X-Ray Microtomography for Studying 3D-Textures of Speleothems Developed inside Historic Walls

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INTRODUCTION.

Speleothems are highly sensitive systems. They are product of the physic-chemical balance between geochemical composition of water and that one of the cavity air where they are growing. Stalactites is one of the most common and abundant speleothem in caves. Stalactites are speleothems formed by water dripping or flowing from fractures on the ceiling of a cavity. Moreover, they can be prolific even outside of caves. In this case, when the stalactite grows outside caves, their presences indicate that some parts of the epigean environment presents the microclimatic conditions necessary for speleothemic growth.

The stalactite studied in this work is a sample of the speleothems found inside the basement of the city wall built around the historic town of Nueva Tabarca. Our stalactite formed under unusual conditions: 1) moderate-high luminosity; 2) proximity to sea water; 3) high connection with external atmosphere; and 4) a both relatively recent and thin man-made substrate. These aspects lead to a characteristic texture which has been studied by means of X-ray microtomography. µCT-RX is a technique which allows analyzing the 3D aspect of the speleothem inner in a non-destructive way.

STUDY AREA AND MATERIALS.

Nueva Tabarca is a small inhabited island located at 8 nautical miles from Alicante (Spain). The small town existing there was fortified (1770) in order to offer a stronger resistance against the Barbary pirates. City walls are formed by external and internal levels of ashlars masonry. The space between both levels is filled by rough stone masonry. The employed stone corresponds to a local Upper-Tortonian calcarenite-calcirrudite. A basement is located inside the city wall. This basement was built as a two vaulted rooms separated by means of semicircular arches (Fig. 1). The basement is connected to exterior with several doors and windows. One of the wall-side is just in contact with the sea. Therefore, the construction is highly saturated with sea water.

Both ceiling and walls of basement are covered by speleothems (Fig. 1). The presence of these speleothems is associated to rain water and/or sea water, which infiltrate through the walls. Water dissolve carbonate rock and it turns more and more ion-saturated. Finally, when water appears at basement ceiling, ions precipitate forming speleothems.

METHODOLOGY.

X-ray microtomography technique was applied on the sampled stalactite in order to know its texture. X-ray computerised tomography (CT) consists of a three dimensional reconstruction of the inside of a sample, obtained by the stacking of two-dimensional images. A CT image, called slice, corresponds to a certain thickness of the sample and is thus composed of 3D volume elements, called voxels. The object being scanned reduces the X rays energy passing through, as a function of its density and atomic number. In CT slices the denser the scanned material the brighter the image.

The industrial micro CT system used in this study is a BIR Actis 130/150, located at the University of Milano-Bicocca. In this system both generator and detector are fixed, while the sample rotates; the scanning plane is horizontal. This device works with a polychromatic X rays generator (i.e. different energy X rays). X rays, passed through the sample, are collected on a detector, which converts them into light radiations. A digital camera transforms light radiations in raw data (sinograms) and sends them to the computer, where they are processed as black/white 2D images. 3D images have been reconstructed both with Actis and Avizo-Fire softwares.

Energy of 100keV/80mA has been used to scan the stalactite. The dimensions of the voxel, corresponding to the resolution of the images, are 24x24x27 µm (Fig. 2a) and 10x10x10 µm (Fig. 2b and c).

fig 1. Interior of the basement and location of the studied stalactite.

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RESULTS AND DISCUSSION.

Figure 2 shows the texture of the stalactite (images obtained with X-ray microtomography). The most important aspects of the stalactite fabric are its lightness, its high porosity, and its crumbly texture. X-ray microtomography reveals a puff-pastry structure with alternating vugs and encrusted layers in a concentric pattern around the hollow channel. The composition, thickness and morphology of the concentric rings and hollows reflect environmental changes (even hiatuses) in the growth of the sample.

In this stalactite, two, probably syngenetic, stalactite types are observed: the central soda straw tube and the cone (crust) stalactite (figure 2a). Soda straw is formed in association to water drops that come off from the roof. The minerals which constitute the soda straw are preferently orientated, showing their main crystallographic axis perpendicular to the vertical axis of the stalactite. However, the formation of the conical growth is due to the crystallization from water flowing on the external walls of the speleothem.

Inside our stalactite, another type of speleothem developed in association to different precipitation mechanisms. This new speleothem, coralloid, is globular in shape and upholster the interior of the central channel of the stalactite (figure 2b and c). This type of speleothems are also subaerial (as well as the stalactites), although in this case the processes of condensation y/o forces of capillarity control their genesis and morphology (Cuevas et al., 2010).

Stalactitic tufa ussually shows typical structures resulting from bryophyte encrustation, from porous spongy framework structures to laminated tufa deposits. However, the high porosity and fine and ordered lamination observed in the analysed stalactite is more indicative of lixiviation of highly soluble mineral precipitates (gypsum, halite). The origin of these soluble minerals is easily understood taken in account the proximity of the suited environment to the sea.

CONCLUSIONS.

Results show that X-ray microtomography is a highly valuable tool in order to study the 3D fabric and morphology of vadose carbonate precipitates such as stalactites. The main goal of this technique is its non-destructive methodology. The obtained images allow distinguishing between three different textures inside the stalactite: a) the central soda straw, with smooth cylindrical walls; b) the cone-crust, characterized by irregular surfaces; and c) the globulite growths, corallid or ramified. These three types are associated to different precipitation mechanisms working simultaneously and/or at different periods. Soda-straw is related to dropping process; the cone-crust is associated to water flowing on the external surfaces of the slatactite; while the globulite growths are due to processes of water condensation y/o forces of capillarity inside the stalactite.

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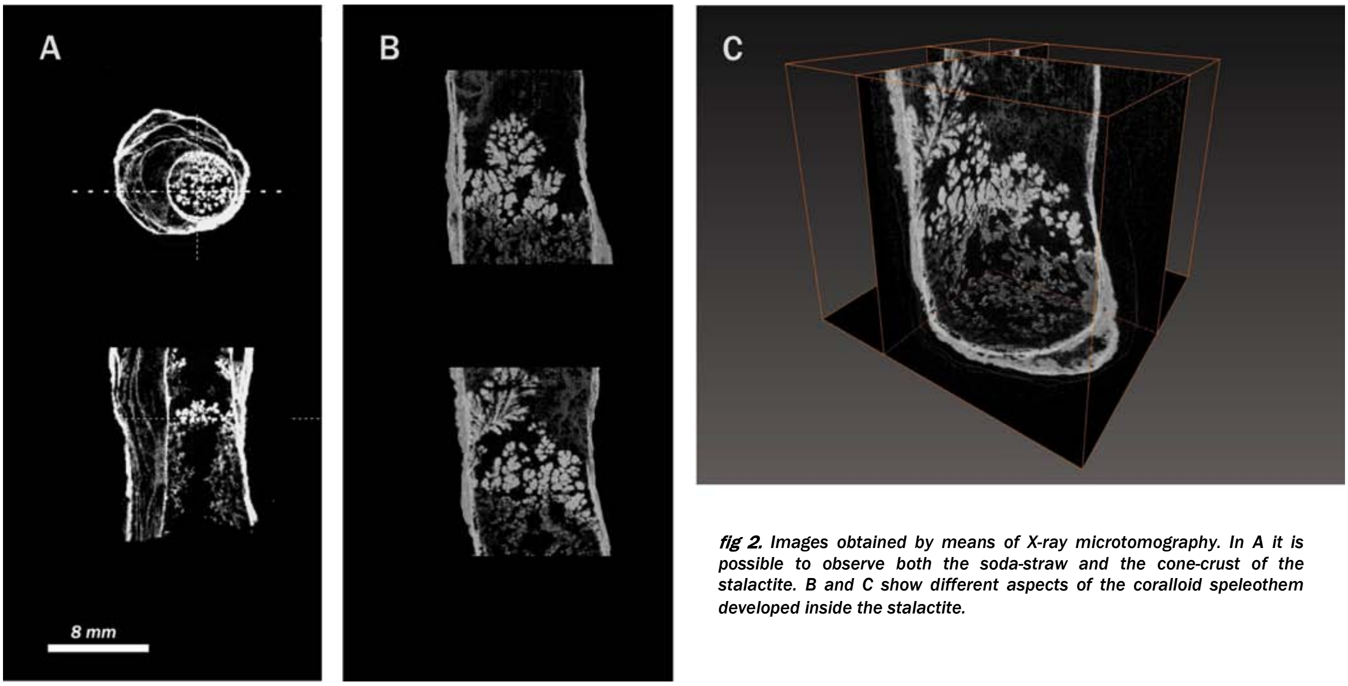

fig 2. Images obtained by means of X-ray microtomography. In A it is possible to observe both the soda-straw and the cone-crust of the stalactite. B and C show different aspects of the coralloid speleothem developed inside the stalactite.