10) as well as in the elaboration of its master plan. In 2007, one of the buildings constructed by Companhia Mauá was restored for the implantation of the São José de Itaboraí Paleontological Park Reference Center. The support of FAPERJ also made possible the acquisition of furniture and equipments for a minimum infrastructure for the development of the activities carried out at the Park.

The Park area is currently in its initial phase of reforestation thanks to a partnership between Chácara Tropical and the Municipality of Itaboraí.

It should also be highlighted the priceless effort of the whole scientific community along the last years in preserving the Park and divulging such valuable geological / paleontological / archeological patrimony of the Rio de Janeiro State.

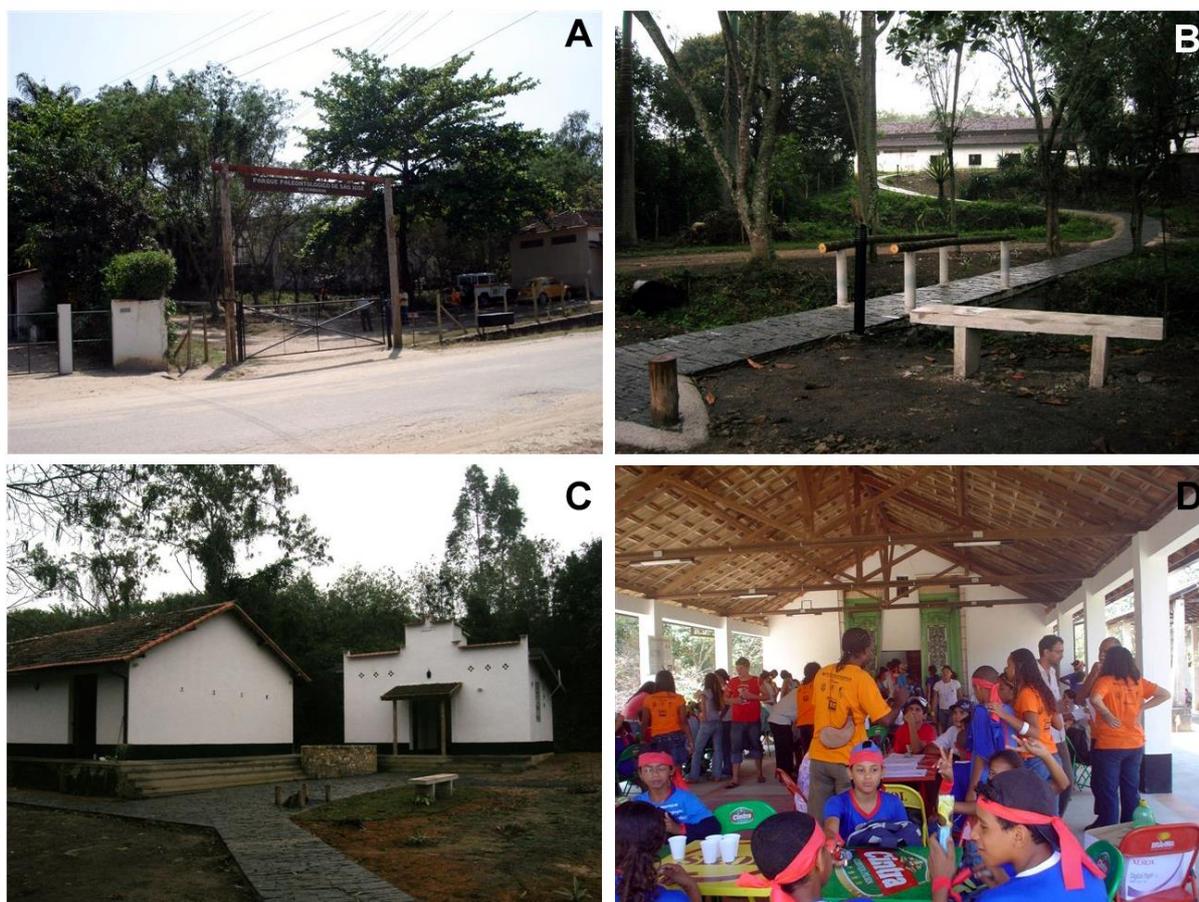


Figure 14 - Paleontological Park of São José de Itaboraí. A, entrance and fence; B, way to Centro de Referência (Reference Center); C, building of Centro de Referência after its renovation; D, students taking part in the activities during the Semana Nacional de Ciência e Tecnologia (Science and Technology National Week).

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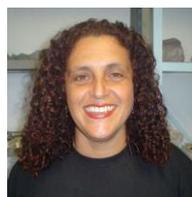
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SYNOPTIC RESUME OF THE AUTHORS



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Graduated in Biological Sciences at Faculdade de Humanidades Pedro II (1983), obtained a M.Sc degree in Zoology at Museu Nacional/UFRJ (1989) and a Doctorate degree in Geosciences at UFRGS (1996). In 1998 she joined the Geology Department staff of UFRJ and since 2004 receives a scholarship on Scientific Production from CNPq (Brazilian equivalent of NSF). She published 36 scientific articles and is the author of 8 book chapters. Her scientific interest has always been related to Cenozoic mammals, but since 1993 she has focused her research in the Itaboraí Basin biota. In 2006 she published a book summoning up the knowledge on the biota, geology and history of the Itaboraí Basin.



Kátia Mansur. Graduated in Geology at the Geosciences Institute at the Rio de Janeiro Federal University (1982) (“Instituto de Geociências da Universidade Federal do Rio de Janeiro”) and currently is studying

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Graduated in Geology (1968), obtained the Master's Degree (1971) at the Geosciences Institute, Rio de Janeiro Federal University – UFRJ and acquired the Doctorate Degree in Geosciences (1982) at the Rio Grande do Sul

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Doctorate degree in 2000, both in Archaeology at the São Paulo University. In 1989 she became archaeologist at the Anthropology Department at the National Museum/UFRJ. She published a book in Brazil, 26 articles in national and international publications, and in the annals of congresses; she is the author of three chapters of books. Since 1979 she studies the pre-historic occupation of the Itaboraí Basin. Currently she orientates undergraduate students and high school students of the Young Talent Project - CECIERJ/FAPERJ.



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Coutinho Beltrão. Graduated and licensed in Geography and History at the Fluminense Faculty of Philosophy in 1955 and 1956. She obtained her Doctorate degree in Anthropology (Archaeology) and in

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