

## SPELEOLOGICAL HERITAGE IN BRAZIL'S PROPOSED GEOPARKS, AS PRESENTED IN THE BOOK "GEOPARQUES DO BRASIL: PROPOSTAS"

### PATRIMÔNIO ESPELEOLÓGICO BRASILEIRO APRESENTADO NO LIVRO "GEOPARQUES DO BRASIL: PROPOSTAS"

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#### Abstract

Brazil, with its vast territory, rich geodiversity, and terrains representative of all geologic eras, has a large potential for the implementation of geoparks. The country's geological service (Serviço Geológico do Brasil/CPRM), in its role of promoter of the creation of geoparks, issued in printed version in 2012, and also posted on the Internet the book "Geoparques do Brasil: propostas" (Geoparks of Brazil: proposals), vol. 1, with 17 geopark proposals, selected by CPRM as the most promising ones at this moment. In this paper, after an overview of geoparks worldwide, an analysis is made about the presence of elements of speleological heritage in this publication. Based on data presented for each proposal, tables and graphs were created, relating these elements to the local geology and particularly petrology. This analysis showed that 54% of the caves and other natural underground cavities listed are concentrated in sedimentary siliciclastic rocks (mostly sandstones), 38% in carbonatic rocks (essentially limestones and marbles) and 8% in rocks of the crystalline basement (orthogneisses and granites). The study also showed that despite the enormous potential, both in quantity and in quality, for the use of these cavities in future geoparks, they represent only a small portion (about 15%) of the proposed geosites.

**Key-Words:** Geopark; Geosite; Speleology; Cave.

#### Resumo

O Brasil, com seu vasto território, rica geodiversidade e terrenos representativos de todas as eras geológicas, tem um grande potencial para a implantação de geoparques. O Serviço Geológico do Brasil/CPRM, no seu papel de indutor da criação de geoparques no país, lançou em versão impressa em 2012, e disponibilizou também na Internet, o importante volume "Geoparques do Brasil: propostas", vol. 1. Nele são apresentadas 17 propostas que a CPRM selecionou como as mais promissoras no momento atual. Neste trabalho, após uma visão geral dos geoparques no mundo, é feita uma análise sobre a presença de elementos do patrimônio espeleológico nessa publicação. Com base nos dados apresentados para cada proposta, foram montadas tabelas e gráficos que dão uma visão geral dessa presença, relacionando-a com a geologia e particularmente com a petrologia locais. Constatou-se que 54% das cavernas e outras cavidades subterrâneas naturais inventariadas concentram-se em rochas sedimentares siliciclásticas (particularmente arenitos), 38% em rochas carbonáticas (essencialmente calcários e mármore) e 8% em rochas do embasamento cristalino (ortogneisses e granitos). Constatou-se também que apesar do enorme potencial, tanto em quantidade, quanto em qualidade, de aproveitamento dessas cavidades nos futuros geoparques, estas representam apenas uma pequena parcela (cerca de 15%) dos geossítios propostos.

**Palavras-Chave:** Geoparque; Geossítio; Espeleologia; Caverna.

#### 1. INTRODUCTION

Brazil is a vast country endowed with a rich geodiversity, with terrains representative of all the geological eras, and thus presents a large potential for the creation of geoparks.

Geoparks, which include a new model of territorial management, represent a successful

worldwide initiative. In the year 2000, just four geoparks, one in each of four European countries, formed the European Geopark Network. As of late 2013, 92 geoparks spread in 28 countries around the world make up the Global Geopark Network (GGN), with UNESCO's seal of approval. According to GGN, a geopark covers a geographical area with a geological heritage represented by geosites with a

unique scientific, educational or touristic value, which are integrated into a holistic concept, including protection, education and sustainable development. In this area, various mechanisms are created for the promotion of educational actions aiming at the popularization of Geosciences, the spreading of scientific knowledge, and the conservation of the geological heritage, but also at the creation of income-generating jobs. One of the results of these actions is the development of the practice of Geotourism, which helps in bringing means of sustainable economic growth.

According to Schobbenhaus & Silva (2012a), the Brazilian Geological Service/CPRM could not be absent from this initiative. Being the most important generator and holder of the geological knowledge about Brazil, CPRM has also the role of stimulating the proposition of new areas with adequate potential for future geoparks. Based on that premise, CPRM launched the Projeto Geoparques do Brasil (Project Geoparks of Brazil) in 2006, and, as one of its results, in 2012 published the book "Geoparques do Brasil: propostas - Vol. 1" (Geoparks of Brazil: proposals - Vol. 1) (SCHOBHENHAUS & SILVA, 2012a), which presents 17 geopark proposals already evaluated, currently under the process of evaluation, or that will in the near future be evaluated by CPRM itself or in partnership with other institutions.

In these proposals a number of specific types of geological interests are presented, being classified into nine categories: stratigraphic, geomorphological, tectonic, paleoenvironmental, metallogenetic, paleontological, igneous, mineralogical and, of course, speleological. Based on this last category, the present paper aims at giving a panoramic set of information about geosites related to the speleological heritage, represented by caves formed in different kinds of rocks, creating unique geomorphological features. Another goal of this paper is to emphasize the presence of examples of speleological heritage in Brazilian proposed geoparks.

## 2. GEOPARKS IN THE WORLD

Aiming at the reinforcement of projects of conservation of the geological heritage, UNESCO, after its 29th General Conference in 1997, started the development of its Geoparks Program, based on four European units. In that year, according to MOREIRA (2011), an important European financing program, Leader +, allowed the initial materialization of the geopark concept, in cooperation with UNESCO, in four countries: the

Natural Geological Reserve of Haute-Provence (France), the Petrified Forest in Lesvos (Greece), the Vulkanaifel Geopark (Germany) and the Maestrazgo Cultural Park (Spain).

The Geoparks Program was presented to the international scientific community in 1999, with the characteristic of addressing the specific need for acknowledgement and conservation of the geological heritage, with the same kind of approach that the Biosphere Reserve Program applies in its dedication to the biological heritage. The program deals with a series of locations with worldwide geological interest based on the philosophical approach expressed in the "Declaration of the Rights of the Memory of the Earth" issued in Digne-les-Bains, France, in 1991.

In 2000, the four areas that started the program founded, under UNESCO's assistance, the European Geopark Network. However, in 2001, UNESCO decided "not to pursue the development of a UNESCO geoparks programme, but instead to support *ad hoc* efforts within individual Member States as appropriate". In this new context, in 2004, during the 1st International Conference on Geoparks, in Beijing, China, the Global Geopark Network (GGN) was officially launched (Martini, 2010). This network was created to establish, with UNESCO's endorsement, a common platform for cooperation and exchanges between specialists and all those interest in the geological heritage. According to UNESCO, "A geopark is a territory with well-defined limits that has a large enough surface area for it to serve local socio-economic development. It comprises a certain number of geological heritage sites (on any scale) or a mosaic of geological entities of special scientific importance, rarity or beauty, representative of an area and its geological history, events or processes. It may not solely be of geological significance but also of ecological, archaeological, historical or cultural value. A geopark serves to foster socio-economic development that is culturally and environmentally sustainable. This has a direct impact on the area by improving human living conditions and the rural environment, thus strengthening identification of the population with their area and triggering cultural renaissance."

The Global Geopark Network, assisted by UNESCO, has been spreading throughout the world, reaching many countries where there is an interest in the conservation and valuation of the geological heritage. In its beginning, it had only four geoparks; when officially created, in 2004, they were already twenty. Presently (late 2013) it congregates 92 geoparks distributed in 28 countries (Figure 1),

namely, in alphabetical order: Austria (2); Brazil (1); Canada (1); China (27); Croatia (1); Czech Republic (1); Finland (1); France (4); Germany (5 geoparks + 1 binational with Poland); Greece (4); Hungary (1 + 1 binational with Slovakia); Iceland (1); Indonesia (1); Ireland (2 + 1 binational with Northern Ireland); Italy (8); Japan (5); Malaysia (1); Northern Ireland (1 binational with Ireland); Norway (2); Poland (1 binational with Germany); Portugal (3); Romania (1); Slovakia (1 binational with Hungary); South Korea (1); Spain (8); United Kingdom (6); Vietnam (1).

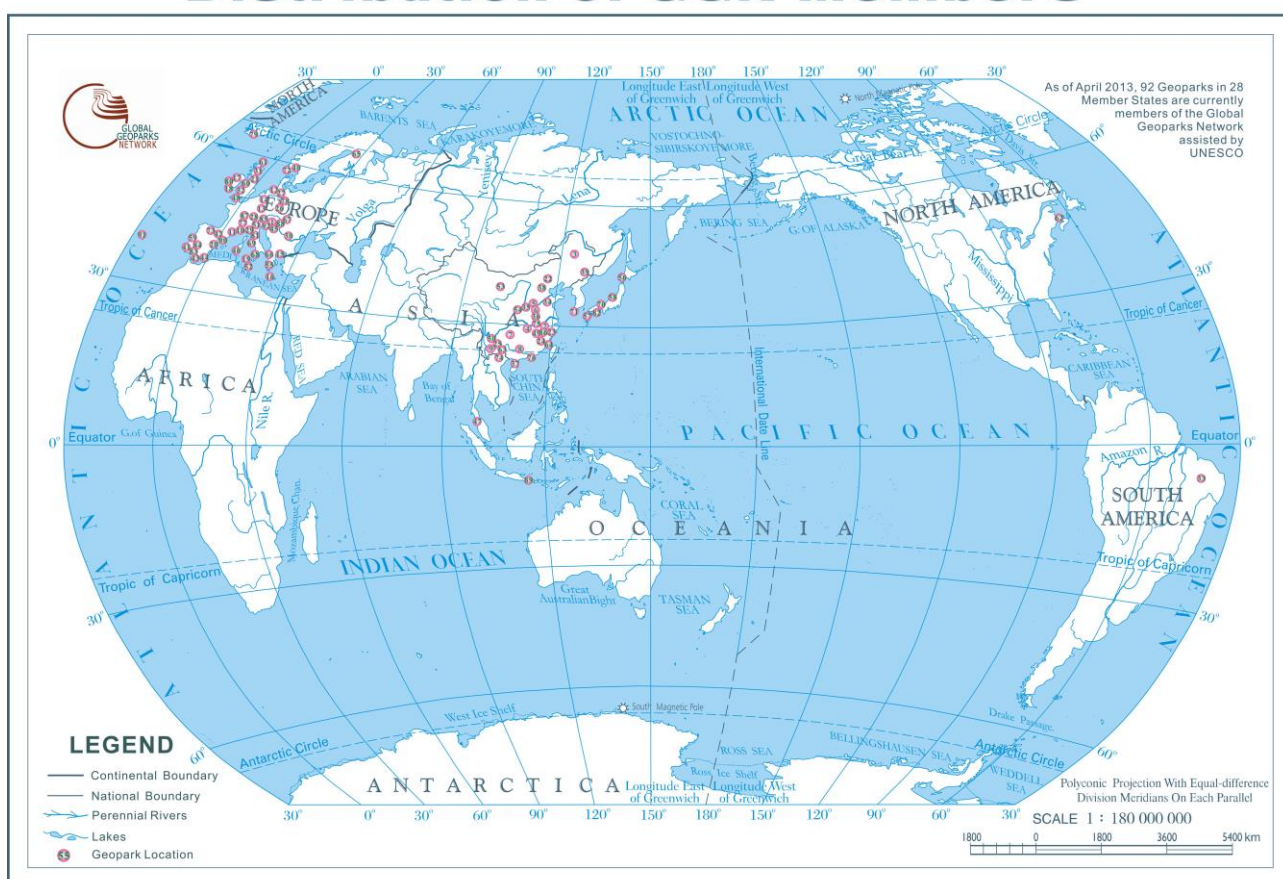
There are 54 geoparks in 23 countries in Europe, 36 in 6 countries in Asia, and 2 in the Americas (<http://en.globalgeopark.org/>), being 1 in Brazil, the Geoparque Araripe\*, the first in the American continent and also the first in the Southern hemisphere (<http://geoparkararipe.org.br/>).

\* NOTE: the names of the one existing geopark and of the proposed ones in Brazil, as well as the names of the geosites in all of them, **will not be translated**, so as to allow searches, both in the book "Geoparques do Brasil: propostas" and on the Internet.

According to Brilha (2012), the Global Geoparks Network has defined as main goals for the geoparks which participate in it:

1. Conservation of the geological heritage;
2. Provision of education about geosciences and environmental issues to the common citizen;
3. Sustainable socio-economic and cultural development;
4. Multicultural cooperation;
5. Promotion of scientific investigation; and
6. Active participation in the network by means of the development of common activities.

## Distribution of GGN Members



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**Fig. 1** - Map of the members of the Global Geoparks Network. Source: [http://en.globalgeopark.org/UploadFiles/2012\\_5\\_7/GGN%20Distribution%202013.04.23.jpg](http://en.globalgeopark.org/UploadFiles/2012_5_7/GGN%20Distribution%202013.04.23.jpg)



### 3. GEOPARKS IN BRAZIL

The Brazilian Geological Service/CPRM, through its Departamento de Gestão Territorial (Department of Territorial Management), launched in early 2006 the Projeto Geoparques do Brasil (Project Geoparks of Brazil) (SCHOBENHAUS, 2006; SCHOBENHAUS & SILVA, 2010; SCHOBENHAUS & SILVA, 2012a), under the executive coordination of the geologist Carlos Schobenhaus and the regional coordination of the representatives of the various regional offices of CPRM. This project plays an important role as inducer of the creation of geoparks in Brazil, and has as its main objectives to identify, classify, describe, catalog, georeference and publicize areas potentially prone to become geoparks, as well as to contribute to the definition of guidelines for their sustainable development. According to SCHOBENHAUS & SILVA (2012a) the wealth of geological surveys existing in the country and the experience accumulated by the company's technical body, as well as the contribution of studies and proposals by the geoscientific community, favor the development of this project. In some cases, this inducing activity is carried out in conjunction with researchers from universities and other federal, state or municipal organisms.

Brazil has an enormous potential for the proposition of geoparks, because in its large territory, a rich geodiversity - including representatives from practically the whole geologic history of the planet - can be found, plus non-geologic sites of ecological, archaeological, historical and cultural value. Important records pertaining to all of these aspects, some absolutely unique, represent part of the nation's heritage, and even of mankind's heritage, and clearly deserve being preserved (SCHOBENHAUS; SILVA, 2012a).

Various proposals of geoparks have already been evaluated, some are under evaluation, and others are scheduled to be evaluated in the future as part of the Projeto Geoparques (Geoparks Project). These proposals are indicated in the map in Figure 2 and in the list presented as Table 1. The technical report of some of these proposals can be found in digital form (in Portuguese) at <http://www.cprm.gov.br/publique/cgi/cgilua.exe/sys/start.htm?sid=134>. Such activities have been carried out partly in partnership with federal, state or municipal institutions, or with universities or private institutions. Besides those mentioned in that list, other proposals for geoparks exist: Campos Gerais (Universidade Estadual de Ponta Grossa e Minérios do Paraná-Mineropar - Ponta Grossa State

University and Mineropar, the Paraná state geological service); Ciclo do Ouro (Prefeitura de Guarulhos, São Paulo - Municipality of Guarulhos, state of São Paulo); and Costões e Lagunas do Rio de Janeiro (Serviço Geológico do Estado do Rio de Janeiro - Diretoria de Recursos Minerais - Rocky shores and lagoons of the state of Rio de Janeiro - State of Rio de Janeiro Geological Service - Department of Mineral Resources).

It is worth pointing out that in this initial stage (Table 1) there are already proposals of geoparks in which speleology appears as a main category, particularly the following: 01. Cachoeira do Amazonas; 06. Bodoquena-Pantanal; 07. Chapada dos Guimarães and 15. Alto Vale do Ribeira.

The practice of presenting geopark proposals has been very well received in the academic community, as well as in government offices at the federal, state and municipal levels, in the private sector of the economy, and by local populations. These positive reactions allow this community, as well as other interested groups, to believe that there will be new geoparks established in Brazil in the near future.

### 4. SPELEOLOGICAL HERITAGE

Speleological heritage can be defined as per Artigo (Article) 5º (5th), inciso (item) I, of the Brazilian Decreto (Decree) nº 99.556/90 as "*the array of biotical, abiotical, socio-economic and historic-cultural, subterranean or surficial, elements represented by natural subterranean cavities or associated to such cavities*". In its abiotical components, this kind of heritage is associated to the geological heritage and usually refers to those cavities that occur mainly in limestones and marbles, but occasionally also in banded-iron formations, sandstones, quartzites and granites.

According to CECAV/ICMBio (2011) the most commonly used definition for cave is "a natural opening formed in rock below the terrain's surface, large enough to allow a person to enter". This definition is adopted by the International Union of Speleology - UIS, the international body that congregates the various national institutions dedicated to speleology and caving. The Brazilian Decreto (Decree) nº 6.640/08, which partially modifies the above mentioned Decreto (Decree) nº 99.556/90, theoretically eliminates the expression "speleological heritage", but this same expression is used in its own text. It is clear, then, that there exists a legal incongruence; that incongruence will not be discussed here, as it is beyond our goals. As far as this paper is concerned, since the expression

“speleological heritage” is of general use by the scientific and speleologic communities, and is maintained in the most recent decree, it is considered by the authors as acceptable. It will be used here, not in a legal sense, but in the sense that it is normally used in those communities, meaning, in broad terms, “elements of speleological environments that deserve being preserved”.

This same Decreto (Decree) n° 6.640/08 defines natural underground cavities as “any and all subterranean spaces, with or without an identified opening, accessible to a human being, known by the population as *caverna*, *gruta*, *lapa*, *toca*, *abismo*, *furna* or *buraco* [\*], including its environment, mineral and water content, fauna and flora therein found, and the rocky body in which they are located, provided they have been formed by natural processes, regardless of their size or type of rock in which they occur”. [\* these are various Brazilian non-technical terms used to name natural underground cavities].

Such cavities tend to be found mostly in soluble rocks (carbonatic rocks, both sedimentary

and metamorphic), where they are generated precisely by dissolution by water of some of the rock components. Most typically, they are formed in limestone (sedimentary rock) and marble (metamorphic rock), in whose masses they generate the karstic morphology. However, nowadays there is a tendency to include siliceous rocks, particularly quartzites (metamorphic) and sandstones (sedimentary) in the group of karstifiable rocks. Such a trend is the result of recent studies that show that silica, until recently considered as a mineral of low solubility, has played a more important role than previously acknowledged in the generation of surficial and subterranean, typically karstic, morphologies (CECAV/ICMBio, 2011). The landscape generated in a karstic environment has a number of characteristic features, some unique to this environment. Along with the caves proper, large exposed rock masses, walls, cliffs, valleys, towers, depressions, dolines, sinkholes, lagoons, speleothems (stalactites, stalagmites, helictites, cave pearls, among others) make up a very scenic, beautiful context.

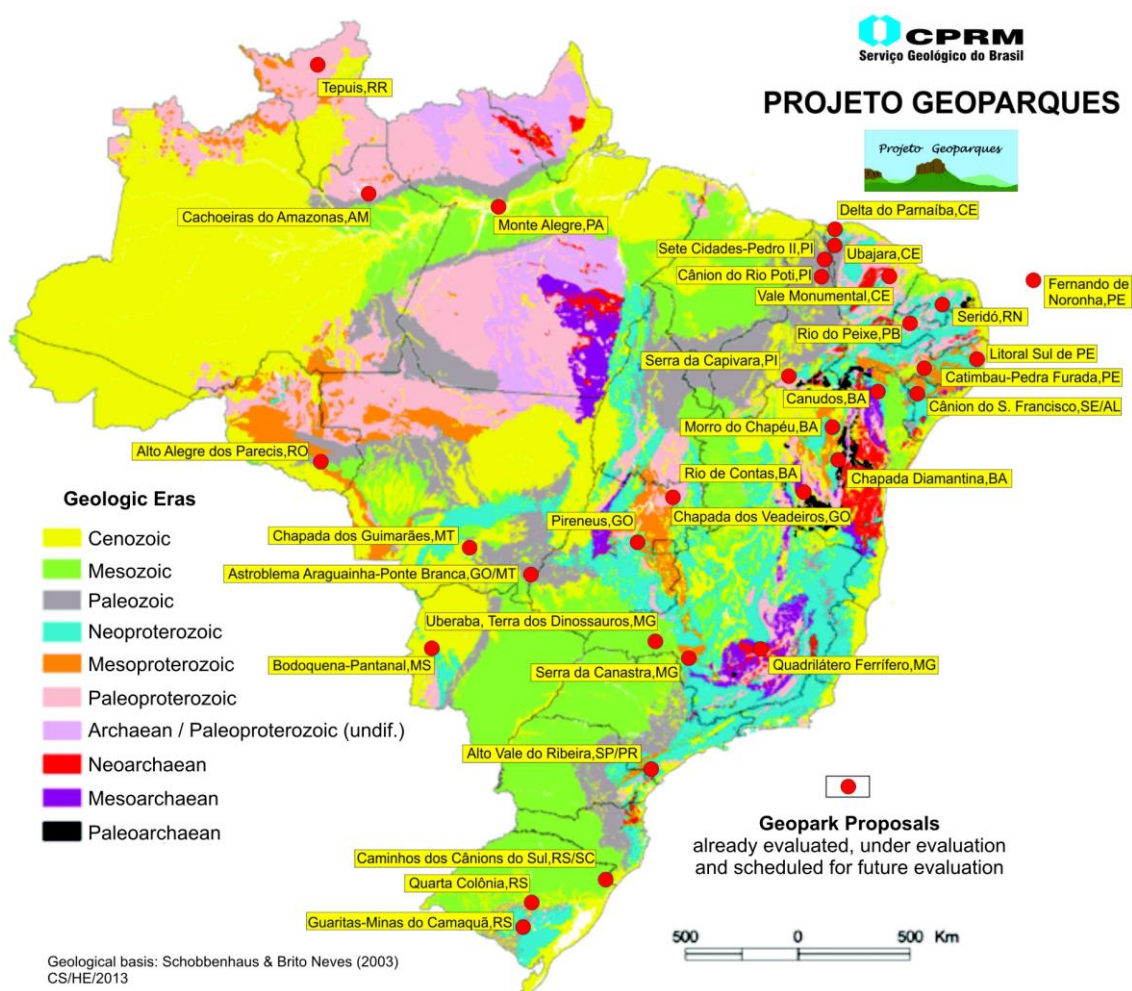


Fig. 2 - Map with the geopark proposals already evaluated, under evaluation and scheduled for future evaluation by the Projeto Geoparques. Based on Schobbenhaus; Silva (2012a)

**Table 1.** List of proposals already evaluated, under evaluation and scheduled for future evaluation by the Projeto Geoparques. Based on Schobbenhaus; Silva (2012a).

	Geopark proposal	State	Main Category(ies)
1	Cachoeira do Amazonas*	AM	Stratigraphic, Speleological, Archaeological
2	Morro do Chapéu*	BA	Stratigraphic, Geomorphological, Historical-Cultural
3	Pireneus*	GO	Stratigraphic, Tectonic, Geomorphological, Historical-Cultural
4	Astroblema Araguainha-Ponte Branca*	GO/MT	Astrobleme (structure formed by a meteorite impact)
5	Quadrilátero Ferrífero*	MG	Stratigraphic, Paleoenvironmental, History of Mining, Geomorphological, Metallogenetic
6	Bodoquena-Pantanal*	MS	Speleological, Paleoenvironmental, Geomorphological, Paleontological, Metallogenetic
7	Chapada dos Guimarães*	MT	Geomorphological, Paleontological, Speleological, Scenic Beauty
8	Fernando de Noronha*	PE	Igneous, Scenic Beauty
9	Seridó*	RN	Stratigraphic, Igneous, Geomorphological, Metallogenetic, Historical-Cultural
10	Quarta Colônia*	RS	Paleontological, Stratigraphic
11	Caminhos dos Cânions do Sul*	RS/SC	Scenic Beauty, Geomorphological, Igneous, Stratigraphic
12	Serra da Capivara*	PI	Stratigraphic, Archaeological
13	Catimbau-Pedra Furada	PE	Stratigraphic, Paleoenvironmental, Geomorphological, Igneous, Archaeological
14	Sete Cidades-Pedro II	PI	Geomorphological, Paleoenvironmental, Mineralogical, Scenic Beauty
15	Alto Vale do Ribeira	SP/PR	Speleological, Paleoenvironmental
16	Chapada Diamantina	BA	Geomorphological, Paleoenvironmental, Scenic Beauty, Historical-Cultural
17	Uberaba, Terra dos Dinossauros do Brasil*	MG	Paleontological
18	Litoral Sul de Pernambuco*	PE	Igneous, Stratigraphic, Scenic Beauty, Historical-Cultural
19	Rio de Contas	BA	Stratigraphic, Geomorphological, Historical
20	Monte Alegre	PA	Stratigraphic, Geomorphological, Tectonic, Archaeological
21	Alto Alegre dos Parecís	RO	Stratigraphic, Geomorphological, Scenic Beauty
22	Serra da Canastra	MG	Scenic Beauty, Geomorphological
23	Chapa dos Veadeiros	GO	Geomorphological, Stratigraphic, Scenic Beauty
24	Canudos	BA	Petrological, Stratigraphic, Igneous, Geomorphological, Metallogenetic, Historical-Cultural
25	Cânion do São Francisco	SE/AL	Geomorphological, Scenic Beauty
26	Rio do Peixe	PB	Paleontological, Stratigraphic
27	Vale Monumental	CE	Geomorphological, Igneous, Scenic Beauty
28	Tepuis	RR	Geomorphological, Stratigraphic, Paleoenvironmental, Scenic Beauty

The asterisk after the name – \* – indicates proposals of national geoparks published in the first volume of the book “Geoparques do Brasil: propostas”.

In Brazil there are a number of karstic areas with caves that show a peculiar landscape. According to AULER & ZOGBI (2005), the country is also very favorable to the discovery of new caves. These authors state that there are more than 4.000 caves already registered, but the country's potential is at least ten times bigger. This statement is confirmed by CECAV/ICMBio (Centro Nacional de Pesquisa e Conservação de Cavernas do Instituto Chico Mendes de Conservação da Biodiversidade - National Center of Research and Conservation of Caves of the Chico Mendes Institute for the Conservation of Biodiversity), which, in its database, shows a little more than 10.000 caves already registered (details can be found, in

Portuguese, at <http://www.icmbio.gov.br/ceav/projetos-e-atividades/inventario-anual-do-patrimonio-espeleologico-brasileiro.html>). According to CECAV/ICMBio (2011) about 90% of the caves known in the world are in carbonatic rocks. In Brazil however, due to peculiarities not yet well understood, but certainly related to geomorphological and climatic factors, sandstones and quartzites are also very liable to generate caves. Furthermore, it has recently been discovered that iron ore and canga (laterite, surficial or subsurficial limonite-cemented unstratified rock, mainly related to the banded-iron formations, a metamorphic rock) are extremely prone to the formation of caves, thus



adding a new component to Brazil's already complex speleological matrix. There are also, albeit in a lesser scale, caves in granites (igneous, plutonic rocks), gneisses (metamorphic rocks) and other metamorphic rocks such as micaschists and phyllites, and even in soils. Table 2 shows, in a preliminary version, the number of caves hitherto identified in each lithology and the probable speleological potential (caves not yet identified, but considered as probably existent).

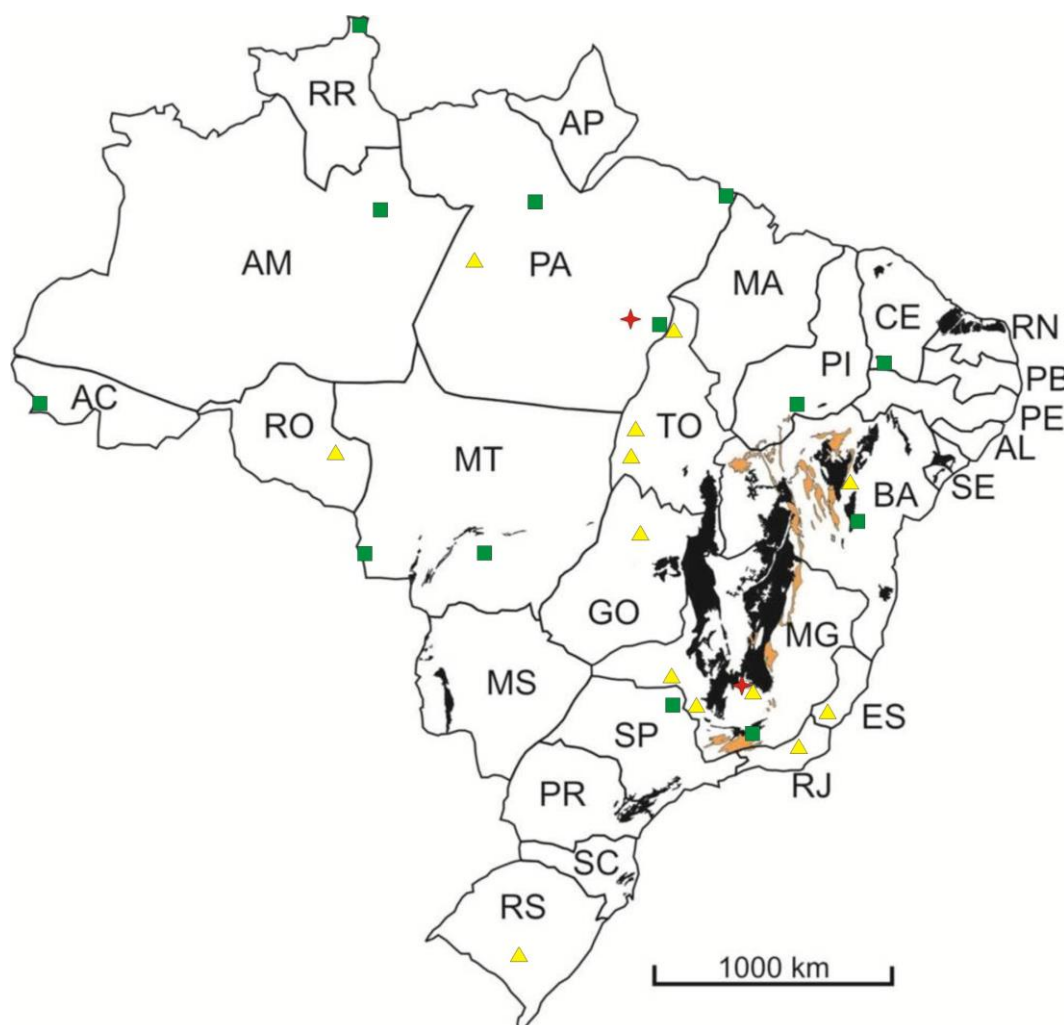
Figure 3, based on CECAV/ICMBio (2011),

shows the vast variety of rocks in which caves occur in Brazil. Black represents main carbonatic areas and orange main quartzitic areas; yellow triangles represent minor carbonatic areas, red stars represent iron ore areas, and green squares represent other lithologies (mainly sandstones) where caves also exist. The apparently larger concentration of rocks hosting known caves in the eastern part of the country may be related, at least partially, to the fact that this area has been subject to more detailed geological mapping.

**Table 2.** Estimate (order of magnitude) of Brazil's speleological potential in relation to known caves and lithology. Based on CECAV/ICMBio (2011) and Jansen *et al.* (2012).

Lithology	Number of known caves	Probable potential (caves not yet known)	Percentage of known caves
Carbonates	7.000	> 150.000	< 5%
Quartzites	510*	> 50.000	< 1%
Sandstones	510*	> 50.000	< 1%
Iron Ore	2.000	> 10.000	< 20%
Other lithologies	200	> 50.000	< 0,5%

\*approximate numbers, compiled from CECAV/ICMBio's database on June 1, 2012.



**Fig. 3** - Map showing the main lithologies hosting natural cavities. Main carbonatic rocks (sedimentary and/or metamorphic) are represented in black. Main quartzitic rocks (metamorphic) are represented in orange. Minor carbonatic (sedimentary and/or metamorphic) areas are represented by yellow triangles. Iron ore areas are represented by red stars. Other lithologies are represented by green squares. Based on CECAV/ICMBio (2011).

It can be clearly seen that Brazil's potential speleological heritage is enormous. The main cave-bearing areas are situated in an oblong zone, running from NE to SW, parallel to the coast, with a higher concentration covering center-W Bahia, eastern Goiás and two branches running N-S crossing the central portion of Minas Gerais. These areas are mostly covered by limestones and dolomites of the Bambuí Group (Auler & Zogbi, 2005; CECAV/ICMBio, 2011). One of the most important clusters, with more than 700 caves already registered, is the region of Lagoa Santa (MG), which can be considered as the cradle of Brazilian speleology. The state of Bahia hosts the five longest caves in the country (Table 3). Crossing the easternmost boundary dividing the states of São Paulo and Paraná there is another important cluster, with more than 300 caves, formed in limestones and dolomites of the Açungui Group. Most of those in the state of São Paulo are situated inside the PETAR (Parque Estadual Turístico do Alto Ribeira - Alto Ribeira Touristic State Park), including Caverna (Cave) Santana, one of the most famous caves in the country, and Casa de Pedra (Stone House), the tallest natural rock opening known in the country (Figure 4); the caves in this region represent a meaningful portion of the geological heritage of the state, and of the country (MANTESSO-NETO *et al.* 2013).

In the NE region of the country, also corresponding to the NE tip of the above mentioned oblong zone in which are concentrated the main cave-bearing areas, many caves exist, but really big ones haven't been found yet. In the state of Ceará one of the best known is the Gruta de Ubajara, situated in one of the country's oldest national parks. In Rio Grande do Norte, most caves are concentrated between Felipe Guerra and Apodi; among them, Casa de Pedra de Martins (Martins' Stone House), considered one of the biggest marble caves in the country.

The map of potentiality of occurrence of caves in Brasil, in the scale 1:2.500.000 was published in 2012 (JANSEN *et al.* 2012). It is based in a new methodology, in which, according to the lithology, five classes of degree of potentiality are established: Very high; High; Medium; Low; and Occurrence unlikely (Table 4).

These classes were identified by the use of the following criteria: a) data about emplacement of the main karstic areas in Brazil; b) geological map of Brazil, scale 1:2.500.000, by the Serviço Geológico do Brasil/CPRM (Brazilian Geological Service), with emphasis in the fields Litologia1 (Lithology1), Litologia2 (Lithology2) and Nome da Unidade (Name of Unit), of the "Tabela de atributos" (Table of Attributes); c) geospatialized data from caves furnished by CECAV/ICMBio (on June 1st, 2012); and d) bibliographical revision about the main lithological formations of the cavities registered in CECAV/ICMBio's database.



**Fig. 4** - Reaching a height of approximately 220m (720') and essentially corresponding to the collapsed descending limb of a metamorphic limestone fold, Casa de Pedra (Stone House), is the tallest natural rock opening known in the country, and is possibly among the tallest in the world. It is situated in the southern portion of the state of São Paulo, in the PETAR Parque Estadual Turístico do

Alto Ribeira - Alto Ribeira Touristic State Park.

Photo by Lalo de Almeida.

**Table 3.** The 10 longest known caves in Brazil, according to CECAV/ICMBio (2011).

By order of length	Municipality	km / mi
1. Toca da Boa Vista*	Campo Formoso (BA)	106,50 / 66.6
2. Toca da Barriguda	Campo Formoso (BA)	33,30 / 20.8
3. Lapa Doce II	Iraquara (BA)	16,50 / 10.3
5. Gruta do Padre	Santana e Santa Maria da Vitória (BA)	16,40 / 10.3
5. Boqueirão	Carinhanha (BA)	15,17 / 9.5
6. Lapa do Angélica	São Domingos (GO)	14,10 / 8.8
7. Gruta da Água Clara	Carinhanha (BA)	13,88 / 8.7
8. Lapa do São Mateus III	São Domingos (GO)	10,61 / 6.6
9. Lapa de São Vicente II	São Domingos (GO)	10,13 / 6.3
10. Lapa Doce I	Iraquara (BA)	10,00 / 6.3

\*The Toca da Boa Vista is considered to be the 18th biggest cave in the world.

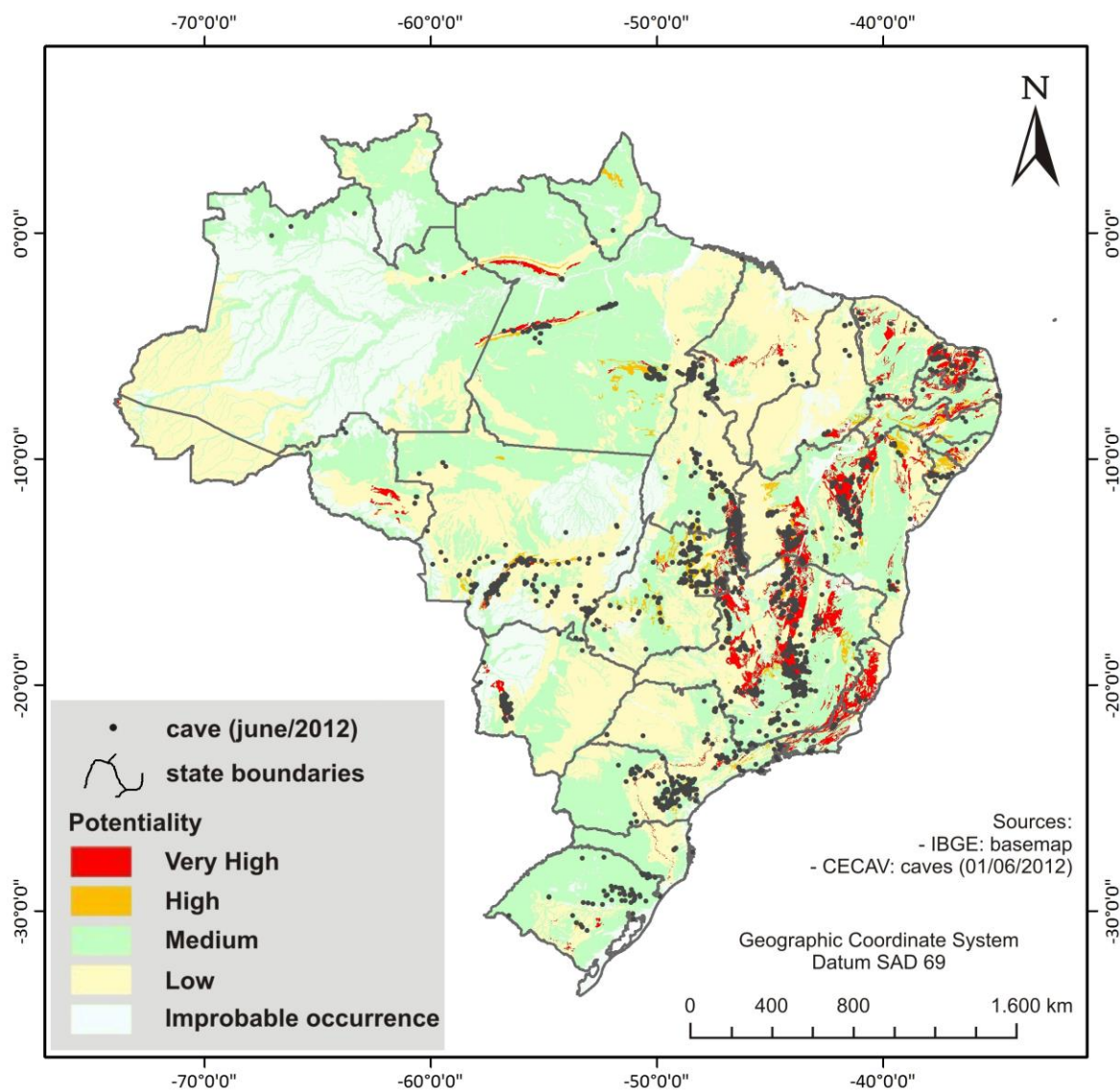


**Table 4.** Degree of potentiality of occurrence of caves in Brasil according to the lithology. Based on Jansen et al. (2012)

Lithotype	Degree of potentiality of occurrence
Limestone, Dolomite, Evaporite, Banded-Iron Formation, Itabirite and Jaspilite	Very high
Calcrete, Carbonatite, Marble, Metalimestone and Marl	High
Sandstone, Conglomerate, Phyllite, Shale, Fosforite, Greywacke, Metaconglomerate, Metapelite, Metasiltstone, Micaschist, Mylonite, Quartzite, Pellite, Rhyolite, Rhythmite, Calcosilicatic Rock, Siltstone and Schist	Medium
Remaining lithotypes (Anorthosite, Arkose, Augen Gnaiss, Basalt, Charnockite, Diabase, Diamictite, Enderbite, Gabbro, Gnaiss, Granite, Granitoids, Granodiorite, Hornfels, Kinzigite, Komatiite, Laterite, Metachert, Migmatite, Monzogranite, Olivine Gabbro, Orthoamphibolite, Syenite, Syenogranite, Tonalite, Trondhjemite, among others)	Low
Alluvium, Sand, Clay, Gravel, Pellite, Lignite, other sediments, Peat and Tuff	Occurrence unlikely

The studies showed that 78,4% of the cavities are situated in areas with degrees of potentiality of occurrence “Very high” and “High”, meaning that they occur basically in carbonatic rocks (sedimentary and/or metamorphic) and in the banded-iron formations (metamorphic). Classes of “Medium” potentiality, including sandstones

(sedimentary) and quartzites (metamorphic) held 12,8% of the cavities, and only 8,7% of the total number were located in the “Low” and “Occurrence unlikely” degrees. It was thus possible to produce the map of potentialities of caves in Brazil, offering to the country an estimate of its potential in terms of speleological heritage (Figure 5).



**Fig. 5** - Map of potentiality of occurrence of caves in Brasil, by Jansen *et al.* (2012)

## 5. THE PRESENCE OF THE SPELEOLOGICAL HERITAGE IN THE PROPOSALS OF BRAZILIAN GEOPARKS

In late 2012, the Serviço Geológico do Brasil/CPRM (Brazilian Geological Service) published the first volume of the book “Geoparques do Brasil: propostas” (Schobbenhaus; Silva, 2012a - Geoparks of Brazil: proposals) which presents a meaningful set of information about 17 geopark proposals spread throughout the country. Beside CPRM's technical staff, these proposals include among their authors university researchers and members of other institutions. Some external proposals were invited by CPRM to participate in the book, and are also included. Besides the chapters describing the proposals, there are also two initial chapters about “O papel do Serviço Geológico do Brasil na criação de Geoparques e na Conservação do Patrimônio Geológico” (SCHOBHENHAUS & SILVA, 2012b - The role of the Geological Service of Brazil in the creation of Geoparks and in the Conservation of the Geological Heritage) and “A Rede Global de Geoparques Nacionais” (BRILHA, 2012 - The Global Network of National Geoparks).

As mentioned in our Introduction, the aim of this paper is to present the speleological heritage present in these 17 different geopark proposals, pointing out their respective characteristics (rock types, degree of conservation, abundance or rarity, among others).

The 17 proposals include the description of 362 geosites, with an average of 21 geosites per proposal. A total of 12 kinds of geological interests

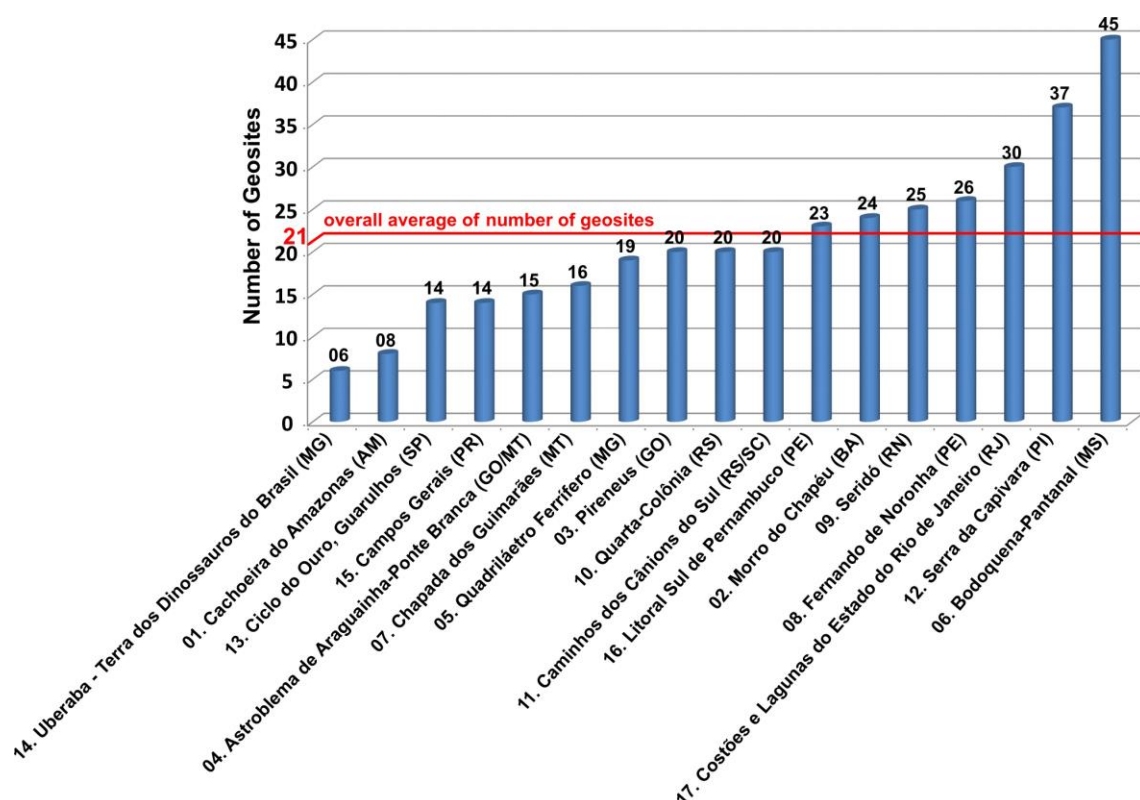
(Astrobleme, Geomorphological, History of Mining, Igneous, Metallogenetic, Mineralogical, Paleoenvironmental, Paleontological, Petrological, Stratigraphic, Tectonic, and, of course, Speleological) are represented, plus the Archaeological, Historical-Cultural, and Scenic Beauty interests. Among the geosites, 54 are related to speleological heritage, represented by caves and other natural underground cavities, thus corresponding to an average of 3 speleological geosites per proposal. Table 5 shows the total number of geosites and the number of those related to speleological heritage for each proposal, while Figure 6 presents, in graph form, the total number of geosites for each of the 17 proposals.

Focusing specifically on the number of geosites related to speleological heritage, the Geoparque Serra da Capivara (PI) is the one with the largest quantity of them: 21; next comes Geoparque Bodoquena-Pantanal (MS) with 12 geosites, and in the third place Geoparque Morro do Chapéu (BA) with 5 geosites (Figure 7).

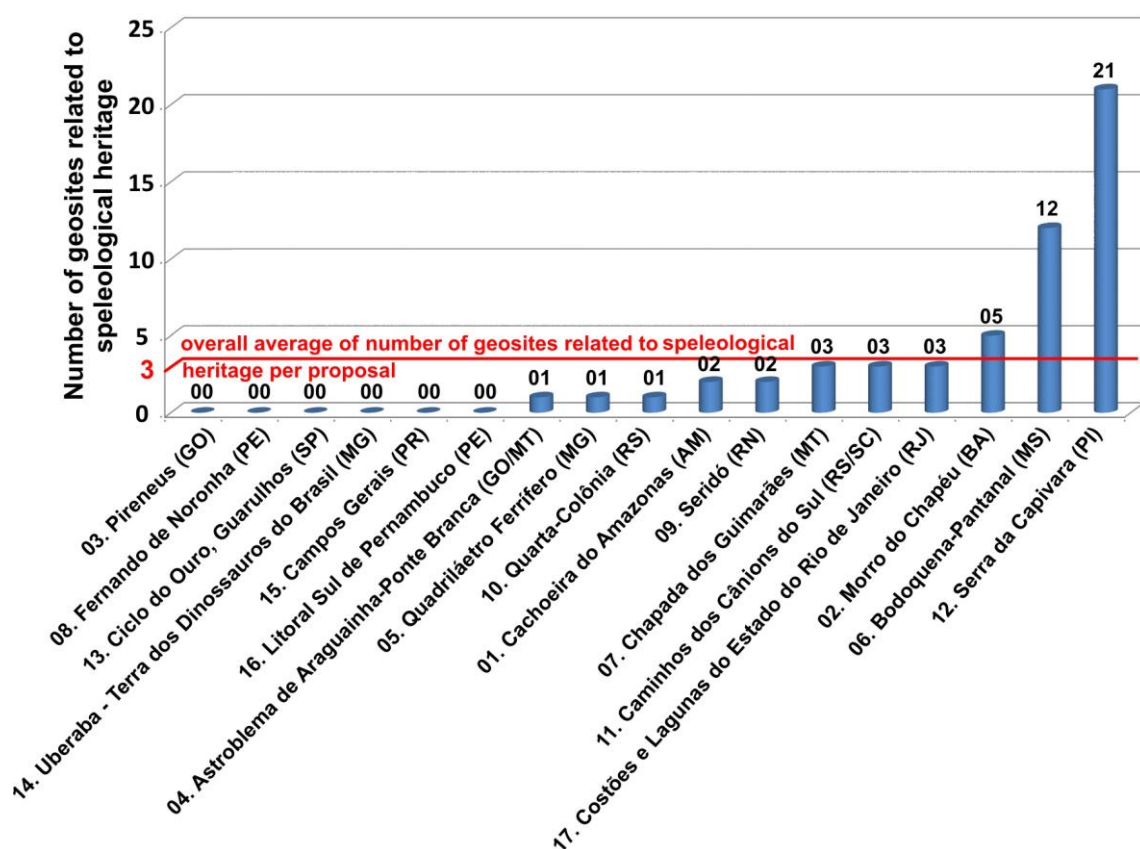
In terms of percentage of geosites related to speleological heritage compared to the total number of geosites, the Geoparque Serra da Capivara (PI) proposal maintains its lead, with 57% (of its 37 geosites, 21 are related to speleological heritage); next comes Geoparque Bodoquena-Pantanal (MS) with 27% (45 geosites, being 12 related to speleological heritage); in third place comes the Geoparque Cachoeira do Amazonas (AM) proposal, with 25% (out of a total of 8 geosites, 2 are related to speleological heritage) (Figure 8).

**Table 5.** Number of Geosites and Number of Geosites of Speleological Heritage in the 17 proposals. In parentheses, the percent value of the latter in respect to the former.

Geopark Proposal	Number of Geosites	Number of Geosites of Speleological Heritage
1. Cachoeira do Amazonas (AM)	08	02 (25%)
2. Morro do Chapéu (BA)	24	05 (21%)
3. Pireneus (GO)	20	00 (00%)
4. Astroblema de Araguinha-Ponte Branca (GO/MT)	15	01 (07%)
5. Quadrilátero Ferrífero (MG)	19	01 (05%)
6. Bodoquena-Pantanal (MS)	45	12 (27%)
7. Chapada dos Guimarães (MT)	16	03 (19%)
8. Fernando de Noronha (PE)	26	00 (00%)
9. Seridó (RN)	25	02 (08%)
10. Quarta-Colônia (RS)	20	01 (05%)
11. Caminhos dos Cânions do Sul (RS/SC)	20	03 (15%)
12. Serra da Capivara (PI)	37	21 (57%)
13. Ciclo do Ouro, Guarulhos (SP)	14	00 (00%)
14. Uberaba – Terra dos Dinossauros do Brasil (MG)	06	00 (00%)
15. Campos Gerais (PR)	14	00 (00%)
16. Litoral Sul de Pernambuco (PE)	23	00 (00%)
17. Costões e Lagunas do Estado do Rio de Janeiro (RJ)	30	03 (10%)
<b>Total</b>	<b>362</b>	<b>54 (15%)</b>

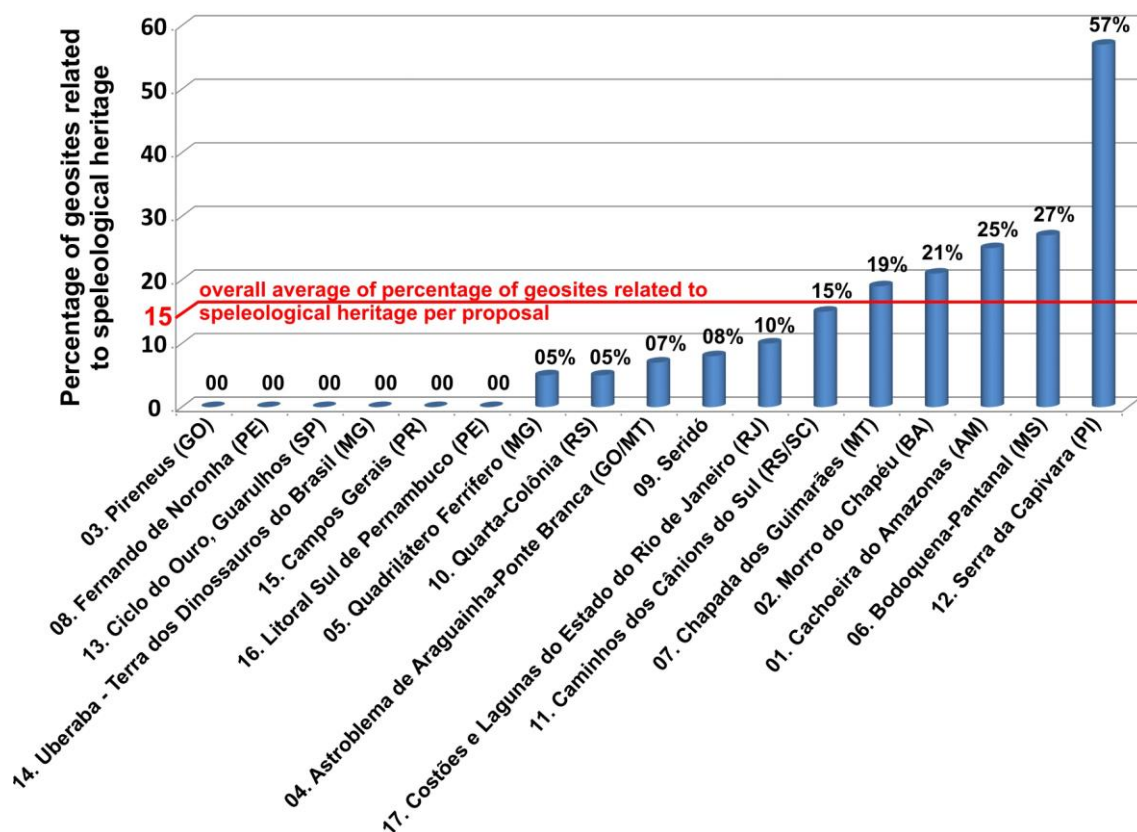


**Fig. 6** - The proposals of geoparks and their respective number of geosites. Overall, 362 geosites were described, yielding an average of 21 geosites per proposal. The Geoparque Bodoquena-Pantanal (MS) proposal is the one with the largest number of geosites (45), whereas the Geoparque Uberaba-Terra dos Dinossauros do Brasil (MG) proposal has the smallest number, 6.



**Fig. 7** - The proposals of geoparks and their respective number of geosites related to speleological heritage. There are 54 geosites with this characteristic, yielding an average of 3 geosites related to speleological heritage per proposal. The 3 proposals with largest number of such geosites are Serra da Capivara (PI) with 21 geosites, Bodoquena-Pantanal (MS) with 12 and Morro do Chapéu (BA) with 5.





**Fig. 8** - The proposals of geoparks and their respective percentages of geosites related to speleological heritage. Out of a total of 362 geosites, 54, or 15%, are related to speleological heritage. The 3 proposals with the largest percentages of geosites related to speleological heritage are Serra da Capivara (PI) with 57% (21 geosites), Bodoquena-Pantanal (MS) with 27% (12 geosites) and Cachoeira do Amazonas (AM) 25% (2 geosites).

In most cases a word in the name given to the geosite indicates the presence of an item of the speleological heritage, or is related to it (Table 6); in some cases, however, the name of the geosite does not indicate that relationship. In such cases, it is necessary to read the description of the geosite or to check its characteristics in one of the tables herein, in order to establish its scientific value.

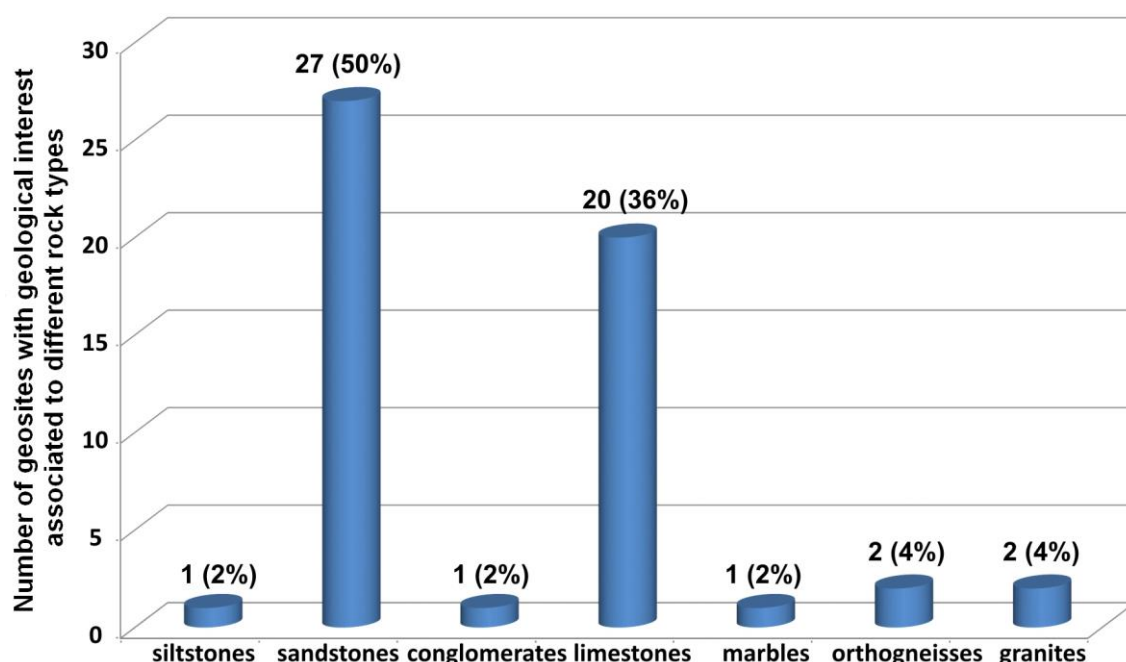
In lithological terms, it is easy to identify the predominance of sedimentary siliciclastic rocks (siltstones, sandstones and conglomerates, with a major participation of sandstones) and carbonatic rocks (limestones) (Figure 9). In a lesser scale, metamorphic carbonatic rocks (marbles), metamorphic rocks of initially igneous origin (orthogneisses), and igneous rocks (granites) are also present. Tables 6 and 7 show which lithotypes are associated to each proposal of geopark (and its respective geosites). They allow us to verify that the Geoparque Serra da Capivara (PI) proposal is the one with the largest variety of geological units hosting natural underground cavities, namely: sandstones of the Cabeças Formation of the Canindé Group; siltstones, sandstones and conglomerates of

the Ipú Formation of the Serra Grande Group; and limestones of the Barra Bonita Formation of the Casa Nova Group. A second proposal with a rich variety of lithologies is Bodoquena-Pantanal (MS), with sandstones of the Aquidauana Formation of the Itararé Group and limestones of the Cerradinho and Bocaina Formations, both of the Corumbá Group. Some proposals have just one lithological unit hosting the natural underground cavities: Cachoeira do Amazonas (AM), sandstones; Astroblema de Araguainha-Ponte Branca (GO/MT), sandstones; Quarta-Colônia (RS), sandstones; and Quadrilátero Ferrífero (MG), limestones.

Of the 54 geosites presenting natural cavities, 29 are associated to sedimentary siliciclastic rocks (being 1 to siltstones, 27 to sandstones and 1 to conglomerates); these represent 54% of the total number of geosites. Carbonatic rocks (limestone and marbles), host 21 geosites, representing 38% of the total number. The remaining 8% are associated to rocks of the crystalline basement (orthogneisses and granites), which together add up to 4 geosites with speleological interest (Figure 9).

**Table 6.** Names of geosites related to speleological heritage in the 11 proposals of national geoparks in which there is (are) one or more natural underground cavity(ies).

<b>Geopark Proposal</b>	<b>Name of Geosite = type of rock to which it is associated</b>
1. Cachoeira do Amazonas (AM)	Geosite 03 – Cachoeira da Iracema = sandstone Geosite 08 – Gruta do Maroaga = sandstone
2. Morro do Chapéu (BA)	Geosite 07 – Buraco Possidônio = limestone Geosite 08 – Gruta Barroco = limestone Geosite 09 – Buraco do Alecrim = limestone Geosite 13 – Gruta do Cristal = limestone Geosite 21 – Gruta dos Brejões = limestone
4. Astroblema de Araguainha-Ponte Branca (GO/MT)	Geosite 09 – Caverna da Gota Santa = sandstone
5. Quadrilátero Ferrífero (MG)	Geosite 18 – Gruta Nossa Senhora da Lapa = limestone
6. Bodoquena-Pantanal (MS)	Geosite 11 – Gruta do Lago Azul = limestone Geosite 12 – Gruta Nossa Senhora Aparecida = limestone Geosite 13 – Gruta São Miguel = limestone Geosite 14 – Abismo Anhumas = limestone Geosite 15 – Grutas do Mimoso = limestone Geosite 16 – Lagoa Misteriosa = limestone Geosite 17 – Buraco das Araras = sandstone Geosite 34 – Buraco das Abelhas = limestone Geosite 35 – Gruta do Urubu Rei = limestone Geosite 41 – Nascentes e Grutas Ceita Corê = limestone Geosite 42 – Buraco do Japonês/dos Fósseis = limestone Geosite 43 – Gruta e Nascente do Rio Formoso = limestone
7. Chapada dos Guimarães (MT)	Geosite 03 – Casa de Pedra = sandstone Geosite 14 – Caverna Aroe Jari = sandstone Geosite 15 – Caverna Aroe Jari – Lagoa Azul = sandstone
9. Seridó (RN)	Geosite 01 – Serra Verde = granite Geosite 13 – Gruta da Caridade = marble
10. Quarta-Colônia (RS)	Geosite 08 – Gruta do Índio = sandstone
11. Caminhos dos Cânions do Sul (RS/SC)	Geosite 01 – Furnas de Sombrio = sandstone Geosite 04 – Furnas Índios Xoclong = sandstone Geosite 06 – Morro dos Conventos = sandstone
12. Serra da Capivara (PI)	Geosite 05 – Toca do Sítio do Meio = siltstone Geosite 08 – Toca da Entrada do Pajaú = sandstone Geosite 09 – Toca do Pajaú = sandstone Geosite 10 – Toca do Barro e Toca do Inferno = conglomerate Geosite 11 – Toca da Entrada do Baixão da Vaca = sandstone Geosite 12 – Trilha do Boqueirão e Toca do Paraguai = sandstone Geosite 17 – Toca do Caboclinho = sandstone Geosite 18 – Toca do Vento, Capim, Dedo e Castiçal = sandstone Geosite 19 – Toca do Cabloco da Serra Branca = sandstone Geosite 20 – Toca da Extrema = sandstone Geosite 21 – Toca da Passagem = sandstone Geosite 22 – Toca do Olho D'Água da Serra Branca = sandstone Geosite 23 – Toca da Mangueira do João Paulo = sandstone Geosite 25 – Toca do Estevo ou da Onça = sandstone Geosite 26 – Circuito da Pedra Caída/Toca da Invenção = sandstone Geosite 27 – Toca do Alexandre = sandstone Geosite 28 – Toca da Ema do Sítio do Brás I = sandstone Geosite 29 – Toca da Roça do Sítio do Brás I = sandstone Geosite 30 – Toca da Janela da Barra do Antonião = limestone Geosite 31 – Serrote do Tenente Luiz = limestone Geosite 32 – Toca dos Pilões = limestone
17. Costões e Lagunas do Estado do Rio de Janeiro (RJ)	Geosite 01 – Costão de Ponta Negra = orthogneiss Geosite 03 – Promontório Igreja de N.S. de Nazaré = orthogneiss Geosite 07 – Ilha do Cabo Frio = granite



**Fig. 9** - Number of geosites with geological interest associated to different rock types in the geopark proposals (total of 54 geosites inventoried). The predominance of geosites in siliciclastic rocks (conglomerates + sandstones + siltstones), with 29 geosites, representing 54% of the total, is clearly visible.

**Table 7.** Identification of the lithological units for each geopark proposal.

Geopark Proposal	Lithologies
1. Cachoeira do Amazonas (AM)	Sandstones of the Nhamundá Formation of the Trombetas Group.
2. Morro do Chapéu (BA)	Limestones of the Salitre Formation of the Una Group. Siltstones and limestones of the Caboclo Formation of the Chapada Diamantina Group.
4. Astroblema de Araguainha-Ponte Branca (GO/MT)	Sandstones of the Aquidauana Formation of the Itararé Group.
5. Quadrilátero Ferrífero (MG)	Limestones of the Gandarela Formation of the Itabira Group.
6. Bodoquena-Pantanal (MS)	Sandstones of the Aquidauana Formation of the Itararé Group. Limestones of the Cerradinho e Bocaina Formations of the Corumbá Group.
7. Chapada dos Guimarães (MT)	Sandstones of the Furnas Formation of the Paraná Group. Sandstones of the Alto Garças Formation of the Rio Ivaí Group.
9. Seridó (RN)	Granites of the Dona Inês Intrusive Suite. Marbles of the Jucurutu Formation of the Seridó Group.
10. Quarta-Colônia (RS)	Sandstones of the Serra Geral Formation of the São Bento Group.
11. Caminhos dos Cânions do Sul (RS/SC)	Sandstones of the Botucatu Formation of the São Bento Group. Sandstones of the Rio do Rastro Formation of the Passa Dois Group.
12. Serra da Capivara (PI)	Sandstones of the Cabeças Formation of the Canindé Group. Siltstones, sandstones and conglomerates of the Ipú Formation of the Serra Grande Group. Limestones of the Barra Bonita Formation of the Casa Nova Group
17. Costões e Lagunas do Estado do Rio de Janeiro (RJ)	Granites of the Alkaline Complex. Orthogneisses of the Região dos Lagos Complexo.

## 6. FINAL REMARKS

The importance of a Geopark project, which allows the association of conservation and use of geologically significant sites (geosites) to the socio-economical and cultural development of the population of its territory is, in many countries, a well-established fact. The Geopark fosters the deployment of various lines of environmental education which include the physical basis (the geodiversity) and point out the close association

between biodiversity and geodiversity, the latter supporting the former.

Brazil has a rich geodiversity, and could not let pass this opportunity to become engaged in this new trend. In fact, a number of federal, state and municipal organisms, plus universities and other institutions are already promoting a series of actions aimed at the establishment of geoparks in its territory. Besides CPRM – Serviço Geológico do Brasil, some examples are the Universidade Estadual



de Ponta Grossa and Minérios do Paraná-Mineropar; Prefeitura de Guarulhos, São Paulo; and Serviço Geológico do Estado do Rio de Janeiro - Diretoria de Recursos Minerais.

The geosites in the geopark proposals address different interests: stratigraphic, geomorphological, tectonic, paleoenvironmental, metallogenetic, paleontological, igneous, mineralogical and speleological. Focusing on this last interest, an analysis shows that out of the 17 proposals, at least 11 of them have one or more geosite(s) related to speleological heritage. Among those, a few stand out, like the Serra da Capivara/PI (with 21 geosites related to speleological heritage, in a total of 37 geosites), Bodoquena-Pantanal/MS (12 in a total of 45) and Morro do Chapéu/BA (5 in a total of 24). Percentagewise, Serra da Capivara/PI is the leader, with 57% of geosites with speleological interest, followed by Bodoquena-Pantanal/MS with 27%, and in third position comes Cachoeira do Amazonas/AM, with 25%. Of the total of 362 geosites listed in the 17 geopark proposals, about 15% are related to speleological interest. This is a low percentage, brought about mainly by the fact that six proposals - Pireneus/GO; Fernando de Noronha/PE; Ciclo do Ouro, Guarulhos/SP;

Uberaba-Terra dos Dinossauros do Brasil (MG); Campos Gerais/PR e Litoral Sul de Pernambuco/PE - do not have any geosites of this kind. Overall, with 54 geosites of speleological interest in 17 proposals, the average comes to a little more than 3 geosites related to speleological heritage per proposal, a low value if the enormous potential that Brazil has in this kind of heritage is taken into account.

Regarding the lithological type to which these cavities are associated, in the 17 proposals, and limiting the analysis to those 54 geosites related to speleological heritage, 29, or 54% of them are related to sedimentary siliciclastic rocks (mainly sandstones); 21, or 38% are related to carbonatic rocks (limestones and marbles), and the remaining 4, or 8%, to the crystalline basement (orthogneisses and granites).

It must be pointed out that the speleological potential presented in these geopark proposals, according to the Brazilian law, must be initially protected by strategic actions for conservation. Only after these actions are implemented, can these areas be used for tourism and educational activities.

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