X-RAY MICROTOMOGRAPHY SHOWS ELLIPSOIDAL INCLUSION-FREE HALO AROUND CUBIC PHASE IN BRAZILIAN CARBONADO: FIRST STRAIN ANALYSIS OF PRE-SOLAR MATERIAL?

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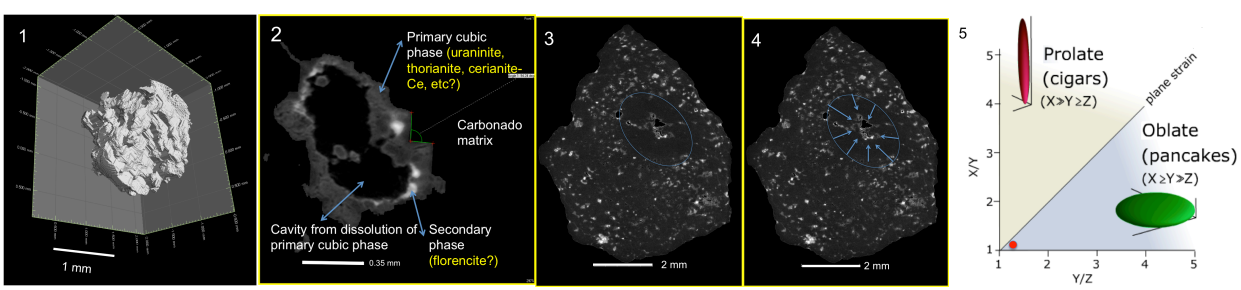
Introduction: Carbonado is a microcrystalline form of diamond, with a porous structure, found in diamondiferous gravels in Brazil and Central African Republic (CAR). It contains inclusions of highly reduced phases and native metals, such as SiC, FeC, Si, Ti, TiN, Fe-Cr, Ni and Ag, and secondary REE-phosphates like florencite, and is not found in kimberlites where gem macro-crystalline diamonds originate [1]. The origin of carbonados is still a very contentious issue, with the latest ideas arguing against a terrestrial origin, but there is no consensus about which extra-terrestrial environment carbonados formed in [1].

Carbonado from Brazil: A carbonado from CAR was examined using X-ray microtomography by [2], who found pseudomorphs, up to 0.3mm across, after what they interpreted as a primary dodecahedral phase. In this study we examine a Brazilian carbonado from the <1.16 Ga Macaubas Group, Minas Gerais [3], also using microfocus X-ray tomographic techniques. We used lower energies and long scans to enhance the contrast between phases of differing densities and X-ray attenuation, with a resolution of 5.2 µm. In common with observations on other carbonados, we have found evidence for a fabric in the Brazilian carbonado, showing up as a preferred planar alignment of inclusions. We also find a thin surficial zone free of inclusions next to surfaces showing a high patina. In addition, we have discovered novel macrostructures, in the form of large inclusion-free haloes (≤ 2.4 mm diameter) surrounding extra-large crystal inclusions (≤1 mm across and 1 mm^3 in volume), which seem to have a cubic morphology.

Strain Analysis: The depleted halo would originally have been spherical in an isotropic medium. Our measurements show it has the shape of a triaxial oblate ellipsoid slightly flattened parallel to the plane of preferred orientation of inclusions (XY) with dimensions a:b:c= 320µm:302µm:237µm (where a>b>c). Using the strain ellipsoid, the following parameters were calculated: R_{XY} = 1.06; R_{YZ} = 1.27; k = $(R_{XY}-1)/(R_{YZ}-1)$ = 0.22; d = $[(R_{XY}-1)^2+(R_{YZ}-1)^2]^{0.5}$ = 0.27; % shortening = $100(1- [1/R_{XZ}])$ = 25.8%. On a Flinn Diagram (R_{XY} vs R_{YZ}), the ellipsoid plots in the field of flattening strain, where 1>k ≥0. This may be the first measured strain ellipsoid in presolar material, and alludes to regions of high stress, possibly in the pre-solar nebula, following the crystallization of carbonados and their primary inclusions. The resultant strain may have been aided by high temperatures produced by radioactive decay of large amounts (more than a few weight %) of U and Th in the primary inclusions in the carbonados. The nature of the original mineral making up the large primary crystals in the centre of the inclusion-free ellipsoids is still unknown, and further studies are needed. Apparent interfacial angles of close to 90° have been measured in a large crystal inclusion within the carbonado, surrounded by a large inclusion-free halo. The crystal was replaced by a secondary phase (which appears medium grey in grey-scale rendering) which was partly removed by dissolution, and then a dense phase (appearing white; probably florencite) was deposited in the cavity.

References: [1] Haggerty, S., 2014. Earth-Science Reviews, 130, 49-72. [2] Ketcham, R., Koeberl, C., 2013. Geosphere, 9(5), 1336-1347. [3] Martins, M., et al., 2008. Revista Brasileiras do Geociências, 38(4), 761-772.



Figures. 1. A 1 mm^3 cubic crystal in centre of the carbonado. 2. Large cubic crystal in carbonado matrix, partly dissolved away, and replaced by a dense secondary phase, possibly florencite. 3. Cross sectional view through carbonado with numerous dense mineral inclusions, showing large cubic crystal surrounded by inclusion-free elliptical halo. 4. Possible growth mechanism of large cubic crystal from concentration of components in surrounding carbonado matrix, resulting in inclusion-free halo. 5. Flinn diagram showing the oblate nature of the inclusion-free halo surrounding the large cubic crystal in the carbonado (red dot).