GeoJournal of Tourism and Geosites Year **VII**, no. **2**, vol. **14, November 2014**, p.**111-124**
ISSN **2065-0817**, E-ISSN **2065-1198** Article no. **14102-153**

GEOLOGICAL AND GEOMORPHOLOGICAL ELEMENTS AS MANAGEMENT TOOLS IN PROTECTED AREAS OPEN TO PUBLIC USE: A CASE STUDY OF THE PEDROSO'S NATURAL MUNICIPAL PARK, SANTO ANDRÉ, BRAZIL

Mikhaela Aloísia Jéssie Santos PLETSCH*
University of São Paulo, School of Arts, Sciences and Humanities, Arlindo Béttio Avenue, 1000, Ermelino Matarazzo, CEP 03828-000, São Paulo, Brasil, e-mail: mikhaela.pletsch@usp.br

Victor Fernandez VELÁZQUEZ
University of São Paulo, School of Arts, Sciences and Humanities, Arlindo Béttio Avenue, 1000, Ermelino Matarazzo, CEP 03828-000, São Paulo, Brasil, e-mail: vvf@usp.br

José Maria AZEVEDO SOBRINHO
Secretary of State for Environment, Geological Institute, Miguel Stéfano Avenue, 3900, CEP 04301-903, São Paulo, Brasil, e-mail: zemaria@igeologico.sp.gov.br

Giácomo Botaro BORGES
Municipal Environmental Sanitation Service of St. Andrew, José Caballero Avenue, 143, Centro, CEP 09040-210, Santo André, Brasil, e-mail: giacombb@semasa.sp.gov.br

Carolinne Serrano COUTINHO
University of São Paulo, School of Arts, Sciences and Humanities, Arlindo Béttio Avenue, 1000, Ermelino Matarazzo, CEP 03828-000, São Paulo, Brasil, e-mail: carolinne.coutinho@usp.br

Abstract: Covering an area of 842 hectares, the Pedroso's Natural Municipal Park lies to the southeastern from the Santo André city centre. The region congregates a large variety of rocks, landforms and natural processes that are important to understand the evolution of our planet and its influence in the current landscape configuration. The catalogued sites illustrate the relationship between the metamorphic and tectonic structures, the effects of the weathering processes and the steep slopes on the soil erosion. Another field of practical application of those geological data is in the natural hazards prevention. With well-preserved outcroppings and easy access at the site, the park provides wide space for scientific research, educational activities and a fascinating place for leisure.

Key words: Pedroso's Natural Municipal Park, protected areas, geological and geomorphological elements

* * * * * *

* Corresponding author

INTRODUCTION

The protected natural areas are territorial spaces with high environmental values and require a special careful to ensure the preservation of an ecologically balanced environment. The term "public use", on the other hand, denotes a set of programs, services, activities and infrastructure that the administration should provide for a safe and comfortable amusement of the visitors, establishing rigorous measures for the preservation of the natural and cultural heritages (Hernández & Gómez-Limón, 2005). In the light of these principles, conciliate use and conservation of natural protected areas have been increasingly more difficult, mainly, when the area is surrounded by a densely populated urban centre, and the demand for leisure, involving outdoor physical activity, has been growing significantly.

In view of the realities presented above, and taking into account the nedd of incorporating new management forms to minimise the environmental damges, since the nineties have been continuously approached in numerous publications (Cendrero et al., 1996; Sharples, 2002; Mata-Perelló, 2005; Brilha, 2005) the importance of the geological elements as an alternative tool for the effective protection of the natural resources (Mata-Lleonart, 2004; Sarmiento, 2005). The practical application of the geodiversity includes several areas of the knowledge, including the aspects scientific, educational, cultural, aesthetic and economic (Brilha, 2005). Wherefore, it was judged timely to perform a systematic survey of the geological and geomorphological units occurring in the Pedroso's Natural Municipal Park (PNMP).

CONTEXTUALISATION OF THE STUDY AREA

The PNMP, located in the midwestern from the Santo André city, has a perimeter of roughly 19.5 km and an area of 842 hectares. With its major axis oriented NE-SW, the northern border is contiguous to a densely urbanised area, whereas the southern limit accompanies lightly the northern margin of the Billings hydrographical basin. The access can be made by the Estrada do Pedroso, No. 3336, and through some trails that cross the park (Figure 1).

The park has the necessary infrastructure for the practice of outdoor sports, besides natural attractions as lakes, river springs, invasive exotic species of pines and eucalyptus, a significant area of remaining Atlantic Forest, as well as important wellsprings. A wide range of animal species, markedly birds, with about 100 species grouped into 79 different genera, forms part of the park's biodiversity. From among these species deserve to be highlighted the opossum (Didelphis spp), the white-eared opossum (Didelphis albiventris), the nine-banded armadillo (Dasypus novemcinctus), little spotted cat (Leopardus tigrinus), brown-throated sloth (Bradypus variegatus), the Brazilian guinea pig (Cavia spp), the Brazilian cottontail (Sylvilagus brasiliensis), the brocket deer (Mazama spp) and red-ruffed fruitcrow (Pyroderus scutatus) (SEMASA, 2007).

The region brings together a diversified natural environment and a landscape of great scenic beauty. In order to preserve this important ecosystem, the whole area of the park was declared a Conservation Unit in 2002. Although the PNMP is under environmental protection measures, approximately 20% of its territory presents severe biophysical transformation, and around 2% is taken by slums.

This critical situation is mainly due to an accelerated urban growth in the surrounding of the park (SEMASA, 2007). The historical aspect of the park can be summarised into three main events: a) dispossession of the ancient farm of the 3 Vianas in the early forties, b) permission of free access to the park for the users in the seventies, and c) recognition of the area as Conservation Unit by the National System of Conservation Units in 2000 (SEMASA, 2007).

A preliminary evaluation of the PNMP environmental conditions indicates that the area has been undergoing a constant and strong anthropogenic pressure. This unfavorable situation can come to trigger in the future an irreversible degradation, compromising the natural resources and the operation of the park. The natural or cultural heritages are the main identity of a region and as such should be preserved. The non-renewable resources of the park should provide new concrete tools to strengthen the protection of the ecosystems and to encourage the implementation of integrated program planning for a sustainable use. Under this perspective, the principal goal of this paper is to characterise the geological elements that occur in the PNMP, describing the peculiarities of the lithological units and the components of the landscape. This way, the intention is to catalogue the most relevant sites to the geotourism practice and to contribute for a possible management strategy and divulgation of the geoscience concepts, which can be inclusive used as an auxiliary tool in activities of environmental education.

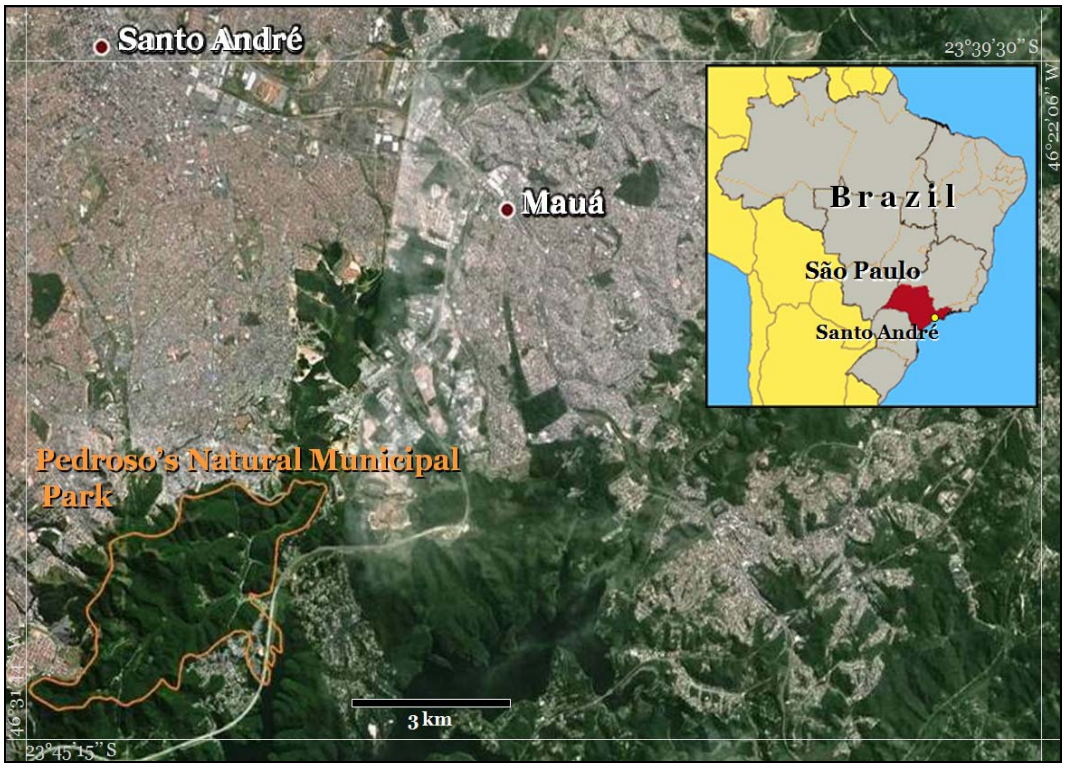

Figure 1. Location map of the Pedroso's Natural Municipal Park

METHODOLOGICAL PROCEDURES

The field survey was performed using geological map of the region, satellite images (IKONOS and CBERS-2), with resolution up to 30 m, provided by the Geologic Institute-SMA/SP, and digital terrain model, generated from the SRTM data (IUGS), about 90 m (3 arc second) of spatial resolution. These iconographic documents have made possible the location and better definition of the geological features and anthropogenic activities. Besides the description of the outcroppings and the assessment of the environmental degradation, the fieldwork also allowed collecting some samples of the main lithologies

that occur in the region. The place visited have been positioned with GPS, GARMIN 12XL, that operates with twelve channels parallel to compute the position. The integration, interpretation and final edition of the data were performed using the software Global Mapper 12, Golden Surfer 11 and CorelDraw Graphic Suite X6.

REGIONAL GEOLOGICAL SETTING

The Neoproterozoic Ribeira Fold Belt is an important geotectonic unit that extends more than 1400 km along the southeastern region of Brazil (Almeida et al., 1973; Hasui et al., 1975), and it is composed of Archean, Paleoproterozoic and Mesoproterozoic rocks, which were reworked during the amalgamation of the Western Gondwana supercontinent (Tassinari et al., 2001). All previous models of tectonic evolution that are available in the literature for the central segment of the Ribeira Fold Belt suggest a simple ensialic mechanism under compressional regime (Tassinari, 1988; Sadowski & Tassinari, 1988; Hackspacher et al., 2000).

According to Tassinari et al. (2001), in São Paulo State can be recognised three geological domains - Costeiro, Embu and São Roque - in the central portion of this complex orogenic belt, and the contacts between the units are markedly controlled by extensive shearing zones. The crystalline basement that occurs in the surroundings of the PNMP (Figure 2) has been historically included into the Embu Domain and comprises three major lithological units: (i) Mica schist and metasandstone, (ii) Migmatite and granitic gneiss and (iii) Granite and granodiorite, which reveal a wide variety of metamorphic environments (Sadowski, 1974; Hasui et al., 1975; Hasui & Sadowski, 1976). Isolated outcrops of Tertiary sediments and Quaternary deposits overlying, locally, the highly heterogeneous Precambrian basement (Coutinho, 1979).

The Mica schist and metasandstone Unit occupies a large part within the area and is essentially constituted of medium grade metamorphic rocks, markedly foliated, with medium to large-grained mica flakes, biotite and/or muscovite, often finely interleaved with quartz and feldspar (Coutinho, 1979). In some cases, the layers are less micaceous and schistose, and the unit is described as metasandstone. The Migmatite and granitic gneiss Unit outcrop mainly outside the park, in the eastern sector, and, to a lesser extent, within the park, in the southern and western portions, and consists of a contrasting rock type, ranging gradually from migmatite, granite to gneiss, interlayered with mica schist (Coutinho, 1979).

An intensive brittle-ductile deformation, evidenced by the stromatic structure and blastomylonitic texture, may be observed in those rocks. The Granite and granodiorite Unit is characterised by congregating a series of igneous rocks of granitic composition that were emplaced throughout ancient faulting zones, forming elongated bodies in the NE-SW direction. According to Coutinho (1972), this lithological association reveals recrystallization texture and progressive comminution of quartz and feldspar, suggesting an accentuated post-magmatic deformation.

The Tertiary sediments occur essentially in the northern sector of the PNMP and correspond to the sedimentary basin of São Paulo. Lithofacies studies carried out by Riccomini & Coimbra (1992) indicate that those sediments were deposited in an environment of alluvial fan system grading progressively for floodplain and braided river, with local occurrence of lacustrine deposits. Quaternary unconsolidated sediments, and other fluvial deposits, are commonly found along the PNMP, forming smaller adjunct basins. The layers usually start with conglomerate or sandstone, passing, invariably, upward into mudstone. Although the radiocarbon datings available in the literature elucidate very little about the event that occurred during the Quaternary, the ages of the oldest colluviums are less than 30 ka B.P. (Turcq et al., 1989; Riccomini et al., 1989).

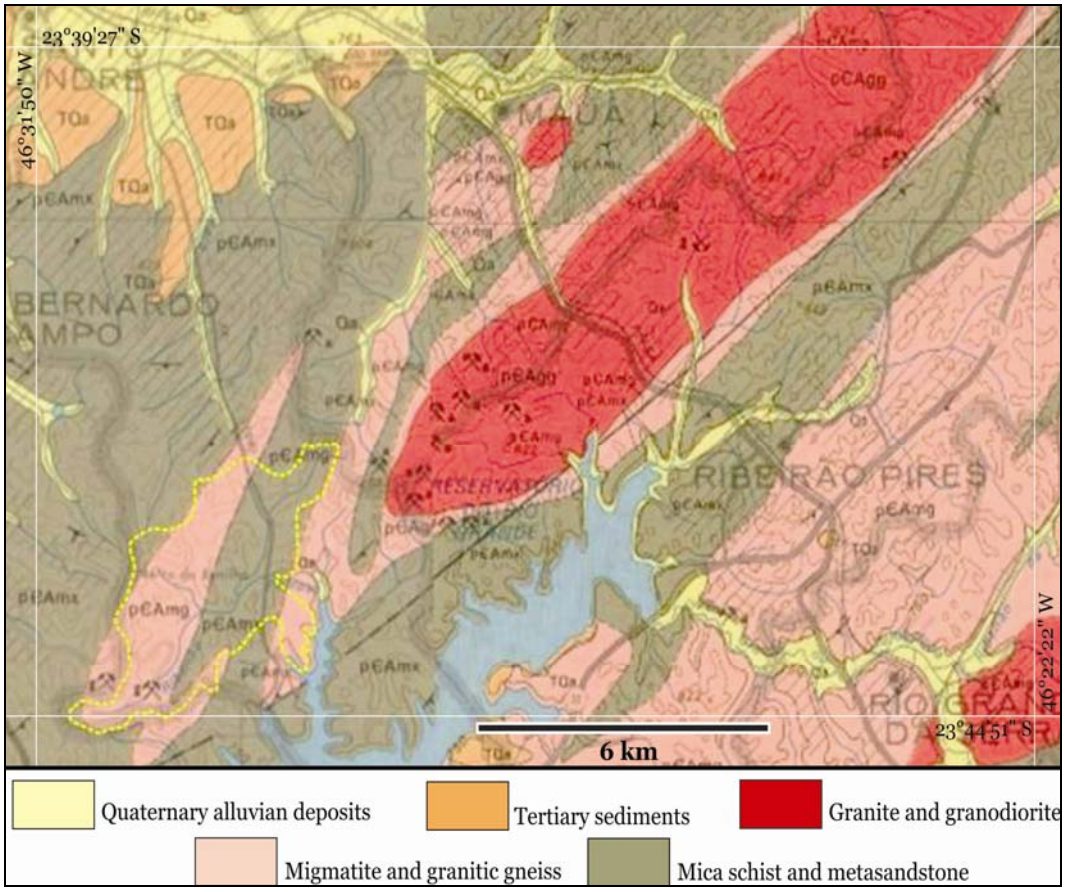

Figure 2. Regional geological map showing the main lithological units in the adjacent areas of the PNMP. Yellow dotted line delimits the region of the park (Source: Coutinho, 1979)

GEOMORPHOLOGICAL ASPECTS

The wide range of relief of the São Paulo State territory is closely associated with the diversity of the geological framework, including an immense variety of the crystalline basement lithological unit, extensive areas of sedimentary basin, different regions of major tectonic domain and a long continuous action of weathering and erosion. The major morphostructural features were grouped by Almeida (1964) and Ponçano et al. (1981) into five geomorphological units: Atlantic plateau, Costal province, Peripheral depression, Basaltic "cuestas" and Occidental plateau (Figure 3). The complexity of the relief forms within each unit led these authors to propose subdivisions for the morphological variations. Thereby, the Atlantic plateau was divided into different geomorphological zones, where the PNMP region has been included into the Paulist plateau zone (Figure 4).

The landscapes that predominate within the PNMP are similar to those regional morphological elements that have been characterised by Almeida (1964) for the Paulist plateau. They are largely constituted of hills and ridges showing flattened tops and an altitude between 720 and 940 m (Figure 5). These topographical expressions are likely sustained by metamorphic rocks, essentially schists and gneisses. The highest point of the park is situated on the western border, where the "Pico do Bonilha" reaches to an altitude

of 940 m, whereas in the eastern sector predominates the ridges of modest heights. Wide valleys, slopes with profiles varying from convex to rectilinear and alluvial plains of limited extension occur along the central portion.

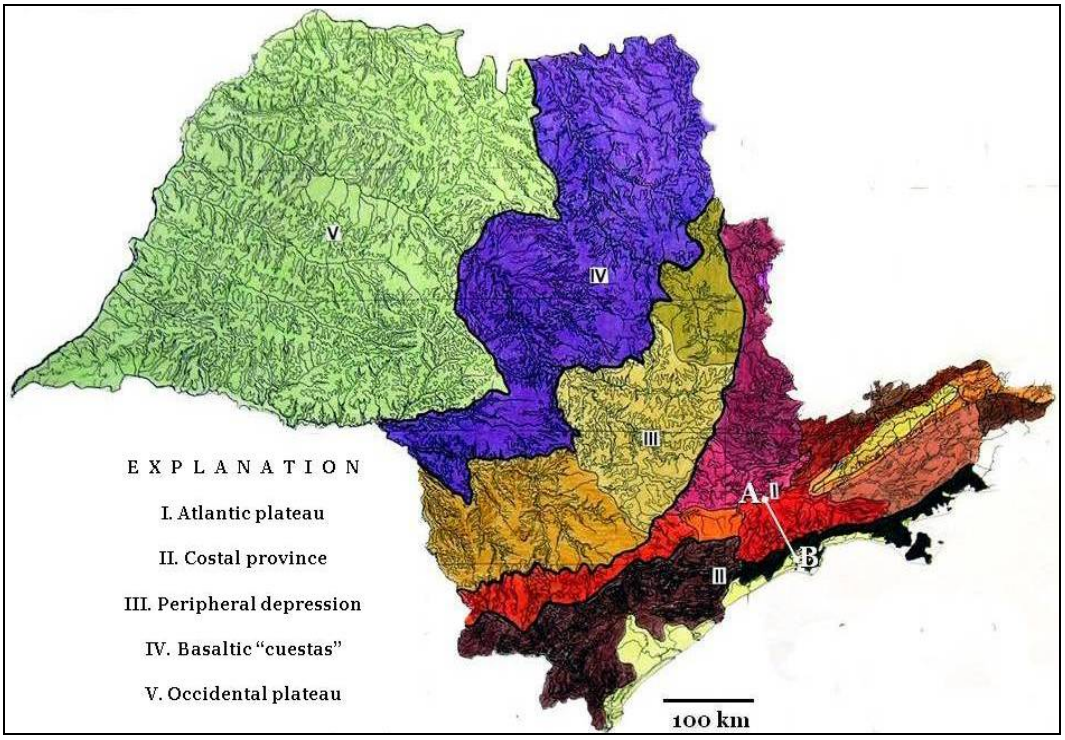

Figure 3. The São Pauto State geomorphological province. The transect A-B indicates the position of the profile shown in Figure 4 (Sources: Almeida, 1964; Ponçano et al., 1981)

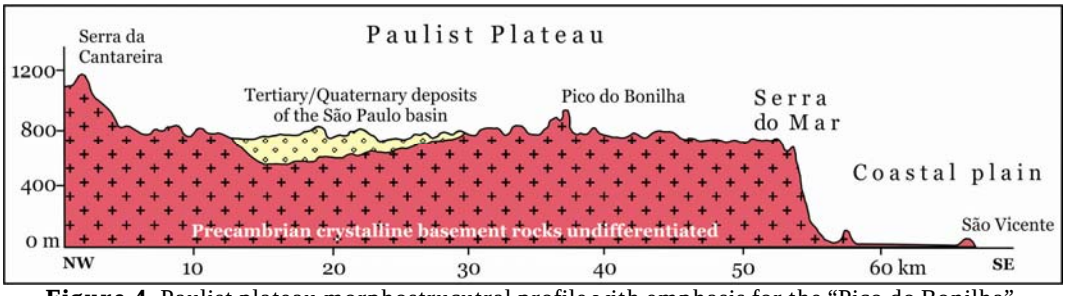

Figure 4. Paulist plateau morphostrucutral profile with emphasis for the "Pico do Bonilha", western border of the PNMP (Source: Ponçano et al., 1981)

According to Coutinho et al. (2012), the arrangement of the hills and ridges configures a broad elongated valley. With steep slopes and its opposite sides in parallel disposition, the runoff of the surface drainage tends to move towards a common centre, characterising a small hydrographical basin. An analysis of topolineaments based on the digital terrain model indicates that the PNMP geographical region is composed of much other minor headwaters (Figure 6). Although the morphological configuration of the park is favourable for the runoff of rainwater to a principal channel, three mains catchment

areas can be recognised along its entire extension. These include: (a) the northern sector, formed by elongated valleys and steep slopes, (b) the central segment, characterised by valleys narrow, steep and craggy with the almost parallel tributaries and (c) the southern portion, constituted of a single V-shaped valley, long and sinuous. Each zone has its particularity in terms of cross profile of the valleys, steepness of the slopes and the flow direction of the tributaries, resulting in a broad variety of topographical forms.

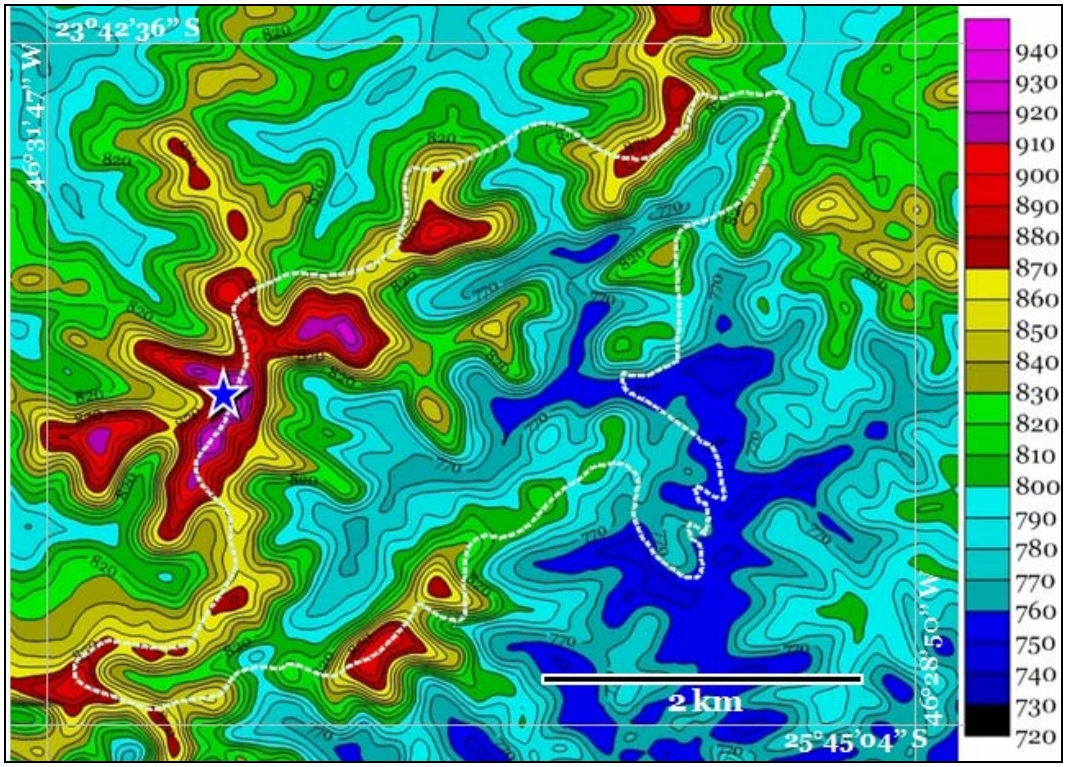

Figure 5. Detail of the PNMP local topographical features obtained from the SRTM data (IUGS). Dotted line and blue star indicate the park boundary, and the "Pico do Bonilha" location, spectively

GEOLOGICAL FEATURES OF SINGULAR IMPORTANCE

During the field survey was prioritised the characterisation of the rock types and the identification of the associated structures, its spatial distribution and the relationship between them, in order to perform a more detailed assessment of the geological features and providing the necessary tools to encourage the practice of the geoconservation. The selection criteria of geological elements were carried in accordance with the guidelines proposed by Brilha (2005) and Carcavilla et al. (2008). For these authors, the geodiversity is an intrinsic property of the territory with a wide variety of the geological, geomorphological and pedological elements. The catalogued sites are shown in Figure 7, having its most relevant aspects briefly listed in Table 1.

PNMP 01

On the left margin of the Estrada do Pedroso occurs a good exposure of mica schist. Although it presents strong evidence of weathering, it is still possible to distinguish the features that characterise a metamorphic rock. In the outcropping, the rock displays a marked schistosity, defined by the preferential orientation of the platy

minerals, and, usually, breaking into thin parallel layers. The most important constituents are mica and quartz, flattened and elongated, and the grains are large enough that can generally be identified with the naked eye. This site is particularly interesting to understand some of the processes that lead to the landslide. Steep hillside, foliation plane with high dip, and cutting unstable portion of a scarp for the road construction can substantially increase the mass wasting.

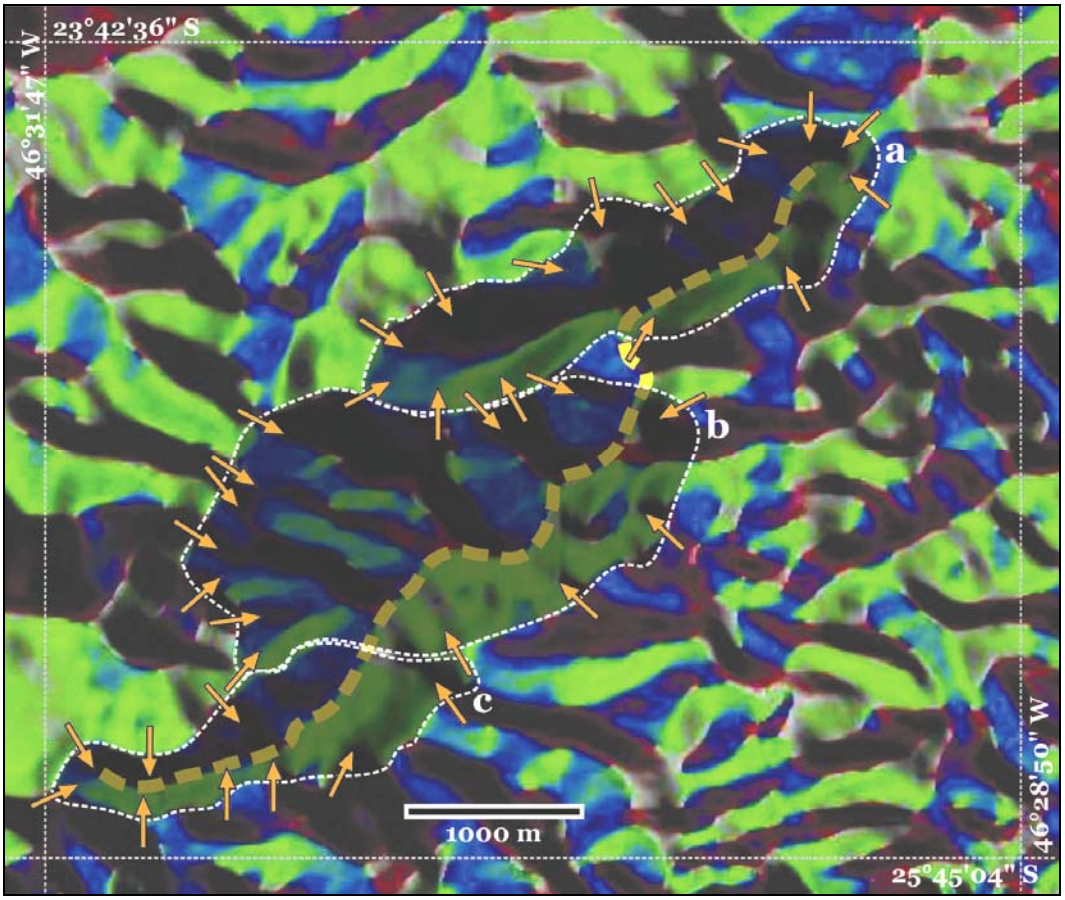

Figure 6. Map of slope shader obtined from the SRTM data (IUGS) illustrating the three mains catchment areas mentioned in the text. The arrows indicate the direction of the overland flow, and the yellow dotted line represents the main runoff channel

PNMP 02

The lithology that occurs at this site is the same as the previous station. However, the presence of a thick layer of reddish soil, with small blocks of the parent rock, partially covered by secondary vegetation in regeneration stage, is a clear indication of an advanced weathering. Although the mica schist has altogether lost its original structure, the residual soil still contains some primary minerals. Quartz, mica and clay minerals are the most common components.

PNMP 03

The site represents an ancient secondary road that is now forbidden to the public access. According to SEMASA, agency responsible by the management of the park, the

interdiction was necessary for the restoration of vegetation cover. During the fieldwork was possible to verify that the forest is in the inicial stage of recomposition, with prevalence for the underbrush and a few trees that exhibit the trunk more developed. Some invasive exotic species, such as eucalyptus and pines, were also observed. In the future, the site could be destined for monitored visitation. With a little less than 2 km, the trail offers a pleasant environment for outdoor exercise, peaceful walk, and a singular panoramic view, where visitors will be able to see several reptiles, birds and mammals, as well as the remnant vegetation of the Atlantic Forest.

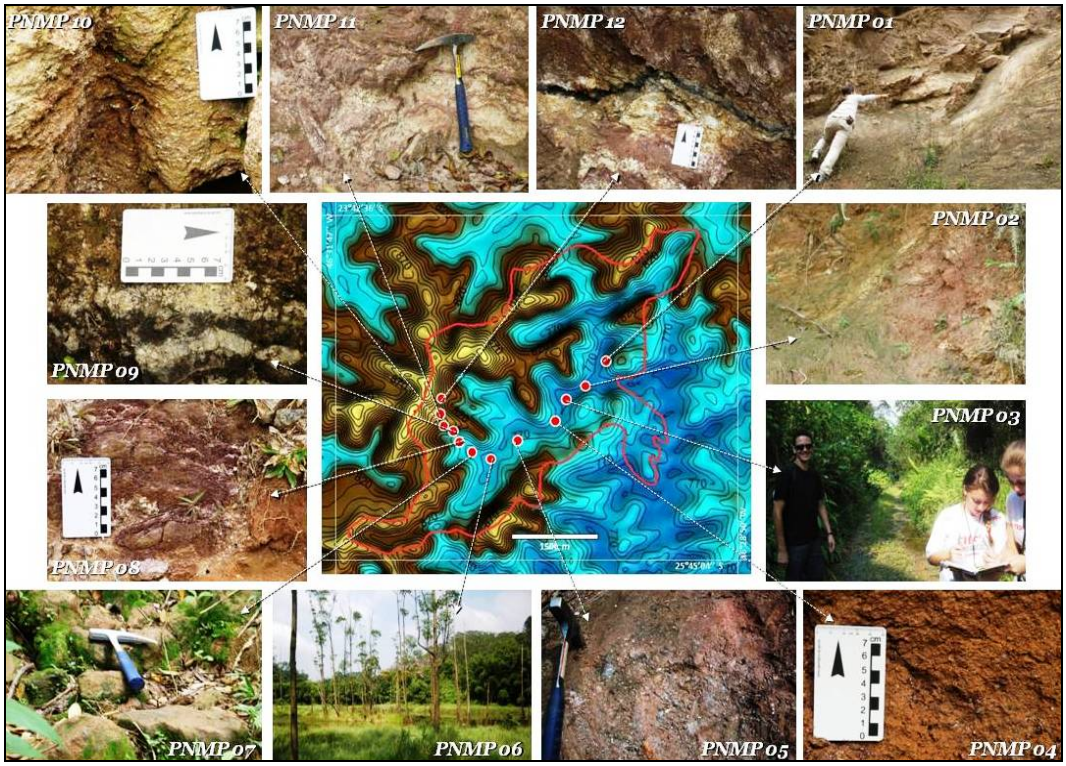

Figure 7. Main sites catalogued in the PNMP

PNMP 04

The site offers a very good exposure of weathered rocks, which are important to understand the processes that have acted so effectively for transforming a parent rock in typical latosol. The weathering mantle, with dozens of meters in thickness, is mostly formed by clay minerals and, to a lesser extent, detrital particle, including lithic fragments and monomineralic grains, essentially, quartz and feldspar. The lack of a continuous sequence of horizontal layers and the abundant presence of oxide and hydroxide of iron are particular aspects of the outcropping.

PNMP 05

The lateritic profile is quite similar to the previous station, but the lithology is different. In cross-section is possible to notice that the layers still preserve the morphology and composition of the parent rock. The occurrence of small angular fragments of granite gneiss, with clearly visible metamorphic textures, is a common characteristic in the weathering profile. Quartz and feldspar are the components that

were less affected by the weathering whereas the mafic minerals have been altogether extinct. Clay's minerals are also abundant compared with the other constituents.

PNMP 06

There is a small lake at the southern end of the park. This water body is stocked by the endorreic superficial drainage. In times of long droughts, an important formation of swamps can occur on the shores of lake. In this case, the environment configures a freshwater wetland ecosystem with prevalence of aquatic vegetation, coexisting, in part, with pine and eucalyptus. The lake has sufficient physical space to sustain a large number of biological communities, providing a remarkable view of various kinds of flora and fauna.

Table 1. Additional information of the main sites catalogued in the PNMP

Site	Latitude/Longitude	Rock type	Structure	Remark
PNMP-01	23°43'41"S 46°29'43"W	Mica schist	Foliated	Strongly foliated rock ranging in texture from medium- to fine-grained.
PNMP-02	23°43'50"S 45°29'51"W	Mica schist	Foliated	Rock showing advanced weathering stage and presence of litholic neosoil.
PNMP-03	23°43'55"S 46°29'58"W			Succession stages of vegetation regeneration in trail of restricted access.
PNMP-04	23°44'12"S 46°30'46"W	Granite gneiss	Foliated	Development of ferruginous clay soil from the granite gneiss.
PNMP-05	23°44'21"S 46°30'38"W	Mica schist	Foliated	Schistose rock with advanced weathering stage.
PNMP-06	23°44'15"S 46°30'31"W			Small lake with marshland vegetation in different stage of regeneration.
PNMP-07	23°44'08"S 46°30'53"W	Metasandstone	Nonfoliated	Metasandstone blocks with sandy deposits occurring locally.
PNMP-08	23°44'02"S 46°30'01"W	Mica schist	Foliated	Schistosity plane with parallel arrangement of relatively large grains of platy minerals.
PNMP-09	23°44'05"S 46°30'52"W	Gneiss	Foliated	Foliation as a resulted from alternating banding of light and dark minerals.
PNMP-10	23°43'58"S 46°30'59"W	Mica schist	Foliated	Schistose rock showing advanced weathering stage and relict sedimentary structure.
PNMP-11	23°43'57"S 46°30'59"W	Mica schist	Foliated	Rock showing advanced weathering stage with several deformation phases.
PNMP-12	23°43'50"S 46°30'5"W	Granite gneiss	Foliated	Gneissic banding with occurrence of tourmaline shaped like of narrow strip.

PNMP 07

At the site occur several blocks of fine to medium-grained metasandstone, very friable, that has preserved the original sedimentary structures. Due to the dense vegetation cover, its spatial distribution is difficult to define. In some outcrops is possible to recognise a typical granoblastic texture, where the quartz grains show boundaries forming 120^{O} triple junctions, locally gruped into small polygonal aggregates. Sand deposits associated with the metasandstone blocks may occur locally.

PNMP 08

The mica schist that occurs at this site, consisting of muscovite and quartz minerals, exhibits a penetrative foliation and subvertical dip of the layers. The texture lepidoblastic is markedly controlled by the fine-grained mica flakes that are aligned parallel to each other. The quartz, that often appears as elongated grains, highlights the planar fabric of the rock. The weathering process has generated a reddish soil sandy loam that obliterated the primary structure partially. Ramps containing pebbles of mica schist are relatively common in the area.

PNMP 09

The outcrop offers an excellent exposure of granite gneiss. This rock occurs widely in the southeastern region of the park, and it is the lithology more frequent of the crystalline basement. The mineralogical assembly consists of quartz, K-feldspar and mafic (biotite and/or amphibole). The texture can range from medium to very coarse-grained, becoming almost pegmatitic in some places. The rocks is characterised by alternating light and dark bands differing in mineral composition. The lighter bands contain mostly quartz and feldspar, and the darker often contain biotite and/or amphibole. The bands present locally chevron-like structure, indicating a polyphasic deformation.

PNMP 10

At this place, the mica schist displays a marked foliation. The rock consists of varying amounts of mica, quartz and feldspar. The planar fabric is clearly defined by the remaining original bedding of the sedimentary protolith. The strong orientation of mica and the stretched quartz grains, partially recrystallized, characterise a typical lepidoblastic texture. In a setting of advanced weathering, the occurrence of quartz grains interbedded between the layers rich in mica is fairly common.

PNMP 11

Excepting the texture, that is particularly fine, the lithology is very similar to the previous station, having mica and quartz as main mineralogical components and a planar fabric with pervasive cleavage, subvertical dip, and a thickness less than few centimetres and. A temporal and spacial analysis of the several structures – schistosity plane, crenulation cleavage, microfolds and minor faults - indicates the region has been subjected to a complex polyphasic deformation.

PNMP 12

In the southeastern sector of the “Pico do Bonilha”, the highest region of the park, there is an outcropping of mica schist. The rock is exposed along an ancient road and it presents strong foliation, showing lepidoblastic texture that ranges from medium to fine-grained. The mineralogical and textural features indicate that this occurrence is a prolongation of the lithology described previously at the PNMP 01 site, having as main difference the pegmatitic veins rich in tourmaline (schorlite), which are cutting orthogonally the foliation plane of rock. The veins are composed of quartz, muscovite and K-feldspar. Field observation suggests that the tourmaline can occur as isolated grains, clusters or still as bands of modest thicknesses.

FINAL CONSIDERATIONS

The nature conservation has historically been debated within the context of the biodiversity. It should also be mentioned that a large part of society still sees the geological components as a physical substrate separated of the landscape, as well as of the territorial space in which we live. An effective conservation strategy should consider the whole of resources, abiotic and biotic, in order to ensure the maintenance of the functions and components of nature during a long period and with the utmost efficiency. In this sense, it is important to emphasize that the geological and geomorphological features that compose the PNMP, with a wide range of landforms and lithological units, exercise an influence on the contemporary landscapes and are particularly relevant for academic activities and scientific researches (Table 2). From among the many themes that can be treated, the questions involving the weathering processes of rocks, the preferential orientation of the metamorphic structures and the effects of the slope gradient on the soil erosion are considered as the most pertinent. At a local scale, the mineralogical compositions of the rocks are factors that control the weathering and the formation of major gullies. Insofar as geological agents operate over

a large interval of time and space, the combination of those data with other physical parameters can provide an enormous diversity of information on the environmental conditions of the park, with emphasis on the potential dangers of geohazards, mainly, rock avalanches and landslide.

Table 2. Potentiality and intrinsic values of the main sites catalogued in the PNMP

Site	Intrinsic value	Potentiality	Practical example
PNMP-01	Lithologic	Academic	Identification of metamorphic rock, particularly, texture and structure. Factors that influence mass wasting.
PNMP-04	Lithologic	Academic	Identification of metamorphic rock , weathering and soil formation.
PNMP-06	Landscape	Recreational	Appreciate the natural environment that compose the lake.
PNMP-07	Lithologic	Academic	Identification of texture and structure in metamorphic rock .
PNMP-09	Lithologic	Academic	Identification of gneissic banding and metamorphism type.
PNMP-10	Lithologic	Academic	Identification of metamorphic rock, particularly, foliation of relict sedimentary structure.
PNMP-11	Lithologic/Tectonic	Academic	Identification of metamorphic processes and tectonic deformation.
PNMP-12	Lithologic/Tectonic	Academic	Identification of metamorphic processes and tectonic deformation.

The lithological units of the Embu Domain that outcrop in the park reveal different metamorphic conditions. The metasandstone and quartzite exhibit granoblastic texture and some sedimentary structures that were partially preserved. Although these rocks are relatively resistant to erosion, the physical weathering process disaggregates the quartz grains to form colluvial boulder deposits in the hillsides. The schistose rocks, represented mostly by mica schist and quartz mica schist, show a well-developed planar fabric, with the thin layers arranged in parallel, and a typical lepidoblastic texture.

Unlike a quartzite, the schist when is exposed to weathering can break into small splinters along the cleavage plane, leading to the V-shaped gullies formation that, in a more advanced stage of the erosion, the slopes of these gullies become naturally in large valleys. Such landforms are common inside the park. The gneissic rocks show banding with centimetric to decimetric thickness, formed by an alternating of mafic (biotite and/or amphibole) and felsic (quartz and K-feldspar) mineral concentrations. Due to its mineralogical composition, the gneiss is less susceptible to weathering and appears on the landscape sustaining rugged hills with steep slopes.

The overlapping tectonic structures, suggesting a complex deformation history, and the thick laterite layers, as a result of an intense weathering process, are features highly variable in local-scale. The most conspicuous deformations are those that were generated under compressional stress during the regional metamorphism. Schistosity plane, crenulation cleavage, gneissic banding and microfolds are fairly frequent.

These structures configure today the major physiographic divisions of the park. Although the climate exerts an important role on soil formation, the textures and structures observed in the weathering profiles suggest that the mineralogical composition of metamorphic rocks has particularly been relevant for the

development of the soil in the PNMP. Two main groups can be found on a regional scale: sandy soil, often associated with the occurrence of metasandstone and quartzite, and clay soil rich in organic matter and iron oxides, having mica schist and gneiss as parent material.

Besides its remarkable scientific importance, the outcroppings offer numerous alternatives that can be included in tourist routes, as well as in environmental education activities, in order to change the conception of the local community about the nature preservation. The mission of supervising those sites is a growing challenge, once the anthropogenic pressure is fairly large around the park. In the context of a successful protection, count with the support of government authorities and an effective environmental legislation are essential. However, a full dissemination of the importance of geological resources that the society uses in the everyday life, encouraging to its conservation, is likewise relevant to meeting the environmental challenges.

Acknowledgments

We are greatly indebted to a large number of people who have contributed to the elaboration of this paper. In particular, we thank SEMASA/Santo André, by the permission for the execution of the project within the park with the logistical support of its team, as well as by the valuable information provided in the bibliographical compilation phase. Our sincere thanks go to IG/SMA, by the images made available, and PEP-USP, by the scholarship granted to M.A.J.S. Pletsch and C.S. Coutinho. We also acknowledge the anonymous peer reviewers for the dedication and critical reading, who helped us to improve the paper.

REFERENCES

Almeida, F., F., M., (1964), *Fundamentos Geológicos do Relevo Paulista*, PhD Thesis, Instituto de Geografia, Universidade de São Paulo, São Paulo, 99p.

Almeida, F., F., M., Amaral, G., Cordani, U., G., Kawashita, K., (1973), *The Pre Cambrian evolution of the South American cratonic margin, south of Amazon river*, in: Nairn, E., M., & Stehli, F.,G., (Editors), *The ocean basins and margins*, New York, Plenun, pp. 411-446.

Brilha, J., (2005), *Patrimônio geológico e geoconservação – a conservação da natureza na sua vertente geológica*, Palimage, Braga, 190p.

Carcavilla, L., Durán, J., J., López-Martínez, J., (2008), *Geodiversidad: concepto y relación con el patrimonio geológico*, VII Congreso Geológico de España, Las Palmas de Gran Canaria, Geo-Temas, 10, pp. 1299- 1303.

Cendrero, A., Elízaga, E., Gallego, E., García-Cortés, A., Morales, J., Palacio, J., (1996), *Patrimonio Geológico. Bases para su valoración, protección, conservación y utilización*, MOPTMA Serie Monográfica, Madrid, 112p.

CorelDraw Graphic Suite X6, (2012), *More than you thought possible: graphic design software for striking visual communication*, http://www.corel.com/servlet/Satellite/ca/en/Product/1191272117978#tabview=tab0

Coutinho, J., M., V., (1972), *Petrologia do Pré-Cambriano em São Paulo e arredores*, Boletim do Instituto de Geociências, USP, 3, pp. 5-100.

Coutinho, J., M., V., (1979), *Carta Geológica da Região Metropolitana da Grande São Paulo (l: 100.000)*, EMPLASA, São Paulo, 2 Folhas.

Coutinho, C., S., Pletsch, M., A., J., S., Velázquez, V., F., Borges, G., B., Azevedo Sobrinho, J., M., (2012), *Avaliação preliminar da potencialidade dos elementos geológicos e geomorfológicos do Parque Natural Municipal do Pedroso no contexto da geoconservação, Santo André, SP*, 46 Congresso Brasileiro de Geologia, Santos, SP. Abstract.

Eagle Globe Software Company, (2013), *Global mapper professional 3D GPS tracking GIS mapping software*, http://www.eagleglobesoftware.com/index.htm

Golden Software Surfer, (2012), *Technologically advance mapping and graphing solutions*, http://www.goldensoftware.com/products/surfer/surfer.shtml

Hackspacher, P., Dantas, E., L., Spoladore, A., Fetter, A., H., Oliverira, M., A., F., (2000), *Evidence of Neoproterozoic backarc basin development in the Central ribeira Belt, Southeastern Brazil: New*

geochronological and Geochemical constrains from the São Roque — Açungui Groups, Revista Brasileira de Geociências, 30, pp. 110–114.

Hasui, Y., Carneiro, C., D., R., Coimbra, A., M., (1975), *The Ribeira folded belt*, Revista Brasileira de Geociências, 5, pp. 257-266.

Hasui, Y., Sadowski, G., R., (1976), *Evolução geológica do Pré-cambriano na região sudeste do Estado de São Paulo*, Revista Brasileira de Geociências, 6, pp. 182-200.

Hernández, J., O., Gómez-Limón, J., G., (2005), *Manual sobre conceptos de uso público en los espacios naturales protegidos*, Fundación Fernando González Bernáldez, Madrid, 94p.

Mata-Lleonart, R., (2004), *El Patrimonio Geológico en una nueva clasificación de los recursos geológicos*, El Patrimonio Geológico: Cultura, Turismo y Medio Ambiente, pp. 197-202.

Mata-Perelló, J., M., (2005) *Datos para el Ordenamiento Territorial de la Comarca del Bages*, Actas del Segundo Simposio sobre la Historia de la Minería y de la Metalurgia en el Mediterráneo Occidental, 10p.

Ponçano, W., L., Carneiro, C., D., R., Bistrichi, C., A., Almeida, F., F., M., Prandini, F., L., (1981), *Mapa Geomorfológico do Estado de São Paulo*, Instituto de Pesquisas Tecnológicas do Estado de São Paulo, 1183(5), 94p.

Riccomini, C., Coimbra, A., M., (1992), *Geologia da Bacia Sedimentar*, in: Negro, Jr., A., Ferreira, A., A., Alonso, U., R., Luz, P., A., C., (eds) *Solos da Cidade de São Paulo*, São Paulo, ABMS/ABEF, pp.37-94.

Riccomini, C., Turcq, B., Martin, L., (1989), *The Colônia Astroblema*, International Symposium on Global Changes in South America during the Quaternary, São Paulo, Excursion field guide, INQUA, 14p.

Sadowski, G., R., (1974), *Tectônica da Serra de Cubatão*, SP, PhD Thesis, Instituto de Geociências, Universidade de São Paulo, São Paulo, 159p.

Sadowski, G.,R., Tassinari, C., C., G., (1988), *The São Roque Volcano-Sedimentary Sequence of Proterozoic age*, Excursion Guide Book, 7th International Gondwana Symposium, São Paulo, 26p.

Sarmiento, G., N., C., (2005), *Aspecto socioeconómico del patrimonio geológico*, IV Seminário Recursos Geológicos, Ambiente e Ordenamento do Território Vila Real, pp. 9-12.

Serviço Municipal de Saneamento Ambiental - SEMASA -, (2007), *Parque Natural do Pedroso Patrimônio da Vida*, http://www.semasa.sp.gov.br/admin/biblioteca/docs/pdf/pedroso_internet.pdf

Sharples, C., (2002), *Concepts and principles of geoconservation*, Tasmanian Parks & Wildlife Service website, Tasmanian, 79p.

Tassinari, C., C., G., (1988), *As idades das rochas e dos eventos metamórficos da porção Sudeste do Estado de São Paulo e sua evolução crustal*, PhD Thesis, Instituto de Geociências, Universidade de São Paulo, São Paulo, 236p.

Tassinari, C., C., G., Munhá, J., M., U., Ribeiro, A., Correia, C., T., (2001), *Neoproterozoic oceans in the Ribeira Belt (southeastern Brazil): The Pirapora do Bom Jesus ophiolitic complex*, Episodes, 24, pp. 245-251.

Turcq, B., Riccomini, C., Fournier, M., Martin, L., Moreira, M., Z., Suguio, K., (1989), *Sedimentação quaternária dos depósitos orgânicos dos últimos 30.000 anos no Brasil Central*, Congresso da Associação Brasileira de Estudos do Quaternário, Rio de Janeiro, ABEQUA, pp. 39-49.

Submitted:	Revised:	Accepted and published online
13.02.2014	12.06.2014	16.06.2014