XCT as a screening tool for quick characterization of silica nodules from a hydrothermal spring

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Aims
Development of a simple qualitative methodology for a quick characterization of silica nodules (case of study for the time being but not limited to), combining the results of reconstruction and 3D visualization provided by x-ray computed tomography (XCT), 2D elemental distribution via micro x-ray fluorescence (μ-XRF), and mineral composition with micro x-ray diffraction (μ-XRD).

The concept is to use XCT as the starting point for further characterization of spherical nodules found in El Tatio, a hot spring located in northern Chile. The 3D visualization provides a powerful tool to decide where to make a cuts to get slices of interest for further μ-XRF analysis of major elements distribution and mineralogy with μ-XRD.

Method
The region of El Tatio, among other hot springs, has become a zone of interest for researching groups aiming at finding potential bio-signatures that could lead to environmental conditions for life development in other planets, particularly Mars being the closest to Earth and the most popular target for recent space exploration funding.

In this hot spring different formations can be found in a variety of shapes including crusts, outcrops, regoliths and nodules, and reminiscence of biotic and abiotic processes are sometimes very well captured and preserved as bio-signatures, hence the interest for these minerals.

In this work we used XCT as the starting point for a characterization workflow of silica-based nodules as follows:

Step 1, sample mounting and tomography set-up: A SkyScan 2211 nano-XCT was used with fixed voltage of 110 kV and 90 μA, respectively, with a 0.5 mm Ti filter; 12 μm per pixel was the scanning resolution achieved for the micro-focus configuration in order to fit the FOV without the need of any further connection in the reconstruction stage; the scan was done for 180° with a rotation step of 0.200° and a frame averaging of 4. Total scanning time of 00:16:01 (hh:mm:ss).

Step 2, reconstruction of images: Nikonim v1.7.0.4 in combination with the InstaRecon v2.0.3.7 reconstruction engine was used to get the set of slices (1161).

Step 3, 3D visualization: With the use of CTvox the full volume was rendered and cropped to define a ROI subject to μ-XRF and μ-XRD in the best interest of the researcher owner of the samples.

Step 4, isolating porosity. A suitable task list was set-up to obtain the porosity from the nodule with the use of CTAn.

Results
A slice showing two-nucleus embedded in the nodule and trapped micro-crystals (figure 1) was the ROI of choice because these features can give information to elucidate about the path followed during the spherical formations of layers under the stressful environmental conditions of the zone. Also, the embedded crystals can serve as proxies of the mineralogical features of the proximity that prevailed at a particular growing stage of the nodules.

With the previous information, the nodule was cut at a specific position. This is important because these features can give information to elucidate about the path followed during the spherical formations of layers under the stressful environmental conditions of the zone. Also, the embedded crystals can serve as proxies of the mineralogical features of the proximity that prevailed at a particular growing stage of the nodules.

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Working with porosity (figure 5) was rather easy as the contrast from the grayscale was good enough for an easy elaboration of a task list for the CTAn software. A minimum threshold was done just to get rid of small volumes neglected as noise, and a 2D analysis was carried out with particular interest in three main features (figure 6): a) the angular orientation because it can be hypothesized that the shape of the pores will be aligned with the growing layers; b) the form of the pores, which are expected to suffer elongation as they get closer to the border of the original seedling minerals; c) the size of the pores. Pore size tends to decrement towards the inner section of the nodule. The shape of the pores tends to be more irregular toward the inner sections and around the spherical features within the sample.

Conclusion
XCT is a powerful tool not only because of the 3D visualization per se, but because it helps to avoid going blindly to sub-sample minerals that require further analysis with complimentary techniques/spectroscopies. From a geochemical/mineralogical point of view, when mineral sample show interesting features on the 3D renders, it makes it subject to XRD and suitable chemical characterization, but if you don’t know where to cut or dissemble you can ruin valuable samples. Other interesting concept for laboratories with the advantage of having a variety of instruments with the capability of making non-destructive analysis, is to linkage all of them after the XCT results, that way you won’t need to create a big set of slices (for the case of geological samples); the tools (software) provided the SkyScan 2211 are good enough for a qualitative characterization with minimal information from μ-XRD and μ-XRF (down to one slide).

References