

New approach of the karstic evolution of the canyon of the Peruacu river (Januária - Itacarambi, Minas Gerais, Brazil)

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Abstract:

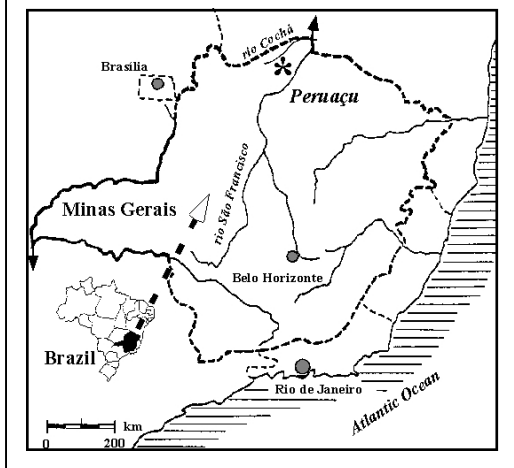
Tributary of the left side of the São Francisco river, the Rio Peruacu Basin is an important site for archaeological and geomorphological studies in the Central Brazil. From its springs in the sandy detritic layers of the São Francisco-Cochá border, the Peruacu River flows out to its confluence with the main river, 100 km farther. In its middle watercourse, it has dug a very impressive karstic relief with canyon into the limestone layers. Resulting in these majestic epikarst and endokarst forms the complex evolution begins to be understood.

The morphological observation of this great canyon and of the associated forms (caves, sediment deposits, landforms, ...) has placed in a prominent position various complex elements, revealing several phases of the karst evolution. From this, appear two great digging phases stored in 50 m and separated by a complex stage of inundations attributed to the roof collapsing of the great gallery which opened the canyon and the Terra Brava polje too. Consequently i) testimonies of a first drainage stage (Janelão I) are hanging and detached of the current geomorphological context, and ii) adapted forms to inundation phases (Terra Brava) iii) or/and water level lowering (Janelão II) can be identified. The karst system evolution during the Cenozoic is explained in a conceptual model which can be extended to other karst systems of the São Francisco middle stream, showing the regional value of the agents responsible for this evolution.

Introduction

The River Peruacu Basin develops on the left margin of the Rio São Francisco (fig.1), north of the Minas Gerais state (Brazil). In its lesser course, the river cross through the Bambuí limestones, of Proterozoic age, lying over the basement of the São Francisco craton, opening an impressive karst landscape with very deep collapse dolinas over a fluvio-karst drainage (fig.2). For over 17 km, it develops a large canyon interrupted by great tunnel caves [Piló & Kohler, 1991]. Always local people was attracted by these features, from early aboriginal tribes to archaeologists and tourists [Prous, 1992]. Geomorphological study is recent with the early research of Piló [1997]. At the end of the nineteen nineties, we realised a multi-field approach [Rodet *et al.*, 2002] reaching to a new proposal for the karst evolution of this area [Rodet & Rodet, 2001].

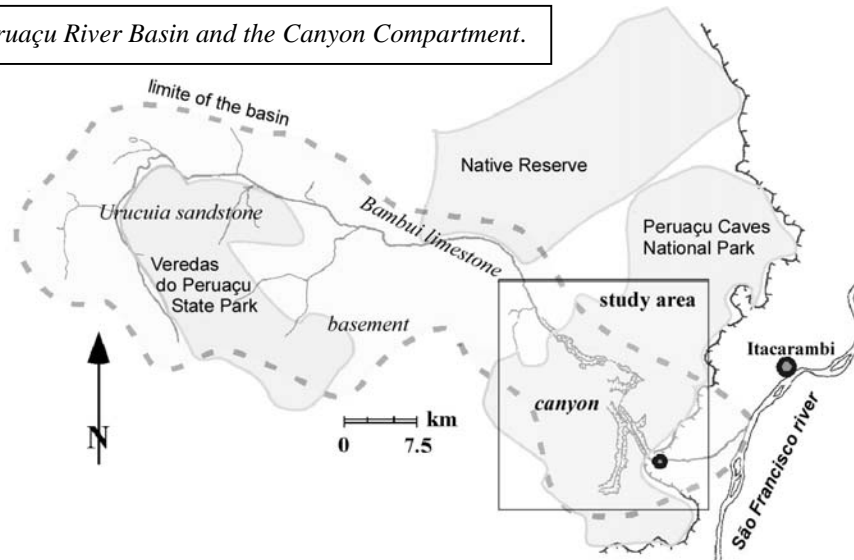
Fig. 1: Location of the Peruacu River Basin, in Minas Gerais state (Brazil).



Most of the Central Brazil develops in the São Francisco Craton formed during the Pre-Cambrian [Almeida & Hasui, 1984]. In Minas Gerais state, it is including the carbonated sequences of the Bambuí group formed at least 580 My ago [Dardenne, 1978]. Over these unities, the detritic Urucua Formation (upper Cretaceous) was occasionally deposited after a hiatus of few hundreds millions of years [Projeto RadamBrasil, 1982]. The basement only points to the surface in the middle basin area where the erosion cut off the sandy cretaceous covering layer. The canyon develops into the limestones, in the lesser part of the Peruacu Basin, between the middle basin with basement rocks and the junction with the main valley of the São Francisco River [Piló, 1997].

During 17 km, the river has dug into the limestone layers a 200 m deep canyon with vertical walls. Six times, the river sinks into galleries, resulting in impressive arches or great tunnels developing several kilometres. The biggest caves are the 'Lapa do Brejal' and over all the 'Lapa do Janelão', with a 100 m high roof in a gallery of over 50 m wide.

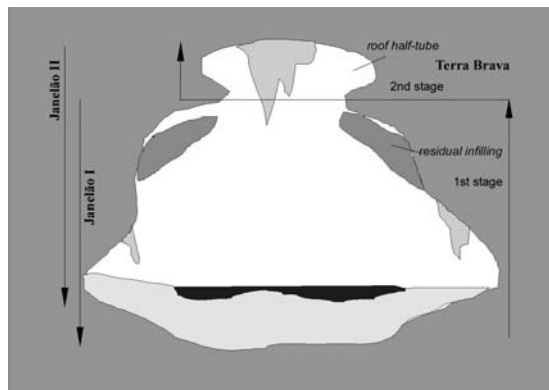
Fig. 2: the Peruaçu River Basin and the Canyon Compartment.



1. Two main karst opening stages: Janelão I and Janelão II

Upstream, the river cross first through the Brejal cave for several hundred metres. Near the resurgence, the cross section shows (fig. 3): i) a roof half-tube, ii) an hanged residual old river deposit at the base of the roof channel, iii) a large basal gallery with a small river. That demonstrates at least two stages of gallery excavation, the upper one being the most recent [Rodet *et al.*, 2004b].

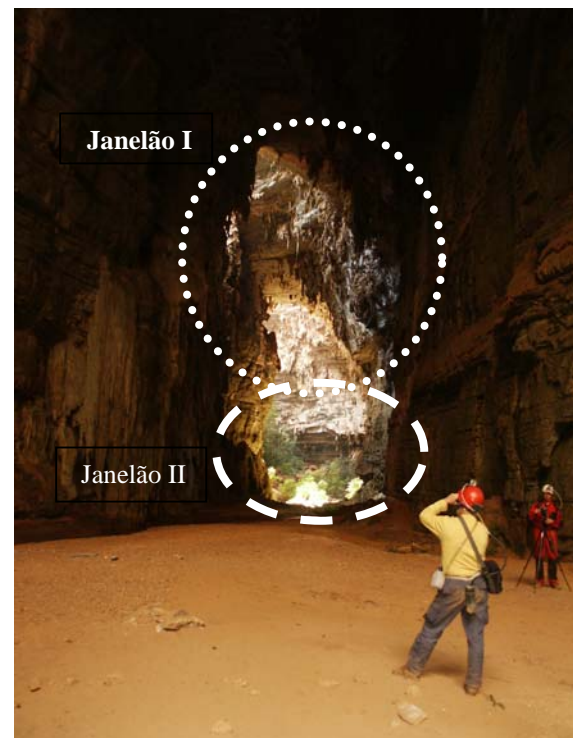
Figure 3: cross section of the Brejal cave



Downstream, the river cross through the Janelão gallery, the largest cave of the Peruaçu karst (fig. 4). The present sinkhole is a small gallery of about few metres diameter, dug fifty metres under the upper entrance. This fossil entrance is bigger, around fifty metres diameter. Few tens metres after the entrance, the two passages joint into a large gallery of about one hundred metres high. These two entrances illustrate two different stages of the cave evolution, separated by fifty metres [Rodet *et al.*, 2004a]. Between these two caves, the Peruaçu river shows several rapids, indicating a present dynamic stage of the river flow.

Near the São Francisco main valley, the Peruaçu canyon is very strait and linear. Both border cliffs contain relict tunnel caves, fifty meter over the current river. We suppose that this part of the canyon is modern and is imposed over the ancient topography, cutting the old features, like the residual bench near the Bichos' cave, on its way [Rodet *et al.*, 2003].

Fig. 4: cross section of the Janelão cave, near the current sinkhole.



2. One karst infilling complex stage: Terra Brava



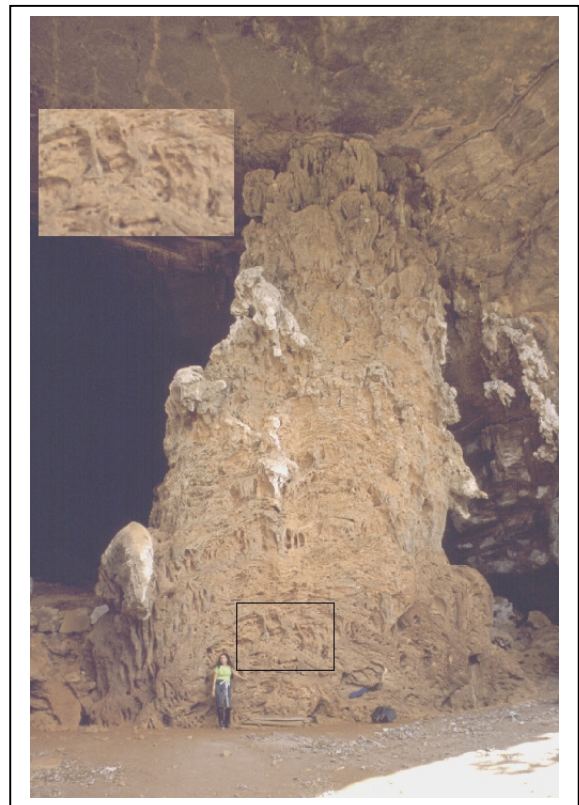
Around the great depression called Terra Brava (fig. 5), a lot of elements demonstrates large phases of inundation at various levels: a gravel-stone terrace near the Janelão upper entrance, a ten metres deep clay terrace lying over a basal pebble conglomerat, with superficial drainage channels, relationed with the landscape features (flat areas, foot notch in the peripheric cliffs near the current Troncos cave, altitudinal similarities in cave drainages and/or in terrigenous terraces, wall speleothems without their wall support in the Bichos cave (fig. 6), and so on.

Fig. 5: The polje of Terra Brava with its two main sedimentary surfaces. View from the Falso Janelão cave.

Fig. 6: The massive speleothem in the Bichos' cave showing its internal structure: its terrigenous support has been removed by the water drainage.

3. A five stage karst regional evolution

The evolution of the karst area can be resumed in five stages [Rodet & Rodet, 2001]. The river crossed through the carbonated compartment protected by the impermeable covering formations, and joined the São Francisco depression (fig. 7.1 – ante-karst stage), until the limestone substrate emerged in the upstream part of the compartment (fig. 7.2 – incipient karst stage). Superficial water began to penetrate underground and formed a large karst network which joined the alluvial plain, while concentrating on its course, several tributaries. resulting from losses into cover layers. Little by little these layers have been involved into the powerful underground drainage (fig. 7.3 – juvenile karst stage). A filling of the main drainage between Terra Brava and the São Francisco valley is responsible for a complex stage of overflow surface allowing the development of the polje of *Terra Brava* (fig. 7.4 – mature karst stage). Then an underground capture of this area by a small river allows the re-opening of the drainage network and the return of an effective erosive incision (palaeo terraces of the river Peruaçu).



The covering layers continue to creep into the endokarst within collapses which punctuate the larger drains, at the origin of the digging of a great number of gullies or *voçorocas* contributing to the dismantling of the cover and carving incisions into the carbonated substrate (fig. 7.5 – rejuvenated karst stage), resulting in a ruiniform evolution of the karst landscape (pitons and towers, hums, ...). Tectonics is of an high importance in this evolution but the numerous faults are not indicated to not complicate too much the scheme. It results to a fluvio karst drainage favourable to the human implantation with very numerous rock shelters in slope and clift, and with a lot of lodgings of mineral resources used for stone tools, illustrating a perfect integration of primitive human groups in a karst region [Rodet *et al.*, 2002].

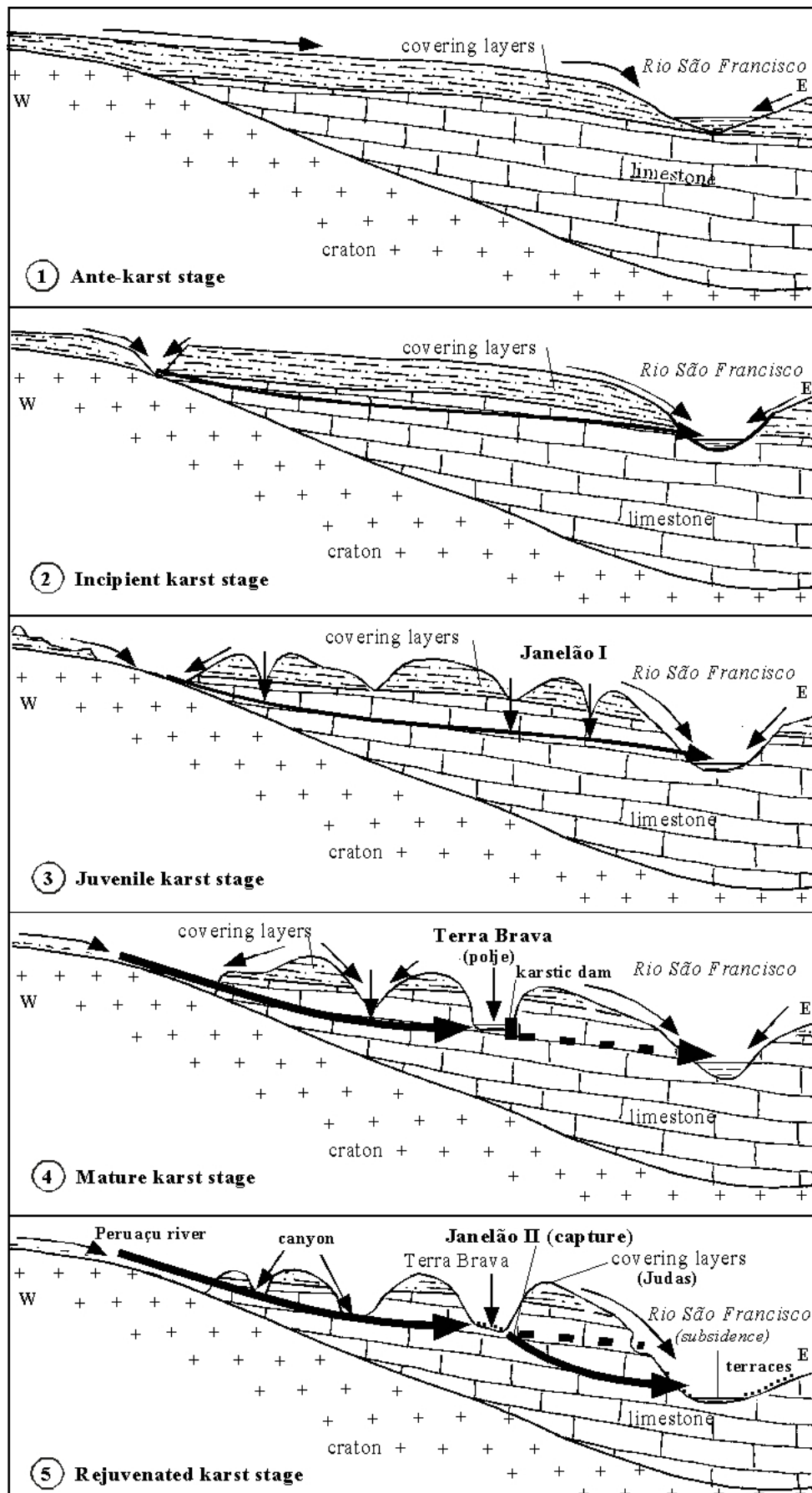


Fig. 7: five evolution stages of the karst of the Peruaçu Basin.

4. Theoretical karst evolution model

The theoretical model of the karst evolution in the Peruaçu Basin [Rodet *et al.*, 2003, 2004a, 2004b] can be presented in three main stages (fig. 8).

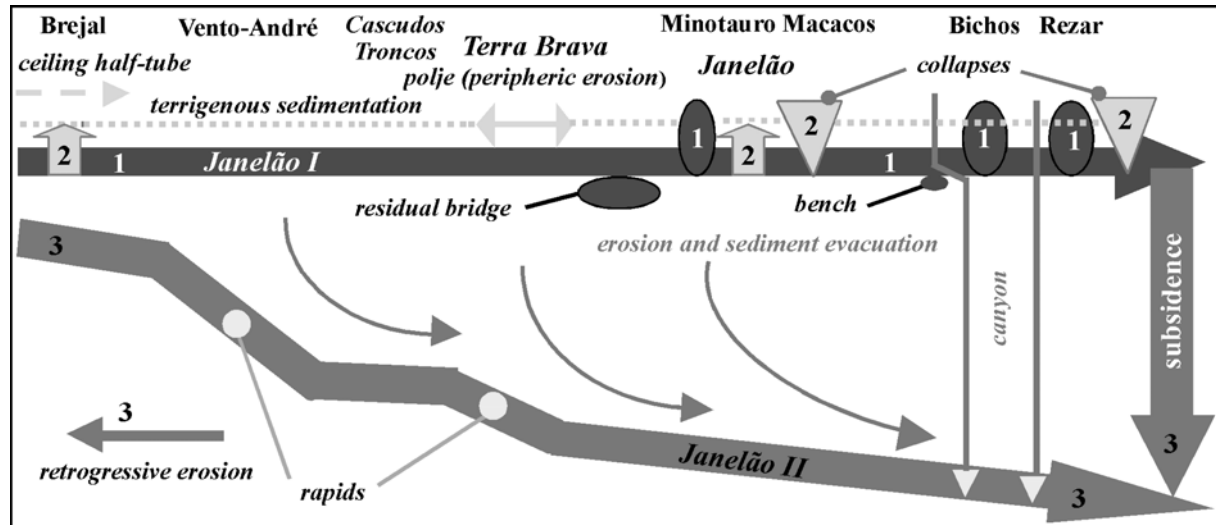


Fig. 8: theoretical evolution model of the Peruaçu River Karst

1- Janelão I : former water level, identified in the upper part of the main conduit of the Janelão cave, in connexion with the Minotauro gallery and the Bichos' cave and the Rezar's cave. It seems that a former Troncos cave was excavated on the right merge of the River Peruaçu, later transformed into a canyon. The current Troncos cave has been opened during the third evolution stage (Janelão II).

2- Terra Brava : damming of the drainage by several collapses of the cave roof between the Janelão main gallery and the confluence to the main valley (São Francisco), giving the great dolina dos Macacos's shafts, infilling all the caves connected on the river drainage from the Rezar to the Brejal, opening a multiphased polje in the Terra Brava site, and digging a ceiling half-tube in the roof of the Brejal's cave. The elevation of this half-tube is similar to water infill testimonies in the Arco do André cave (Piló, pers. comm.).

3- Janelão II : important subsidence of the water level (over 50 m), digging out the lower part of the canyon (residual bench), cutting the connexion between Bichos and Rezar. The river retrogressive erosion opens the lower part of the Janelão's gallery, taking away elements of the collapse and infillings, and leaving a residual bridge out. Around the Terra Brava polje, caves as Bonita, Suspiro and Indio are definitely deconnected out of the drainage, hanging over the depression with piping effects into their terrigenous infills. Upstream, the Troncos cave has been opened as its lateral canyon fossilised. The Brejal cave is dug down again, hanging a part of its filling over the basal gallery. The river profile is cut by several rapid zones, illustrating that this third stage is always working on today.



Fig. 9: Peebles of a paleo-terrace in the Terra Brava polje, near the former Janelão sinkhole.

Conclusion

The karst of the Peruaçu offers a complex and old evolution, directed by three main stages. The first period, Janelão I, concerns the genesis and the development of the karst network. The second period illustrates the passage from the karst drainage to the fluvio-karst drainage, when caves open and give the impressive canyon. The resulting great collapses are responsible for several cave damming phases and surface drainage adaptations, like lake with peripheric corrosion (Terra Brava polje) and underground adaptations (Brejal ceiling half-tube). An important regional subsidence influence the water base level and all the karst system in the São Francisco valley from Bahia state to Minas Gerais state [Bitencourt, 1998 ; Bitencourt & Rodet, 2001]. This neotectonics was attribute to the Cenozoic Period, and is identified as responsible of the rejuvenated karst period, illustrated by the second digging stage of the Peruaçu karst (Janelão II). Further studies will be realized to refine the chronology and to try to date the main events.

References :

- Almeida F. & Hasui Y. - 1984. *O pré-Cambriano do Brasil*. Edg. Blücher, São Paulo, 378 p.
- Bitencourt A.L. V. - 1998. *Morphogenèse, Quaternaire et archéologie en milieu karstique : le site du Morro Furado, Serra do Ramalho (Bahia) – Brésil*. Thèse de l'Université de Caen, Centre de Géomorphologie du CNRS : 212 p.
- Bitencourt A.L. V. & Rodet J. - 2001. Premiers éléments d'évolution karstique sous contrôle tectonique d'un massif calcaire : la Serra do Ramalho (Bahia, Brésil). *Geologica Belgica*, 2001, **4** (3-4): 251-261.
- Dardenne M.A. - 1978. Síntese sobre a estratigrafia do Grupo Bambuí no Brasil Central. 30º Congresso Brasileiro de Geologia, Recife, vol. 2 : 597-610.
- Piló L.B. - 1989. A morfologia cárstica do baixo curso do rio Peruaçu, Januária/Itacarambi, MG. Departamento de Geografia do Instituto de Geociências da UFMG, monografia de graduação/ bacharelado em Geografia Física : 97 p.
- Piló L.B. - 1997. Caracterização regional do carste do Vale do Rio Peruaçu. *O-Carste*, **9** (2) : 22-29.
- Piló L.B. & Köhler H.C. - 1991. Do Vale do Peruaçu ao São Francisco : uma viagem ao interior da terra. Anais do III Congresso da Associação Brasileira do Estudo do Quaternário, Belo Horizonte, **2** : 57-73.
- Projeto RadamBrasil - 1982. Folha SD.23 : Brasília. Ministério das Minas e Energia, Rio de Janeiro, Levantamento de recursos naturais, vol. 29 : 644 p.
- Prous A. - 1992. Arqueologia brasileira. Editora UnB, Brasília: 613 p.
- Rodet J. & Rodet M.J. - 2001. Evolution karstique et ressources lithiques archéologiques. L'exemple du Rio Peruaçu (Januária – Itacarambi, Minas Gerais, Brésil). Actes du XIème Congrès National de Spéléologie, Genève (Switzerland), 14-16 september 2001: 129-134.
- Rodet J., Mariano D.F., Rodet M.J., Pouclet A., Piló L.B., Willems L. - 2003. Evolução cárstica do vale do rio Peruaçu (Minas Gerais): uma nova abordagem. XIIe Simpósio de Geologia de Minas Gerais, Ouro Preto (Brazil), 4-8 november 2003, resumo: 97.
- Rodet J., Rodet M.J., Mariano D.F., Do Nascimento S.P., Huguet Y. - 2004a. La grotte du Janelão, élément-clé de l'évolution géomorphologique de la vallée karstique du Peruaçu (Januária-Itacarambi, Minas Gerais, Brésil) – the Janelão cave, key-element of the geomorphological evolution of the karst of the Peruaçu Basin (Januária-Itacarambi, Minas Gerais, Brazil). Proceedings of the 2003 AFK European Meeting, Rouen (France), 10-12 september 2003: 62-63.
- Rodet J., Rodet M.J., Mariano D.F., Willems L., Pouclet A., Piló L.B. - 2004b. Do Brejal ao Janelão, uma historia geomorfológica do Terra Brava. Carste-2004, Belo Horizonte (Brazil), 27-31 july 2004, Caderno de Resumos: 23.
- Rodet M.J., Rodet J., Do Nascimento S.P., Mariano D.F., Huguet Y., Silva J.R. - 2002. Metodologia de prospecções geoarqueológicas dentro de uma bacia (exemplo da bacia do Rio Peruaçu, Minas Gerais, Brasil). *Revista do Museu de Arqueologia e Etnologia da Universidade de São Paulo*, **12** : 25-41.