GRANITE PSEUDOKARST

Pseudokarst en granitos

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Abstract: The so-called granite pseudokarst is a geomorphologic process that has been poorly studied so far. In this work, references on their dimensions, morphology, genesis, etc. taken from previous literature and the authors' personal experience are stated. Granite caves have great similarities with the karstic caves s.s., though both the magnitude of the physical and chemical erosions and the final dimensions of the resulting cavities are clearly less. Like in karstic caves, the structure of the rocky massif marks the beginning of the process though, in our case, the influence of the chemical dissolution is highly inferior, the most remarkable aspect of which is the interaction with the organisms that live in this particular ecological niche.

Palabras clave: pseudokarst, granito, cueva, erosion, system
Key words: pseudokarst, granite, cave, erosion, system

1. INTRODUCTION

A cave is a natural cavity formed under the terrestrial surface, with metric dimensions where the walls, ceiling and floor are rocky, and with total darkness (Stone 1953). They are not exclusive of karstic zones because they are also known in other lithologies (quartzites, sandstones, basalts, etc.) where karstic processes do not exist (Urban y Oteska 1998).
The term "pseudokarst" encompasses all the non karstic cavities. The concept was introduced for the first time in 1906: "*... but in the fields of lava one can only speak of 'Pseudo Karst Phenomena'...*" (von Knebel 1906) though the last definition of the term was agreed at the 12th *International Congress of Speleology* of 1997: "Pseudokarsts are places with morphologies similar to karst, where there is an underground drainage of runoff through voids which act as conduits, but the evolution element at long term by dissolution and physical erosion is not present" (Halliday 2007). It is clearly evident for any geologist or geomorphologist the lack of scientific basis, or the prejudices that exist about the definition of pseudokarst in general, and especially of the development of this process in granites. Since the dimensions are not considered, the 3 factors ruling karst and pseudokarst are the same: water circulation, rock structure, and physical and chemical processes and gravitational processes.
This work exclusively refers to granite pseudokarst though may be applied to the rest of igneous rocks. Normally, the works on granitic geomorphology (Migón 2006) are focussed on their surface forms to the detriment of the underground landscape, which is ignored in many occasions, or it is taken for granted that it does not exist. This is not inconsistent with the fact that some works do consider the underground systems developed in these types of rocks (Twidale and Vidal Romaní 2005; Vidal Romaní y Vaqueiro 2007; Vidal Romaní et al. 2014).The data stated herein are not therefore an exception, but describe processes related to any granitic outcrop. Following Wheeland's criterion (1982) an update (October 2013) of the Atlas on pseudokarst of Charbert and Courbon (1997) was made, compiling more than 286 references on caves with certain importance, distributed in 37 countries and five continents. All are related to granitic rock.
Cavities of more than 15 m long were considered and in the case of rocky shelters, only those whose depth from front to end is longer than the entrance width; for the roofless caves were considered, either sinkholes or dry sinkholes, only the ones of more than 7 m deep. These size limitations were not taken into account when the cavity had a historical, archaeological, paleontological, biological or geological interest (Wheeland 1982)
The inventory here presented shows that these cavities are of micro- or mesoforms according to their dimensions, out of which 50% has less than 100 m long, 80% less than 300 m, and only 4% more than 1,000 m. We highlight the following:

T.S.O.D. Cave System (New York, U.S.A.), with 3,950 m long and 52 m of vertical difference in height, is the largest cave in the World.
The worldwide deepest caves developed in granite are *Faille du Mont Sapey* (Savoie, France) of -180 m depth, and *Hurricane Cave* (Colorado, USA) of 169 m depth and 1,180 m long.
The largest granite cave of Europe is *Boda Grottor Cave* (Ingesund, Sweden) of 2,600-2,900 m long.
In Spain, there are 8 cavities with more than 200 m of longitudinal length so far:

- A Trapa (Pontevedra, Spain) of 1,526.6 m long and 86.6 m of difference in height.
- O Folón (Pontevedra, Spain) of 905 m long and 32 m of difference in height.
- Albarellos (Ourense, Spain), under study, but of more than 430 m long and 33.2 m of difference in height.
- Adeghas (Ourense, Spain), under study.
- O Cibro, O Pindo (A Coruña, Spain), under study.
- Os Profundos, Monte Louro (A Coruña, Spain), under study.
- A Chousa (Pontevedra, Spain), incomplete tophography.
- A Porteliña (Pontevedra, Spain) of 105 m long and 7 m of difference in height.
- Las Potras de Montehermoso (Cáceres, Spain), under study.

Though the term pseudokarst stresses the "lack of evolution at long term by dissolution and erosion", it is convenient to underline that for the Galician caves the ages range from the Paleogene (Vidal Romaní et al. 2014) up to the present. On the other hand, they have an archaeological value for they are the first troglodyte shelters described up to the moment outside the Galician karstic zones (Sanjurjo et al. 2013). In this sense, the ages assigned to the granite caves of *Boda Grottor* (9,663 BP) and *Höllick* (9,813-9,663 BP) in Sweden obtained from the dating of paleoseismic events that originated them (Mörner and Sjöberg 2011) indicate that they would be more modern than the Galician ones, which is understandable taking into consideration that they were covered by ice during the Quaternary glaciations.

2. TYPES OF GRANITE CAVES

There are different morphogenetic and genetic classifications for the pseudokarstic cavities. (Striebel 1996; Gaál y Bella 1994).
In agreement with the authors' experience and revision of the main specialized texst on the subject (Twidale 1982; Vidal Romaní and Twidale 1998; Twidale and Vidal Roman, 2005) the types of granite caves are classified as follows:

- Caves developed along major fracture planes. Widening is essentially due to weathering and ulterior washing, leading to further enlargement of the sizes of the fracture.
- Caves in blockfields accumulated by gravity or associated to collapses due to sismic movements.
- Tafone is the third type of cavity. The term refers to a cave or hollow developed inside a diaclase system-defined block. Inside the cave, the vault may show clusters of alveoles (honeycomb structure), mamillated (convex relief) or scalloped (concave relief) forms (Twidale and Vidal Romaní 2005).

The largest systems of cavities developed in granite mainly correspond to the first two types.

3. EROSIONAL GRANITE CAVE SYSTEMS

The most evolved cavities are formed when the superficial drainage system totally or partially captures the diffuse or concentrated runoff channelizing it underground through the discontinuities of the structural system of the rocky massif. Two subtypes are considered (Vidal Romaní and Vaqueiro 2007):
Structural caves (Vidal Romaní 1989): are related to fracturation or jointing zones of the rocky massif that lead the rock weathering. The evacuation of the regolith will create the cavity increasing its size. In other cases, it is the ice wedge combined with jointing that originates the cave. (Boda Grottor, Sweden).
Boulder caves or erosion boulder caves (Striebel 1996): are formed after the lineal incision made by a watercourse of a rocky massif originating a narrow, water-carrying gorge of vertical walls. The following stage is produced when the collapse of slopes takes place, temporarily blocking the channel with the blocks. Later, the watercourse will be reorganized through the chaos of blocks.

3.1. Characterization of the cave and its system of galleries.

The caves of blocks are characterized for having an outline in discontinuous sections with variable dimensions and morphology formed by the voids left between adjacent blocks. In structural caves, the system of galleries digged in the rocky substratum is led first by the structural plane that channelizes the water, and its final length will depend on the flow and relative base level. The distribution of the galleries, at least initially, is associated with the 3 main systems of factures which affect the massif: horizontal and vertical plane, and sheet structure with variable dipping and direction. The dependence of the structure makes the most common cave pattern be a network which consists of intersecting discontinuities arranged in a (quasi) orthogonal pattern.

3.2. Morphology of the galleries

Due to the "chaos" of blocks that generally fills the channels, it is difficult to represent the cross-section profile of the conduit, which requires complex cross-sections drawn from the partial sections of conduits located on the same reference plane, which are finally put together to obtain the longitudinal profile of the channel (Vaqueiro et al., 2007). The most common cross-sectional patterns are vadose and incised passages (key-hole profile).

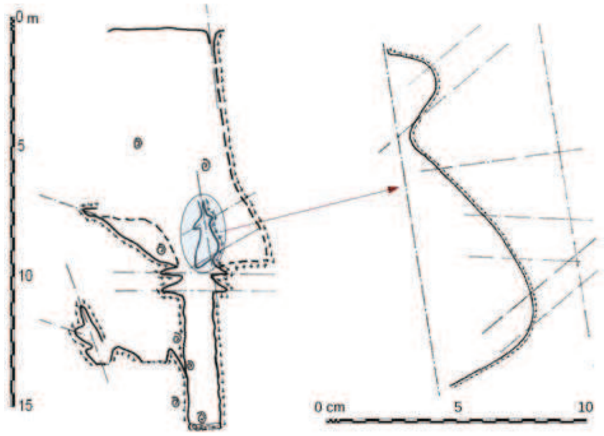

Fig. 1. Perfil complejo transversal del cañón subterráneo de O Folón. Detalle y correlación de distintos tramos de pasaje con la estructura local.
Fig. 1. Complex cross-sectional profile of the underground canyon of the O Folón. Detail and correlation of different passage sections with local structure.

The upper and intermediate levels of a keyhole cross-sectional pattern have circular to elliptical cross-sections. In some granite cavities, passages of complete elliptical section and continuous boundaries, similar to the ones of a phreatic conduit in a karstic system s.s. were identified (Veni 2005). Some authors (Osborne et al. 2013) describe caves in gneisses, called tunnel caves, completely formed in bedrock. They are tubes with elliptical cross-section, which may be horizontal, vertical or sloping depending on the structural setting.

3.3. Cave development and evolution

Given that caves are formed by flowing water, cave development is strongly controlled by base level. These caves are developed in the vadose zone (above base level), and underground streams carve narrow galleries that lead downward in the fastest possible manner until the base level is reached (Anthony, 2005).

These systems have been developed taking advantage of the discontinuity system of the granite massif. The formation of the cavity is carried out in two stages. During the first one, the subedaphic weathering advances in depth along the system of discontinuities encompassed with the incision of the drainage network (ruled by isostatic, eustatic or tectonic movements). Weathering produces alterites associated with the discontinuities that later lead the water infiltration.

Fig. 2. Tubo en el nacimiento de un manantial estacional subterráneo. Cota -13 m. Cueva de A Furna, Castelo de A Furna, Valença (Portugal)
Fig. 2. Tube at the mouth of an underground seasonal spring. Height -13 m. A Furna cave, Castelo de A Furna, Valença (Portugal).

During the second stage, the water circulation produces mechanical erosion thus cleaning of alterites progressively, and the cave becomes free of obstacles. So, water circulation becomes easier and the erosion contributes to enlarge the pseudokarstic system producing other types of forms as potholes, rills, scallops, etc. Once exists a great availability of space, the rock blocks may move or fall giving rise to the present aspect of the cavity, mix of blocks chaos and straight passages along the main discontinuities.

4. SCIENTIFIC INTEREST

The pseudokarstic cavities allow the reconstruction of the evolution of the terrain/landscape where they are located. On the one hand, it is the most appropriate place where they are preserved...: "... Types of sediments filling the caves often enable recognition of essential data on rock formation, age and type of tectonic/gravitational movements or significant features of relief and its development." (Urban and Oteska-Budzyn 1998).

In these cavities, a varied mineralogy of speleothems is developed, having been cited up to now: amorphous opal, evansite, bolivarite, struvite, pigotite, taranakite, allophane, hematite and goethite (Vidal Romaní et al. 2013).

The granite caves preserve remains of successive episodes of human occupation, which in Galicia were documented from the Epipaleolithic to the Middle Ages, with an intense use in the Neolithic-Calcolithic and Bronze Age (Sanjurgo et al. 2013).

In Sweden, tectonic caves like Pukeberg Cave (Enköping-Upsala) preserve sites of the Bronze Age (Mörner y Sjöber, 2011).

Cave art is preserved on a tafone located at the Barruecos de Malpartida (Cáceres). Also, in Matobo Hill's (Zimbawe), UNESCO heritage, where numerous caves and rocky shelters in granite contain Paleolithic sites and preserve cave art.

Fig. 3. Cerámica en el nivel TL 7,05 +/-0,86 kyrBP. Cota -37 m. Sistema de A Trapa, Ribadelouro-Tui (Galicia, España)
Fig. 2. Potery from the level TL 7,05 +/-0,86 kyrBP. Height -37 m. A Trapa cave system, Ribadelouro-Tui (Galicia, España)

REFERENCES

Anthony, D.M. 2005. Multilevel Caves and Landscape Evolution, Encyclopedia of Caves (David C. Culver & William B. White). Elsevier, 397-400.

Charbert C., Courbon, J. 1997. Atlas des cavités non calcaires du monde. Ed. Pre de Mme Carles, Paris.

Gaál, L, Bella, P. 1994. Genetic types of caves in non-karstic rocks in Slovakia. 5Th Pseudokarst Symposium, Szczyrk 1994. Proceedings Bielsko-Biala; 20-24.

Halliday, W.R. 2007. Pseudokarst in the 21st century. Journal of Cave and Karst Studies, v. 69 no.1.

Knevel, W. Von. 1906. Höhlenkunde mit Berücksichtigung der Karstphänomene. Druck und Verlag von Friedrich Viehweg u. Sohn, Braunschweig, 183.

Migon, P. 2006. Granite Landscapes of the World. Oxford University Press, Great Britain.

Mörner, N.A., Sjöberg, R. 2011 Excursion Guide for the local and main Excursions. Second International Conference on Granite Caves. Svenska Grottor, nr 12,21-27.

Osborne, R.A.L., Jayasingha, P., Weliange, W.S. 2013. An introduction to Sri Lankan gneiss and granite caves. Proceedings of 16th International Congress of Speleology, Brno – Czec Republic, Vol. 3, 280-285.

Sanjurjo, J., Vidal, J.R., Vaqueiro, M., Costas, R., Grandal, A. 2013. TL estimation of ages of pottery fragments recovered from granite caves in the NW coast of Spain. Cadernos do Laboratorio Xeolóxico de Laxe, Coruña, 37, 73-88.

Striebel, T. 1996. The Genetic Classification of some Types of Non-Karstic Caves, Proceeding of International Working Meeting “Preserving of Pseudokarst Caves”, Rimavska Sobota-Salgótarján Banska Bystrica, 46-57.

Twidale, C.R. 1982. Granite Landforms. Elsevier Publishing Company, Amsterdam.

Twidale, C.R., Vidal Romaní, J.R. 2005. Landforms and Geology of Granite Terrains. Ed. Balkema, The Netherlands, Amsterdam.

Urban, J., Oteska-Budzyn, J. 1998. Geodiversity of pseudokarst caves as the reason for their scientific importance and motive of protection. Geologica Balcanica, 28, 3-4.

Vaqueiro, M., Barreiro, B., Costas, R., Suárez, R.M. 2007. Mapping and modelling of granite cavities: Problems in the representation of forms and work scale. Proceedings of Interantional Conference on Granite Caves, Cadernos do Laboratorio Xeolóxico e Laxe, 33, XX-YY

Vaqueiro, M., Costas, R., Suárez, R.M., López, J.M., Vidal Romaní, J.R. 2011. Psuedokarst in granites: How granite caves are developed – the case of Galician caves. Proceedings of the 11th International Symposium on Pseudokarst, Höhlen- und Karstforschung Dresden, Dresden, 144-159.

Veni, G. 2005. Passages. Encyclopedia of Caves (David C. Culver & William B. White). Elsevier, 436-440.

Vidal Romaní, J.R., 1989. Granite geomorphology in Galicia (NW España). Cuadernos do Laboratorio Xeolóxico de Laxe, 13, 123-124.

Vidal Romaní, J.R., Twidale, C.R. 1998. Formas y paisajes graníticos. Universidade de A Couruña, A Coruña.

Vidal Romaní, J.R., Vaqueiro, M. 2007. Types of granite cavitites and associated speleothems: Genesis and evolution. Nature Conservation, 63 (6) 2007, 41-46.

Vidal Romaní, J.R., Sanjurjo, J., Vaqueiro, M., González, L., López, M.J. 2013. Speleothemes in cavities developed in magmatic rocks. 16Th International Congress of Speleology Proceedings, Brno-Czech Republic, Vol. 3, 479-482

Vidal Romaní, J.R., Vaqueiro, M., Sanjurjo, J.. 2014. Granite landforms in Galicia In Landscapes and landforms of Spain Eds. Gutierrez M. And Gutierrez M. Springer Verlag.