GEOMORPHOLOGICAL MAPPING OF THE SISMOTECTONIC CAVE SYSTEM OF "A TRAPA", RIBADELOURO - TUI (GALICIA, SPAIN)

Cartografía Geomorfológica del Sistema de Cavidades de "A Trapa", Ribadelouro - Tui (Galicia, España)

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Abstract: Up to now, the A Trapa system is the largest cave of granite blocks in the Iberian Peninsula, the second of Europe and the fifth worldwide. The cave is associated to a reverse fault, and its development, morphology and evolution seems to be influenced by the fault dynamics and the successive movements of blocks toward the axis of the valley bottom. The central sector of the cavity preserves a large pigotite flowstone, the oldest speleothem of this type up to the present. The different deposits allowed establishing minimum Late Holocene ages for the last evolution stage of the cave.

Palabras clave: Granito, cueva, sismo-tectónica, mapa, geomorfología granítica
Key words: Granite, cave, sismo-tectonics, mapping, granite geomorphology

1. INTRODUCTION

The A Trapa system is a group of granite cavities, which channels the underground watercourse of the San Simón River in a section of 240 m, with 94 m difference in height between the sinkhole and the emergence, and a mean watercourse slope of 27º.
1,526.6 m of passages and galleries were mapped, with a difference in height of 86.6 m between the highest and the lowest levels.
The A Trapa system is associated with a reverse fault of N125ºE direction, which coincides with the main underground channel.
The dynamics of the fault (Vidal Romaní et al. 2014) during the Paleogene seems to have triggered a large mass rocky slide with a surface of 5400 m^2 and partially covered the original watercourse of the San Simón River displacing the watercourse toward the North. During dry season, the watercourse has an underground section through the A Trapa cave, but during the periods of big floods, the river works as a double channel: the main watercourse that is displaced by the front of the slide, and the underground one that sometimes drains through A Trapa cave, 15 m below the present surface of the terrain.

1.1. Localization

The system is located at the Ribadelouro parish, Tui township (Pontevedra) on the southern slope of the mountain branch: Aloia Mount – Serra do Galiñeiro. Their permanent sinkhole is located at UTM X:526950, Y:4661152; Z:260 m.

1.2. Geology

The lithology of the area where A Trapa is located consists of a less-deformed two-mica alkaline granite with equigranular texture of medium to coarse grain. In spite of not having influence on the development of the cave, the granite was affected by the phase F2 of the Hercynian deformation with N160ºE direction. IGME (1981).

1.3. Seismo-tectonic characterization

The A Trapa system is located at the Galicia-Trás-os-Montes area of the Variscan massif. It is in the seismic-tectonic dominion I (S Galicia - N Portugal) structurally characterized by the existence of several faults active from the Tertiary up to the Upper Quaternary with prevailing NNE-SSO and N-S orientations (Viveen et al., 2012).
In this seismic-tectonic domain, more than 40 historical earthquakes have been recorded concentrated on the Atlantic littoral and northwest of Portugal. The maximum intensities confirm the existence of an important seismic activity of moderate magnitude in the boundaries of this cave and also epicentres of different importance distributed in the cross-border zone with Portugal. López (2008).
The tectonic horst Monte Aloia – Sierra do Galiñeiro reaches its present position after the

uplift of the zone between the Paleogene and the present. Between 58-24 Myr from the present, the relief uplifts and the Sierra reaches its maximum height of 700 m above present sea-level (Vidal Romaní et al. 2014). From the beginning to the middle Pleistocene the average uplift rate was about 0,8 m·ka^{-1} (Viveen et al., 2013). The uplift continues nowadays about 0.3 m·ka^{-1} with a moderate associated seismic activity (Vidal Romaní et al. 2014).

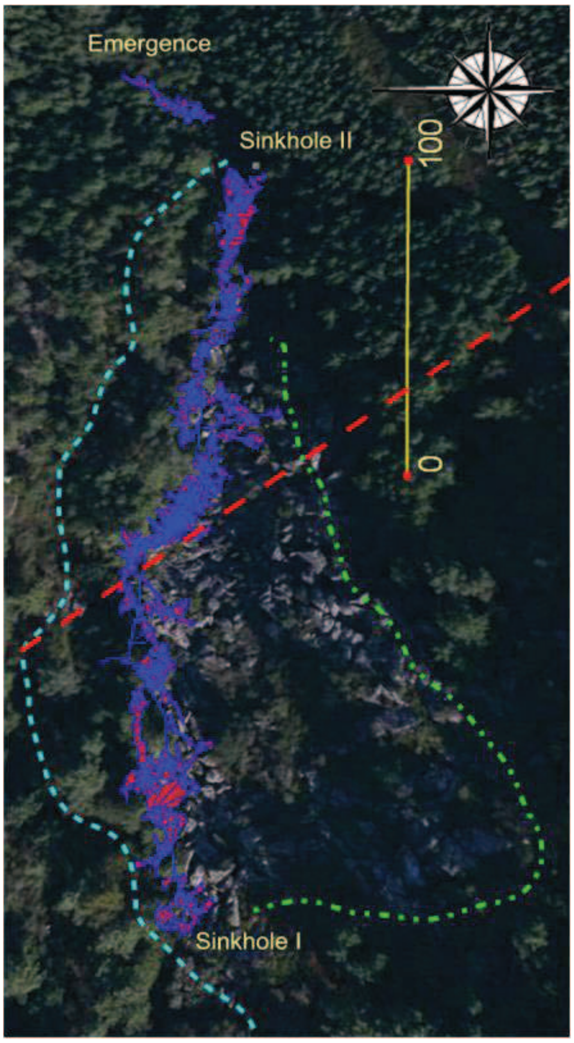

Fig. 1. Ortofotografía con proyección KML de la cueva (azul oscuro). La falla inversa se ha marcado en rojo. El límite del deslizamiento en verde y el curso superficial en cián.
Fig. 1.KML cave model (dark blue) overlaying local orthophotography . Green: head of the rock slide. Red: reverse fault: Cyan: river surface.

1.4. Hydrological and climatic characterization

The watercourse of the San Simón River evolves to ESE of the Serra do Galiñeiro, in an area of pluviometric gradient III (93-100 mm/100 m high) Martínez et al.(1999).
Its headwaters are located close to the top of the Aloia Mount (Tui). The station set on this top recorded an accumulated rainfall for 12 months of 2,356 l/m^2 during the period 2012-2013, with monthly maximum intensities of 408.2 l/m^2.
In spite of this important rainfall, the upstream basin of the permanent sinkhole has a small size (the length of the watercourse is slightly over 1.7 km), thus the large quantities of the river flows are due to the topographic effect of the Serra do Galiñeiro (700 m height) acting as a barrier to the Atlantic storms.

2. MORPHOLOGY OF THE SYSTEM

The A Trapa system formation is very old and perhaps it has followed the following stages: first the release of the rocky substratum from the weathering cover followed by an active dynamics of rocky slopes with collapse of blocks which filled in the lowest parts of the relief originating a system of cavities of "blocks caves" type (Vidal y Vaqueiro, 2007) crossed by the San Simón River.
The relationship between the cave structure and the fault N125ºE allows dividing A Trapa into three large areas: sinkhole or high zone, central or fault zone, and emergence zone.
The present underground watercourse is a channel delimited by either tilted blocks or continuous walls excavated in the "in situ" rock with undulating surfaces. Intermittently, small accumulations of decimetric boulders appear. Small-sized cylindrical potholes and numerous *scallops* were also identified. These erosive forms are located at different height above the present watercourse marking the incision stages of the San Simón River.

Fig. 2. Paleocanal normal a la dirección falla inversa
Fig. 2. Paleoflow orthogonal to the reverse fault

The erosion carried out by the river not only affects the rocky substratum but also the collapsed blocks, which filled the watercourse, thus the slide of the blocks is previous to the channel incision. However, the movements of blocks may have continued later because the potholes were tilted as the greatest axis is not in vertical position. The existence of several phases (at least two) in the slide of blocks, which covers the San Simón River in the A Trapa zone, is clearly seen. In a first phase, a generalized slide would be produced toward the bottom of the valley and would infill it. In a second phase, there was a new slide, limited to the central area of the A Trapa System, and the accumulation of blocks would cover the underground system. On the blocks of this second phase, which would be located quite above the watercourse, developed potholes are never seen as it happens on the lower blocks.

Both gravitational movements may have been helped by the basal scour made by the river, although they are mainly due to the movement of the N125ºE fault. The successive slides of blocks which took place in the zone are also seen in the changes underwent by the watercourse of the San Simón River in its underground zone. For example, it is normal to observe how the pigotite speleothems cover some old potholes or even the nascent terrace deposits. All this indicates that the conditions of the watercourse along the time went from erosive (development of pothole) to underwater accumulative (deposits of gravels) to subaerial accumulative (pigotite speleothems).

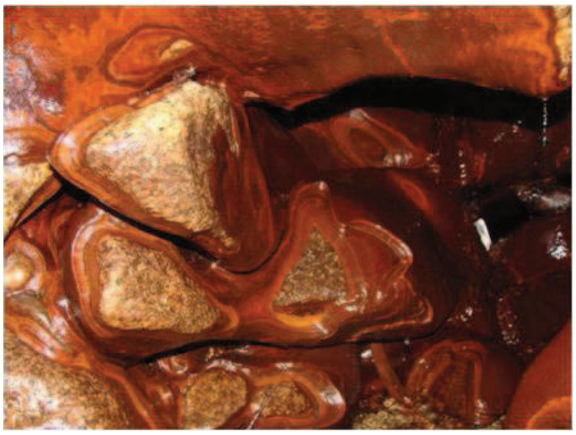

Fig. 3. Cantos rodados fosilizados por pigotita y en proceso de exhumación tras la reactivación del proceso erosivo.
Fig. 3. Boulders fossilized by pigotite are now being exhumed due to the flow reactivation

Up to now, no detailed chronology of the cave evolution could be established but only based on geomorphologic criterion. The sector called Féveros, located at the middle section of the A Trapa cave (heights between -25 and -50 m), shows the most complete sequence of forms and deposits. From floor to ceiling there are: a permanently active channel (- 44 m) and above a hanging watercourse that is only active during rise stage; above there is an intermediate hanging paleolevel (-39 m) only active exceptionally. Above there is a clearly inactive upper paleolevel (-34 m), and finally, there is a relatively superficial cave level (-28 m) which coincides with the second slide of blocks stated before.

Fig. 4. Paleonivel superior de Féveros (-34 m).
Fig. 4. Féveros sector: Upper paleolevel (-34 m)

The dating of the deposits (Sanjurjo et al.(2013), in the paleowatercourse below level -28 m, would have a minimum age of 2.7+-0.60 kyr BP (TL) while the upper level would have a minimum age of 7.05+-0.86 kyr BP (TL). Most of the Paleolithic sites of A Trapa are located at this height (Sanjurjo et al., 2013).

Fig. 5. Paleonivel inferior de Féveros (-42 m).
Féveros sector: Lower paleolevel (-42 m).

The best preserved flowstone of this area of the cave connects the three described paleolevels between heights -36 and -44 m. Its inner zone is 3,670 cal yr BP (C14) and its external part (at present eroded by migration of the river watercourse during flood periods) 2,960 cal yr BP (C14) (Figure 6).

The last section of A Trapa, emergence zone, has a different morphology. It starts after the superficial and underground courses junction, and channellings the course of the San Simón River underground on the last 26 m difference in height

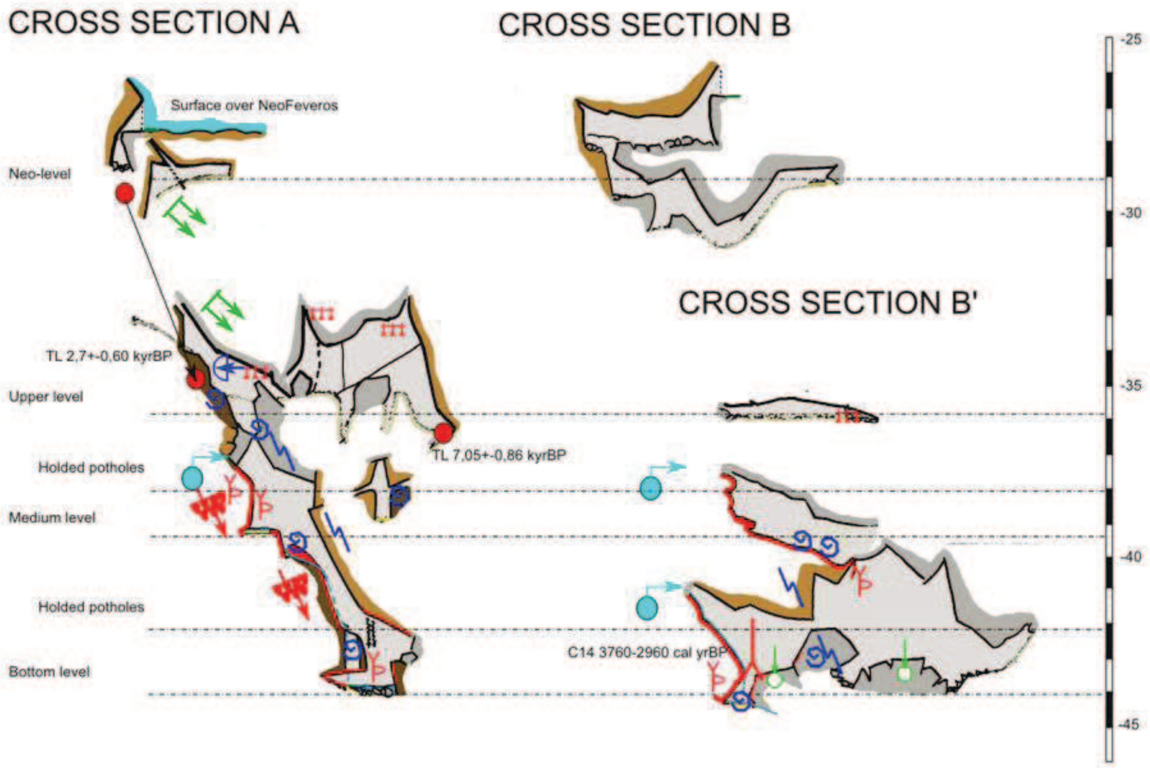

Fig. 6. Dos secciones compuestas sucesivas del sector Féveros. Las formas deposicionales fosilizan formas erosivas previas. Neoformas de erosión se desarrollan sobre las superficies concrecionadas. Colores y símbolos detallados en Costas et al (2013).
Fig. 6 Two successive composed sections of the Féveros sector. The depositional forms fossilize previous erosive forms. Erosion neoforms are developed over the concreted surfaces. Colours and symbols detailed in Costas et al (2013).

as in the rest of the cave through a chaos of blocks and in the incised parts of the watercourse in the rocky substratum "in situ", in a vadose channel with a locally asymmetrical *keyhole* profile similar to the incised conduits of the karstic systems. The widenings of the profile take advantage of the shears zones of the rock in the A Trapa system (Vaqueiro et al. 2011) like in the O Folón.

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