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Where the sunshine turns blue

Paulo Cesar Boggiani[1]
William Sallun Filho[3]
Ivo Karmann[1,2]
Ana Lúcia Gesicki[4]
Nicoletta Moracchioli Philadelphi[5]
Marcos Philadelphi [5]

[1] **Departamento de Geologia Sedimentar e Ambiental – Instituto de Geociências, USP – Rua do Lago, 562, 05508-900 São Paulo – SP,** boggiani@usp.br
[2] ikarmann@usp.br
[3] **Instituto Geológico, Secretaria do Meio Ambiente do Estado de São Paulo – Av. Miguel Stefano 3900, 04301-903 São Paulo – SP,** wsallun@igeologico.sp.gov.br
[4] **DNPM – Departamento Nacional da Produção Mineral – São Paulo - Rua Loefgren, 2225, CEP 04040-033 – São Paulo – SP,** ana.gesicki@dnpm.gov.br
[5] **Neotrópica,** mphiladelphi@uol.com.br

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The Gruta do Lago Azul (Blue Lake Cave), located at the Bonito municipality, Mato Grosso do Sul State, is developed in carbonate rocks of the Corumbá Group (Ediacaran) in the Serra da Bodoquena geomorphological context. Along the September to February, the sunlight penetrates the wide chamber, going down 150 meters from the surface, to the subterranean lake, turning the colour of the water intensely blue, what is the motivation for the site's name. At the floor of the subterranean lake occur bones of pleistocenic mammals and the cave is also important due to the presence of nesquehonite speleothems. This cave and the neighboring Nossa Senhora Aparecida Cave are considered national heritage and a formal conservation unit of the Mato Grosso do Sul state is concerned by the *Monumeto Natural Gruta do Lago Azul* (Blue Lake Cave Nature Monument), a conservation unit of the Mato Grosso do Sul State. The Lago Azul Cave is one of the most important touristic attraction of the region with touristic guides prepared to geoscience education.
Keywords: Lago Azul Cave, Planalto da Bodoquena, Bonito, Mato Grosso do Sul State

INTRODUCTION

The Lago Azul Cave (Blue Lake Cave) is one of the most important caves in Brazil and the one of the mainly natural touristic attractions of the state of Mato Grosso do Sul, with emphasis on the underground lake that acquires an intense blue color during the period of the day that it is exposed to rays of sunlight (Fig. 1). The exceptional value was the reason for been declared as a heritage site by the "Instituto do Patrimônio Histórico e Artístico Nacional - IPHAN" (National Historical and Artistic Heritage Institute), together with the Nossa Senhora Aparecida Cave situated in the vicinity.

Besides its exceptional underground view, the Lago Azul Cave is noted for its fossils of Pleistocene mammals (Salles *et al.*, 2006) and the occurrence of rare minerals (e.g., nesquehonite), in the form of fragile agglomerates and by the occurrence of endemic crustaceans that inhabit the underground lake.

The cave is easily accessed with great potential for geotourism activities, partly achieved by tourism guides to relatively intense tourist flow (44,786 visitors in 2003 according to the "Secretaria de Turismo de Bonito" (Secretariat of Tourism of Bonito Town). The cave have a big entrance to the outside, allows natural light, it has been possible to implement low environmental impact, wich comes to be refined through implementation of the "Monumento Natural Gruta do Lago Azul" (Blue Lake Cave Nature Monument), a kind of brazilian conservation unit special to geological and geomorphological features, created in 2001, in the areas where the two declared national heritage are found, and by the implementation of the measures and internal and external infrastructure established in the "Plano de Manejo Espeleológico" (Speleological Management Plan), submitted to IBAMA in February 2002 and approved in 2008. By initiative of IPHAN (brazilian heritage institute) the area has been proposed as geopark.

LOCATION

The Lago Azul Cave is located to the west of the town of Bonito, between the Anhumas creek to the North and the Taquaral cave to the south, at coordinates 56°35'26.53"W and 21°08'40.79"S. From the town of Bonito (Fig. 2), it is possible to access the site after 19 km on an unpaved road (Fig 2).

Bonito can be accessed by taking a paved highway from Campo Grande (state capital), following the route that comprises Campo Grande – Sidrolândia – Guia Lopes da Laguna – Bonito cities, totaling 280 km. It is also possible to access the town of Bonito by regular bus service and the there is an International Airport, although this is currently restricted to charter flights. Given that it is a tourist town, Bonito has innumerous travel agencies, hotels and professional services in the form of tourist guides (around 50 registers guide by the Brazilian Tourism Minister).

Figure 1 – General view of the Gruta do Lago Azul (Blue Lake Cave - Bonito, MS), wich subway lake becomes blue under the incidence of sunlight. Phtotography of J. Sabino

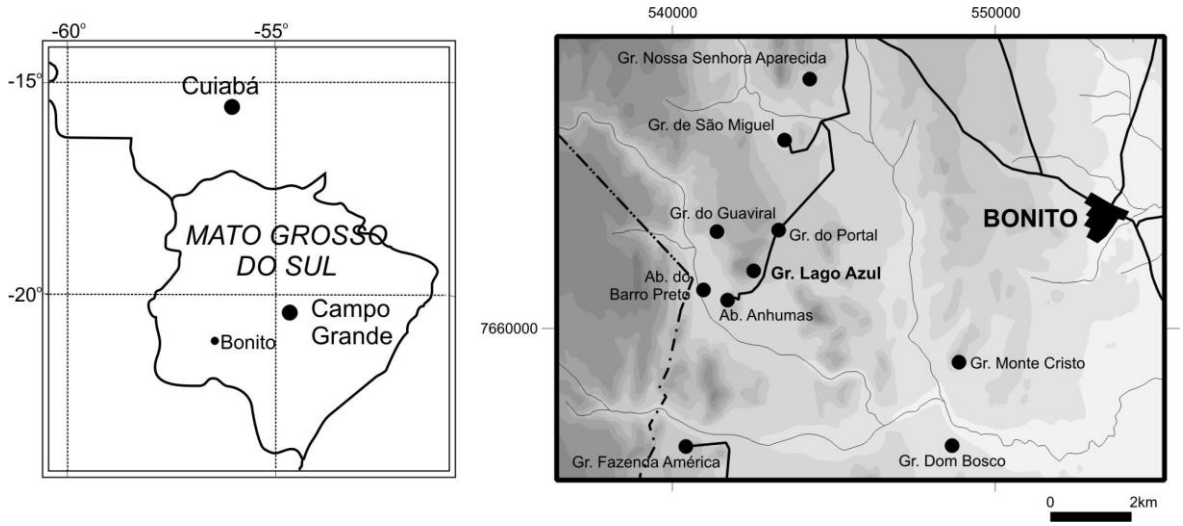

Figure 02 – Location and access of Lago Azul Cave.

HISTORICAL ASPECTS

The Lago Azul and the Nossa Senhora Aparecida caves were frequently visited by the local population in the past, around 1940, given that these locations were easily accessed and situated near the town of Bonito.

There is no factual basis for the information frequently disclosed in the press and by some tourist guides that the cave was originally discovered by a Terena Indian in 1924. Furthermore, there are no written records of such a discovery, which is currently considered to be a legend rather than a proven historical fact.

The first scientific publication of the caves was of the Mendes (1957). In this study, the Lago Azul and Nossa Senhora Aparecida were identified as Fazenda Anhumas and Fazenda Três Irmãos caves,

respectively. Worthy of note is the fact that, at that time, the lake at the bottom of the Lago Azul Cave was considered to be relatively shallow, with a depth of one to two meters, and actually this lake has more than 90 m deeper. The Nossa Sra. Aparecida has no lake.

According to Lino *et al.* (1984), tourist visits were only initiated in 1970, through the efforts of Hélio Loureiro, as municipal secretary, and tourist guide Sérgio Ferreira Gonzáles, more widely known as "Sérgio da Gruta".

Still in 1970, studies with a view to making use of water, as mineral water, of the lake at the botton of the Lago Azul cave were performed by the "Empresa Turística do Mato Grosso - TURIMAT" (State of Mato Grosso Tourism Company) – in that time, the state were not divided yet as two states, the Mato Grosso, the north part, and Mato Grosso do Sul at south part. After the idea of extracting mineral water was abandoned, in 1978, a study performed by Prof. Ronaldo Teixeira of the Universidade Federal de Minas Gerais – UFMG (Federal University of Minas Gerais) resulted in the proposal entitled "Programa para utilização de um turismo científico-cultural na área sudeste do Estado de Mato Grosso" (Program for implementation of scientific-cultural tourism in the southeastern area of the state of Mato Grosso), put forward by members of the Secretaria de Indústria e Comércio de Mato Grosso (State of Mato Grosso Industry and Commerce Department), with the involvement of EMBRATUR (National Tourism Institute).

A request for declareted of the two caves as national heritage sites was made by the Secretary of State, Mr. David Balaniue, this process being approved by the Instituto do Patrimônio Histórico e Artístico Nacional – IPHAN (National Historical and Artistic Heritage Institute) and ratified by the Ministry of Education and Culture on 13/10/1978 (process no 979-T-1978).

In April 1982, the two caves were acquired by the Empresa de Turismo de Mato Grosso do Sul - MSTUR (Mato Grosso do Sul Tourism Company) of the State Government of Mato Grosso do Sul. At that time, there was no definition of ownership of naturally cavities in Brazil, which are currently considered to be Union owned under the brazilian federal constitution. The surface area acquired of the Lago Azul cave was that of 25 hectares and 1,700 m2 (251,700 m2 - part of the former Fazenda Anhumas property) and 10 hectares and 2 m2 for the Nossa Sra. Aparecida cave (100,002 m2 - part of the Fazenda Jaraguá property).

In 1984, a project was doing, coordinated by architect Clayton Ferreira Lino, during which, together with a multi and inter-disciplinary team, topographic surveys were made of the caves and guidelines were put forward for a regional tourism management plan (Caves of Bonito project - Lino *et al.* 1984). Besides characterization and mapping of the caves that had become national heritage sites, the main result of this project was that the zoning type of use of the caves in question and proposing the type of infrastructure to be installed to visit. Based on this proposal, a trail constructed inside the Lago Azul cave, using blocks of limestone joined with cement, with the proposal to facility the movement within the cave, while maintaining a minimal visual impact. During performance of this project, other caves were explored and mapped, including that known as "Abismo Anhumas", situated in the vicinity of the Lago Azul Cave.

The Lago Azul Cave and its potential in terms of natural beauty came to be more widely known due to the "Expedição Franco-Brasileira BONITO/92" (Franco-Brazilian BONITO/92 Expedition) in September 1992, organized by the Grupo Bambuí de Pesquisas Espeleológicas (Bambuí Speleological Research Group). During this expedition, at the bottom of the lake in the Lago Azul cave, mammals Pleistocenic fossils were discovered. The part of the bones corresponding to the giant sleeping and saber-toothed tigers, probably represented by genus *Eremotherium* and *Smilodon*, identified by Prof. Castor Cartelle using subaquatic images.

Figure 3 – View from the floor of the subterranean lake of Lago Azul cave whith pleistocenic mammals fossils (photography by Ismael Escote).

Two tourist guide training courses were held by the Universidade Federal de Mato Grosso do Sul (UFMS) and the Serviço de Apoio às Micro e Pequenas Empresas no Mato Grosso do Sul - SEBRAE (Mato Grosso do Sul - Micro and Small Business Support Service) in 1993 and 1994. From this time onwards, visits to the Lago Azul cave came to be made only with the accompaniment of a qualified tourist guide (Boggiani 2001). Ever since this period, it is possible to note the dedication and appreciation that these guides give in their activities inside the cave, where they provide explanations ranging from the geological formation of the Serra da Bodoquena to aspects regarding the formation of the

cave, as well as the cultural characteristics of the region.

On June 11th 2001, the "Monumento Natural Gruta do Lago Azul" (Blue Lake Cave Nature Monument) was created by the State Government of Mato Grosso do Sul, through Decrete no. 10.394, in a form of two non-continuous areas totaling 260 hectares (2,600,000 m2) . The environmental license for tourism activities in the cave, only to the Lago Azul Cave, was approved in 2008 May by an Environmental Impact Study/Report, submitted to IBAMA in February 2002.

GEOLOGY AND GEOMORPHOLOGY OF THE SERRA DA BODOQUENA

The Lago Azul Cave occurs in the geological and geomorphological setting of the "Serra da Bodoquena" (Bodoquena ridge) (Almeida, 1965), which constitutes a localized highland feature located in the central-southern portion of Mato Grosso do Sul State, at the boundary of the region known as Pantanal do Nabileque, where the towns of Bonito and Bodoquena and part of the municipalities of Jardim, Guia Lopes, Porto Murtinho and Miranda are located. This highland feature essentially comprises Neoproterozoic carbonate rocks of the Corumbá Group (Almeida, 1965; Boggiani *et al.*, 1993) and is elongated in format, oriented in a north-south direction, with a length of 200 km and a width varying between 10 and 70 km.

The Corumbá Group lies within the geotectonic unit identified as the Paraguay Fold Belt, related to the Pan-African/Brazilian orogenetic event, which extends for a distance of 1,500 km, beginning in the southwest of the state of Goiás, passing through Mato Grosso State and terminating in the state of *Mato Grosso do Sul*, thus forming a large arc, with convexity towards the craton (Almeida, 1984). It is situated in an intermediary position, covering the Puga Formation (glacial), in the meridional portion of the belt, and is correlated with the Araras Group to the north, although with paleoenvironmental settings and distinct stratigraphic patterns (Boggiani and Alvarenga, 2004). The Corumbá Group (Almeida 1965, Boggiani *et al.*, 1993), with outcrops in the Urucum Massif and the Serra da Bodoquena, is represented by a succession (with a thickness of approximately 1,000 m) of conglomerates, sandstones and basal pelites (Cadiueus and Cerradinho Formations), under dolomites, silexites and phosphatic rocks (Bocaina Formation) and limestones rocks and fossiliferous graphitous pelites (Tamengo Formation), covered by a thick pellitic package at the top (Guaicurus Formation).

It is possible to identify two main geomorphological compartments that can be fully characterized as the Serra da Bodoquena area. The first is the Bodoquena Plateau (Alvarenga *et al.*, 1982) or the actual Serra da Bodoquena (Almeida, 1965), in the form of a high calcareous massif, and the second is the Rio Miranda lowlands (Alvarenga *et al.*, 1982), a region of lower topographic elevation, lying to the east. The Bodoquena Plateau consists of a plateau that slopes to the east, with a 200-meter escarpment at its western border, facing towards the Pantanal region. In this rocky massif, calcareous rocks outcrop at the surface and, in those portions covered with soil, a dense forest has developed that is still preserved, due to difficulty of access, which has made the creation of the "Parque Nacional da Serra da Bodoquena" (Bodoquena Highlands National Park). The Rio Miranda Lowlands (Alvarenga *et al.*, 1982), which includes the "*Zona Serrana Oriental*" (Eastern Highland Zone) (Almeida, 1965), constitutes a vast lowland area (elevation of 100-350 m), bordered to the east by the Maracaju-Campo Grande Plateau, which can be seen when traveling to Bonito, between the towns of Sidrolândia and Nioaque.

In both the Bodoquena Plateau and the Rio Miranda River Lowlands, the landscape is influenced by the presence of Corumbá Group carbonate rocks, which give rise to karstic surface relief with innumerous caves, dolines and other typical features. In this setting, the Lago Azul cave is situated in the Rio Miranda Lowlands in dolomites of the Corumbá Group (Bocaina Formation). According to the classification of Sallun Filho and Karmann (2007), the Lago Azul Cave is situated in the domain represented by karstic plains with residual hills.

The headwaters of rivers that drain the plateau in the direction of lower areas are to be found in karstic springs, with rivers of clear bicarbonate waters that give rise to the abundant growth of fluvial carbonate deposits known as calcareous tufas (Boggiani and Coimbra, 1995). These rivers and calcareous tufas have great scenic value, although the latter are very fragile, being directly dependant upon water quality and are an important touristic attraction.

Besides their landscape value, the tufas are important too for paleontological and paleoenvironmental studies and, for this reason, the "Tufas Calcárias da Serra da Bodoquena" (*Bodoquena* Highland Calcareous Tufas) have been included in the "Lista Mundial Indicativa de Sítios Geológicos e Paleobiológicos" (Global Indicative List of Geological and Paleobiological Sites) in order to compete in the process of being awarded World Heritage status by UNESCO (Boggiani *et al.* 2001).

Besides the rivers and tufas, the innumerous features of the karstic landscape, together with portions of forest that are still preserved, place the Serra da Bodoquena in a landscape setting of exceptional beauty, which has recently subject for innumerous tourism activities. As an example, the Bonito region has around thirty caves (Lino *et al.*,

1984; Gnaspini Netto *et al.*, 1994; Sallun Filho, 2005), with around 150 in the Serra da Bodoquena

Caves found within the karstic plain domain occur in residual hills as chambers of large dimensions. In this domain, submerged underground cavities with lakes are a common occurrence, and those that have underground conduits and rivers are rarely found. The depth of underground cavities, in the order of dozens of meters, is a particular characteristic of the region. During the first expedition, organized by the "Grupo Bambuí de Pesquisas Espeleológicas" (Bambuí Speleological Survey Group) in 1992, the lake at the bottom of the Lago Azul Cave was found to have a depth of 55 meters. After that, the depth was measured at 90 meters (Navarro Júnior, 2002). Other underground cavities showed depths of more than 60 meters, as in the case of that known as "Abismo Anhumas" (Anhumas Abyss). To the south of Bonito lies the lake known as "Lagoa Misteriosa" (Misterious Lake), which originated in a dissolution doline with a depth of 220 meters. Such characteristics have attracted the attention of Brazilian and foreign divers, which has resulted in the region being classified as one of the best in the world for cave-diving activities.

THE LAGO AZUL CAVE DESCRIPTION

The Lago Azul Cave is composed of a large main chamber, extending 224 meters in a NW-SE direction and 184 meters in a NE-SW direction, with a difference in level of 150 meters (Fig. 4), most of which is submerged (around 65%). The cave has been developed in dolomites (CaO content of 29.7% and MgO content of 20.2%) of Bocaina Formation (Corumbá Group) which are light gray in color, rich in quartz veins and show an average angle of dip of layers of 24º to the southeast. At first sight, the intense degree of fracturing with quartz veins may be mistaken for layering of the rock, however, both are practically orthogonal (Almeida, 1965).

At the entrance of the cave, there is the "Salão do Lago" (Lake Chamber) with a length of 143 meters and a difference in level of 50 meters. The Lake Chamber has a floor rich in speleothems, mainly on the northwestern side, where the current tourist trail is located, besides innumerous blocks and speleothems that have fallen from the roof, which is inclined, accompanying the slope of the floor, with heights ranging from 20 to 25 meters, and sparse characteristic stalactites. The lake, with a depth of more than ninety meters (Navarro Junior, 2002), is to be found at the end of this chamber. The Lake Chamber has a circular entrance, with a diameter of approximately forty meters, which allows rays of sunlight to reach the lake.

The lake water is totally colorless and the blue color that it acquires is an optical phenomenon known as Rayleigh Dispersion. White light is the sum of several colors, however, the color blue is that disperses to the greatest extent on passing through particulates in suspension in the water, due to its shortest wavelength, in the same way that the sky is blue during the day.

Seasonal variation in the level of the lake is that of around 3 meters (Sallun Filho, 2005), which has resulted in the floor blocks being covered by calcium carbonate at its edge. On a stalagmite with a height of around 12 meters and a diameter of 4 meters, it is possible to observe dissolution grooves at a height of 6 meters above the current average level of the lake. This indicates a water level that was higher in the past than it is at present, after the predominant formation of stalagmites.

At the bottom of the cave, near the water level of the lake, there is a small condute known as the "Salão do Quartinho" (Little Room Chamber), with a length of 10 meters, accompanying existing fracturing. Its walls and speleothems are covered with a millimetric calcitic crust and, on the floor, there is a 5 to 10-cm layer of loose calcite crystals in the form of plates of sub-millimetric thickness, brought about by the accumulation of millimetric calcite rafts, both of which formed when the level of the lake was higher.

A lateral chamber, named as "Salão Superior" (Upper Room) is accessed at the furthest western extremity of the cave, where visits are only permitted following prior authorization. This chamber divides and there is a slope that accompanies the ceiling in an abrupt descent to the next level of the lake, where the chamber known as "Salão dos Corais" (Corals Room) is found, with a large number of beautiful speleothems that remind one of mushrooms or corals, formed by the mineral nesquehonite. The "Salão Superior" chamber, from which the whole Salão do Lago chamber can be seen, is highly ornamented by stalactites, stalagmites and columns covered by speleothems of the "cauliflower" type.

In the lake occurs a troglobite species of the Spelaeogriphacea Order (Pires 1987, Moracchioli 2002), represented by millimetric, blind and unpigmented crustaceans that inhabit the illuminated portion of the lake.

The Lago Azul Cave stands out within the biospeleology to be a type-locality of *Potiicoara brasiliensis*, described by Pires (1987) and amphipods *Megagidiella azul*, described by Koenemann and Holsinger (1999), the order Spelaeogriphacea, which is highlighted worldwide to be a exclusively group of underground freshwater crustaceans, blind and despigmentados, which covers the distribution Brazil, South Africa and Australia (Moracchioli, 2002).

GENESIS OF THE LAGO AZUL CAVE

A theory formulated for the origin of the Lago Azul cave has been proposed by Kohler *et al.* (1998),

based on the similarity between inclined conduit profiles at the Lago Azul cave and the cave known as "Nascente do Rio Formoso" (Formoso River Spring). According to this model, these chambers were probably former springs active at a time when the eastern escarpment, situated between the Serra da Bodoquena and the Rio Miranda River Lowlands, was likely situated further to the east, prior to its progressive retreat to the west. According to these authors, evolution of the Serra da Bodoquena karst came about in two different ways, where drainage that surfaces at the base of the plateau has dissected the landscape, with progressive lowering of surface relief, and the opening up of karstic plains, leaving residual hills where the Lago Azul Nossa Sra. Aparecida and São Miguel caves are to be found, besides others that comprise this system (Fig. 4). In this process, the largest caves likely formed through turbulent flows with resurgences, when the escarpment was situated further to the east than its current position. With the retreat of the escarpment to the west, the caves were left isolated in calcareous hills and became dry through continuous lowering of the water level, and terrain collapses occurred concurrently with the formation of subaerial speleothems, as in the Nossa Senhora Aparecida Cave.

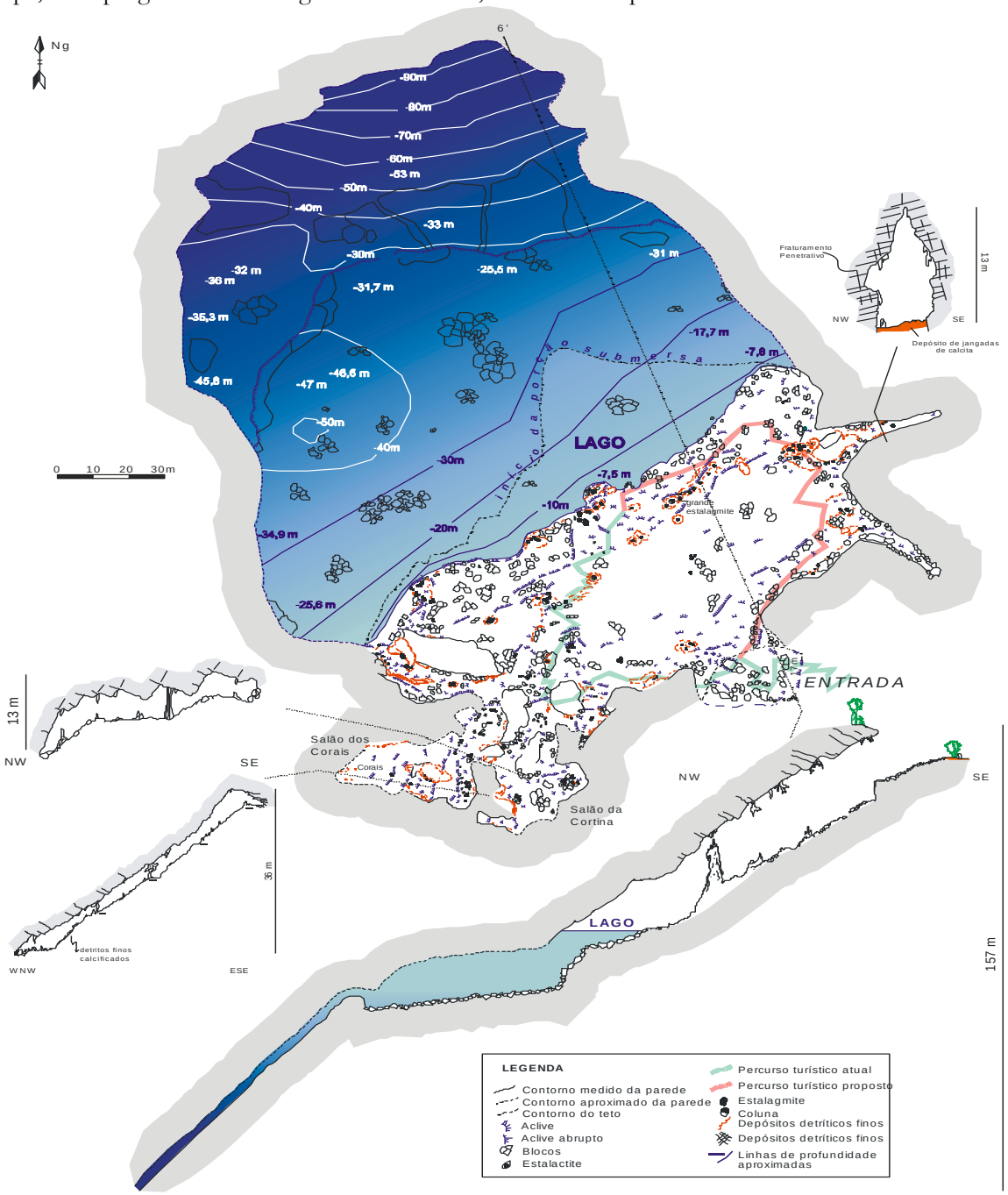

Figure 4 – Map and seccions of the Lago Azul Cave compiled by Sallun Filho (2005) from: 1) Dry part of the cave is from Lino *et al.* (1984), topography by Ivo Karmann e Paulo Cesar Boggiani; 2) Submerged part is from Marcos Augusto Philadelphi (unpublished work), Topography by Ismael Escote; Fernando Martins; Jaime Navarro Jr.; Marcos Augusto Philadelphi; Nicoletta Moracchiolli; Ricardo Meurrer.

Sallun Filho (2005) considers that, in the Lago Azul, Nossa Senhora Aparecida, São Miguel and Fazenda América caves, evidence is preserved of the original conduites, rising upwards in the form of fissures, developed at the bedding/fracture intersection. These caves, such as the Lago Azul cave, represent former ascending conduits of slow-flowing deep circulation water that were part of deep conduit systems and are currently only found as relict features in residual hills. These ascending conduits are present at such active springs as the source of the Formoso river and that known as Ceita-Corê. However, no evidence can be seen that the fissures occurring in relict chambers were springs, as proposed by Kohler *et al.* (1998). At the present time, existing springs principally occur in calcareous rocks of the Tamengo Formation, at the base of the eastern escarpment of the highlands and the chambers are to be found in the dolomites of the Bocaina Formation. An example is the "Nascente do Rio Formoso" (Formoso River Spring), which develops in an E-W and NE-SW direction, always west to east, and exhibits an anastomose pattern that is not encountered in any cave in the dolomites. On the other hand, the relict chambers show various directions, although they demonstrate an overall N20E alignment, which seems to be related to regional fracturing. Alignment in a N20E direction might represent former ascending conduit systems directed by an impermeable barrier, like a layer of phyllites intercalated in the carbonate rocks.

In the work of Kohler *et al.* (1998), it is considered that the Lago Azul aquifer has no current connection with nearby caves, not even that known as Abismo Anhuma at around 1,200 meters, due to hydrochemical differences between the two waters. This supposition needs to be revised under the light of the discovery of crustaceans that were formerly considered to be endemic in the two caves, besides others. In addition, measurements of variation in the current water level show that a correlation exists between variation in the lakes present in the Lago Azul cave and Anhumas sinkhole, suggesting the existence of an inaccessible connection in the phreatic environment (Sallun Filho, 2005). It is interpreted that the Lago Azul cave originated at the beddin/fracture intersection, with subsequent development and enlargement of the cave in a phreatic environment. After this phase, there was lowering of the water level with deposition of subaerial speleothems and terrain collapses, followed by a new, more recent, phase involving a rise in water level in the Quaternary Period, with the lake taking on the format that is observed at the present time.

SYNOPSIS ON THE ORIGIN AND GEOLOGICAL EVOLUTION OF THE LAGO AZUL CAVE

The geological record of the Lago Azul cave can be divided into two distinct stages; the first relative to the origin and evolution of the rocks found where the cave has formed, and the second regarding the history of the cave and the local landscape.

The Lago Azul cave has developed in dolomites of the Bocaina Formation (Corumbá Group), rocks that have the characteristic property of being soluble when exposed to the action of acidic waters, thus giving rise to the development of the regional karstic landscape.

Corumbá Group carbonate rocks originally formed during the Neoproterozoic Era, around 580 million years ago, following a period when the planet was subject to glaciation processes that were supposedly of great intensity, it being possible that the Earth was totally covered with ice (Snowball Earth Hypothesis - Hoffann and Shrag, 2002). Evidence of such glaciation is to be found in the region in the form of Puga Formation conglomerates. Following the glaciation period, an ocean formed through the separation of continental landmasses, which were formerly joined in the form of a supercontinent known as Rodinia. This ocean was only home to primitive forms of life, most of which were microbial, which gave rise to the intense carbonate sedimentation of the Corumbá Group. At the end of the carbonate sedimentation period, prior to the Precambrian-Phanerozoic transition, the first forms of animal life likely arose in the form of *Cloudina* and *Corumbella* fossils (Hahn *et al.,* 1982; Zaine and Fairchild, 1985), encountered in Corumbá (Mato Grosso do Sul State). Around 520 to 530 million years ago, the continental landmasses that had previously separated started to join again and, as a result, the sediments deposited previously underwent intense folding and that which was formerly an ocean became transformed into a high mountain range (Paraguay Fold Belt). Formation of this mountain range placed the carbonate rocks in a continental setting and exposed to the erosion and weathering processes that have been molding the karstic landscape up to the present time.

In the second chapter of the geological history of the region, related to the shaping of current surface relief and evolution of the flora and fauna and, in a general manner, the current landscape that characterizes the area. Such processes were initiated around 60 million years ago, during the Cenozoic Era, when the formation also began of the Lago Azul cave, as well as other caves in the region, which yet continue in process of formation.

On observing the Lago Azul cave, it is possible to distinguish two important phases in the formation of a cave. The first involves the initial opening up of the cave, brought about by the dissolution of calcareous rocks and dolomites below the water level. When the water level (water table) drops, the chambers are exposed and the collapse of blocks of rock may occur, which explains the large number of blocks of rock found on the floor of caves.

Once the chamber is dry, without the presence of any bodies of water, the second phase in the development of a cave begins, with the formation of stalactites and stalagmites and innumerous other types of carbonate deposits, collectively known as speleothems. These speleothems grow very slowly (in the order of one millimeter per year) and register the climatic variations to which the region has been exposed. It is for this reason, as well as the fact that they form beautiful shapes, that speleothems are protected by law and their degradation or unauthorized collection is considered to be a crime.

Climate change in the Quaternary, during glacial and inter-glacial periods, led to water level variations over the last few thousand years, with both higher and lower levels. Besides this, during certain periods of time, the dominance of grass species made the landscape similar to that found in the African savannah, with open grasslands that were inhabited by such large mammals as giant sloths and armadillos, mastodons and saber-toothed tigers, the fossilized remains of which are to be found preserved in the lake of the cave (Fig. 4) and others in the region. During more humid recent periods, the current vegetation became established and the formation began of waterfalls and natural lakes of calcareous tufas in drainage channels, probably between 4 and 5 thousand years ago, from which time the forms of landscape features gradually came to resemble those existing at present, in a process that occurred at a velocity that allowed for harmony with existing environmental dynamics. Such harmony is currently being drastically impacted by accelerated human occupation of the region, although it is hoped that there is still sufficient time for its recovery. If not, future visitors will only have the limited area of the Parque da Serra da Bodoquena (Bodoquena Highlands Park) in order to have an idea of the former nature of the region and, in an even more isolated manner, the caves of the "Monumento Natural da Gruta do Lago Azul" (Blue Lake Cave Natural Monument) (Fig. 5).

CONSERVATION ACTIONS

The Lago Azul and Nossa Senhora Aparecida caves has been declared a national heritage site and, therefore, is also under the protection of the "Instituto do Patrimônio Histórico e Artístico Nacional - IPHAN" (National Historical and Artistic Heritage Institute), as well under IBAMA protection, responsible for the conservation of caves in Brazil. During the process of developing the Lago Azul cave and Nossa Sra. Aparecida cave "Plano de Manejo Eespelelógico" (Speleological Management Plan), the Monumento Natural da Gruta do Lago Azul was created, covering the surface area where the caves are found., but the unit has not yet been demarcated and only part of the surface is under public domain. Currently, the visitation of the cave is administered by the Bonito Town Hall and monitoring of tourism guide, which has enabled its preservation.

Actual actions

Only the Lago Azul Cave receives visitors and the actual tour route in the cave was built in 1984 already with guidance to cause minimal cave environmental impact. At the time of its installation, there was discussion about the rudimentary aspect of the way, with the goal of not causing negative impact on the cave landscape. There was also a proposal to build metallic stairs inside the cave, but that project was abandoned.

The current tourist activity does not cause negative impact to the cave and Environmental Impact Study/Report (EIA) and "Plano de Manejo Eespelelógico" (Speleological Management Plan) was made and submitted for analysis by IBAMA in February 2002 for request licensing of tourist activity with proposal for future expansion, including the visitation in Nossa Senhora Aparecida Cave.

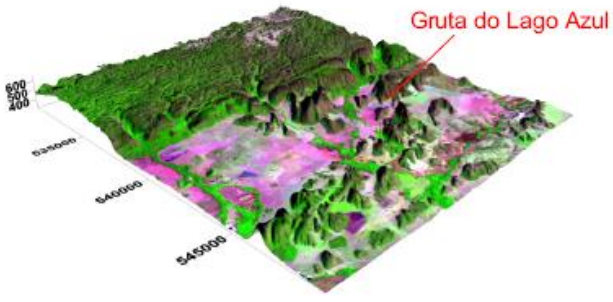

Figure 05 – East part of Serra da Bodoquena, where the Lago Azul cave is located in the isolated hill over the plain. Note the deforestation of the plain area and the preservation of the forest only in the limestone massif at west, in the Parque Nacional da Serra da Bodoquena..

Today is charged an entry fee of R$ 25.00 per person, by Bonito Town Hall, also responsible for protection and conservation of the area.

Among the main caves with tourism potential in the region, only the Lago Azul cave and the Nossa Sra. Aparecida cave that are to be found on public property, and are the only ones considered as heritage sites by federal legislation. The remaining caves are

encountered on private property and those known as São Miguel Cave and Anhumas Abyss have come to be used as private tourism ventures, despite the fact that they are located in the vicinity of heritage site caves and neighbor the conservation unit that has been created.

Proposed actions

In the Environmental Impact Study/Report (EIA) submitted for analysis by IBAMA, a proposal was made for a new trail for visitors in the Lago Azul cave and a suited infrastructure to visitors in the outside, including the building of a museum.

The new trail for visitors in the Lago Azul Cave aims to prevent congestion of the group of visitors who currently use the same route to enter and return to the entrance of the cave. In these studies, a proposal was made for a new trail for visitors in the Lago Azul Cave, in the form of a closed circuit, with visits made in an anti-clockwise direction, beggining on the right corner of the cave (northeast), until near the lake from where he will return to the entrance by the former path. Thus, visitors will have the possibility of expanded contemplation, and the problems from using the same route to enter and exit the room will be prevented.

In the mentioned study, there are still improvements of the trail, with maintenance of the use of the limestone blocks in order to maintain the most natural possible inside the cave. These improvements are to make the steps more regular, especially in relation to steps height, making the transposition easier.

Have been proposed as outside infrastructure, building a visitor center for support the way to the Lago Azul Cave, to replace the existing structure. This visitor center would be linked to a larger, whose construction was proposed to already deforested area near the Nossa Senhora Aparecida Cave. In these major center, is proposed the construction of a museum to display replicas of fossils of Pleistocene mammals and other information regarding the caves and the region.

It is currently being suggested that a Geopark be created for the whole region, along the lines recently proposed by UNESCO, by the IPHAN in which the caves of Nature Monument would be a geotope and the museum could be a support and management center of the Geopark.

Implementation problems

Despite the creation of the Monumento Natural da Gruta do Lago Azul, the state conservation unit has not yet been implemented, or at least demarcated. The implementation of outside infrastructure (visitors center, museum and restrooms) is subject to final review of the Environmental Impact Study/Report by IBAMA, submitted for analysis in February 2002, which has already received requests for complementation with its latest version submitted in May 2007 and approved in 2008.

The conservation unit is a state property, but who manages the visitation of the cave is the Bonito Town Hall.

Recomendations

There is the urgent need for implementation of the state conservation unit, which depends on understanding between the municipal and state governments and federal agencies IPHAN and IBAMA, related to the administration of the unit. Solved this problem, the unit should be demarcated and the inside and outside infrastructure, proposed by the management plans, made after review by IBAMA.

It is of great importance the museum implementation because in the region lack an appropriate place for that visitors understand the evolution of the cultural landscape of the cave and Serra da Bodoquena region.

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[1] Departamento de Geologia Sedimentar e Ambienal _ Instituto de Geociências – USP – Rua do Lago, 562, 05508-900 São Paulo – SP, boggiani@usp.br

[2] ikarmann@usp.br

[3] Instituto Geológico, Secretaria de Meio Ambiente do Estado de São Paulo – Avenida Miguel Stefano 3900, 04301-903 São Paulo – SP, wsallun@igeologico.sp.gov.br

[4] DNPM – Departamento Nacional da Produção Mineral– São Paulo – Rua Loefgren 2225, 04040-033 – São Paulo – SP, ana.gesicki@dnpm.gov.br

[5] Neotrópica, mphiladelphi@uol.com.br

AUTHOR'S SYNOPTIC *CURRÍCULUM*

Paulo César Boggiani - Geologist with Masther and Phd (Instituto de Geociências – Universidade de São Paulo), professor of Instituto de Geociências –USP since 2002.

William Sallun Filho - Geologist with Master degree and Phd in Geosceinces on the Geosciences Instituto of São Paulo Univesity. His research areas are the precambrian paleobiology and karst terrains studies. Work since 2005 in Geological Institute of Environmental Secretariat of São Paulo State.

Ivo Karmann
Geologist with Masther and Phd (Instituto de Geociências – Universidade de São Paulo), professor of Instituto de Geociências –USP with research in karst geology.

Ana Lúcia Desenzi Gesicki
Geologist with Masther and Phd (Instituto de Geociências – Universidade de São Paulo), especialista in mineral resource of Departamento Nacional de Pesquisa Mineral (São Paulo) since 2006.

Nicoletta Moracchioli
Biologist with Master degree and Phd in Zoology on São Paulo Univesity, with research areas in Ecology, of underground populations. Professor of Universidade Federal do Ceará from 2004 to 2007.

Marcos Philadelphi
Geologist in São Paulo Univesity, working with cave diving e educational activities in Geosciences.