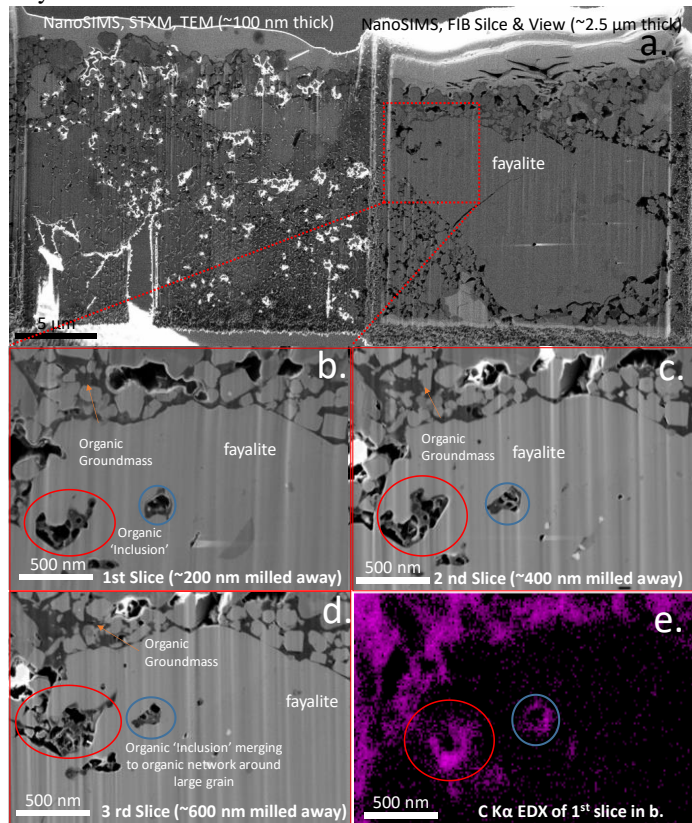


REDUCING INFORMATION LOSS FROM TRADITIONAL FOCUSED ION BEAM THINNING OF CARBONACEOUS CHONDRITE MATRICES USING SLICE & VIEW METHODS: APPLICATION FOR CARBONACEOUS ASTEROID SAMPLE RETURN.

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Introduction: The characterisation of samples returned from carbonaceous asteroids will provide ground truths on the makeup of primitive bodies that seeded the Earth, examples being the *Hayabusa-2* and *OSIRIS-ReX* missions from Asteroids 162173 Ryugu and 101955 Benu respectively. Carbonaceous chondrites (CCs), providing potential C-type asteroid analogues, have matrices containing microscopic to nanoscopic phases and morphologies including porosity, minerals, amorphous grains and organic material (OM). This means that their accurate characterisation requires the ability to discriminate between different phases at the nano scale. Characterization of the morphology, functional chemistry and microscopic setting of OM by coordinating synchrotron X-ray and electron microscopy techniques will be paramount. Traditional FIB methods extract ~10 µm wide x 5 µm high x 2 µm thick sections that are subsequently thinned down to electron and soft X-ray transparency at ~100 nm thicknesses. In this current work we are preparing multiple times bigger FIB sections. In addition, rather than FIB polishing via destruction to the desired 100 nm thickness, we are applying slice and view methods whilst thinning down in order to reduce information losses. We are performing this on the unclassified anhydrous CC fall Ningqiang that uniquely has affinities with anhydrous CV and CKs but with organic abundances similar to the more hydrated CCs.

Figure 1. FIB thinning using slice and view methods. (a) An unconventional ~40 x 20 x 2.5 µm section was extracted from a fresh chip of Ningqiang thus eliminating EPOXY. The dark grey material is organic material. One half was thinned down to soft X-ray and electron transparency for STXM and TEM. The right hand side had slice and view after the initial identification of seemingly an organic 'inclusion' in a fayalite grain (red rectangle). (b)-(d) High magnification of red rectangle in (a). (b) First slice of right hand right of FIB section in (a) taking away ~200 nm. The 'organic inclusion' is circled in red. Note the smaller 'inclusion' circled in blue. (c) 2nd slice and (d) 3rd slice. Slicing away of the 3 layers and sequentially imaging shows the 'organic inclusion' to merge towards the edge of the grain and connect to the organic network surrounding finer fayalite grains. Based on this, the blue phase should also merge to the grain margin after further slicing along this profile. The similar composition between the finer fayalite grains and the larger one suggests that organic fluids disseminated the large grain into finer ones along its margins. Thus rather than an inclusion in fayalite, this phase is actually part of the organic ground-mass/network surrounding the irregularly shaped large fayalite grain. If the sample was directly thinned using traditional methods, this information would have been lost. Due to the fine scale submicron heterogeneity of CC matrices, FIB methods for ultra thinning samples should employ slice and view techniques when thinning down to electron transparency, preventing information loss.



Implications for Sample Return from C-type Asteroids: Whilst traditional FIB techniques prove vital for analysing CC matrices *in situ*, the nanoscopic heterogeneity of CC matrices implies that important sample information is being lost. However, it could be retained if samples are imaged and elementally EDX mapped by simple FIB slice and view methods when thinning. Furthermore, FIB techniques can be applied to sample sections multiple times bigger than traditional samples (Fig. 1). By adopting this method on a chip of Ningqiang, important information on the organic groundmass/network in its matrix would have been lost if traditional FIB methods were employed.

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