

The Rio Peruaçu Basin: An Impressive Multiphased Karst System

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Abstract

The Rio Peruaçu basin is located on the left bank of the Rio São Francisco, in the north of the state of Minas Gerais. While its upper portion collects the waters flowing from the sandstone formations of the Urucuia, its lower part cuts into the Bambuí limestones, carving out a narrow canyon about 200 m deep for which the site is known. Over more than 17 km, the stream opens a bed that disappears underground six times. These underground sections are the remainders of an extensive and complex primitive karst network. Although some segments consist merely of simple but majestic arches, others, such as the Brejal and especially the Janelão, offer kilometers of underground galleries that can attain exceptional dimensions. For example, the Janelão cave reaches a ceiling height of 106 m and a width of 60 m. This canyon is punctuated by large and flat areas that function as reservoirs, namely the poljes of Silu and Terra Brava, and at the confluence with the Rio dos Sonhos. The system results from a complex Cenozoic evolution, including several spectacular episodes. As currently reconstituted, this evolution comprises at least three main episodes. The impressive landscapes of this region are not its only interesting feature: humans have occupied the basin since prehistoric times, as attested by about a hundred rock shelters and open-air dwelling sites that have not yet revealed all their secrets.

Keywords

Multiphased karst • Geomorphological evolution • Neoproterozoic Bambuí limestones • Peruaçu

15.1 Introduction

Located in the north of the state of Minas Gerais, the Rio Peruaçu is a perennial left-bank tributary of the Rio São Francisco, which meets between the cities of Januária and Itacarambi (Fig. 15.1). The beginning of the European colonization of the region is dated to 1686 and marked by the foundation of the “arraial of Brejo do Salgado” (former Januária) by a “bandeirante” group came from the south, from São Paulo. With a population of about 65,000 inhabitants, Januária lies today in an agro-pastoral region. Important crops are sugar, manioc, beans, mango, breadfruit, coconut, orange, avocado, cashew, and bananas. Like almost all cities in this area of Minas Gerais, cattle breeding is an important economic activity. Small industries produce vinegar, cotton

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Fig. 15.1 Location of the Peruaçu basin, location in Brazil and Minas Gerais state



products, shoes, furniture, and one of the best rums in Brazil. Some changes have been implemented in recent years such as irrigation and soybean cultivation, while cotton cultivation has declined. Despite great natural potential, tourism in the area continues to be weak.

Over its 195 km², the basin offers a relatively simple and homogeneous spatial organization. It extends over 100 km from WNW to ESE and its width varying from about 25 km in the upstream region to about 10 km once the carbonate substratum is reached. Its altitude ranges from 830 m on the upper sandy plateau to 440 m at the confluence with the Rio São Francisco, in a large alluvial plain. From a relatively concentric spring area, the perennial stream crosses the plateau, opening a narrow corridor to the Rio São Francisco valley. The plateau is formed by sandstones of the Urucua Formation, but the outstanding feature of the Peruaçu basin is the morphology resulting from its passage through the carbonate formations of the Serra do Cardoso das Minas, before it enters the alluvial plain of the Rio São Francisco (Piló 1989). This segment offers a spectacular landscape, including a canyon about 17 km long, carved deeply into the limestones of the Bambuí Group (Fig. 15.2a). This canyon is the feature to which the basin owes its name, “Peruaçu” meaning “great opening” or “gorge” in the Tupi-Guarani language (Silveira Bueno 2008). It is certainly one of the most grandiose karst systems of South America, located within a natural park.

Piló and Kohler (1991) suggested that the Rio Peruaçu formed an enormous cave in the great calcareous massif that extended over tens of kilometers. Collapse of walls and galleries during the Middle to Late Pleistocene contributed

to the formation of karst relief (Fig. 15.2b), the major feature of which is the canyon. Regional evolution caused the walls to recede and conduits used until then by water became abandoned or opened up.

15.2 Climate

Winds from the west, south, and northeast are responsible for regional climate features (Radambrasil 1982). In autumn (April–June) and spring (September–December), the climate is governed by warm, dry winds from the northeast (tropical Atlantic climate system), generated by the South Atlantic high-pressure center. Yet winds from the south and west can perturb the system. During winter (June to August), the south polar anticyclone invades the region, causing temperature to drop and humidity to rise, and thus creating the possibility of brief rainfall. At the end of winter, the return of warm winds from the northeast again leads to warmer, drier weather. Tropical instability oscillations bring winds from the west in late spring and from the west or northwest in early fall.

Generally, temperatures are high, with minor oscillations above 20 °C throughout the year. The almost semiarid climate is very contrasted, with a long dry season. In this weather conditions, the average rainfall is 875 mm/year, too weak to impact deeply the geomorphologic features which result from a protracted Cenozoic evolution. The two main impacts are the erosion of residual hills developed in the soft cover formation and the temporary quick flow in gullies excavated in limestone outcrops only during the rainy season. The major effect on karst features is rock sliding.



Fig. 15.2 a the 200-m-deep canyon between Janelão Cave (16) and Bichos Cave (18) (photograph by J. Rodet); b Dolina dos Macacos, 200 m above the subterranean river (photo. by J. Rodet)

15.3 Geological Context

The geological history of the region, as it relates to the evolution of karst morphology, is very long, with alternating large periods of land denudation, marine transgressions, and lacustrine sedimentation (Mantesso-Neto et al. 2004). To the west of the São Francisco valley, the stromatolitic limestones of the Neoproterozoic were deposited directly above the Archean granite bedrock. This granite cropped out as a result of the uplift of the western margin of the large Mesoproterozoic basin of the Espinhaço. The subsidence axis of the basin was shifted westward, allowing deposition of a carbonate ramp. Later on, during the Paleozoic, various episodes of sedimentation and erosion took place. Of these, there remains nothing in the region, because of epirogenesis during the Cretaceous. Pre-Uruçua peneplanation leveled the Archean granite bedrock with its Neoproterozoic carbonate cover that was partly preserved in the São Francisco graben (Dardenne 1978).

It would appear that this graben zone has always remained active, being located between an Archean craton and a block that was cratonized during the Amazonian and Brasiliano orogenies (850–500 My). The Cenozoic tectonic reworking of the São Francisco graben is a fundamental factor in the geomorphological history of the region, and particularly in the evolution of the Peruaçu karst system, for which it constitutes the base level.

Deposition of the Cenozoic Uruçua detrital formation took place above a more or less leveled substratum, but whose limestone residual outcrops could have registered an earlier karstification. Post-Paleocene tectonics reworked the faults of the São Francisco graben. The rift trough collapsed and its edges uplifted. The Uruçua Formation was then eroded and limestones emerged on the raised edges of the valley. Karstification could then resume.

On the basis of field observations and interpretation of Landsat images, we have drawn a simplified geological map of the Peruaçu basin at 1:50,000 scale (Fig. 15.3). As compared to the 1994 and 2003 versions of the general geological map at 1:1,000,000 produced by COMIG (Geological Survey of Minas Gerais State), this map shows the same stratigraphic succession, but provides a refined geological picture of the middle Peruaçu region (Poucllet 2003). Modifications mainly concern the extension of the Bambuí limestones (NP2sl) into the valley's centre, where we identified a major granite inlier. Analysis of lineaments on maps and remote sensing images, associated with field observations, makes it possible to establish a hierarchy of major faults. The following directions can be distinguished: (1) $N.155^{\circ} \pm 10^{\circ}$, (2) $N.0^{\circ}$ – $N.15^{\circ}$, (3) $N.35^{\circ}$ – $N.50^{\circ}$, and (4) $N.110^{\circ}$ – $N.125^{\circ}$. All faults observed show a final movement with a normal component and a strike-slip component, most often dextral for the sub-meridian and NW–SE directions.

15.4 Crossing the Limestones: A Spectacular Karst Landscape

The upper basin is developed upon an overlying deposit of sand derived from the sandstones of the Uruçua Formation (Figs. 15.1 and 15.3). Alteration has been so effective that at the surface, it is hard to find a block of solid rock. Local cerrado-type vegetation is thus xerophilic and adapted to the sandy environment, characterized by small, crooked, spiny trees. This vegetation has been markedly degraded by intensive deforestation linked to charcoal production, but over the past twenty years, its restoration has been in progress, thanks to the management of the Instituto Florestal Estadual in its “Veredas” park (30,700 ha).

Further downstream from this monotonous landscape, after crossing the central segment of the basin around Olha Aqui with its more complex geology (limestone, granite,

Geological map of the Peruaçu Basin

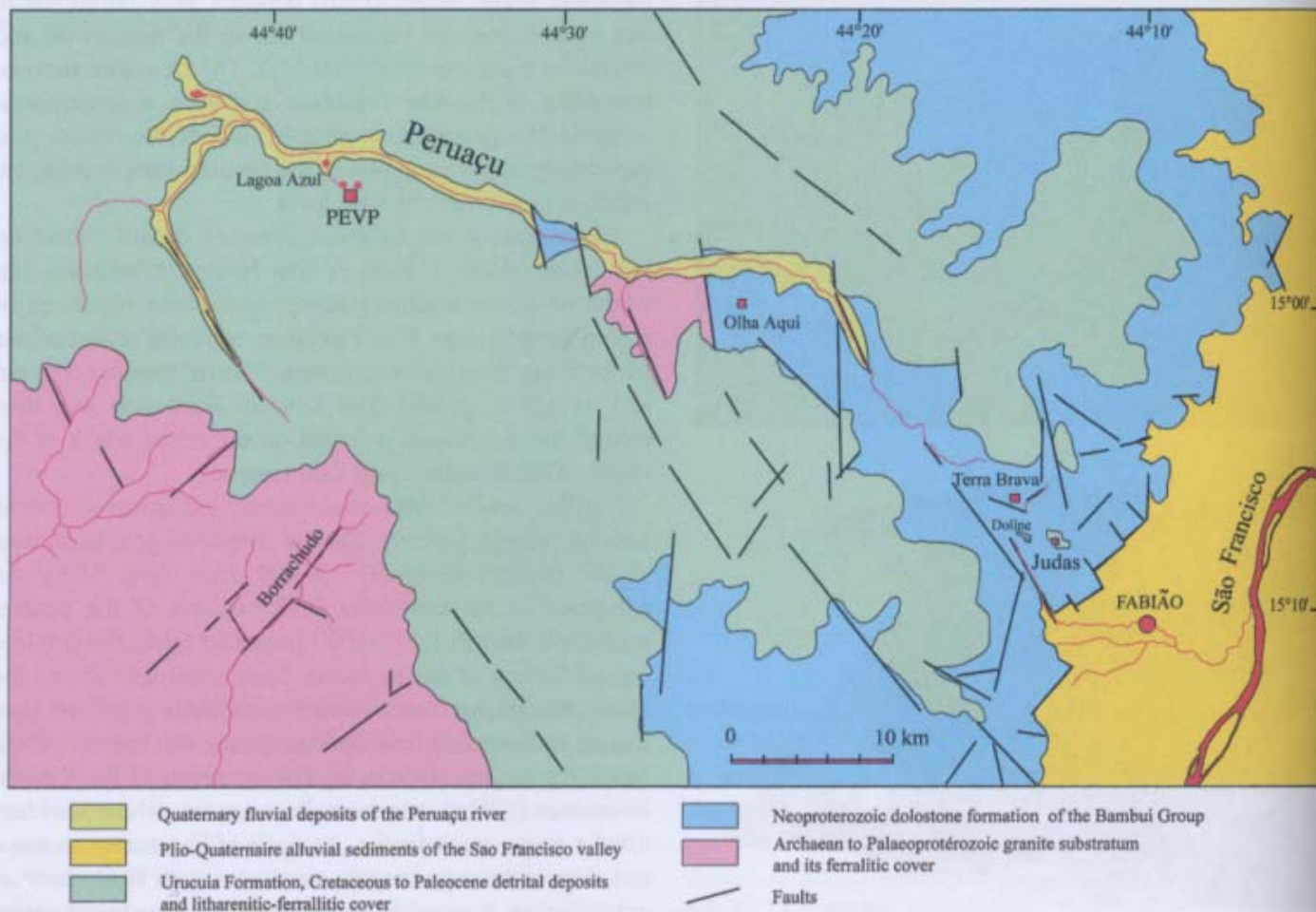


Fig. 15.3 Geological map of the Peruaçu Basin (after Pouclet 2003). Red squares locations cited in the text; red circles lakes and ponds; red lines surface drainage network

faulted bedrock), one gradually enters the canyon to which the basin owes its name, a spectacular domain of karstified limestone (Fig. 15.4a). In addition to the famous 17-km-long canyon interrupted six times by imposing tunnel-caves, one can note the development of numerous underground caverns, while residual landforms at the surface include towers, hums, lapiaz, dolines, chasms, rock shelters, and poljes (Fig. 15.4b). Epigene streams are rare, and many sloping ravines function only when it rains.

This segment is characterized not only by its karst relief (rock shelters, caves, deep canyon, dolines, ravines...), but also by intense human occupation (about a hundred prehistoric sites) that has probably been constant since the Pleistocene/Holocene transition. The area is partially integrated into the Cavernas do Peruaçu National Park (56,900 ha). Linked to the limestone formations, one notes the presence of bromeliads and gameleira trees (*Ficus insipida*), whose deep roots insert into the fissures of the substratum. On limestone outcrops, deciduous vegetation (caatinga) is present, harboring a specific fauna, notably the mocó

(*Kerodon rupestris*). Other animals, such as the collared peccary (*Tayassu tajacu*), are endemic to the sector's gallery forests. This area is also visited by many other animals, since it is a passageway between the high valley and the alluvial plain (IBAMA 2005).

We can divide the canyon in five sectors as follows:

- Entrance to the Canyon from upstream
Following the flow (Fig. 15.5), one observes at the entrance to the canyon a large flooded surface with a seasonal marsh (Silu), surrounded by cliffs pierced by karst caves of all sizes. Worth mentioning on the left bank is the Lapa do Carlucio (1 in Fig. 15.5), studied for its fossil fauna (Mascarenhas 2008). On the right bank, there are the Lapa do Caboclo (2), Lapa das Abelinhas, Lapa dos Morcegos, Lapa dos Ossos, and Lapa do Cavalho (3), revealing a more complex endokarstic development than the Brejal cave-tunnel (4), where the Rio Peruaçu flows underground over more than a kilometer. The stream disappears in this way six times before reaching the São Francisco valley.

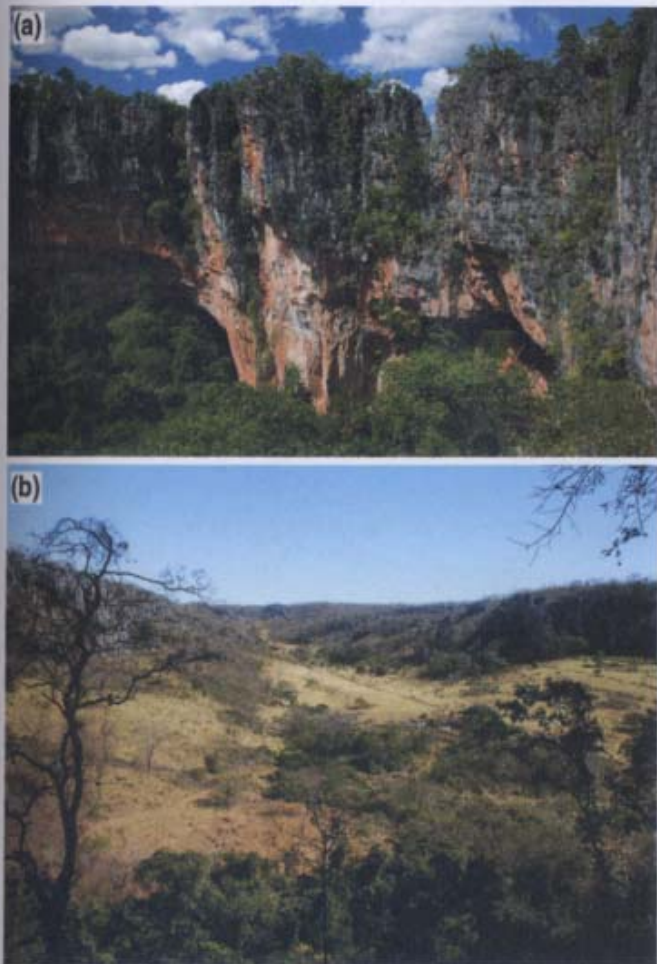


Fig. 15.4 a The dual entrance of the Arco do Vento, with its exokarst features (karrens, towers, etc.) (photo. by A. Coelho); b The Terra Brava paleo-polje with its two main levels (photo. by J. Rodet)

(b) The Upper Canyon

After the underground passage through the Lapa do Brejal (4) with its wide section, the stream flows again in open air in the middle of a valley, where steep slopes are interrupted by residual towers and vertical cliffs. Twice it passes under residual arches, the Arcos do Vento (5) (Fig. 15.4a) and Arco do André (6), both a testimony to the fact that Rio Peruaçu once flowed underground at this location. This is the segment that is hardest to access and least known. Beyond, one reaches two smaller tunnels with a roughly rectangular section, the Lapa do Cascudo (7) and Lapa dos Troncos (8), which extend below a small canyon.

(c) The Terra Brava Polje

When the river again emerges in open air, the Rio Peruaçu offers a waterfall 2 m high, before reaching the Terra Brava polje of roughly triangular shape (Fig. 15.4b). The polje is typified by a flat upper level with several caves opening onto it: Lapa Bonita, Lapa do Suspiro, Lapa do Índio (12), Falso Janelão (13), and Janelão superior (15). Into this level, a flat lower level

is carved and it bears an old farm, supported by a residual hum Antônio Cardoso (14), bordering the modern notch of the Rio Peruaçu. This polje is thus complex and multiphased.

(d) The Janelão Greatest Cave

Downstream lies in the largest underground complex, the Lapa do Janelão (15), explored over about 5 km of galleries (Fig. 15.6).

(e) The Straight Lower Canyon

From this complex, the stream re-emerges into the lower canyon leading to the São Francisco valley (Fig. 15.2). This is the zone of confluence with the Rio dos Sonhos (22) and with the Boqueirão (21)-Malhador (20) valley.

The complexity of the Peruaçu karst system is due to its long evolution. One must distinguish the main exogenous drainage axis and secondary endogenous drainage axis (Fig. 15.5). The main axis, illustrated by the canyon, is a fluviokarst (Piló 1997). Lateral discharge is primarily from the ravines, and any active emergences, notably upstream from the canyon, are very discrete. The hydrochemical studies by Mascarenhas (2011) highlight the low level of exchange between the water flow and its carbonate encasement. The flow volume is low. In the Lapa do Brejal (4), it averages less than 90 m/h. In other sections, the water flows faster, but the flow rate remains well below the drainage capacity of the system.

However, as in the case of the Vale dos Sonhos (22), one should note that the current karst drainage feeds epigene flows or emergences that do not converge toward the canyon. For example, springs at the foot of the Serra do Cardoso das Minas feed flows toward the São Francisco plain (Fig. 15.5), as the Lapa Olhos d'Água (Auler et al. 2001), etc. The chemical signature of the Rio Peruaçu differs from that of the Rio do Vale dos Sonhos. Along the former, there is no trace of travertine formations, whereas they can be impressive (several meters thick) along the Rio do Vale dos Sonhos (22), creating subhorizontal levels in the longitudinal profile of the river. Today, one can no longer speak of a single Peruaçu hydrokarst system, but of several independent systems.

15.5 A Complex Geomorphological Evolution

As the upper section offers no relief and is limited to the sandstone formation, no significant geomorphological evolution can be discerned. It is thus necessary to look at the other sectors, particularly the canyon. According to previous studies (Rodet and Rodet 2001; Rodet et al. 2003a, b), we display a model comprising three major chronological stages, with some overlap between episodes (Fig. 15.7). The first stage named Janelão I is related to the initiation of a

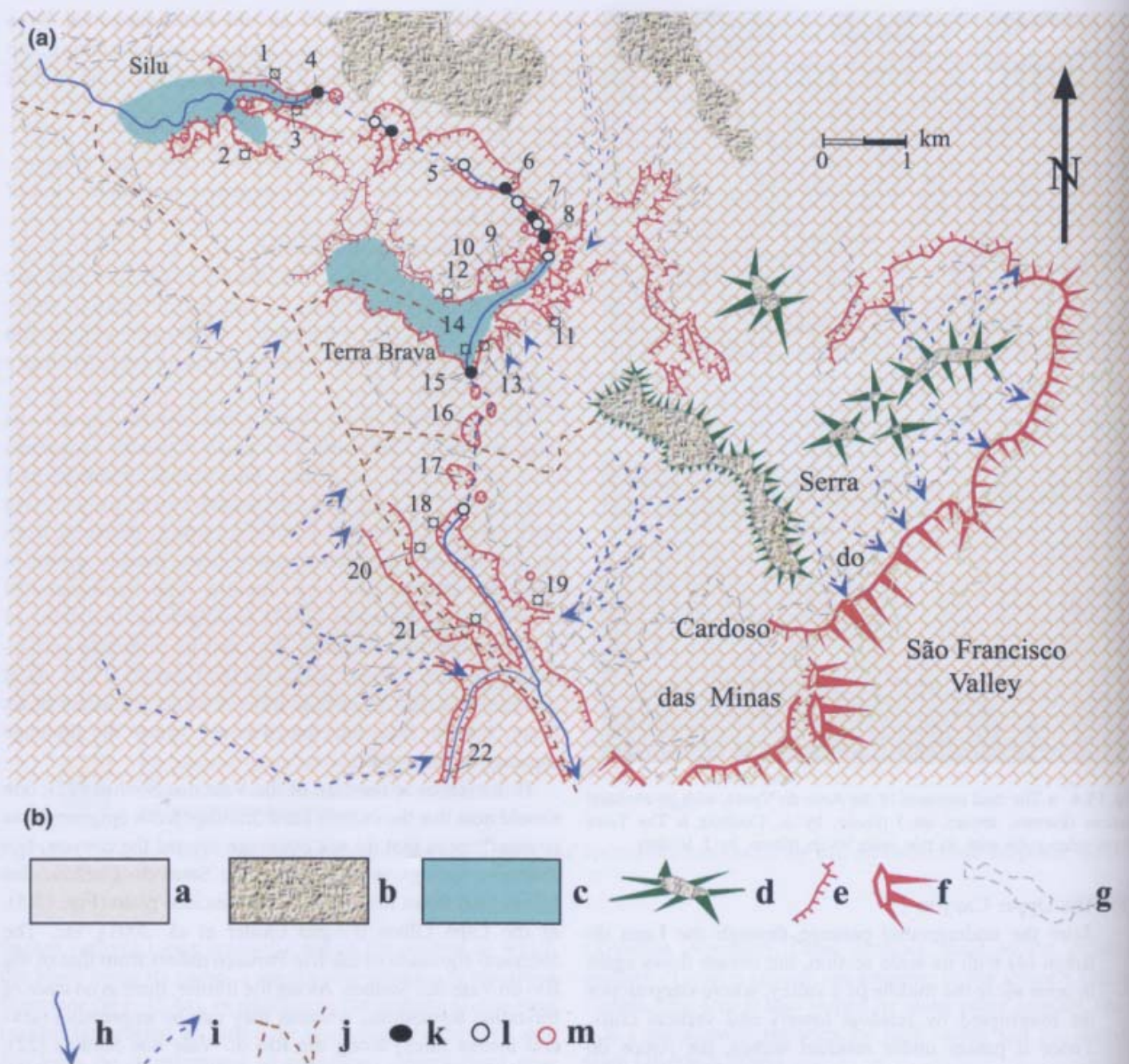


Fig. 15.5 Peruaçu karst canyon. Location of the main sites mentioned in the text. **a** Bambui limestone; **b** Urucua cover; **c** paleo-polje; **d** Urucua residual hill; **e** small escarpment; **f** large escarpment; **g** 700 m

asl elevation line; **h** perenne river; **i** seasonal creek; **j** main vehicle track; **k** swallow hole; **l** spring cave; **m** shaft, vertical doline

large karst network of the draining system. The second stage consists to flooding and filling of this network together with sinking of karstic depressions or poljes in several protracted phases. This stage is named “Terra Brava” after the most impressive depression. The third stage named Janelão II consists in a major and sudden lowering of the base level. The draining system is crosscut and reorganized along a single axis (Rodet et al. 2009).

15.5.1 First Stage: Janelão I

An original underground drainage network must have developed as a dense and anastomosed system with confluences and diffuence (Auler et al. 2005). It was moderately hierarchic (with several master caves), a sign of drowned low-energy karstification. Relicts from this first karstification period are numerous:

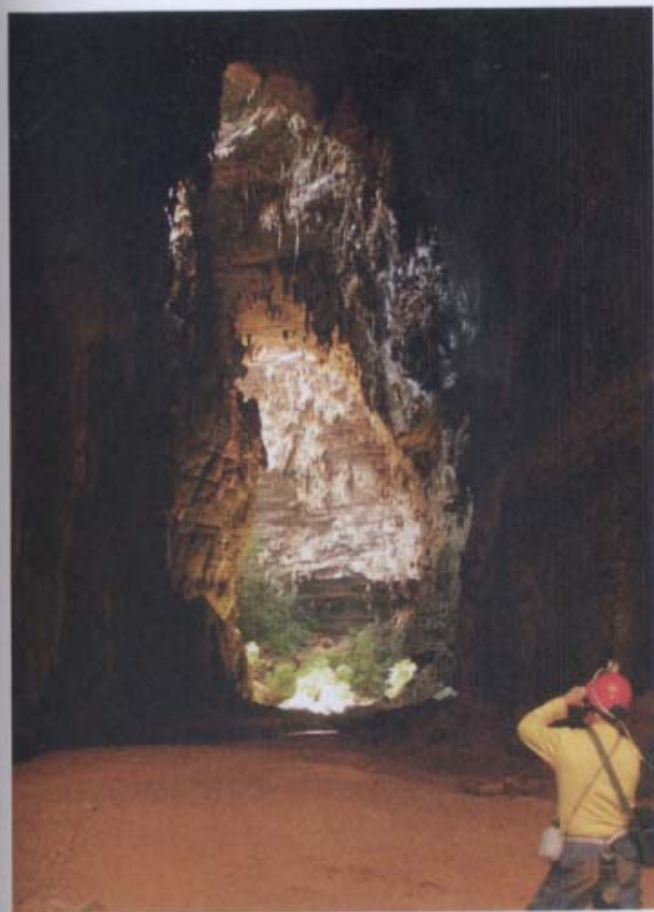


Fig. 15.6 The Janelão main gallery, a 100-m high complex conduit (photograph by J. Rodet)

- Downstream, between Terra Brava (14) and the São Francisco valley, one observes several caves with large sections, isolated in the current topography but which must have formed a network. These include the Lapa do

Rezar (19) and Lapa dos Bichos (18) (Fig. 15.8), each limited upstream by collapse of the cave roof; the underground Janelão ensemble (15), at least the upper part of the mega-gallery, including the Minotauro diffluence (Chabert et al. 2003) and the Dolina dos Macacos (16), which is actually a canyon resulting from the collapse of a primitive Rio Peruaçu master cave (Fig. 15.7), the upper entrance of the Janelão sinkhole, and the various underground passages accompanying the dolines opening into the Janelão drain (Moura 2001). The base of these various features, practically all on the same level, roughly indicates the altitude of the original drainage system.

- In the depression of the Terra Brava (14), which was not yet open, this drainage level is indicated by numerous relict caves: Falso Janelão (13), Indio, Suspiro (12), Bonita (Rubbioli 1999c), Pimpo II (10), Boquete (9), Desenhos (11), etc., which must be part of the same network.
- At the level of the Lapa dos Troncos and Lapa Cascudo (Rubbioli 1999b), which did not yet exist, a hanging canyon illustrates this first drainage level. This canyon may have formed from a primitive underground gallery.
- Further upstream, the Arco do André (Rubbioli 1999b) and Arcos do Vento (Fig. 15.4a) indicate this primitive level with a set of residual drains, to be found also in the Lapa do Brejal (Rubbioli 1999a). Upstream from this large cave, on both sides of the current Silu flood zone, one can see the Lapa do Carlúcio (1) on the left bank, and the Lapa do Caboclo (2), Lapa dos Morcegos (3), Lapa dos Ossos (3), and Lapa do Cavalo (3) on the right bank, to mention only the major ones.
- In the adjoining valleys, much less studied, the large Malhador shelter (20) is certainly a relict cave from this

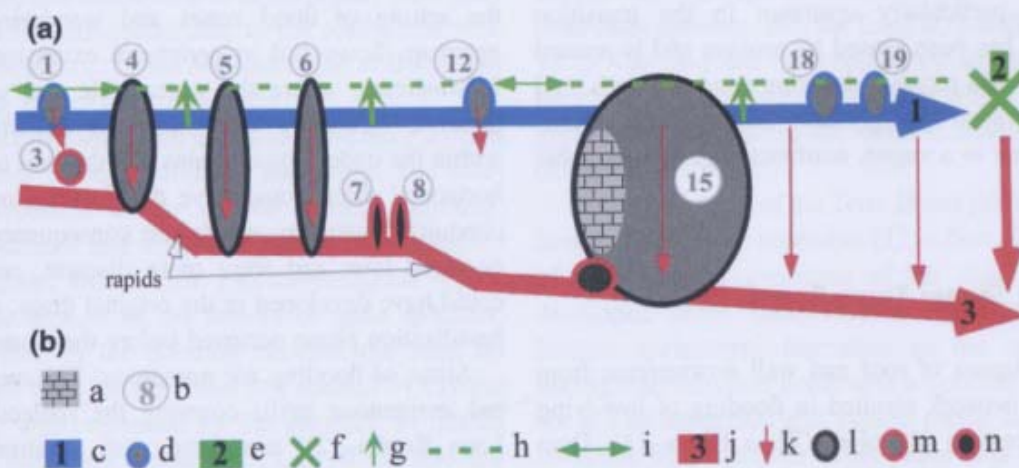


Fig. 15.7 Theoretical model of karst evolution. **a** calcareous substrate; **b** karst feature number mentioned in the text; **c** first karst stage or "Janelão I stage"; **d** operational cave drain during the Janelão I stage; **e** second karst stage or "Terra Brava stage"; **f** damming effect; **g** upward water level (waterlogging); **h** gallery infilling phase; **i** polje opening

upstream: Silu (1); downstream: Terra Brava, between (12) and (16); **j** third karst stage or "Janelão II stage"; **k** downward water level with dynamic regressive erosion; **l** current flow gallery adapted from the first karst stage; **m** current inactive gallery adapted from the first karst stage; **n** third-stage swallow gallery of the Janelão Cave



Fig. 15.8 The Bichos Cave, large fossil gallery testimony of the “Janelão I stage” (photograph by J. Rodet)

phase. Several caves of the Vale dos Sonhos must also belong to this phase. Note that the major part of this initial maze, particularly upstream in the transition compartment, has been erased by erosion and is present in the form of cliff recesses, hanging conduits, dells, and depressions invaded by vegetation. Only the major drains contribute today to a vague, nonfunctional hydrographic network.

15.5.2 Second Stage: Terra Brava

Damming by collapses of roof and wall downstream from the underground network resulted in flooding of low-lying zones and the creation of poljes (Terra Brava–14). Dam formation led to dynamic geomorphological adaptations, temporally and spatially staged, and the delay increasing with the distance of the studied point from the dam. This resulted in downstream-to-upstream terracing of flood land-forms. The main consequence was decreased flow dynamics,

leading to the deposition of alluvial sediments (finer and finer in the upstream direction) on a coarser basal layer, to the setting of flood zones and wandering channels for upstream flows and to peripheral extension of the poljes. Downstream, where the water table rise was earliest and greatest, classically there appeared equilibrium chimneys within the underground drains. On the roof of such a shaft, a horizontal drain could have developed (duplication of the conduit). Upstream, where the consequences of damming occurred later and were more discrete, ceiling half-tubes could have developed in the original drain, especially if the fossilization phase occurred before the water table rose.

Signs of flooding are numerous. The most common are red terrigenous infills covering the speleothems (e.g., the Lapa Bonita–12), associated with equilibrium chimneys: Lapa do Boquete (9), Dolina da Onça caves (17), etc. (Moura 2001). There are also many signs of clasto-alluvial filling: lithified paleo-deposits in the Lapa dos Bichos (18), Lapa do Janelão (e.g., the Galeria do Minotauro–15), Abrigo do Malhador (20), Lapa dos Desenhos (11), Lapa do

Carlúcio (1), etc. It clearly appears that there was not just a single flooding episode but several successive ones, including two major episodes that had an impact on the Terra Brava polje (Fig. 15.4b).

Signs of the opening of the Terra Brava depression (14) are diverse and include more than 10 m of fine lacustrine sediments, with wandering channels, upstream from the Lapa dos Troncos (8), basal notch of the small left-bank cliffs, associated with an alluvial terrace deposit between Troncos and Terra Brava, the residual Antônio Cardoso inselberg (14) covered with the lacustrine deposits of Terra Brava, the upper and lower levels of Terra Brava, the paleo-terrace with sand and pebbles below the upper entry Janelão ponor, etc. Lastly, one can envisage that this infill, responsible for the rise in the water table, might have also been responsible for the creation of ceiling half-tubes and/or upper drains, as found in certain caves of the Silu flood zone (Carlúcio, Ossos).

15.5.3 Third Stage: Janelão II, a Fluviokarst

The flow subsided to a 50 m lower level causing a major process of retrogressive erosion, thereby eroding and remodeling the old drains. The cause is located in the São Francisco valley and seems to be due to sudden collapse of the graben floor. The consequences of this major, rapid subsidence phase are as follows:

- conduits were left hanging,
- partial clearing of drains,
- fissure-guided carving (with shortening) of a new, straight canyon between Fabião and the resurgences of the Lapa do Janelão,
- concentration of flows along a single axis, from the Brejal to the Janelão, and abandonment of secondary axes such as the valley that connected Silu to the confluence with the Rio dos Sonhos (22), via Malhador (20) et Boqueirão (21), creating fluvio-karstic dynamics,
- adaptation mechanisms, with drainage subsidence toward the water table through suffosion and scour. The morphoclastic evolution of the canyon caused damming, leading to localized and temporary phases of flooding up to present time, but whose geomorphological traces remain slight because of the brevity of these episodes. This is the case of the flooding between the Arco do André (5) and the Lapa do Brejal (4), studied by Coelho et al. (2011) and evidenced by the presence of floated plant trunks (Rubbioli 1999a, p. 37), or of the flooding further upstream in the Lapa do Carlúcio (1) (Mascarenhas 2008).
- acceleration of the flux, remodeling the main drain and transforming the canyon into a privileged flow axis, generating a fluvio-karst.

The signs of subsidence of the water table are numerous along the course of the Rio Peruaçu. At the downstream end, the subsidence of the water table gave rise to the greatest difference in height, sometimes exceeding 50 m, this being the site of the longest exposure to the effects of subsidence. In this section, one often observes duplication of the drain and disconnection of the modern drain from the primitive one. The latter displays "paleokarst"-type elements, isolated when the modern drain was carved out. In the Peruaçu system, this evolution is illustrated by the isolated mega-drains of Rezar (19) and Bichos (18) and also the capture mechanism of the flow of the Abrigo do Malhador (20) by leaks through the pass of the previous Boqueirão cave (21).

The disjunction point between the two "Janelão" morphodynamic stages is evidenced by the following elements. In the downstream part of the Janelão cave, the mega-gallery runs up against a huge, largely calcified rock slide at the downstream part of the drain, while at the foot of the gallery, two smaller openings lead to the modern canyon isolating the primitive drains of Bichos (18) and Rezar (19).

The mega-gallery of the Janelão reaches exceptional dimensions: 106 m in height and 60 m in length (Fig. 15.6). Examination of the drain reveals (i) remains of cemented infill stuck to the walls several meters above the ground, (ii) the diffuent gallery of the Minotaure (Chabert et al. 2003), hanging more than 30 m above the stream bed, and (iii) all lateral galleries or openings of the main drain hang tens of meters above the current bed, including the Dolina dos Macacos (16), which is in fact a canyon (Fig. 15.2b).

The mega-gallery actually results from duplication of the drain (Fig. 15.6), which reaches its utmost dimension without resulting in disjunction, as attested by the superimposition of two drains on successive levels, the upper, primitive fossil drain and the new drain through which the stream runs. This can be seen at the ponor where the Peruaçu penetrates upstream into the Lapa do Janelão (Figs. 15.5 and 15.7). The cave can be accessed via an upper opening, distinct from the relatively small ponor which contrasts with the gigantic dimensions of the drain immediately downstream (Rodet et al. 2005).

At the periphery of the Terra Brava polje (14), the Bonita-Suspiro-Indio cave ensemble (12) offers elements indicative of chronological evolution of the depression. The well-developed caves underwent a fossilization phase, with intense speleothem formation in the drains. Then, the underground cavities underwent a flooding phase that buried the lowest stalactites and caused partial dissolution of speleothems by floodwater. This phase was contemporaneous with the upper level of the two flat extensions of the Terra Brava polje (fine reddish sediments forming flat ground). In the third phase, emptying of the polje occurred, causing the fine elements accumulated in the drain to be carried away through suffosion and drying (Indio cave is suspended above

the depression, one notes racking of sediments in Bonita cave, and terrigenous relicts in Suspiro cave, etc.). These caves are no longer active and are disconnected from the Rio Peruaçu drainage system.

Upstream from the Terra Brava depression, below a canyon (an initial drain re-carved by the topography), one can observe a new drain of smaller dimensions than the Janelão. It consists of the Cascudo (7) and Troncos (8) caves located immediately upstream from the first rapids. These rapids show that the stream has not yet re-equilibrated its longitudinal profile. The cumulative height of the canyon and of the newly formed drain is smaller than that of the Lapa do Janelão.

Upstream, relict endokarst elements (Arco do André-6, Arcos do Vento-5; Fig. 15.4a) alternate with widely open canyon segments where rapids are more numerous but of lesser amplitude, before reaching the Lapa do Brejal (4) whose basal incision is only a few meters and whose base is greatly encumbered with terrigenous sediments. The secondary drains of the Brejinho appear several tens of meters above the modern stream.

Upstream from the Brejal, around the large Silu flood zone, the canyon is flanked by two sets of caves, Carlucio (1) on the left bank and Ossos/Abelhas (3) on the right bank. These two ensembles display signs of subsidence of the water table from an upper level to a level 20–30 m lower, from drains with a large cross-section (1–3 in Fig. 15.7). Further upstream, we exit the canyon and the morphological elements become less evident and harder to interpret. No significant data are available because the water table variations were very small and exploration of the caves has not yet been completed.

Even in the Vale dos Sonhos (22), tributary of the Peruaçu, there is a 22-m difference in level between the emergence and the basal platform, in the narrow passage duplicated by a high, narrow cave with several drainage levels and a spectacular ceiling half-tube. This difference is highlighted by many temporary dams generated by abundant accumulation of biochemical travertine.

What caused subsidence of the water table? It seems that one can rule out a local cause, as Bitencourt (1998) and Bitencourt and Rodet (2001, 2002) observed a water table subsidence of the same magnitude (40–50 m) in the Morro Furado Canyon (Serra do Ramalho), 200 km further downstream in the state of Bahia. This canyon is also a tributary of the Rio São Francisco. It thus seems logical to envisage a regional cause, on the scale of the São Francisco basin, in its mid-lower part (state of Bahia). Brazilian structural geologists have identified several tectonic phases (Saadi 1991) that might have caused this major activity of the graben (Lopes 1981). This infra-plate tectonic activity is still ongoing, with several earthquakes since May 2007 reaching a magnitude of 3.5–4.9 on the Richter scale (França and Barros 2007), with some epicenters located in the Peruaçu basin.

15.6 Conclusions

The Rio Peruaçu basin is a spectacular example of karst system evolution accompanying the Cenozoic history of the Rio São Francisco valley, resulting from interrelations between the carbonate substratum, tectonic re-shifting of the graben, and climate forcing. It offers an illustration of karst evolution with its major initial phases, its juvenile organization, its mature concentration along a fluvio-karstic axis with spectacular morphologies, and its relicts of abandoned and disconnected paleokarst. The result is a unique, grandiose, highly diverse landscape that struck the imagination of its first inhabitants. These people decorated many rock shelters, buried their dead there, hunted, camped, looked for stone material with which to make their tools, and crossed the great canyon to seek upstream, on the sandstone Veredas plateau, the products needed for their well-being. In their eyes, it became the "Peruaçu," the same "Peruaçu" that attracts tourists and researchers from Minas Gerais, from Brazil and beyond, even from the other continents. This is why the Parque Nacional Cavernas do Peruaçu was created.

Acknowledgments In memory of two great friends, Helena David (1955–2010), speleologist of the heart depths and Claude Chabert (1939–2009), leader of the survey project of the Janelão Cave. We wish to thank everyone who helped us access information and locations, in particular the IEF (State Institute for Forests) and its manager of the "Veredas do Peruaçu" State Park (João Roberto), the IBAMA and its Fabião office (Emerck Cipriano, Danilo, Flavio), and the Grupo Bambuí de Pesquisas Espeleológicas who enabled us to discover the underground Peruaçu (Luís B. Piló, Augusto S. Auler), without forgetting the friendly and unconditional support of Sueli Aparecida do Nascimento.

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