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A BRIEF INTRODUCTION TO KARST AND CAVES IN BRAZIL

by

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ABSTRACT

Karst terrains cover a large part of Brazil and form an important component in the country's landscape. As yet much of Brazil's karst areas have only been superficially studied and cave exploration is still in its infancy. Karst features are developed in a wide variety of lithologies, mainly in Proterozoic carbonates, but also in a number of other rocks, such as quartzite, sandstone and granite. About 81% of all known caves in Brazil occurs in four karst regions, defined by their lithology; the Bambuí, Una, Açungui and Corumbá Groups. This paper attempts to summarise and briefly describe the major karst areas and cave systems in these regions. A summary of the current status of karst science in Brazil is presented, together with an updated bibliography.

INTRODUCTION

Karst terrains are widespread throughout Brazil (Figure 1). It is estimated that between 5 and 7% (425,000 - 600,000 km^2) of the total surface of the country is carbonate karst (Karmann, 1994). Most of the carbonate karst areas in Brazil are developed on Upper Proterozoic and Lower Cambrian limestone and dolomites. The most extensive karst regions occur in central Brazil, developed on rocks belonging to the Bambuí and Una Groups. Many cave systems are known in these areas including the longest and largest caves in the country, such as the 65.5 km long Toca da Boa Vista. Significant karst development also occurs in carbonates of Açungui Group in south-eastern Brazil and in the Corumbá Group in western Brazil. Several other areas contains well developed karst features, but little or no scientific reconnaissance has been carried out in them. A preliminary classification of karst areas in Brazil, based mainly in geological criteria, was produced by Karmann and Sánchez (1986).

In general, Brazilian carbonate karst is characterised by large areas of horizontally bedded limestones and dolomites, which form extensive regions of little or no relief, and are drained by low gradient rivers. In the regions of the most extensive karst, the climate is very seasonal in character (wet during the summer and dry during the winter) and rainfall is usually less than 150 cm/yr, including extensive areas under semiarid climate.

Very little is known about the timescales of karst evolution in Brazil. Proterozoic palaeokarst associated with ore deposits has been described (Pericón, 1981) from rocks of the Bambuí and Açungui groups. In many karst regions, extensive areas of carbonate have been covered by thick sequences of impermeable sediments. Subjacent karst occurs in selected areas (Montanheiro *et al.*, 1981).

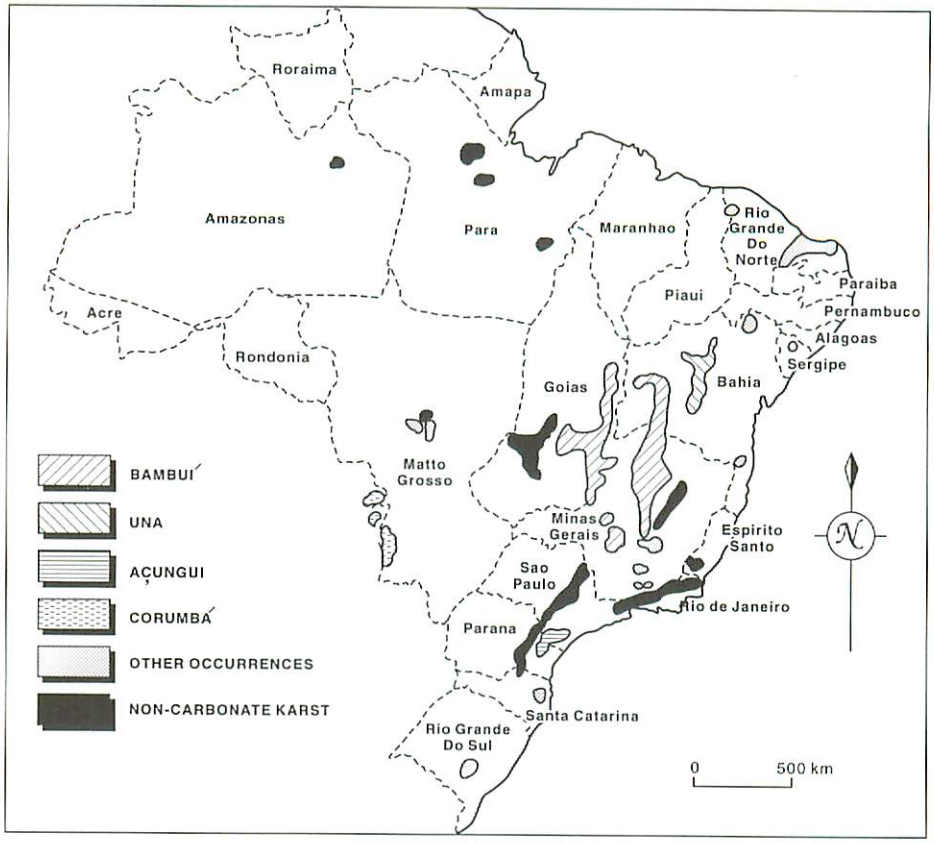

Figure 1. *Karst areas in Brazil, after Lino (1989).*

NON-CARBONATE KARST.

Significant karst areas occur in rocks other than carbonate lithologies. Quartzite caves are found throughout much of central Brazil (Brichta *et al.*, 1980), including some of the longest quartzite caves known in the world (Correa Neto *et al.*, 1993) such as Gruta das Bromélias, at 2,750 m in length (Figure 2). The recent exploration of the 360 m deep Gruta do Centenário, produced the deepest cave in Brazil and one of the deepest quartzite caves in the world. Also of note is the widespread occurrence of large dolines (Soares, 1989) and caves in sandstone (Martins, 1985; Veríssimo and Spoladore, 1994). A gypsum palaeokarst has been reported in north-eastern Brazil (Silva, 1986). Pseudokarst landforms in igneous rocks include extensive karren fields in syenite (Ribeiro Filho, 1969), depressions in granite (Domingues, 1952), and erosional caves of both coastal (Gomes and Ab'Saber, 1969) and fluvial (Levis *et al.*, 1992) origin. Caves have been reported in the Banded Iron Formation, superficial weathering products such as canga (Simmons, 1963; Pinheiro and Maurity, 1988) and even in bauxite (Lins *et al.*, 1983).

CARBONATE KARST

The better known karst landforms and the most well explored and studied caves among the several different karst regions in Brazil are concentrated in the Bambuí, Una, Açungui and Corumbá carbonate areas. Out of the nearly 2,000 caves registered in the database of the Brazilian Spelaeological Society in 1993, about 81% occur in these lithologies. These regions are described in more detail below.

The Bambuí Karst

The rocks of Bambuí Group occur widely throughout the states of Minas Gerais, Goiás and Bahia. They comprise predominantly horizontally bedded Upper Proterozoic limestones over much of the area, with thickness rarely exceeding 200 metres. The karst develops in two distinct geological units, namely the Sete Lagoas Formation and the Lagoa do Jacaré Formation. The areal distribution of the outcrops of Bambuí Group and the surrounding topography comprise several physiographical domains, imprinting distinct morphological patterns on the karst landforms. On the basis of geomorphological features, distinct karst areas can be recognised. Other areas certainly exist, but at present they are not sufficiently well documented to identify them. The main caving areas are described below.

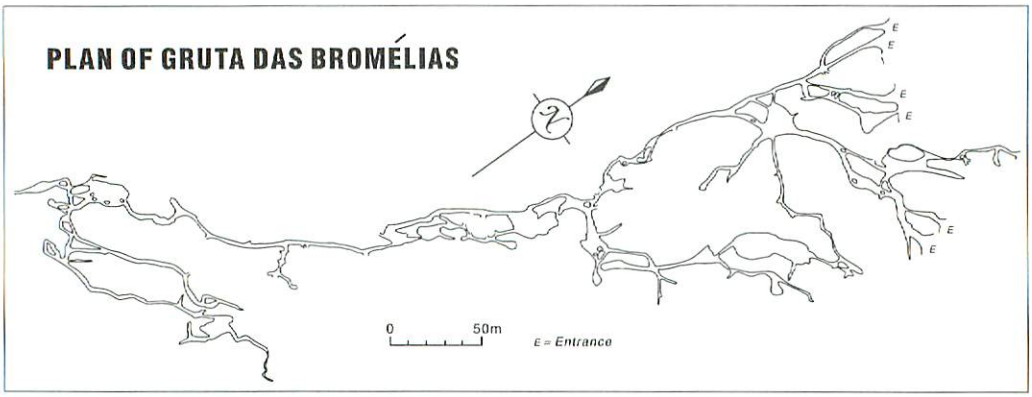

Figure 2. *Plan of Gruta das Bromélias, Ibitipoca State Park, Minas Gerais state. At 2,750 m in length, it is one of the longest quartzite caves in the world.*
Survey courtesy of Sociedade Carioca de Pesquisas Espeleológicas (SPEC).

Arcos-Pains Area. Very little is known, spelaeologically speaking, of this area. As it is conveniently located near Brazil's most populated region, the region is being subjected to extensive uncontrolled mining. This region possesses an extensive underground drainage network, although little is known about it. The longest known cave discovered so far is Gruta do Eden (1.7 km).

Lagoa Santa Area. This region, located close to Belo Horizonte in Minas Gerias state, forms the cradle of Brazilian speleology. Here, Peter Lund did the first systematic studies of Brazilian

caves. The area has the highest density of caves in Brazil with more than 300 known caves. A well developed, varied karst topography is characterised by many isolated limestone crags and limestone cliffs, with low-lying valleys and closed depressions in between, often dotted with seasonal lakes. Most caves are fairly small, and have developed either on the lake margins (Auler, 1995a) or as influent caves draining neighbouring shale covered areas. Many of the influent caves are sediment choked and show much evidence of paragenetic cave development.

Cordisburgo-Baldim Area. The karst terrain in this area is largely covered by pellitic rocks. The caves show a typical dendritic pattern with an active drainage. The largest cave is Gruta da Morena, over 4 km long, which has a series of tributaries converging into a main trunk passage. The oldest and best known commercial cave in Brazil, Gruta de Maquiné, is also located in this area.

Montes Claros Area. This area contains several large caves, many of them allowing through trips from swallet to resurgence. The large network maze of Lapa Sem Fim, with over 8 km of mapped passages, is the longest cave in the area.

Middle São Francisco Area. On the left margin of the middle course of São Francisco River, there is a long strip of limestone that hosts a number of significant caves. The Peruaçú Valley National Park contains the impressive Lapa do Janelão, with gigantic passages over 100 m high, bisected by huge skylights. Important archaeological sites occur associated with cave entrances. Several swallets in the top of the limestone drain towards resurgences in the alluvial plain below. Some of these swallets have yielded long caves such as the 7.8 km long Gruta Olhos D'Água.

Ramalho Range Area. This area comprises a large and intensively karstified plateau, although very little research has been carried on in this area. Major caves, such as Boca da Lapa (3 km long) and Gruna do Engrunado (5 km) have been explored, and there is great potential for other long caves.

Santana Area. This area is located on the west bank of the Sao Francisco river. The karst topography is marked by a number of residual limestone hills with several minor caves in them. However, the major active systems are located below the plain level and drain to nearby rivers which are incised below the level of the plain. Some of the caves are fed by allogenic drainage from sandstone outcrops several kilometres to the west. Large meandering vadose passages are characteristic, with entrances associated with collapse dolines. The Padre system (Figure 3) contains the longest caves in the area, including Gruta do Padre itself, a major river passage with extensive high-level abandoned passages above. It is currently the second longest cave in Brazil. The stream passage is several kilometres long and ends in a sump still many kilometres from the resurgence.

São Domingos Area. A series of allogenic rivers draining an extensive area of sandstone sink into the limestone creating several caves. The passages are often extremely large, and have extensive upper level galleries. The present level of cave development has reached the contact with the underlying granite. Among the longest caves of this area are Lapa do Angélica (13.8

km), Gruta São Vicente I (9.4 km), Lapa de São Mateus (10.8 km) and a large number of lesser systems.

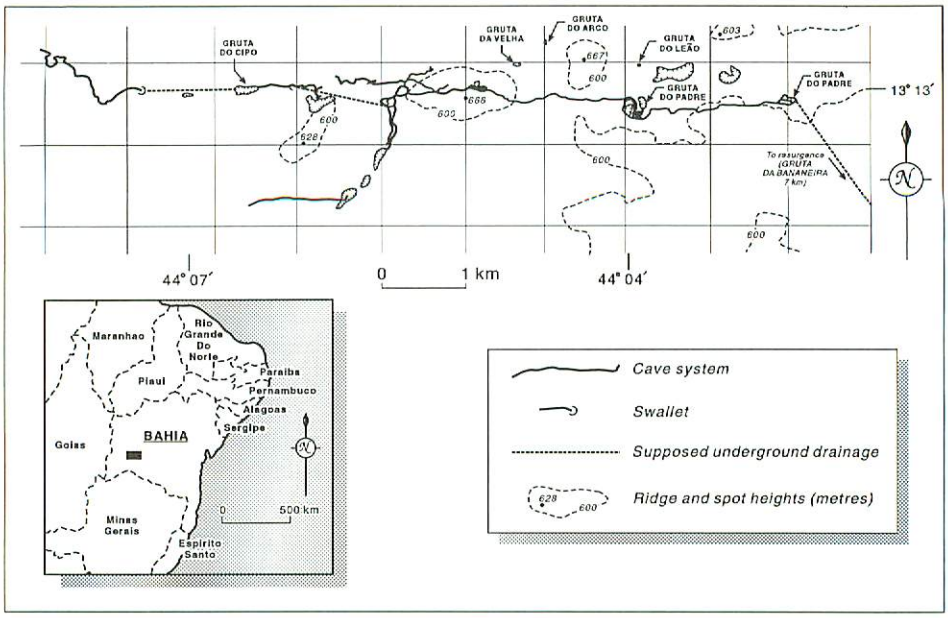

Figure 3. *Major surveyed caves in Gruta do Padre area. The arrows point towards the entrances. Velhas, Arcos, Leão and Bananeira have not been surveyed. Gruta da Bananeira is the supposed resurgence of the system, several km away.*
Survey by GBPE/EGMS/ECA.

The Una Karst

The rocks of the Una Group are of the same age as rocks of the Bambuí Group. However, there are marked differences between them, and these are reflected in the karst landforms. The karst development is concentrated in the limestone and dolomites of the Salitre Formation. The surface karst and relief is very subdued with few if any characteristic features. This contrasts markedly with the underground scenery, which is very impressive and features some of Brazil's largest cave systems. Many of the caves in the Una group carbonates probably owes their existence to the oxidation of sulphide layers within the carbonate by groundwater, forming sulphuric acid and causing increased dissolution (Auler, 1995b). These autogenic caves form some of the longest caves in the country. Active and abandoned stream systems are also known. The most common karst landforms are the caves and collapse dolines, few other karst features are well developed. The karst landforms, however, are mostly relict forms related to wetter palaeoclimates, as most of the Una Karst region has a semi-arid climate. Again, the Una karst region can be divided up into smaller morphologically distinct areas, which are detailed below.

Iraquara Area. This area is located in central Bahia and occupies a low lying area in the centre of a large syncline. Most of the known cave entrances occur at the bottom of the numerous collapse dolines. Figure 4 shows the main systems which have been mapped up to now. Several other large caves have been explored but mapping is still in progress. Cave morphology varies between branchwork caves, such as the 9.8 km long Lapa Doce II, and ramiform caves such as the Torrinha (6.5 km) system. Partially flooded network caves are also to be found, such as the Impossível and Ioiô (4 km long each) caves. Nearly all the caves are characterised by large horizontal passages often cloaked with thick mud banks deposited by backflooding from the main river during the wet season. Exploration continues and this area will probably soon hold the highest density of known cave passages in Brazil.

Jacobina-Morro do Chapéu Area. The Jacaré River forms the main drainage in the area, cutting a deep valley through the region. This valley is divided along its course into segments by a series of extremely impressive caves, such as the 6.6 km long Lapa dos Brejões. This system has enormous passages, some over 100 m high fragmented by a series of skylights. Nearly all the known caves in the area are located along this valley, which may have partly originated by cavern collapse. The remoteness of the area and the poor road network has precluded much research in this area, although there is great potential.

Campo Formoso Area. Surface karst in this area is far from being representative of the scale of cave development in this region. However, under the extensive monotonous flat plain are found some of the longest caves in South America. As yet, exploration is at a very early stage, but some impressive cave systems are being slowly mapped. The 65.5 km long Toca da Boa Vista is the longest cave in Brazil (Figure 5), and has the potential to become one of the longest caves in the world. The caves in the area show a basically ramiform pattern. This area is a good example of a sulphuric acid karst of shallow origin, showing a series of features typical of hypogenic caves, such as lack of relationship with the surface landforms, lack of fluvial sediments, chemical weathering in the walls, sulphate precipitates and an extensive maze of passages developed along the joint network. Many of the major passage in Toca da Boa Vista are aligned along shallow anticlines, with smaller interlinking passages. In the same region of the Una Karst, other lithologies also show significant karst landforms. The carbonates of the Caboclo Formation contain important caves and deep collapse dolines. The Quaternary Caatinga limestone, which occurs in the Salitre, Jacaré and Verde river valleys, has several long caves. One of the longest is the 9.2 km long Gruta do Convento, about 20 km from Toca da Boa Vista, a large horizontal abandoned stream passage. These are all either active or abandoned stream caves.

The Açungui Karst

The Middle Proterozoic carbonate rocks of Açungui Group occur in the southern part of São Paulo state and the eastern part of Paraná state. They comprise lenses of metamorphic limestone and dolomitic limestone intercalated with lenses of insoluble rocks, all intensively folded. The area is characterised by a well developed polygonal karst, with conical hills conditioned by the rock structure (Karmann, 1994). The area around the town of Iporanga is the best studied area. In this area Karmann (1994) recognised a series of stages in the development

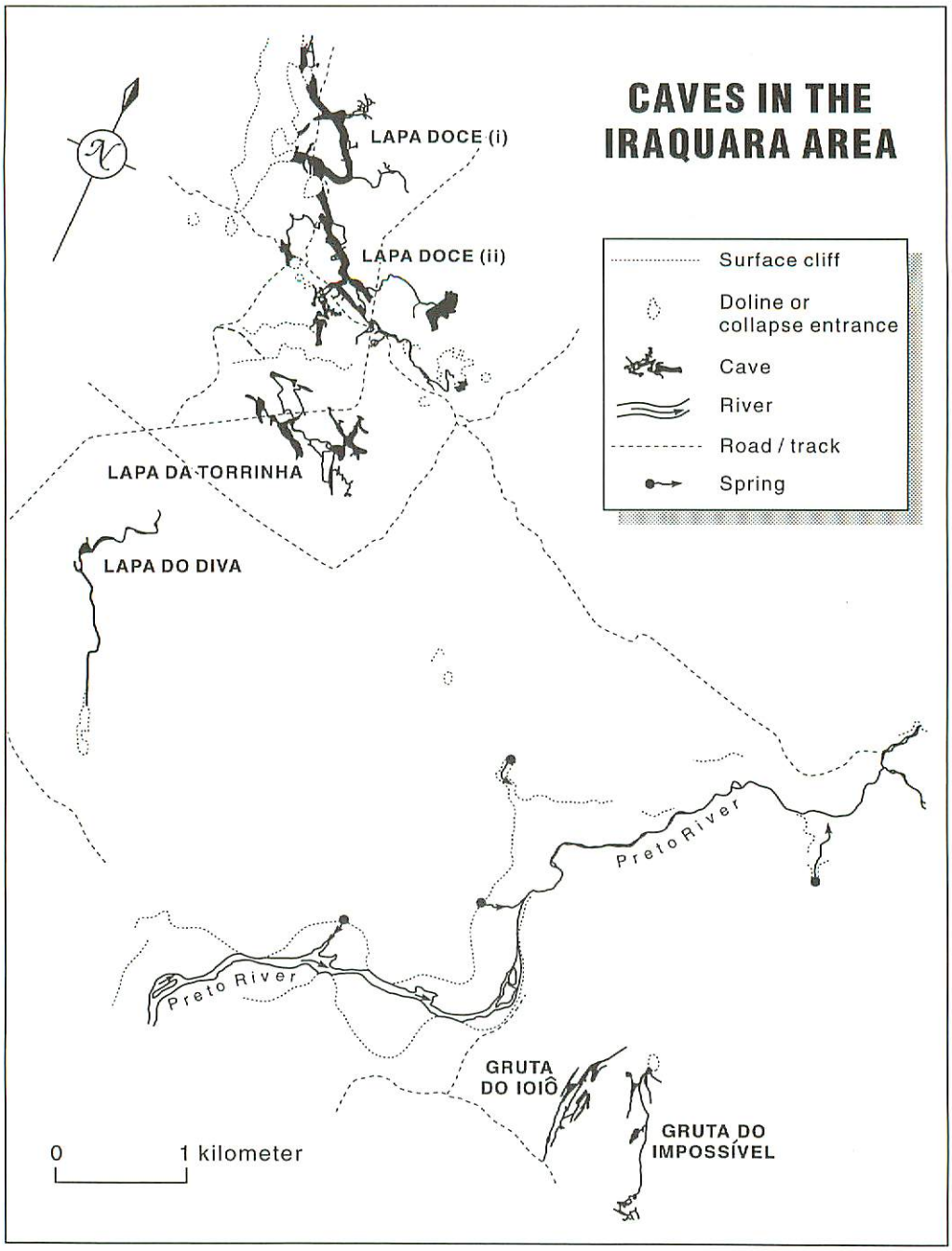

Figure 4. *Caves in the Iraquara area.*
After surveys by GBPE, Brasil'86 French expedition and Gabriel Hez.

of the karst, beginning with fluvial valleys, which then gradually become segmented by closed depressions, and then evolve into a classical polygonal karst. A large number of caves occur, many showing predominantly vertical development. The majority of the deepest limestone caves in Brazil occur in this area. Among the most important cave systems are Caverna de Santana (5.8 km) and Caverna do Diabo (5.7 km). The caves and the beautiful rainforest scenery has led to the creation of a state park in order to protect part of this area.

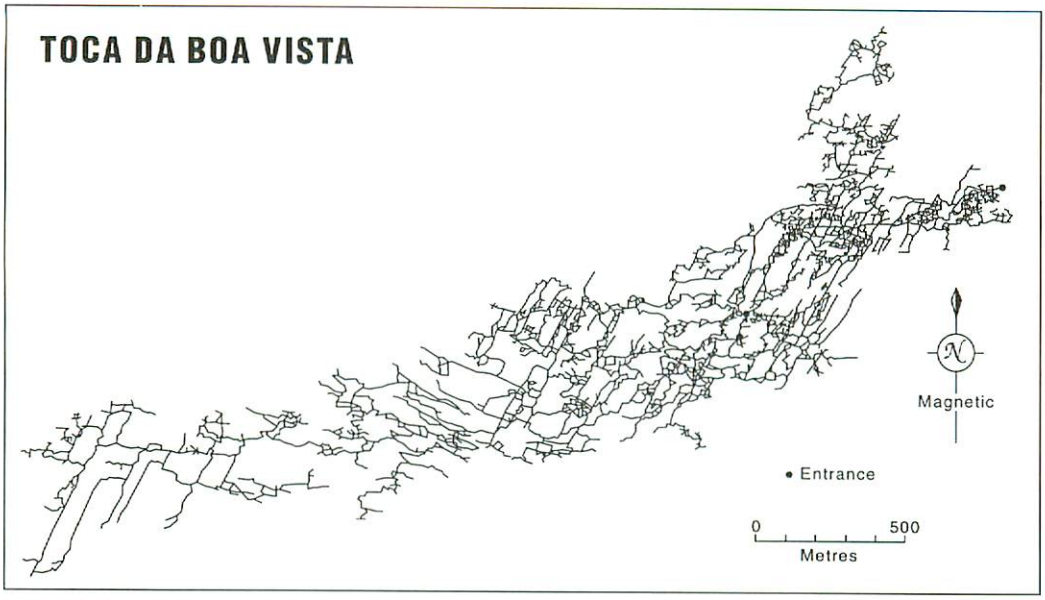

Figure 5. *Plan view of Toca da Boa Vista.*
Survey by Grupo Bambuí de Pesquisas Espeleológicas.

The Corumbá Karst

The limestone and dolomites of the Corumbá Group, also of Upper Proterozoic age, possess an important yet largely unexplored karst terrain. The area around the town of Bonito is the best explored so far. Large underground lakes and crystal clear springs are characteristic of the region. Cave diving exploration has revealed some very deep flooded passages, such as the 150m deep Lagoa Misteriosa, where the bottom has not yet been reached. The whole area is undergoing tectonic subsidence, and several dry caves are sinking below the water table. The most prominent geomorphological feature in the area is the Bodoquena range of hills, at the base of which issue several large springs. Several large relict caves occur in mogote-like residual hills in this region. Gruta do Lago Azul with its huge passage (over 50 m wide underwater) and deep blue lake is probably the best known cave in the area.

Other Areas

Several other karst areas occur throughout Brazil. Some of them are limited in area, thus potentially containing only a small number of caves, such as the Ubajara area, in the north-east. Most of them, however, have not been prospected. Such is the case for the Curaçá-Canudos, Vaza Barris, Cáceres and São Desidério areas, among others. Karmann and Sánchez (1979) give more detailed information about the geology and physiography of these areas. Other areas, such as Chapada do Apodi, Vazante-Paracatu, Alto Paraguaçu, have received a preliminary investigation only.

KARST RESEARCH IN BRAZIL

Karst research in Brazil is still at an early stage, although descriptive work on karst areas and their associated cave systems began in the last century (Lund, 1837; Krone, 1898). Following the beginning of organised caving in 1937, there has been a steady flow of data from cave surveying throughout the country. However, up to now, few serious karst related studies have been performed. Geomorphological descriptive regional work has been done for several regions including the Santana do Riacho area (Auler and Basílio, 1988), Peruaçú Valley (Piló, 1989), Lagoa Santa, near Belo Horizonte (Tricart, 1956; Coutard *et al.*, 1978; Kohler, 1989), Prudente de Morais (Moura, 1990), all in Minas Gerais state and for the Bom Jesus da Lapa area (Tricart and Silva, 1960), and Iraquara areas in Bahia state (Ferrari, 1990). Karren morphology in northern Minas Gerais karst has been studied by Campos *et al.* (1992)

Hydrogeology has been the subject of the majority of Brazilian karst studies, mainly in the dry semi arid-areas of Bahia and Minas Gerais states. General hydrogeological studies have been done by Guerra (1986) in the Irecê area, Bahia state, Silva (1984) in the Jaíba area and Auler (1994) for the Lagoa Santa area, both in Minas Gerais. Hydrochemical studies have been performed by Negrão (1987) in the Irecê area, Bahia. Isotopes have been used in a number of studies, such as the ones by Chandra *et al.* (1981) for the Açungui karst area, Bedmar and Silva (1980) for the Jaíba area and Bedmar *et al.* (1980), Siqueira (1978) and Gomes and Cabral (1981) for the Irecê area. Escodino and Silva (1982) applied geoelectrical methods for defining favourable sites for well drilling in the Jaíba Karst. In the same area, Silva *et al.* (1981) studied the development of wells through blasting. Some of the hydrogeological work had an applied focus. This is the case of the study by Meneses *et al.* (1990) on remote sensing applications for water supply in the Iuiú Range, southern Bahia state, Pessoa (1996) on karst groundwater resources in the Sete Lagoas urban area, Minas Gerais, and by Bonacim (1996) for the Curitiba metropolitan area. A thorough geomorphological and hydrological quantitative study has been performed in the Iporanga area, Açungui Karst, São Paulo state by Karmann (1994). Several large and medium sized towns occur near or entirely over karst terrains. Environmental problems, associated with karst terrains such as doline collapse, have been studied by Silva, (1988); Prandini *et al.*, (1990), and Mendonça *et al.*, (1994), although much work is still needed.

Cave research in Brazil is still in its infancy. Speleogenesis in several regions, notably in Bahia state has been examined by Karmann (1994) and Auler (1995a,b). Cave mineralogy has been studied by Guimarães (1974) and Barbieri (1993), both in the Açungui Karst. Little

dating work has been carried out although Ikeya *et al.*, (1984); Tatumi *et al*, (1993) and Rossi, (1987) have done some preliminary work on Electron Spin Resonance. A general textbook on Brazilian caves and karst was produced by Lino (1989). Sánchez (1986) gives detailed bibliographical information on Brazilian karst and caves.

In general, the majority of the Brazilian karst areas remain to be adequately explored, let alone studied. The small number of active cavers and the large distances to be covered are some of the factors that have restricted spelaeological work in Brazil. The current status of Brazilian caving is shown in Table 1, which shows the longest and deepest caves in Brazil. New exploration and scientific research currently being performed should add much to our present, and far from complete, knowledge of Brazil's extensive and spectacular karst regions.

CAVE	KARST AREA	LENGTH metres.
Toca da Boa Vista	Campo Formoso/Una	65,500.
Gruta do Padre	Santana/Bambuí	15,800.
Lapa do Angélica	São Domingos/Bambuí	13,800.
Lapa São Mateus III	São Domingos/Bambuí	10,828.
Lapa Doce II	Iraquara/Una	9,800.
Lapa São Vicente I	São Domingos/Bambuí	9,450.
Lapa do Convento	Campo Formoso/Caatinga	9,200.
Lapa SemFim	Montes Claros/Bambuí	8,558.
Lapa do Bezerra	São Domingos/Bambuí	8,100.
Gruta Olhos D'Água	Middle São Francisco/Bambui	7,800.
CAVE	**KARST AREA**	**DEPTH metres.**
Gruta do Centenário	Caraça Range/quartzite	360.
Gruta Casa de Pedra	Açungui	292.
Abismo do Juvenal	Açungui	252.
Gruta da Água Suja	Açungui	202.
Gruta do Córrego Fundo	Açungui	195.
Abismo Jatobá	Açungui	193.
Gruta do Ouro Grosso	Açungui	192.
Caverna Ribeirãozinho III	Açungui	174.
Gruta da Tapagem	Açungui	173.
Sistema Terra Ronca II/Malhada	São Domingos/Bambuí	155.

Table 1. *Longest and deepest caves in Brazil.*

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