

THE COMPLEX HISTORY OF A SANDSTONE-HOSTED CAVE IN THE STATE OF SANTA CATARINA, BRAZIL

LA COMPLEJA HISTORIA DE UNA CUEVA ALOJADA EN PIEDRA ARENISCA EN EL ESTADO DE SANTA CATARINA, BRASIL

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Abstract

The cave known as "Toca do Tatu" ("armadillo shelter") (28°46'21.2"S, 49°53'45.9"W) is located in the municipality of Timbé do Sul, in the state of Santa Catarina (Brazil) and is 48.5 m long, with two almost parallel tunnels that converge to a larger space within the cave. The general morphology of the cave and locally abundant claw scratches on the walls show that the cave was created as a shelter probably dug by ground sloths during the Cenozoic. In the euphotic and disphotic zones of both tunnels more than 35 m² of the walls are covered by rock art with over 5 different geometries, showing that the cave was reoccupied later by pre-Columbian populations. Witnesses report that treasure hunters opened the cave entrance by removing the predominantly sandy sediments accumulated in the front of the cave, which almost completely blocked its entrances. These treasure hunters left tool traces on the cave walls and widened another access to the deeper spaces of the cave. Finally, tourists who visited the site over the past decades have left signs such as names, dates and symbols on the walls, ending the cycle of agents that created this cave and left their traces in it.

Palavras-Chave: Speleology; Cave; Vertebrate burrow; Ground sloths; Petroglyphs.

Resumen

La cueva conocida como "Toca do Tatú" (Cueva del Tatú) (28°46'21.2" S, 49°53'45.9" W), ubicada en el municipio de Timbé do Sul, estado de Santa Catarina, Brasil, presenta un desarrollo lineal de 48.5 metros y consta de dos túneles casi paralelos que convergen a un espacio más grande dentro de la cueva. La morfología general de la cueva y las marcas de garras localmente abundantes en las paredes muestran que la cueva tuvo su origen como una madriguera excavada probablemente por perezosos terrestres durante el Cenozoico. En las zonas eufóticas y disfóticas de los dos túneles hay más de 35 m² cubiertos por petroglifos de más de 5 geometrías diferentes, lo que demuestra la reocupación de la cueva por pueblos precolombinos. Testigos aseguran que la entrada de la cueva fue abierta por cazadores de tesoros mediante la eliminación de los sedimentos predominantemente arenosos acumulados delante de la cueva y que casi bloqueó completamente sus entradas. Estos cazadores de tesoros han dejado marcas de herramientas en las paredes de la cueva y ampliaron otro acceso en la parte posterior de la misma. Por último, los turistas que visitaron el sitio durante los últimos decenios han dejado gráficos, tales como nombres, fechas y símbolos en las paredes, encerrando el ciclo de los agentes que crearon esta cueva y dejaron sus marcas.

Palabras-Clave: Espeleología; Cueva; Paleocueva; Perezosos terrestres; Petroglifos.

1. INTRODUCTION

The hundreds of caves that can be found in southern Brazil, in the region of the states of Rio Grande do Sul (RS) and Santa Catarina (SC), have the most varying but usually inorganic origins, commonly related to geological factors acting on a very complex regional context (DNPM, 1986; HOLZ; DE ROS, 2000). Carbonate sedimentary rocks and the associated caves formed through the dissolution of the rocks by rainwater, occur only in the region ranging from the northeast to the north of Santa Catarina (e.g., Caverna de Botuverá) (AULER; FARRANT, 1996). In the state of Rio Grande do Sul, all the rocks known popularly as limestones are actually marbles (BORTOLOTO, 1987), in which there are no known caves. Cavities located behind waterfalls are very common in the South of Brazil. Such spaces usually are very scenic and have been transformed into tourist attractions (e.g. Grutão dos Índios, Caxias do Sul, RS). In regions with outcropping granitic rocks, cavities between big boulders are very common (e.g., Abrigo do Tigre, Viamão, RS). At the foot of cliffs, the irregular stacking of large fallen blocks also form cavities (e.g. Caverna do Ferrabraz, Sapiranga, RS), and many caves are formed when vertical fractures and faults open on the sides of the mountains (e.g., Toca dos Corvos, Cruzeiro do Sul, RS). Along the Atlantic coast, the action of the waves against rocky cliffs in the state of Santa Catarina forms marine caves (e.g., Caverna do Pântano do Sul, Florianópolis, SC). Very rare are caves located in basaltic lava flows, whose genesis can be traced to volcanic processes of the Lower Cretaceous (e.g., Caverna de Formosa, Santa Cruz do Sul, RS). Caves of anthropogenic origin, as those found in Europe (e.g., WIMMER, 2000) and Turkey (e.g., KOSTOF, 1989), are virtually absent.

Popular thinking has attributed the presence of pre-Columbian people to many of these caves over time. However, the confirmation of such occupation depends on the finding of archaeological sites at these places, such as workshop sites, burial sites, rock art sites and others (e.g., BLEYER, 1922, PROUS, 1992), which is rather rare. In the vast majority of the caves, there are no archaeological remains of pre-Columbian people. European settlers, on the other hand, marked their presence in many caves through artwork on the walls, especially names, dates and symbols, an ingrained practice that is nowadays discouraged through more conscious forms of tourism such as ecotourism and geotourism (NASCIMENTO et al., 2007).

In this contribution we feature a large cave that arose through biogenic action, and which was

later reoccupied by Indians and still later by post-Columbian settlers with varied interests. Since the cave shows a low degree of impact by inorganic factors, each one of the steps related to the genesis and uses of the cave remain documented on its walls. This makes it possible to portray in detail, for the first time in Brazilian speleological literature, a cave of this origin and with this evolution.

2. STUDY AREA

The prospecting efforts that resulted in the identification of the cave were developed in a study area that covers the states of RS and SC in the south of Brazil. Geologically, the region is composed of 3 domains: the Basement, the Paraná Basin and the Marginal Basins of Pelotas and Santos (Fig. 1).

The Basement, a complex assembly of sedimentary, metamorphic and igneous (plutonic and volcanic) rocks with up to 2.0 b.y (HOLZ; DE ROS, 2000), covers the center of RS and, in SC, a narrow strip along the coast of the Atlantic Ocean going north.

The Paraná Basin (Upper Ordovician – Cretaceous) is an intracratonic basin with an area of more than 1.10^6 km² (MILANI et al., 1998, ZALÁN et al., 1990). It is located west of the outcropping basement and filled with a lower sequence of sedimentary rocks and an upper sequence of volcanic rocks. The sedimentary rocks have been grouped into a single unit in the geological map of Fig. 1. The youngest sedimentary formation, located immediately below the volcanic sequence, is formed by the Late Jurassic – Early Cretaceous aeolian continental sandstones of the Botucatu Formation (SCHERER, 2000). This medium- to coarse-grained reddish rock with large scale aeolian cross-bedding is the relict of a >1.5 million km² arid continental area that extended beyond the limits of the basin. The volcanic rocks constitute the Lower Cretaceous Serra Geral Formation (Paraná-Etendeka Continental Flood Basalt Province) (PEATE, 1997). Usually these rocks form a pile of more or less horizontal tabular bodies (the former lava flows) whose thickness is highly variable, but which is most often of less than ~40 m. In the northeast of RS and the southeast of SC, these rocks form a plateau, whose eastern escarpment exhibits a series of more than 70 canyons with lengths of up to several km and heights of up to 1 km.

The marginal basins Pelotas (in the south) and Santos (in the north) are located east of the basement. Their subaerial parts constitute the coastal plains both of the states of RS and SC. The plains are formed mainly of unconsolidated sands and

clays, some conglomeratic sediments in alluvial fans and minor peat deposits in lakes and swamps (VILLWOCK et al., 1986). The basins extends deep into the ocean, forming the continental platform and its associated deep-seated sedimentary deposits.

The cave was found in the sandstones of the Botucatu Fm., in the lower part of one of the canyons of the escarpment of the Serra Geral Fm., in the municipality of Timbé do Sul, SC (28°46'21.2''S, 49°53'45.9''W) (Fig. 1). Many of the canyons located along this escarpment show outcropping sandstones in the lower part and volcanic rocks in the upper part.

3. DIMENSIONS AND SECTIONS OF THE CAVE

The cave is located on a steep hillside facing SW, approximately 100 m from the left bank of the river that flows at the bottom of the canyon, at an altitude between 20 and 30 m above the river. Its outline is that of an “U”, with two almost parallel tunnels that converge to a larger space inside the cave (Figs. 2 e 3). In this contribution, the tunnels will be called “North Tunnel” (Fig. 3-B) and “South Tunnel” (Fig. 3-C). The tunnels are separated by less than 3 m of rock (Fig. 3-A). The larger space inside the cave will be called “Hall” (Fig. 3-D).

The North Tunnel is practically straight and presents an initial width of almost 4 m, which decreases to 2.6 m when reaching the Hall (Tab. 1). Its height is nearly constant at 2.0 m. The tunnel section is a well defined ellipse (Figs. 2, 3-B) with a nearly constant form.

The South Tunnel, on the other hand, presents 3 distinct segments that form a gentle arc facing north. From the entrance to the Hall, these 3 segments become successively smaller (Figs. 2, 3-C). The 1st segment has widths and heights of more than 2.0 and 1.5 m, respectively. The 2nd segment has widths of less than approximately 2.0 m and heights of around 1.5 m. The 3rd segment is the smallest one, with widths and heights of less than 1.5 m. The 3 segments are well compartmentalized, with a narrower area separating them. While the first 2 segments have an ellipsoidal shape, with the major axis aligned parallel to the axis of the tunnel, the 3rd segment is elongated, with characteristics of a tunnel or conduit. The sections of the segments perpendicular to the tunnel axis tend to be spherical (Fig. 2) and show continuity.

The Hall has very irregular lateral walls and roof. Its height varies between 1.48 and 2.86 m, possibly with some higher points that were not detected during the survey. The lateral walls have some concave portions (usually in the lower areas) and other more irregular portions (Fig. 3-F). On the farthest point from the entrances, there is a small ($\varnothing < 1,5$ m) tunnel (Figs. 3-F, 3-G) which gives access to the surface behind the cave.

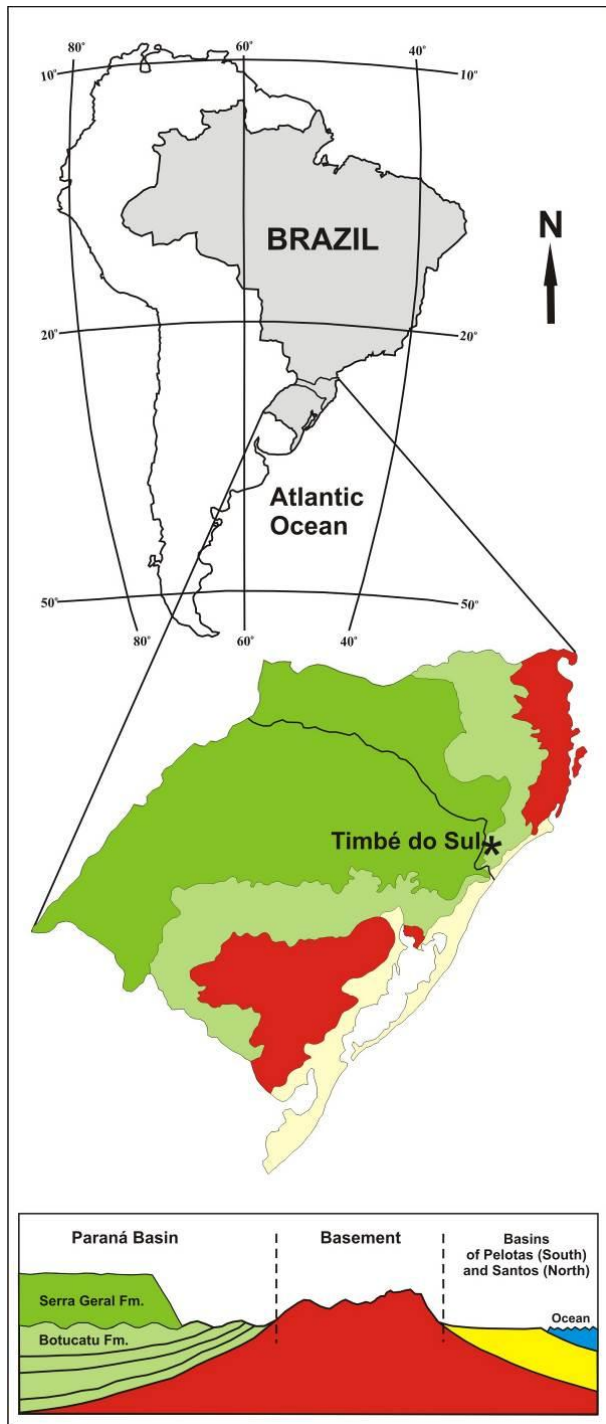


Fig. 1: Top: Location map of the study area in Brazil. **Middle:** Simplified geological outline of the states of Rio Grande do Sul (lower) and Santa Catarina (upper) with the town of Timbé do Sul. **Bottom:** Schematic geological NW-SE section without scale. Basement: red. Paraná basin: green (darker green: Serra Geral Fm.; lighter green: sedimentary sequence). Marginal basins: yellow. Atlantic Ocean: blue.

4. INTERNAL SURFACE MORPHOLOGY

The walls of the cave are the testimony to the processes that gave rise to the cave and those that subsequently changed its morphology and the appearance of the cave walls. It is a complex set of features whose description will be divided into (i) wall morphology and (ii) surface structures found on the walls. The morphology refers to the overall look of the walls, while the description of the surface

structures details the features printed on the walls.

4.1. Wall Morphology

Where the morphology is concerned, the walls of the cave can be classified into three distinct types: smooth, uneven smooth and uneven rough.

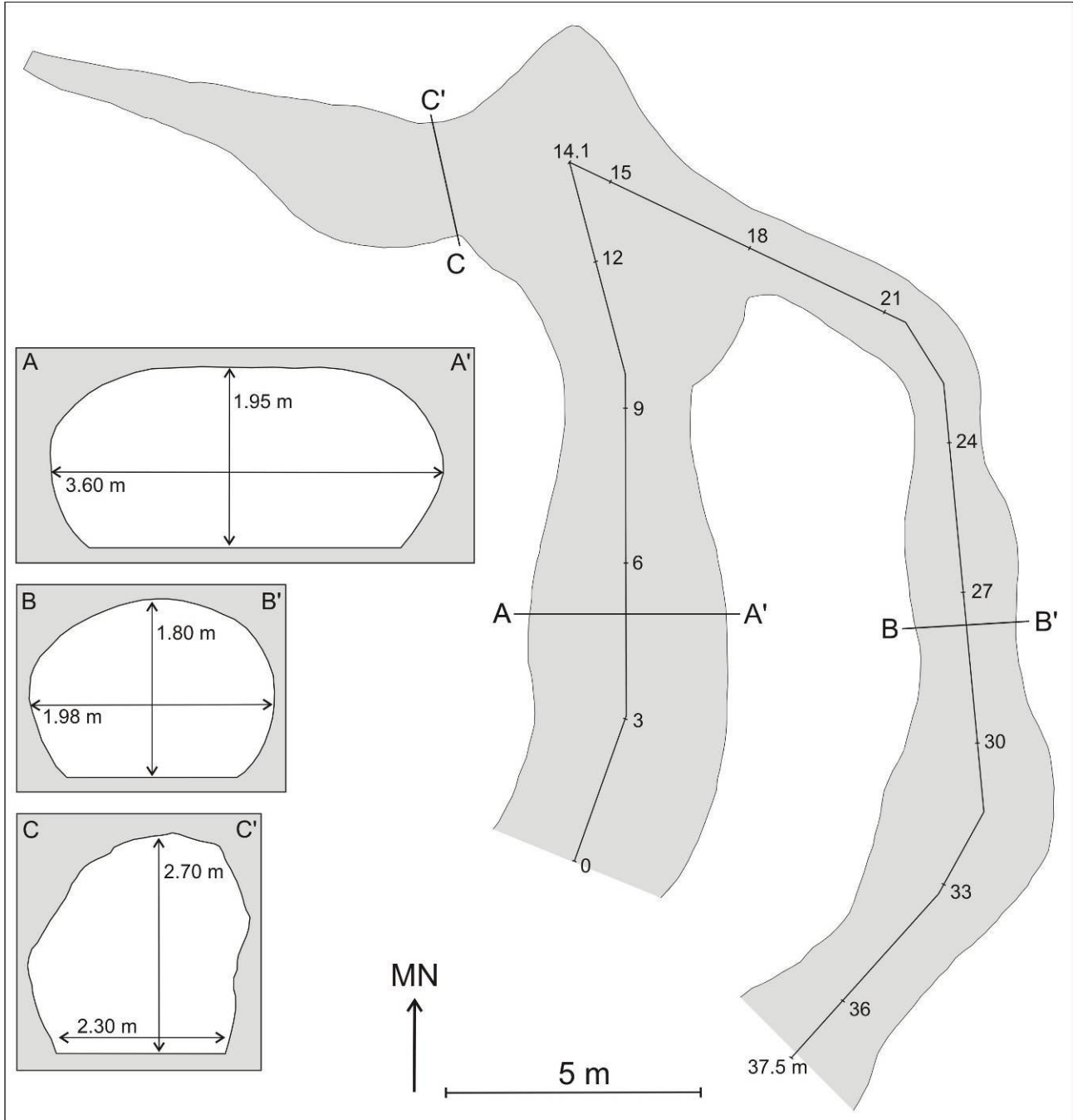


Fig. 2: Floor plan of the “Toca do Tatu” cave. See Tab. 1 for widths and heights along alignment from 0 – 37.5 m. Three characteristic profiles are shown: A-A’: elliptical tunnel; B-B’: spherical tunnel; C-C’: complex tunnel with collapse features on the roof.



Fig. 3: General aspects of the “Toca do Tatu” cave. (A) Entries of the cave, with the North Tunnel at the left and the South Tunnel at the right. Right observer = 1.77 m (B) The North Tunnel, seen from the entrance towards the Hall. People in the back = 1.77 m. (C) The South Tunnel, seen from the entrance towards the Hall. (D) Image of the Hall seen towards the tunnels. Observer: 1.77 cm. (E) Image of the smooth concave walls of the intermediate segment of the South Tunnel. (F) One of the lateral walls of the Hall, with a lower smooth wall and an upper irregular wall. Behind the observer is the rear exit of the cave. (G) The rear exit of the cave seen from outside.

The smooth walls (Fig. 4-A) are formed by completely regular and flat continuous surfaces which can stretch for over 10 meters along the progression of the tunnels. They can be rectilinear or curved, following the morphology of the tunnels. In the North Tunnel, virtually all the lateral walls and the greater part of the roof (Fig. 3-B) are formed by smooth walls. In the South Tunnel, all the walls are smooth (Fig. 3-C, E). In the Hall, smooth walls are restricted to some of the lower portions of the lateral walls (Fig. 3-F). The smooth walls concentrate the most complex surface structures found in the cave.

The uneven smooth walls are composed of undulating surfaces, deeply modified by grooves that form an irregular assembly that covers the entire wall surface (Fig. 4-B). In addition to the grooves, these walls show scattered small ($\varnothing < 5$ cm) and shallow (< 5 cm) cavities. At one point in the Hall, a surface with these characteristics stretches more than 5 m with a height of 1.5 m. Some isolated grooves of this type also occur at the base of the lateral walls of the North Tunnel, at some spots of the roof of the South Tunnel and elsewhere in the Hall, sometimes

forming small areas with the characteristics of this wall type.

The uneven rough walls form surfaces constituted by many minor more or less flat surfaces with many different orientations. Individually, these surfaces are more or less smooth, but as a whole they constitute a very irregular surface (Fig. 4-C). They occur in various parts of the roof of the North Tunnel and cover much of the walls of the Hall. The flat surfaces coincide in many points with the large-scale stratification of the sandstone that makes up the cave. On these surfaces the small cavities described above also can be found, sometimes forming larger clusters, as at one point near the rear exit of the Hall.

4.2. Surface structures on the walls.

In this descriptive section, the structures that can be found on the walls will be presented individually, classified in types. A key difference between the types of structures is the appearance of its surface, which can be classified in two different ways, here called "White Surfaces" and "Pink Surfaces" (Fig. 5).

"White Surfaces" present a rough and coarse texture and are uniformly covered with small irregularities of the same size of the quartz grains of the sandstone of the Botucatu Fm. that makes up the cave. The surface color tends to be whitish, with different shades of white and light gray due to the irregular distribution of white spots.

The "Pink Surfaces" show a smoother and more uniform texture. The color is a medium and uniform pink, which is the original color of the host sandstone. The differences between the two surfaces apply not only to the continuous surfaces, but also to any kind of grooves.

4.2.1 Type A – "Small Holes"

The small holes are formed by cavities of irregular shapes, mostly circular or elongated and with depths of less than ~5 cm (Fig. 6-A). When circular, they have diameters of less than ~5 cm. When elongated, they have major axes of less than ~15 cm. They are found unevenly dispersed across the roof and on the upper portions of the smooth lateral walls and concentrated on some points of the lower portions of these lateral walls. Without any pattern, they have a random distribution. Their density varies from 20 to 40/m². A few dozen slightly larger holes are associated in a well defined way with a geometric pattern of fine grooves (Type D-3), described below. The vast majority of small holes occur on the White Surfaces. On the uneven

rough walls a locally much higher concentration of these holes may occur, such as close to the rear exit of the cave.

Table 1: Dimensions of the "Toca do Tatu" cave

Meter (see Fig. 2)	Width	Height	Component
0.0	3.75	2.00	North Tunnel
3.0	3.93	2.00	North Tunnel
3,5	3.95	2.05	North Tunnel
5.0	3.92	2.05	North Tunnel
6.0	3.60	1.96	North Tunnel
7.0	3.15	1.90	North Tunnel
8.0	2.70	2.00	North Tunnel
9.0	2.50	2.05	North Tunnel
9.7	2.53	2.15	North Tunnel
10.0	2.61	2.10	North Tunnel
14.1	-	2.50	Hall
19.0	1.43	1.40	South Tunnel
20.0	1.48	1.46	South Tunnel
21.0	1.58	1.40	South Tunnel
22.0	1.56	1.35	South Tunnel
22.8	1.40	1.37	South Tunnel
23.0	1.36	1.35	South Tunnel
23.5	1.32	1.34	South Tunnel
25.0	1.75	1.47	South Tunnel
25.5	1.96	1.45	South Tunnel
26.0	2.17	1.55	South Tunnel
26.5	2.20	1.60	South Tunnel
27.0	2.17	1.62	South Tunnel
27.5	2.04	1.70	South Tunnel
28.0	1.98	1.80	South Tunnel
28.5	2.00	1.75	South Tunnel
29.0	2.05	1.82	South Tunnel
29.5	2.40	1.91	South Tunnel
30.0	2.78	1.95	South Tunnel
30.5	2.17	2.00	South Tunnel
31.0	3.41	2.00	South Tunnel
31.6	3.52	1.95	South Tunnel
32.0	3.36	1.94	South Tunnel
32.5	3.15	1.85	South Tunnel
33.0	2.83	1.78	South Tunnel
33.5	2.65	1.73	South Tunnel
34.0	2.40	1.70	South Tunnel
34.5	2.25	1.70	South Tunnel
35.0	2.20	1.71	South Tunnel
35.5	2.30	1.73	South Tunnel
36.0	2.34	1.76	South Tunnel
36.5	2.60	1.83	South Tunnel
37.0	3.00	1.93	South Tunnel
37.5	3.22	1.95	South Tunnel

4.2.2 Type B – "Big Holes"

The big holes also form cavities in the lateral walls and the roof, but are of larger size (Fig. 6-B). They may have an irregular or conical shape, the latter with several straight faces. Their diameters lie between 9 and 24 cm and the depths between 6 and

15 cm. Big holes occur sparsely, randomly scattered, with a density of less than 1/m². Usually they are associated with a defined radial pattern of geometrical grooves (Type D-3) and are located on the White Surfaces.

respectively. Typically, the width is not constant along an individual groove, but varies between certain limits around an average value. The depth is also not constant, but tends to be highest in the middle portion of the groove or near one of its ends. The gradual decrease of the depth of the groove from the middle of the groove towards each one of its ends is very common. The faces that define the grooves are gently concave and there are no sharp edges at the bottom of the grooves (Fig. 8-A, top), which differentiates these grooves from Types D, E and F, described below. The grooves are never aligned horizontally, but always are vertically or oblique and can be found at a height of up to ~2.5 m from the floor of the cave. The highest concentration of these grooves is on the base of the lateral walls of both tunnels, on some spots of the roof of the South Tunnel and on some points of the Hall. In several places there are 2 or 3 grooves with a significant parallelism (Fig. 7-B). Wide grooves always display White Surfaces identical to the cave walls.

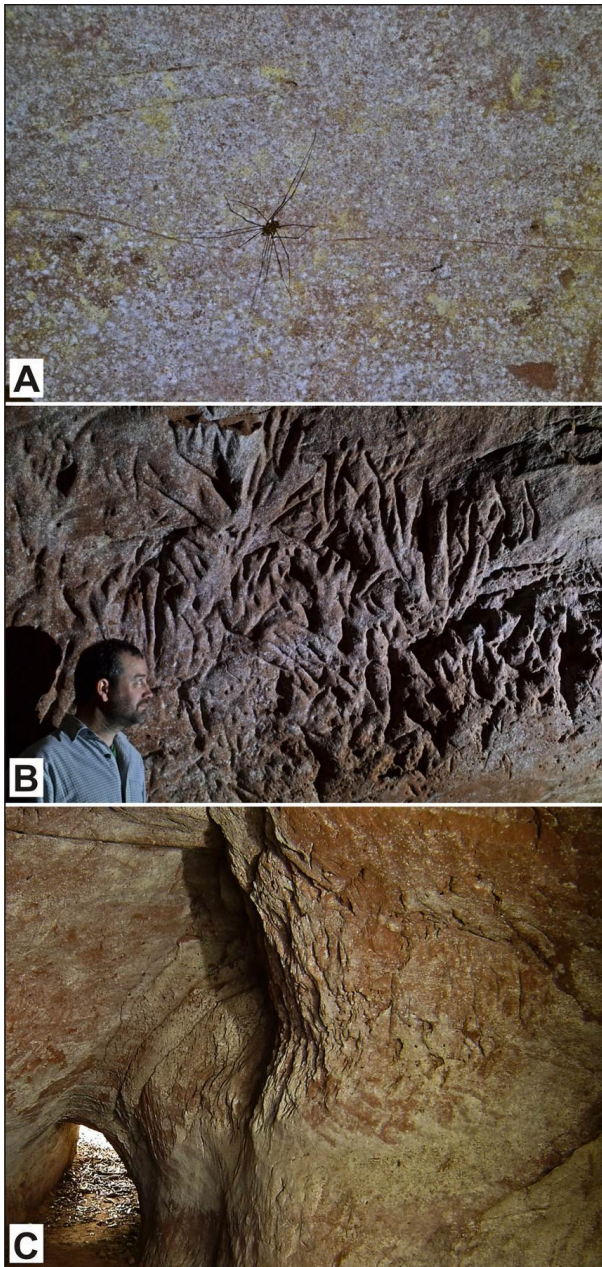


Fig. 4: Morphology of the cave walls.

- (A) Smooth wall in a vertical plane. Harvestman: ~10 cm.
- (B) Uneven smooth wall, located in the Hall. Observer (standing) = 1.78 m.
- (C) Uneven rough wall in the Hall, in front of the picture 4-B. Image height: ~ 3 m.

4.2.3 Type C – “Wide Grooves”

Wide grooves are formed by grooves which do not possess a defined geometric arrangement (Figs. 4-B and 7-A), reaching maximum values of width, depth and length of ~5, ~6 and ~50 cm,



Fig. 5: Extract of one of the smooth lateral walls of the North Tunnel of the “Toca do Tatu” cave. On the left is a “Pink Surface” and on the right a “White Surface”.
Scale = 15 cm.

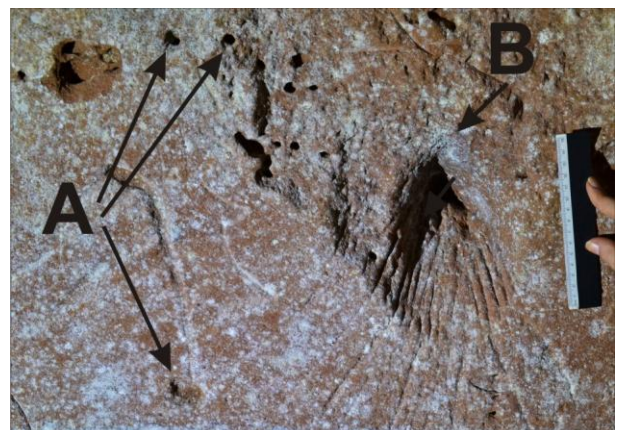


Fig. 6: Structures of Type A and Type B at the “Toca do Tatu” cave. Both are on a smooth wall with White Surface. (A) “Small Holes” and a (B) “Big Hole”.
Scale = 15 cm.

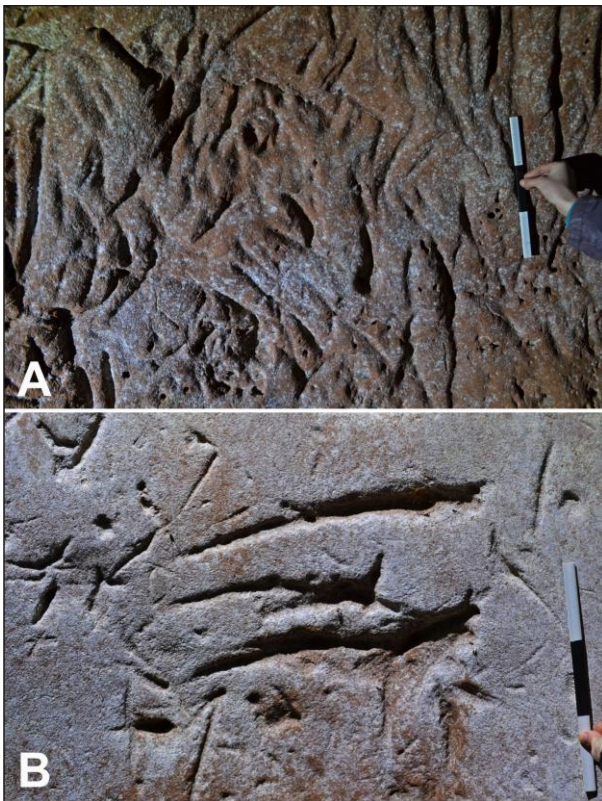


Fig. 7: Structures of Type C (“Wide Grooves”) at the “Toca do Tatu” cave. (A) Surface of the Hall (Fig. 4-B) evenly covered with wide grooves. Scale = 30 cm. (B) Wide grooves which tend to be parallel, located at the roof of the South Tunnel, approximately at 27.5 m (Tab. 1, Fig. 2). Scale = 30 cm.

4.2.4 Type D – “Fine Grooves”

The fine grooves are formed by continuous grooves with approximately equal widths and depths, both most commonly of around 5 mm. The spread of widths and depths is remarkably constant for all the grooves (Fig. 8-B). The faces of the grooves are straight and there is a sharp edge along the bottom of the groove (Fig. 8-B, top). The fine grooves always exhibit White Surfaces and form geometric figures, described below. In many cases there are two or more superposed figures. This type of groove is concentrated on the first 11 m of the North Tunnel, where it covers just over 35 m² of both lateral walls and of the roof. In the South Tunnel there are just a few isolated grooves and in the Hall they are absent. The most common patterns formed by these grooves are described below.

Type D-1: “Vertical Grooves”

Vertical grooves form a parallel set of some 10-20 grooves, usually aligned vertically, with a constant width of 3-4 mm and lengths of several dozen cm, with a maximum of approximately 60 cm

(Fig. 9-A). They can be found in two places on the lateral walls of the North Tunnel.

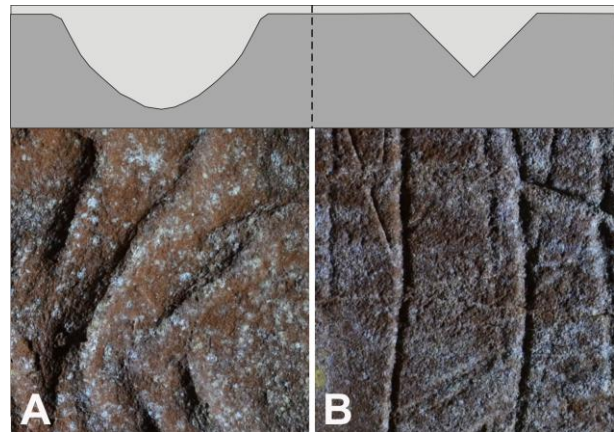


Fig. 8: Diagnostic aspects of the grooves found on the walls with White Surfaces at the “Toca do Tatu” cave. (A) “Wide Grooves” rarely are straight and always have concave walls (section without scale on the top) and various widths and depths. (B) “Fine Grooves” rarely are curved and always have straight walls (section without scale on the top) and constant widths and depths. Width of both images = 20 cm.

Type D-2: “Grid”

Grids are formed by 2 sets of usually straight and parallel grooves that intersect at approximately 90° (Fig. 9-B). The distance between the individual grooves vary from 1.5 to 3.5 cm. The length of the individual grooves may reach 1.0 m and the number of grooves of each set of parallel grooves reaches 22. There are 25 grids distributed more or less uniformly on the lateral walls and the roof of the North Tunnel. In the South Tunnel and in the Hall the grids are absent.

Type D-3: “Radial Grooves”

This type is formed by a figure that consists of a set of radial grooves distributed around a cavity in the wall (Fig. 8-B). The diameter of the cavities varies from 1.5 to 11.5 cm and the length of the grooves varies from 15 to 90 cm. The grooves may be straight or curved and its maximum number, in a single figure, is of approximately 23. There are 8 of these figures along the North Tunnel, with the 2 largest ones located on the roof (e.g., Fig. 9-C). The diameters of these 2 largest figures are of 1.0 and 1.2 m.

Type D-4: “Angular Ripples”

Angular ripples are formed by a set of oblique grooves with alternating orientations. The grooves

have individual lengths between 10 and 17 cm (Fig. 9-D). There are 4 of these alignments on the walls of the North Tunnel. Individual alignments may be up to 3.0 m long. The alignments on the lateral walls are slightly curved upwards.

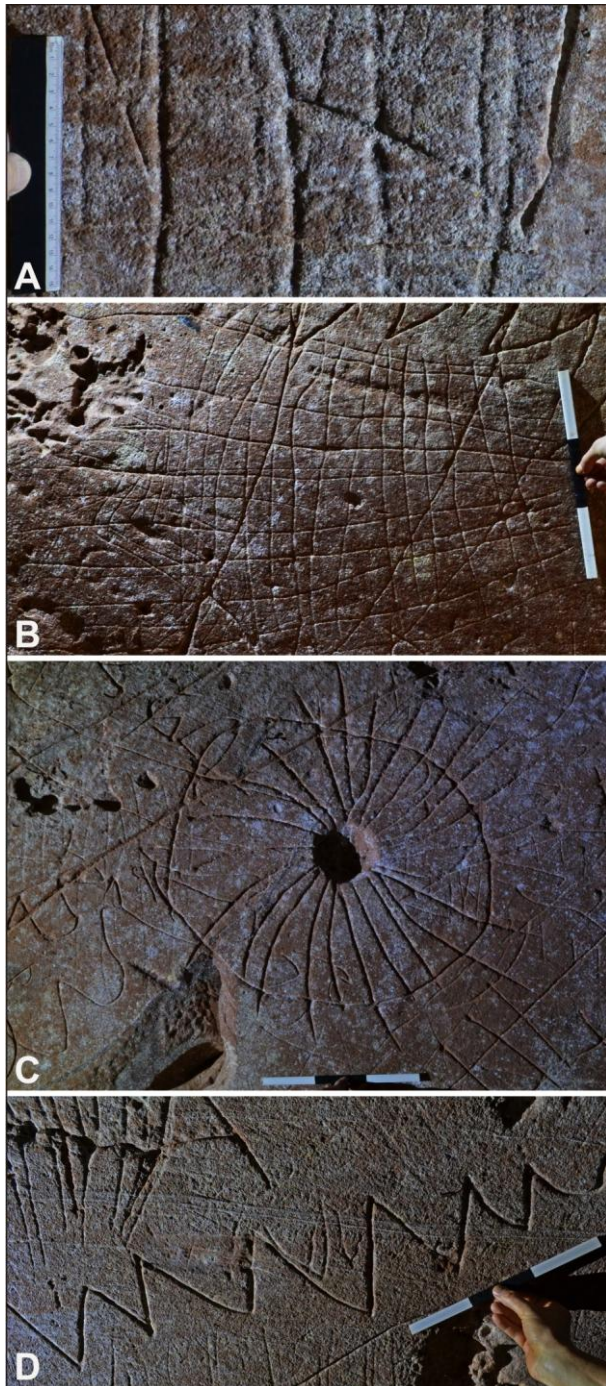


Fig. 9: Structures of Type D (“Fine Grooves”) at the “Toca do Tatu” cave. Most common patterns of the walls of the North Tunnel.

- (A) Type D-1: Vertical grooves. Scale = 15 cm.
- (B) Type D-2: Grid. Scale = 30 cm.
- (C) Type D-3: Radial grooves. Scale = 30 cm.
- (D) Type D-4: Angular ripples. Scale = 30 cm.

Type D-5: “Complex Geometries”

There are approximately a dozen drawings of much more complex geometries represented only once in the North Tunnel and its detailing is beyond the scope of this contribution. All of them are formed by grooves identical to those of the previous types (Types D-1 to D-4), they are always on smooth walls (see item 4.1) and they always show White Surfaces.

4.2.5 Type E – “Sharp Bounded Traces”

These traces are formed by straight faces that tend to be vertical and parallel to the wall where they are. Its boundaries are sharp, straight or slightly curved. The faces have individual lengths of up to ~30 cm (possibly more), widths of up to ~10 cm and they may group to cover an area not exceeding 1.0 m² (Fig. 10). In these cases, the faces may exhibit a pattern that tends to be radial. Several of these areas have a cavity located near their center; others have inscriptions (see Type F). The individual faces and the areas they cover when grouped show Pink Surfaces with a very uniform texture, with well defined contrasts against the White Surfaces. In the Pink Surfaces it is possible to observe clearly the structure of the sandstone that makes up the cave. The traces are distributed irregularly in the front portions of both tunnels. In the North Tunnel, there are 30 areas of the same type as in Fig. 10 between the 2.0 and 9.0 meter mark (Fig. 2). In the South Tunnel, such areas are much rarer and occur until approximately the 30.0 meter mark (Fig. 2). The areas are rare to absent on the roof of the tunnels and their overall distribution has no geometric pattern. In the rear exit of the cave, the walls are covered with this type of traces.

4.2.6 Type F – “Letters, Numbers and Symbols”

This type is found concentrated in the initial portions of the North Tunnel and the South Tunnel, up until approximately 10-12 m from the entrances. The engravings are irregularly distributed on the lateral walls and the roof of the tunnels. There are 119 individualized sets (full names, full dates or individual symbols) in the first 10 m of the North Tunnel and a slightly lower density can be found in the South Tunnel; in the Hall such engravings are virtually nonexistent. The engravings are always formed by grooves of slightly varying thicknesses and always exhibit Pink Surfaces. They can be found mainly on the smooth walls and in much lower quantities on the uneven smooth walls. The grooves of these engravings always overlap other structures of the walls like the wide grooves (Type C), the fine

grooves (Type D) and the sharp bounded traces (Type E). The engravings may be subdivided in letters, numbers and symbols, described below.

tunnels there are some other engravings that can be classified as symbols, but their detailing was postponed.



Fig. 10: Structures of Type E (“sharp bonded traces”) at the “Toca do Tatu” cave. Grouping of sharp bonded traces, predominantly vertical and with sharp boundaries (e.g., white arrows), displaying Pink Surfaces in contrast to the White Surfaces surrounding them. Scale = 15 cm.

Type F-1: “Letters”

The letters which can be found are in the Latin alphabet and, with rare exceptions, are capitalized. Their height normally varies between 10 and 20 cm and they form mainly names (Fig. 11-A). They are often only first names, both male (“Edio”, “José”, “Sander”, “Reni”, etc.) and female (“Monica”, “Tania”, “Verônica”, etc.). Some full names also are present (e.g., “Sérgio Boff”, “Andréia Scussel”). Other words appear very infrequently (e.g. “Misionário” – with only one “s”), including city names (e.g., “Sombrio”).

Type F-2: “Numbers”

The numbers engraved on the walls are formed by Arabic numerals. Only in one case are they represented by Roman numerals. The numbers, much rarer than the letters, always form dates and their sizes are similar to the letters. The dates refer to the years 1956, 1957 (Fig. 11-B), 1970, 1972, 1974, 1978, 1980, 1982, 1986, 1989 and 1991, among others.

Type F-3: “Symbols”

In the North Tunnel there are 15 engravings of symbols between the 2.0 and 7.0 meter mark (Fig. 2), both on the walls and on the roof. The vast majority is formed by crosses, with heights reaching 65 cm, but most are smaller (Fig. 11-C). In both

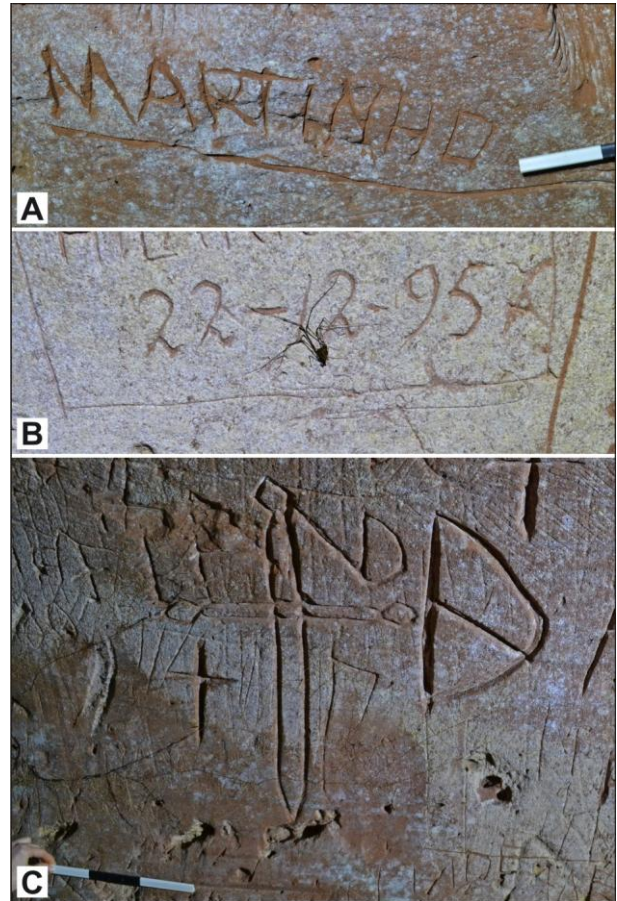


Fig. 11: Structures of Type F (letters, numbers and symbols) at the “Toca do Tatu” cave. (A) Letters (Type F-1) forming names. White scale bar = 10 cm. (B) Numbers (Type F-2) forming dates. This date was inscribed with the characteristic calligraphy of that time. Harvestman: ~10 cm. (C) Symbols (Type F-3) are usually crosses, as in this example. Scale = 30 cm.

5. DISCUSSION

The discussion about the genesis of the cave has to focus initially on the host rock and on the morphology of the cave. The sandstone of the Botucatu Fm. that makes up this cave is not soluble, which rules out an origin of the cave from the dissolution of the rock by meteoric waters, such as is the case with limestones. Speleogenesis in sandstones usually is related to the impact of groundwater on the structural pattern of the rock. These waters create erosion, liquefaction and piping processes, generating highly asymmetric caves (MONTEIRO; RIBEIRO, 2001). Usually, the caves generated by these processes show underground drainage or features related to this, but there is no sign of such a drainage, both in the present or of past, in the “Toca do Tatu” cave.

The origin of the “Toca do Tatu” cave can be deduced from (i) the morphology, (ii) some of the surface structures on the walls and (iii) its size. The morphology of the cave is well-defined, with the North Tunnel forming a corridor of more or less constant widths and heights (Figs. 2, 3-B; Tab. 1) and with a sequence of 3 successively smaller chambers in the South Tunnel (Figs. 2, 3-C; Tab. 1). This morphology is characteristic of tunnels excavated by fossorial animals of the Cenozoic Megafauna (FIGUEIREDO et al., 2012). Such huge tunnels probably were excavated in steps, each step consisting of the excavation of the rock and the subsequent removal of the loose material out of the tunnel. In sandstones, the loose material has a density of over 2.0 t/m³. The volume of the “Toca do Tatu” cave as a whole is more than 100 m³, which means that more than 200 tons of sandstone has been excavated. The exceedingly high amount of energy needed by the diggers suggests that they most probably dug such tunnels in steps over lengthy periods of time. The excavation steps stay preserved as chambers along the tunnel length, often identifiable through a sequence of successive concave surfaces best preserved on the roofs of the tunnels.

Among the surface structures on the walls, the wide grooves engraved on White Surfaces also are related to the origin of the cave. When grouped, they characterize the uneven smooth surfaces. Grooves of this kind always are found on the walls of the tunnels dug by some of the Cenozoic vertebrates. Their size and position on the walls are very characteristic and allow for their interpretation as digging scratches or claw scratches. The digging action is revealed by the fact that the ends of the grooves enter and leave the surface of the walls, representing a friction action that loosens the sand grains of the rock, which does not have a very high degree of cementation. Particularly significant in this context is the continuous surface covered with such claw scratches that can be seen in the Hall, extending to a height of 2.5 m (Fig. 4-B). Since the floor of the cave at this point is probably close to its original level, the grooves must be attributed to very large animals. The overall size of the cave, especially the original heights of 2.0 m of the North Tunnel and of the beginning of the South Tunnel, permits us to attribute the cave to ground sloths, possibly to one of the genera *Scelidotherium*, *Mylodon*, *Glossotherium* or possibly *Lestodon*. Sloths had the necessary morphological adaptations for digging tunnels (BARGO et al., 2000, NAISH, 2005). Tunnels of similar sizes, morphologies and surface structures on the walls have been found on several other places in Southern Brazil (e.g.,

FRANK et al., 2010). The diagnostic features of these big-sized tunnels are the completely smooth, almost polished, surfaces of the lateral walls and the roof. If there is no sign of an actual or ancient flow of water inside the cave, as in the “Toca do Tatu” cave, the origin of the smooth surfaces must be attributed to other processes. If the cave was excavated by a paleovertebrate, the smooth walls can be explained by the continuous rubbing of the bodies of the animals against the walls, which implies a long-term use of the tunnel, probably by successive generations of family groups of sloths over the centuries. In this particular cave, there is a feature on one of the walls that supports that interpretation. Almost at the intersection of the South Tunnel with the Hall, there is a recess in the smooth wall of the South Tunnel. And in this recess, which protected them against the contact with the bodies of the sloths, there are several preserved digging scratches (Fig. 12-A).

There are two other facts that assist in the interpretation of the cave as a shelter dug by paleovertebrates. The first one is the location of the cave, next to a water source, but well above the level of flooding and with access to moderate sunlight. Secondly, the shape of the cave near the rear exit. The wall at this point is formed, in the lower portion, of a smooth concave surface. The upper portion, on the other hand, does not follow the concavity of the lower part, but goes straight upwards, with an uneven smooth surface type and extends to more than 2.5 m in height (Fig. 3-F). It is possible to suggest that at this site initially a lower tunnel of a little more than 1.0 m in height was excavated, whose walls were smoothed out by long use. Subsequently, the tunnel was raised to the height of the highest digging scratches that can be seen today. The uneven rough surfaces found elsewhere in the Hall show a lot of straight fracture planes produced by the collapsing of sandstone blocks whose shapes tend to follow the cross-bedded structure of the sandstone. The associated small holes (Type A of the surface structures) seem to be of inorganic origin, whereas the big holes (Type B) and the accompanying fine grooves are discussed below.

In the assessment of the surface structures, it is necessary to recognize the meaning of the “White Surfaces” and of the “Pink Surfaces”. Most of the surfaces of the cave walls, especially those of the South Tunnel (Fig. 3-C), show up completely white, a frequent feature in tunnels excavated by paleovertebrates in the sandstones of the Botucatu Fm. (Fig. 12-B)

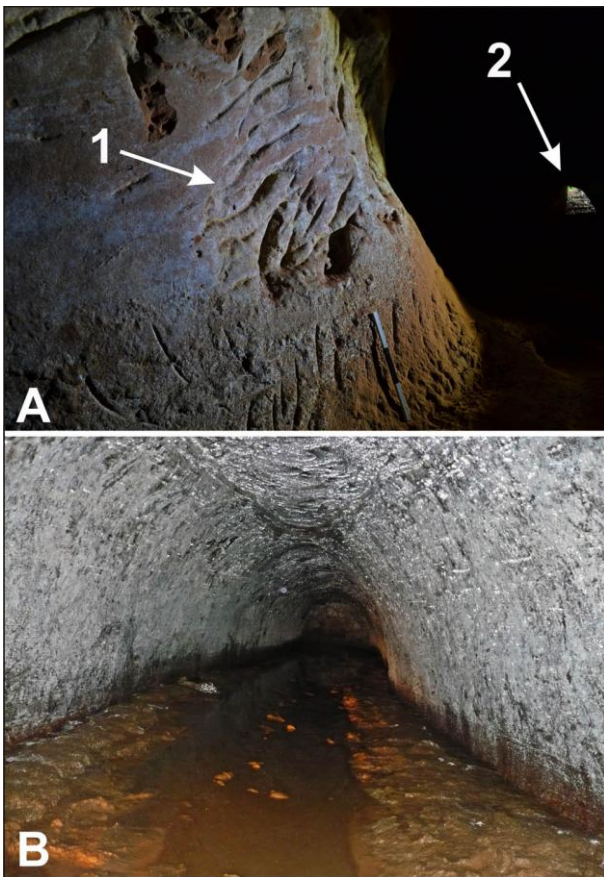


Fig. 12: Two aspects of the surfaces of tunnels of Cenozoic fossorial vertebrates. **(A)** In the “Toca do Tatu” cave, a concave portion of a smooth lateral wall of the South Tunnel, almost at the intersection with the Hall, shows several preserved digging scratches (Arrow 1). In the back is the rear exit (Arrow 2). Scale (near the floor) = 30 cm. **(B)** Paleovertebrate tunnel in the municipality of Bom Retiro do Sul (RS) with completely white walls. Width of the tunnel: ~1.2 m.

Thus, the White Surfaces have to be seen as the original and oldest surfaces of the cave walls, which were present before the presence of other characters in the cave, detailed below. The Pink Surfaces, with the characteristic original color of the sandstone, must be considered to be much younger. As can be seen in Fig. 11-B, the numbers that form the date (especially the “5” and the “7”) still show the pink color of the rock, despite having been engraved in the rock more than half a century ago. A similar situation was found in a cave in the municipality of Vale Real (RS). There, the cave was excavated in the same rock as the “Toca do Tatu” cave and on one of the lateral walls of the cave the date of 1897 was engraved. During this period the region was occupied by European settlers. The grooves that form the numbers of this date still have Pink Surfaces, showing that even after more than a century the exposed surface of the sandstone does not turn white.

The fine grooves, with their characteristic White Surfaces, geometric patterns and careful preparation, must be assigned to indigenous populations, most probably in pre-colonial times. Cave paintings and drawings are among the most intriguing traces left by ancient human populations. The representations, also called rock art, have been commonly recorded in places like caves, grottos and rocky outcrops, using techniques such as painting, polishing and pecking of the rocky surface. Among the repeatedly used motifs are hunting scenes, zoomorphic figures, abstract figures and, as in the “Toca do Tatu” cave, geometric patterns. Archaeological research, using fieldwork and interpretations based on semiology, is constantly expanding our knowledge about the rock art and their craftsmen. Several interpretative trends attribute communicative functions, ritualistic meanings or a simple aesthetic presence to the rock paintings.

Paintings and rock drawings made by prehistoric populations are found from the north to the south of Brazil, in many different representative forms and styles. Regionally, Brazil is divided in “Traditions”, a term used in Archaeology to classify a given set of stylistic patterns and manufacture techniques (MALLMANN VICROSKI, 2009). The “Toca do Tatu” cave features rock art that is compatible with the southern expressions of the Geometric Tradition, specifically of the Morro do Avencal Sub-Tradition (PROUS, 1992). However, some of its geometric patterns can be found also in the Southern Tradition.

The techno-typological analysis of the features and of the recurring patterns allows us to relate them to two of the pre-colonial populations that inhabited the region: the hunter-gatherers or the potters of the linguistic group Gê (COMERLATO, 2005a, 2005b). In the highlands of the state of Santa Catarina there are several other archaeological sites of the same kind as the “Toca do Tatu” cave. Traditionally, Archaeology assigns an anthropogenic origin to these tunnels, calling them “subterranean Indian galleries”. However, the articulated and interdisciplinary analysis of the features of the “Toca do Tatu” cave allows for the revision of these theories and the extension of the knowledge about the pre-colonial populations who used these structures.

Observing the entries of the “Toca do Tatu” cave (Fig. 3-A), it becomes clear that a large (>20m³) volume of loose sandy sediments has been removed at this site. These sediments formed originally a fan-shaped accumulation in front of the entries. The top of the fan followed the general

inclination of the slope. This sediment removal is confirmed by the testimony of the people who live in the region. There are reports of a strong activity by treasure hunters digging at the site in the early 1970s. Similar activities have been confirmed in at least two other caves in the region. In the “Toca do Tatu” cave, the treasure hunters not only opened the entries, but also carved a niche in the wall between the two entries (Fig. 3-A), placing there the image of a saint who was later vandalized. Most likely the same people widened the rear exit, leaving the traces of their tools on this passage. Given the present appearance, the rear exit was opened initially by the roots of a tree and only later widened with tools.

The sharp bounded traces (Type E, Fig. 10) found at the walls were most likely produced by scraping the wall with a machete, smoothing and homogenizing the surface for the subsequent engraving of the traces of Type F (letters, numbers and symbols). Religious symbols are often found on cave walls and probably represent a Christian “occupation” of a supposedly pagan space. Likewise, the engraving of names and dates does not have the character of simple vandalism. Subliminally, it probably represents a “space occupation”, in opposition to all the entities and hidden forces that supposedly created or occupied the cave. In the “Toca do Tatu” cave, this occupation is seen in the large quantity of traces of this type on the cave walls, always restricted to the euphotic and the disphotic zones of both tunnels.

Based on the discussion above, the origin and the evolution of the cave “Toca do Tatu” cave can be structured in 5 stages. (1) Initially the cave was excavated in steps and inhabited by family groups of ground sloths for a long time, probably for centuries. Since the South American Megafauna became extinct approximately 10.000 years ago (FARIÑA, VZCAÍNO, 1995), the lower age limit of the cave is of this order. (2) Finding the cave abandoned, open and with smooth walls due to its long-time use, indigenous people used the site to record their geometric engravings on the walls. Other remains of this Indian occupation, like remains of campfires, lithic artifacts, burials and others, were not recorded. (3) Later the cave entrances were buried by sediments caused by landslides. Along the escarpment of the Serra Geral Fm. in the northeast of RS and the southeast of SC, these phenomena are very common after periods of heavy rainfall. (4) When the region was occupied by European settlers, the entire area was searched for game and forest products like hardwoods and palm. An access to the cave was probably found during this process and the site was interpreted as a possible hiding place for treasures. As always in such situations, a group of

treasure hunters formed who took charge of excavating the cave. (5) After the site was abandoned by the treasure hunters, the cave was and still is visited by tourists, who continue the process of writing their names on the walls, a habit that is only recently being discouraged.

Based on the description of PADBERG-DRENKPOL (1933) and own fieldwork, it can be concluded that another cave, known as “Caverna do Rio dos Bugres” (“Indian River Cave”), located in the municipality of Urubici, SC (27°57’55.42’’S, 49°30’33.67’’W), has the same origin and probably the same evolution as the “Toca do Tatu” cave. The “Indian River Cave” is a paleovertebrate tunnel too, but of smaller size and with a more complex geometry than the “Toca do Tatu” cave. Its rock art was formed of only 22 small engravings (15 of them remain today) but it was also excavated by treasure hunters after its discovery by European settlers and today it is a tourist attraction.

The recognizing of the “Toca do Tatu” cave as a paleovertebrate tunnel with rock art on its walls enhanced the importance of the cave and urges the local population, tourist guides and tourists in general to cease immediately any action inside the cave that can potentially destroy it even more. The preservation of this speleological and archaeological heritage will be reinforced in future with the founding of a geopark in this region. The geopark, called “Caminhos dos Cânions do Sul” (“Paths of the Southern Canyons”), nowadays is being proposed by the Geological Survey of Brazil (Companhia de Pesquisa de Recursos Minerais – CPRM) and emphasizes the importance of our research done at the “Toca do Tatu” cave.

6. CONCLUSIONS

The analysis of the morphology, the size and the surface structures on the walls of the cave known as “Toca do Tatu” allow us to conclude that the cave is a shelter excavated by one of the many species of ground sloths of the South American Megafauna. The finer grooves with geometric designs that adorn the walls are similar or identical to other engravings found in many archaeological sites in Southern Brazil, showing that pre-colonial populations frequented the cave. Traces of metallic tools and engravings of names, dates and symbols showed the presence of European settlers in the cave in recent times.

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