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Underground erosion features in Devonian sandstones of the Paraná Basin, southern Brazil

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The Buraco do Padre is a very beautiful furna located at NW-SE and NE-SW faults and fractures intersection in sandstones of the Furnas Formation (Devonian of the Paraná Basin) that outcrops in the Campos Gerais Region, center-eastern of the Paraná state, southern of Brazil. The furnas are subterranean erosion features that extended up to the terrain surface. They are typical of the Furnas Formation sandstones with argillaceous cement that in suffering dissolution favors the rock decomposition. The Buraco do Padre is a notable furna for allowing easy access on foot to its interior through the Quebra-Pedra subterranean riverbed which is controlled by NE-SW direction faults. The river enters the furna through other subterranean passage, controlled by NW-SE direction fractures. Other features near the main furna are: a second smaller furna, tunnels, grikes and scarps associated to faults and fractures. This set of features is very illustrative of the subterranean landscapes in the sandstones of the Furnas Formation, an important structural aquifer placed in a region with increasing needs of water resources.

Key-words: furna, subterranean erosion, Furnas Formation, structural aquifer.

INTRODUCTION

Furnas are landforms resulting from subterranean erosion where the rocky cover caves in (Maack, 1946 and 1956; Soares, 1989). This results in large holes measuring up to 110 metres in depth and 500 metres in diameter. Furnas are typical of the sandstones of the Furnas Formation, Devonian of the Paraná Basin, southern Brazil, where the dissolution of some of the mineral components facilitates subterranean erosion. In the state of Paraná, furnas are mostly found in areas where the Furnas Formation outcrops, the most notable being the ones in the Vila Velha State Park, among them the Lagoa Dourada, a silted up furna (Melo, 2002).

The Buraco do Padre is a very attractive and illustrative furna, easily reached on foot. Upon entering it, the furna displays tunnels, grikes and associated subterranean rivers beautifully exposing the sandstones of the Furnas Formation on its walls. It is an outcropping example of deep subterranean cavities found in a geological unit of increasing importance as a structural acquifer in a region of expanding demand for hydric resources. Furthermore, these unique landforms enable the formation of micro-ecosystems with many endemic species which have yet to be studied. Rupestrian plants proliferate on the walls of the furnas, tunnels and grikes, while swallows make their nests in the uneven rocky surface. A strange freshwater crustacean, similar to a small lobster (*Aegla castro* Schmitt), lives on the bottom of the river and the small sandy pond inside the furna.

In the areas surrounding the furna there are three different ecosystems - open fields, *Araucaria* woods and remnants of savanna-type vegetation. In addition, there are archaeological sites with rupestrian paintings and other landforms typical of the region (scarps, grikes, ruiniform relief and other furnas). These attributes attract not only the local population who frequently visit the place for leisure or natural sports activities, but also elementary and secondary scholars because of their subjects on Environmental Education or related scientific studies. Researchers on Geology, Geomorphology and Biology from different regions in Brazil, as well as from abroad, come to visit. Despite this, the site needs to be studied in greater detail and scientific documentation needs to be compiled as well as providing adequate infrastructure for the many visitors going there.

LOCATION

The Buraco do Padre furna is located approximately 24 km east-southeast from the centre of the city of Ponta Grossa in the centre-east of the state of Paraná (Fig. 1), near the geographical coordinates 24°34' S and 50°14' W. From Ponta Grossa, access to the area is gained initially along the

PR-513 highway (about 18km) followed by a secondary dirt road (about 6km). This secondary road begins on the right of the highway about 2km before the village of Passo do Pupo.

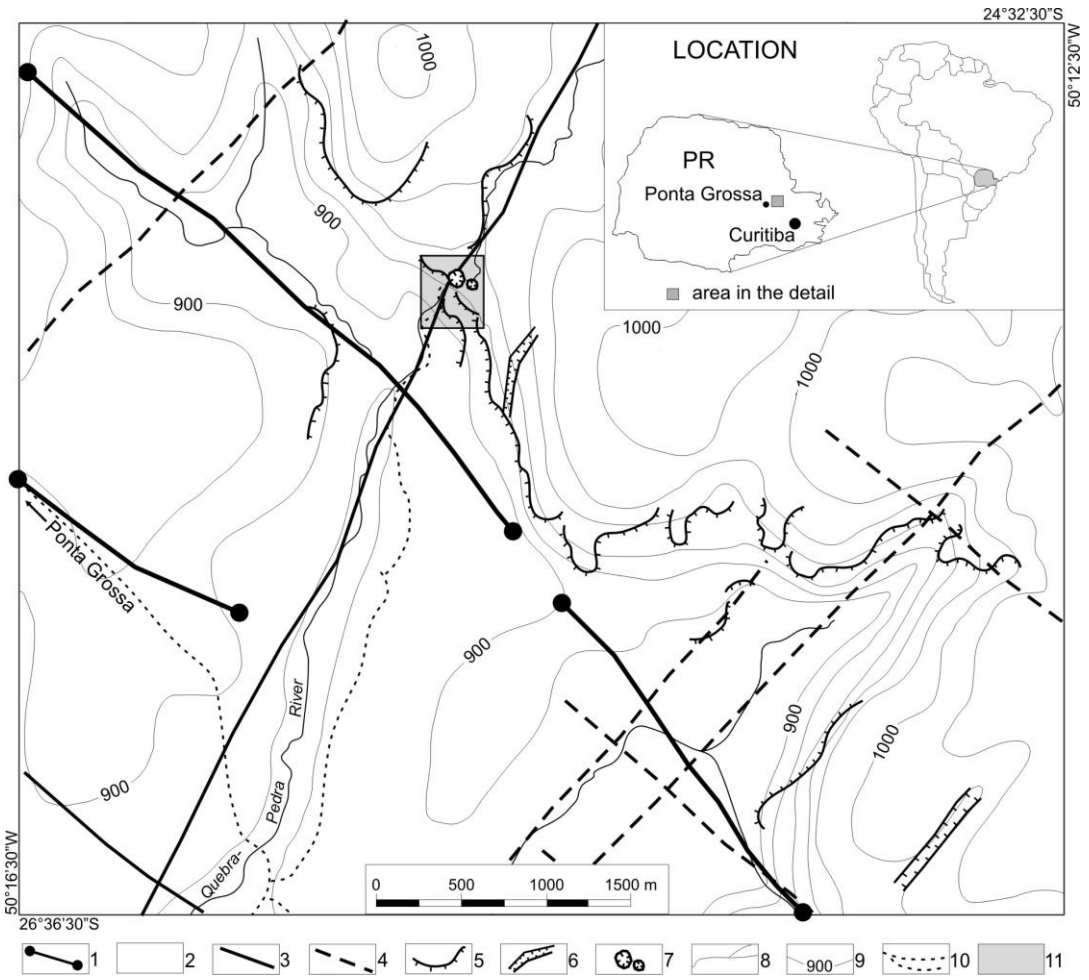

Figure 1 - Location and geology of the Furna of the Buraco do Padre. 1: diabase dikes; 2: Furnas Formation; 3: faults; 4: structural lineaments; 5: scarps; 6: grikes; 7: drainage; 8: contour lines; 10: roads and trails; 11: area detailed on Figure 4. Topography: map of Itaiacoca 1:50.000, DSG, 1959.Geology from Trein et al., 1967.

DESCRIPTION OF THE SITE

The origins of the name "Buraco do Padre" ("The Priest's Hole") are uncertain. No registers of its use has been found prior to the last 50 years so it can be concluded that the name is fairly recent. It is said that the name comes from the fact that a priest was known to visit the intriguing subterranean cavity, remote, calm and favourable to introspection, for his spiritual retreats.

Rocks and geological structures

The Buraco do Padre is located on the eastern edge of the Paraná Basin, heavily affected by the crustal upwarping called the Ponta Grossa Arch, that was predominantly active in the Mezozoic Era. This upwarping raised the rocks in the region and fractured them intensely. The subsequent erosion that followed exposed sedimentary rocks of the base of the Paraná Basin, among them the sandstones of the Furnas Formation where the Buraco do Padre and other furnas are found.

The basement of the Paraná Basin, two kilometres east of the Buraco do Padre, is made up of Proterozoic low-to-medium grade metamorphic rocks of the Açungui Supergroup (phyllites, schists, marbles, quartzites) and associated large calcium-alkaline granitoid complexes (Cunhaporanga and Três Córregos granites) (MINEROPAR, 1989).

The Paraná Basin is a vast South American intracractonic depression stretching across Brazil, Uruguay, Argentina and Paraguay. The Furnas Formation constitutes the main basal unit of the Paraná Basin in the region of the Buraco do Padre. It lies discordantly on rocks of the Proterozoic basement or on the Iapó Formation, while the transition for the overlapping units is either gradual, when it passes to the Ponta Grossa Formation, or erosive, when rocks from the Itararé Group follow the Furnas Sandstones. These consist predominantly of medium to coarse sandstones of light colouring, feldspatic and/or

kaolinitic, with regularly selected angular to subangular grains. The sandstones are arranged in sets of 0,5 to 5 metres thick with tabular, lenticular and cuneiform geometry, displaying a marked cross-stratification, tabular, trough or tangential at its base (Assine, 1996).

The sandstones of the Furnas Formation had a complex evolution, including the formation of clay cement (kaolinite and illite) during diagenetic processes. These filled in the spaces between the quartz grains joining them firmly and significantly reducing the original porosity of the rock (De Ros, 1998). On the other hand, this clay cement may undergo dissolution due to the action of water (Melo, 2004), a process which benefits the formation of cavities such as furnas or subterranean river beds.

Vertical NW-SE diabase dikes of relatively small thickness (less than ten metres) occur near the Buraco do Padre. They are parallel to the axis of the Ponta Grossa Arch. The presence of these dikes favours the formation of morphostructural lineaments (scarps, tunnels, grikes, linear river beds), as well as generating more fertile soils, where arboreal vegetation develops and contrasts with the dominant grasslands around.

The Buraco do Padre developed at the intersection of two structures: i) an important system of fractures in the NW-SE direction, parallel to the axis of the Ponta Grossa Arch, which controls the Quebra-Pedra River upstream from the furna; and ii) a long, important fault in the NE-SW direction, parallel to the Proterozoic basement structures, which control the Quebra-Pedra River downstream from the furna.

Inside the Buraco do Padre, there is a notable display of sets of the Furnas Sandstones with their typical horizontal and cross-stratification. The NE-SW fault caused blocks to rotate about 15°; on the rocky walls, one can see the change in the layers caused by the movement (Figs. 5 and 7). On the left bank of the Quebra-Pedra River, downstream from the Buraco do Padre, there are blocks of diabase of a dike intruded in another NW-SE structure associated with the Ponta Grossa Arch.

Relief and hydrography

The Buraco do Padre furna is located in the goemorphological compartment called the Second Paraná Plateau. It is the second step of the *en échelon* relief in the State of Paraná, with the Devonian Scarp limiting its east and the Serra Geral on its west. The relief of the Second Paraná Plateau is quite contrasting: far from the bordering scarps predominate large hills with a height of less than 50 metres. Tops vary from 1200 metres in the back slope of the Devonian Scarp to 800 metres near the Serra Geral. Near the scarps there are high cliffs, canyons and inselbergs.

In the area of the Buraco do Padre, it is possible to notice the effect of the transitional relief between the First and Second Paraná Plateaux, the Devonian Scarp, whose name is derived from the Devonian sandstones of the Furnas Formation. In this place, the relief shows erosive scarps that fall up to one hundred metres (Fig. 2) being influenced by brittle structures (faults, fractures, dikes) in some places. This area near the Devonian Scarp has steep hydraulic gradients, which helps infiltration and water mobility inside the rocks and is responsible for the formation of the furnas, subterranean rivers and tunnels and the opening of grikes (Fig. 3).

The stream that passes through the Buraco do Padre and associated tunnels is the Quebra-Pedra River, a right-margin tributary of the Quebra-Perna River. This flows into the Guabiroba River, an affluent of the Tibagi River, an important watercourse in the State of Paraná, running south-north and flowing into the left-margin of the Paranapanema River.

The hydrographic basin of the Quebra-Pedra and Quebra-Perna rivers is significantly unique. Contrary to the regional relief, it is the only one in the region that displays scarps looking west on the opposite side of the Devonian Scarp. In addition, there are other known furnas besides Buraco do Padre, reflecting pronounced subterranean erosion. Examples of these are the Furna Grande, the Furnas Gêmeas, and the furnas of the Vila Velha State Park, among others. They are all situated on an elongated strip of terrain in the NE-SW direction, coinciding with geological faults that cuts rocks belonging to the Proterozoic basement and rocks of the Paraná Basin of which the sandstones of the Furnas Formation form a part. This indicates that the subterranean erosion responsible for the creation of furnas is largely influenced by these geological structures (faults, fractures) in the NE-SW direction.

The Buraco do Padre is a furna with a maximum of 30 metres in diameter and little more than 40 metres of visible depth. Approximately 25 metres above its base, it receives the waters of the Quebra-Pedra River, forming a beautiful waterfall and a small pond with sandy bottom (Figs. 4, 5 and 6). The river enters the furna through a tunnel 40 metres in length and a maximum of 8 metres in height, controlled by fractures in the NW-SE direction, associated with the Ponta Grossa Arch (Fig. 6). It exits through another tunnel of about 30 metres in length and 25 metres in height, this having been escavated along the fault of regional extension in the NE-SW direction (Fig. 7), which affects the occurrence of other features of similar subterranean erosion (Furnas Gêmeas, Furna Grande). On the riverbed and at the bottom of the furna, there is sandy sediment, the total depth of the subterranean cavity not being known. About 50 metres upstream from the Buraco do Padre the Quebra-Pedra River, that flows on the surface of the terrain, empties into a smaller furna of about 20

metres in diameter and 5 metres in depth (Figs. 4 and 5).

Figure 2 - Scarp controlled by NW-SE faults in sandstones of the Furnas Formation , left riverside of the Quebra-Pedra River downstream of the Buraco do Padre.

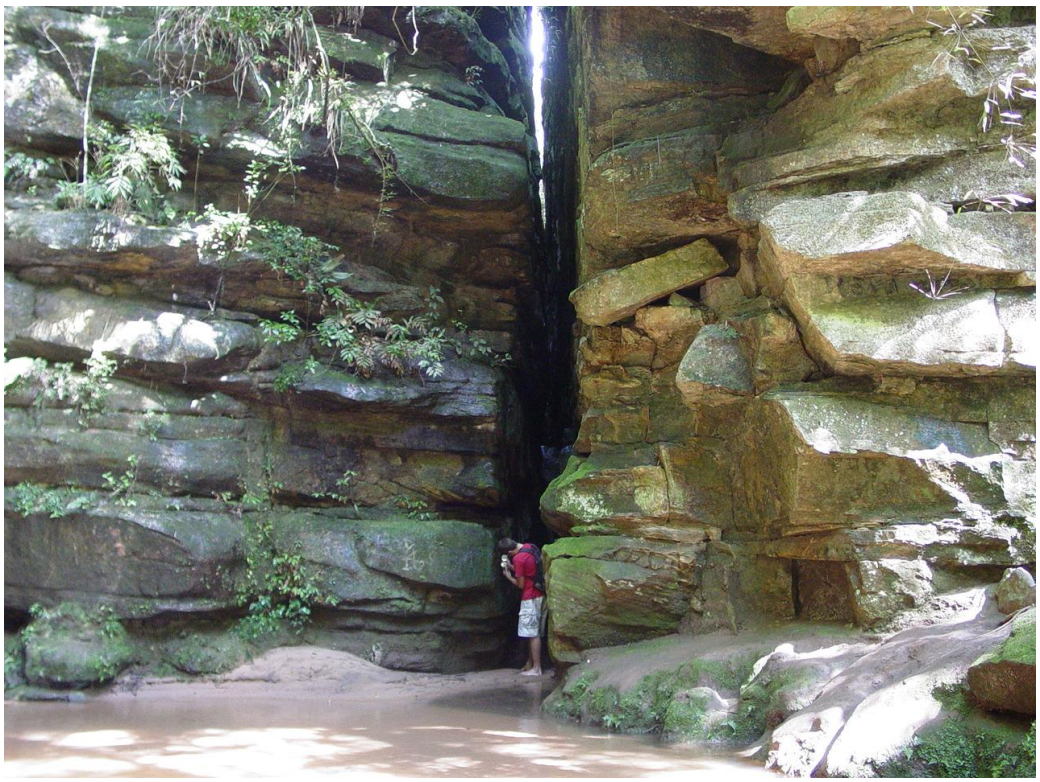

Figure 3 - Grike developed in a NW-SE fracture in the entry of the Buraco do Padre.

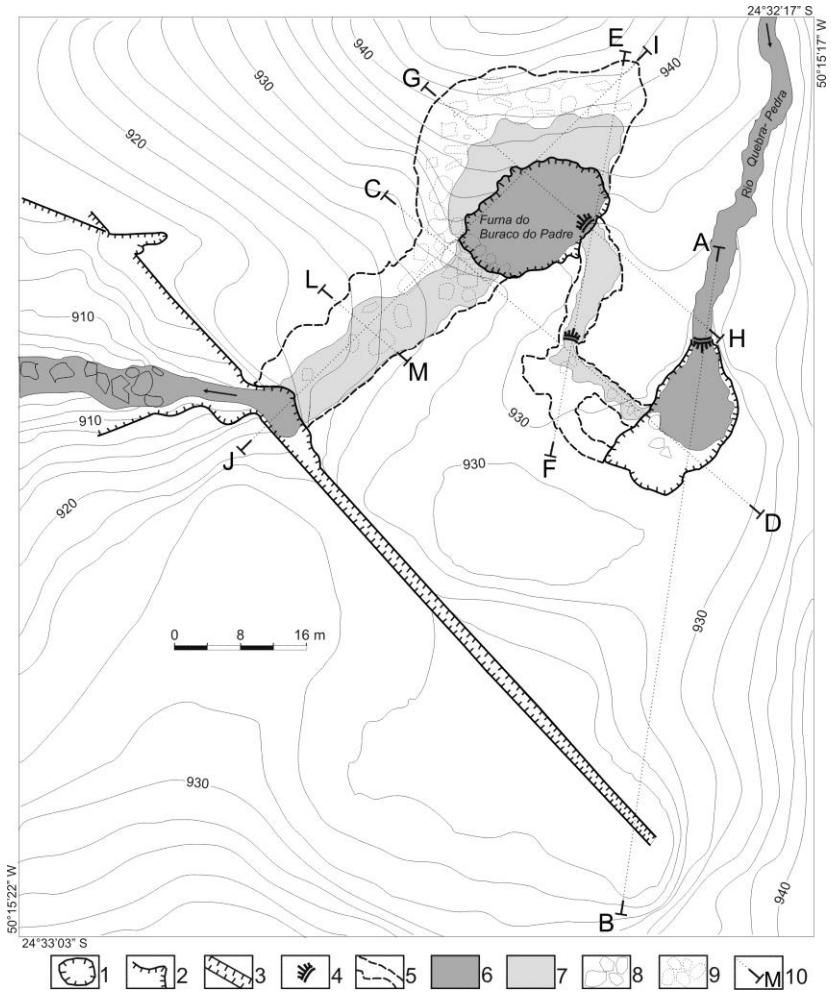

Figure 4 - Geomorphology of the Buraco do Padre and associated landforms. 1: furnas; 2: scarps; 3: grikes; 4: waterfalls; 5: projection of the basal perimeter of subterranean cavities; 6: surface waters (arroyos and lakes inside the furnas); 7: underground waters; 8: surface rocky blocks; 9: rocky blocks in subterranean cavities; 10: extremities of vertical sections on Figure 5.

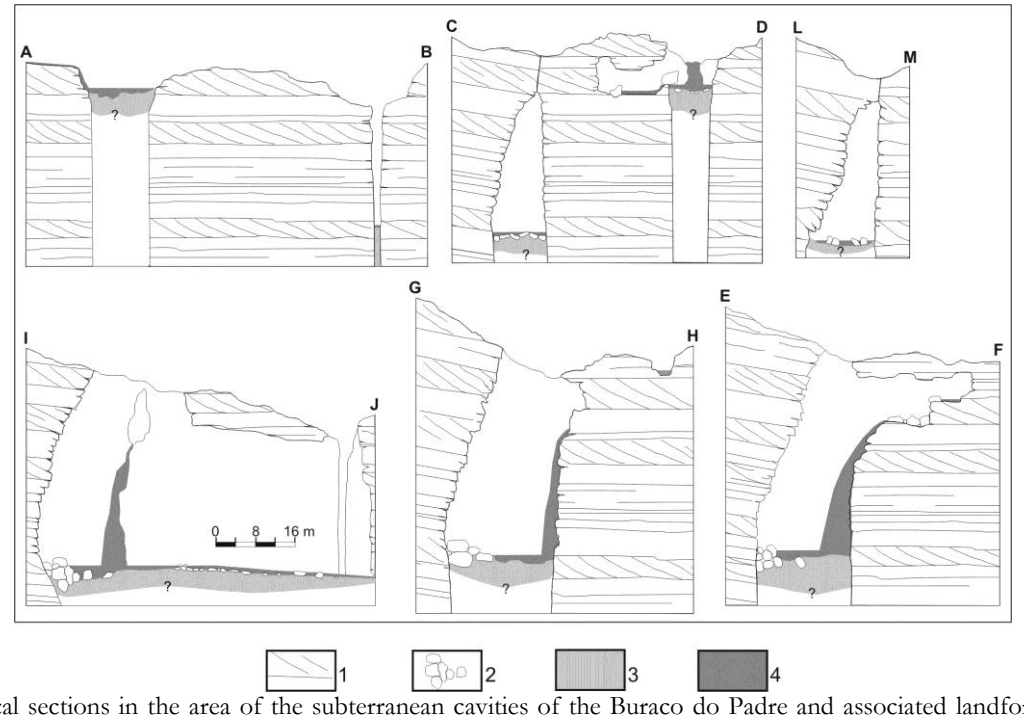

Figure 5 - Vertical sections in the area of the subterranean cavities of the Buraco do Padre and associated landforms (see location on Figure 4). 1: sandstones of the Furnas Formation; 2: rocky blocks; 3: sandy sediments; 4: surface and underground water.

Figure 6 - Entry of the Quebra-Pedra River into the Buraco do Padre through a subterranean riverbed controlled by a NW-SE fracture.

Figure 7 - Tunnel in a NE-SW fault through which the Quebra-Pedra River goes out of the Buraco do Padre. See the change in the stratification at both sides of the fault.

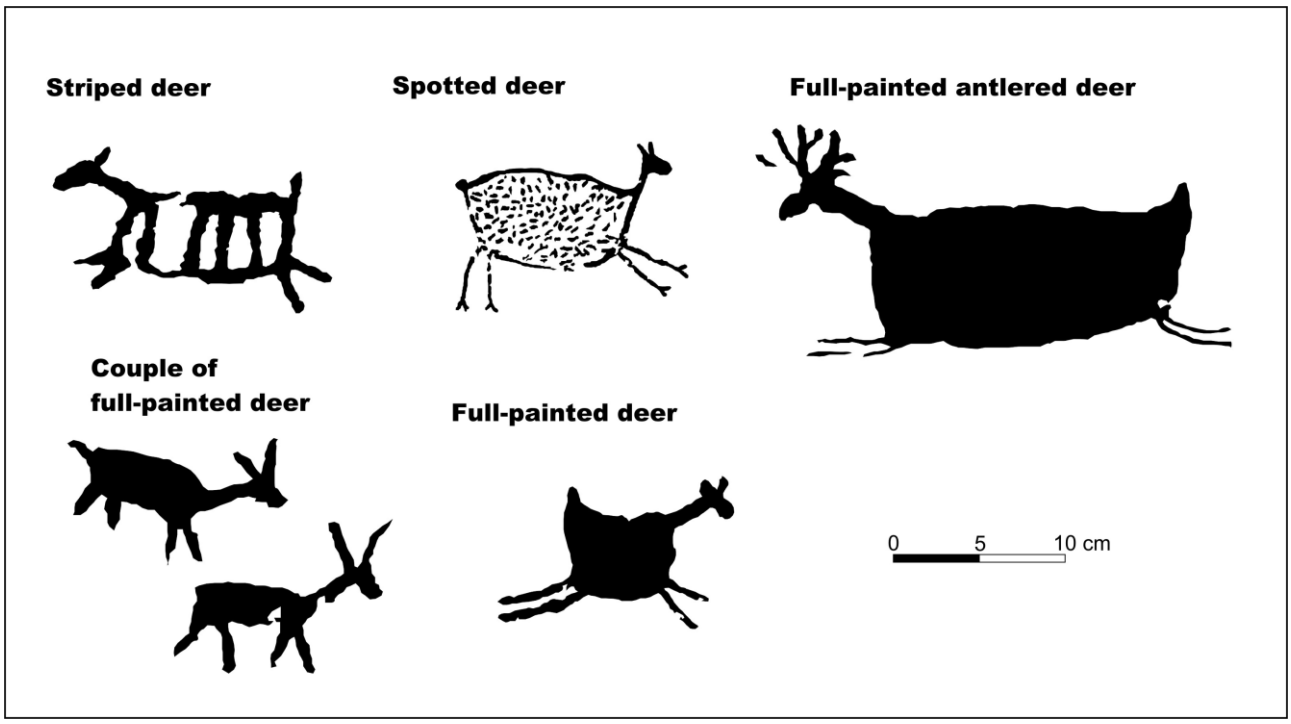

Figure 8 - Decalcomania of rupestrian paintings representing deers attributed to the Planalto Cultural Tradition. They are found in the Sumidouro do Rio Quebra-Pedra, downstream of the Buraco do Padre (Silva & Melo, s.d.).

Ecosystems

Open fields of the savanna-type arboreal vegetation predominate in the Buraco do Padre and neighbouring areas, covering most of the slopes and relief tops. Woods with *Araucaria* are found as riparian woods or as isolated coppices. This type of wood formation is included in the phytoecological zone of the mixed ombrophyla forest (Veloso & Góes-Filho, 1982), situated in Maack's so-called "region of open grasslands with coppices and riparian woods along the rivers and creeks (also *Araucaria* zones)". The vegetation of the grasslands consists mainly of grasses, Cyperaceae, Compostae, Verbenaceae and Leguminosae, that form a dense herbaceous covering.

The coppices present several successive stages. In the young nuclei, heliophila species of the Myrtaceae, Anacardiaceae and Euphorbiaceae families predominate, in the absence of *Araucaria*. In the more developed nuclei "...the *Araucaria* is surrounded by an undergrowth of Myrtaceae and Lauraceae while, around its edges, Melastomataceae and Compositae occur in abundance" (Moro, 1998, p.14).

In the woods that flank the watercourses, such as the Quebra-Pedra River and the furnas, Palmae, bamboos and ferns can be found, as well as other families that appear in more developed nuclei. In the riparian forests there are also angico trees (Leguminosae).

There are also marshy fields around the Buraco do Padre, controlled by humid depressions of the ground due to the subterranean erosion of the sandstone. On small landings on the nearby rocky walls there can still be found relicts of savanna where there is a predomiance of marmeleiro-do-campo (*Austroplenckia populnea*) and other bioindicator species (Estreiechen *et al.*, 2001).

Archaeological sites

The hydrographic basin of the Quebra-Perna and Quebra-Pedra rivers, where the Buraco do Padre is situated, has many archaeological sites sheltered beneath the rocks. This is evidence of the passage of prehistoric indigenous bands of nomadic hunters and collectors who passed through the area, moving between inland and the coast in search of food. These shelters contain lithic vestiges (stone artifacts), pottery and, above all, rupestrian paintings which could be over 3000 years old (Chmyz, 1976).

The rupestrian paintings are found on the rocky walls of the scarp above the Buraco do Padre, and in nearby natural shelters, mainly in a place called Sumidouro do Rio Quebra-Perna (Sinkhole of the Quebra-Perna River), about 2 km downstream from the Buraco do Padre. These paintings are mostly attributed to the Plateau Tradition, characterized by etchings that mainly represent animals (deer, birds, fish, armadillos, etc., Fig. 8), very rare human beings, and even more rare scenes suggesting lifestyles of the age. They are principally done using red pigment (hematite).

These archaeological remains have not been adequately studied although they may bring to light many important subsidies for anthropological, paleoenvironmental and paleoclimactic interpretations. By ignoring their meaning, the local population has allowed the paintings to undergo accidental or even deliberate depredation, sometimes destroying this important heritage.

PROTECTIVE MEASURES

The Buraco do Padre is situated within the boundaries of the APA - Área de Proteção Ambiental (Area of Environmental Protection) – of the Devonian Scarp. A decree was passed in 1992, with 324,260.56 ha, spreading through Paraná from the borders of Santa Catarina, to the south, to the borders of São Paulo, to the northeast. There has also been a municipal law since 1992 (n° 4,832) making it into a park of the city of Ponta Grossa. However for diverse reasons, these laws, which acknowledge the immense natural heritage of the region, have not been put into practice regarding the areas of preservation.

The land where the Buraco do Padre is found is private property. Due to the interest in the area and the great number of visitors, the owners made improvements in the late 1990s, including a minimal infra-structure for a nearby camp-site and upgraded the access trail to the furna, running parallel to the Quebra-Pedra River. These improvements increased the number of visitors, but with no orientation or control over the visits. These visitors damaged the area, spoiling the flora and rocky walls, causing soil erosion, putting pressure on the fauna and disposing of waste material into the Quebra-Pedra River.

The rocky scarps and nearby fields are frequently used for sports such as climbing, rappel, walking, camping and trekking (walking for more than a day). Those who do indulge in these activities, although in the most part being respectful and lovers of nature, have sometimes caused negative impacts. These include the inadvertent destruction of rupestrian paintings, discarding waste material, depredation of the rocky walls as well as the flora, and causing accidental or deliberate fires. In addition, frequent accidents such as falls occur and are sometimes fatal.

However, the greatest risks to the natural heritage around the Buraco do Padre are the economic activities clashing with the natural vocation of the area and current environmental legislation. In the last two decades, many of the natural fields covering sandy, shallow and poor soil originating from the Furnas Formation, were replaced by intensive farming (soya, corn, wheat), or *pinus* forestry for the paper industry. The new plantations and forestry frequently do not respect the areas along the riverbanks which demand permanent protection. Although the agricultural techniques used (no tillage and others) result in compensating harvests at the beginning, the tendency in the medium term is that there is erosion and depletion of the very fragile soil and the polluting of the watercourses from silt and agrotoxics.

These circumstances require urgent measures to be taken for the protection of the Buraco do Padre and other nearby sites of rich natural heritage such as the Devonian Scarp, Furnas Gêmeas, Furna Grande, the Sinkhole of the Quebra-Perna River, the Mariquinha Waterfall, the Swallows' Cave and others. Among the possible solutions for the protection of this important area of natural heritage, the one that seems the most effective is turning the area into a national park. A project of the IBAMA - Instuto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (Brazilian Institute for Environment and Renewable Natural Resources) was established and presented to the local population in February 2005, with a view to creating the National Park of the Campos Gerais. Having roughly a surface area of 23,000 ha, it extends from the *Araucaria* forests on the First Paraná Plateau to the natural grasslands close to the Buraco do Padre on the Second Plateau thereby encircling part of the Devonian Scarp. Although it was very well conceived from an environmental point of view, this proposition of creating a national park has met with great resistance from producers and companies. They have still not realized the importance of preserving the equilibrium of the region, bringing benefits in the medium term even to the economic forces that today are against it.

REFERENCES

Assine,M.L. 1996. *Aspectos da estratigrafia das seqüências pré-carboníferas da Bacia do Paraná no Brasil*. Tese de Doutoramento, Instituto de Geociências da Universidade de São Paulo, 207p.

Chmyz,I. 1976. Nota prévia sobre o sítio PR PG 1: abrigo-sob-rocha Cambiju. Curitiba, *Estudos Brasileiros*, 2: 231-246.

De Ros,L.F. 1998. Heterogeneous generation and evolution of diagenetic quartzarenites in the Silurian-Devonian Furnas Formation of the Paraná Basin, southern Brazil. *Sedimentary Geology*, 116(1-2): 99-128.

Estreiechen,L.; Ritter,L.M.O.; Maia,D.C.; Moro,R.S. 2001. Caracterização da vegetação da área do Buraco do Padre, Ponta Grossa, PR. *In*: UEPG, Jornada Científica de Geografia, 3, Ponta Grossa, *Boletim de Resumos*, p.73-74.

Maack,R. 1946. Geologia e geografia da região de Vila Velha e considerações sobre a glaciação carbonífera do Brasil. Curitiba, *Arquivos do Museu Paranaense*, v.5, 305p.

Maack,R. 1956. Fenômenos carstiformes de natureza climática e estrutural de arenitos do Estado do Paraná. Curitiba, *Arquivos de Biologia e Tecnologia,* 11: 151-162.

Melo,M.S. 2002. Lagoa Dourada, PR - Furna assoreada do Parque Estadual de Vila Velha. *In*: Schobbenhaus, C.; Campos, D.A.; Queiroz, E.T.; Winge, M.; Berbert-Born, M. (Eds.), *Sítios geológicos e paleontológicos do Brasil*. Brasília, DNPM-CPRM-SIGEP, p.289-298 (SIGEP 99).

Melo,M.S. 2004. *Controle estrutural e litológico da erosão subterrânea e superficial de arenitos da região dos Campos Gerais do Paraná*. Relatório de pesquisa de pós-doutorado, Instituto de Geociências da Universidade de São Paulo, 61p.

MINEROPAR – Minerais do Paraná S/A. 1989. *Mapa Geológico do Estado do Paraná*: escala 1:650.000. MINEROPAR, Curitiba.

Moro,R.S. 1998. *Interpretações paleocológicas do Quaternário através da análise de diatomáceas (Bacillariophyta) nos sedimentos da Lagoa Dourada, Ponta Grossa, PR*. Tese de Doutoramento, Instituto de Biociências da Universidade Estadual Paulista, Rio Claro, 141p.

Silva,A.G.C.; Melo,M.S. s.d. Pinturas rupestres em abrigo sob rocha no Rio Quebra-Perna, Ponta Grossa, Paraná. *Revista Publicatio UEPG* (*in print*).

Soares,O. 1989. *Furnas dos Campos Gerais, Paraná*. Scientia et Labor, Curitiba, 82p. (Editora da UFPR, Série Didática).

Trein,E.; Marini,O.J.; Fuck,R.A. 1967. *Folha geológica de Itaiacoca 1:50.000*. Comissão da Carta Geológica do Paraná.

Veloso,H.P.; Góes Filho,L. 1982. Fitogeografia brasileira - classificação fisionômica-ecológica da vegetação neotropical. Salvador, *Bol.etim Técnico do Projeto RADAMBRASIL*, série vegetação, n.1, p.1-80.

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