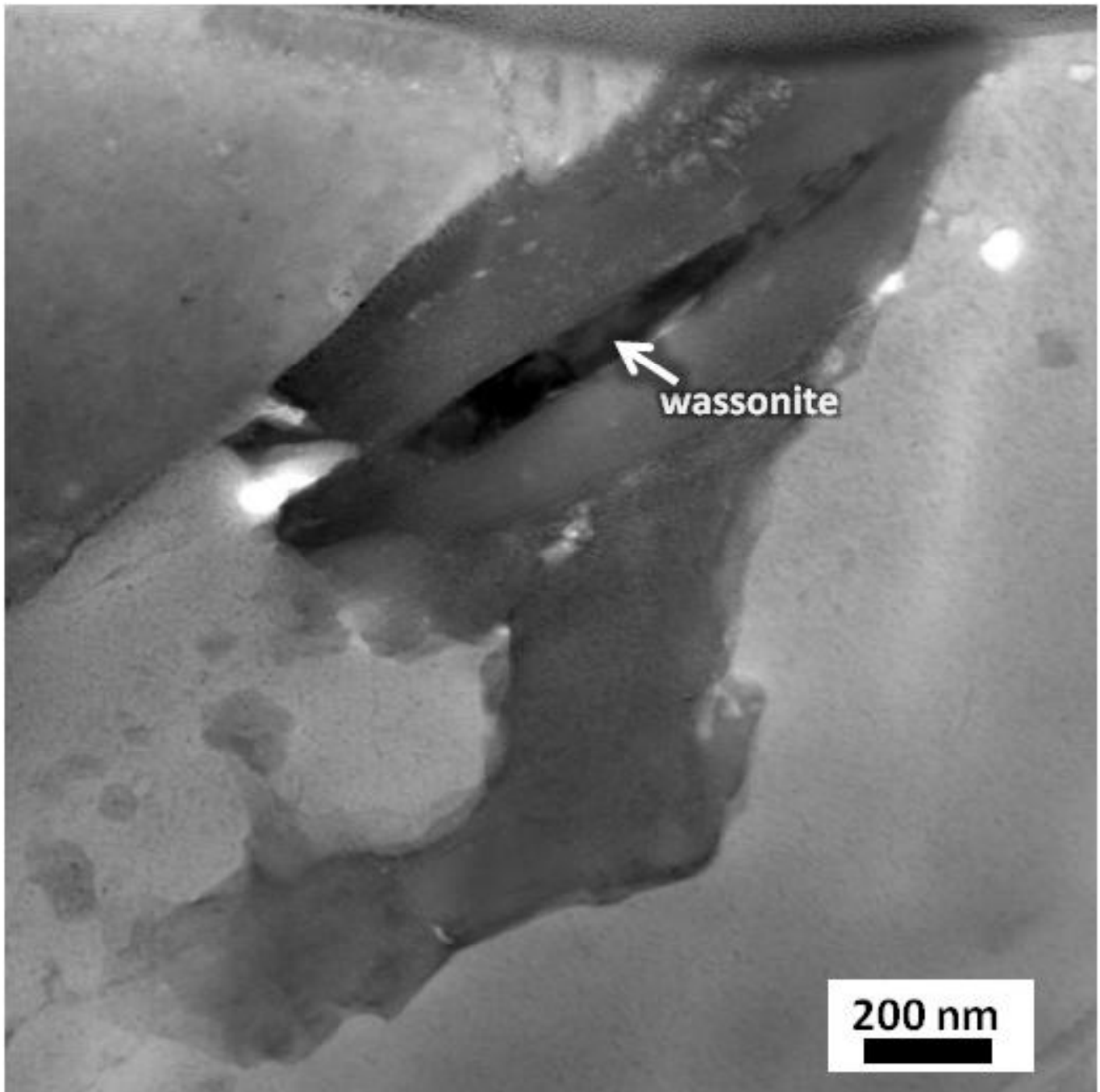
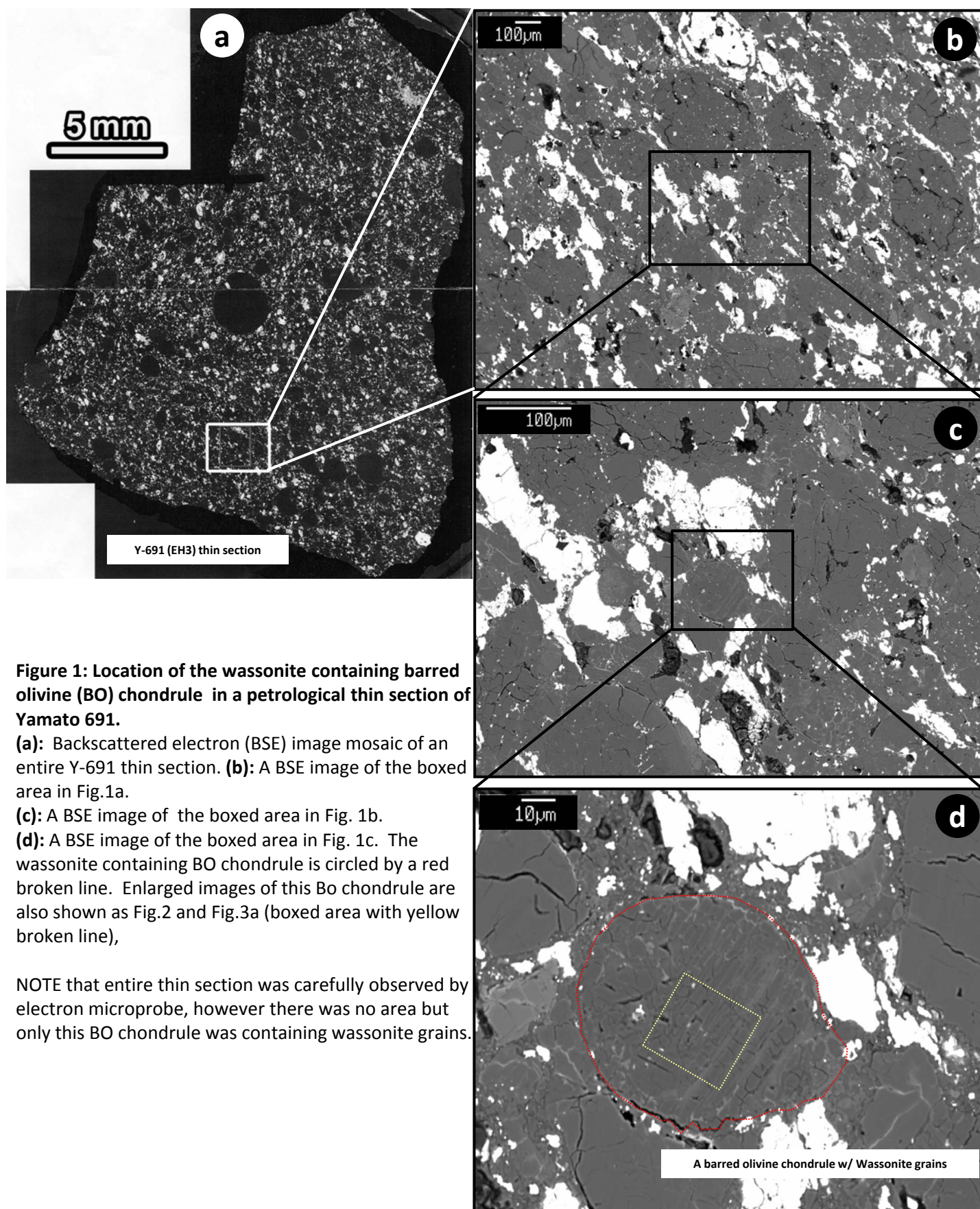


A bright field scanning transmission electron microscope (STEM) micrograph showing a Wassonite grain in dark contrast.





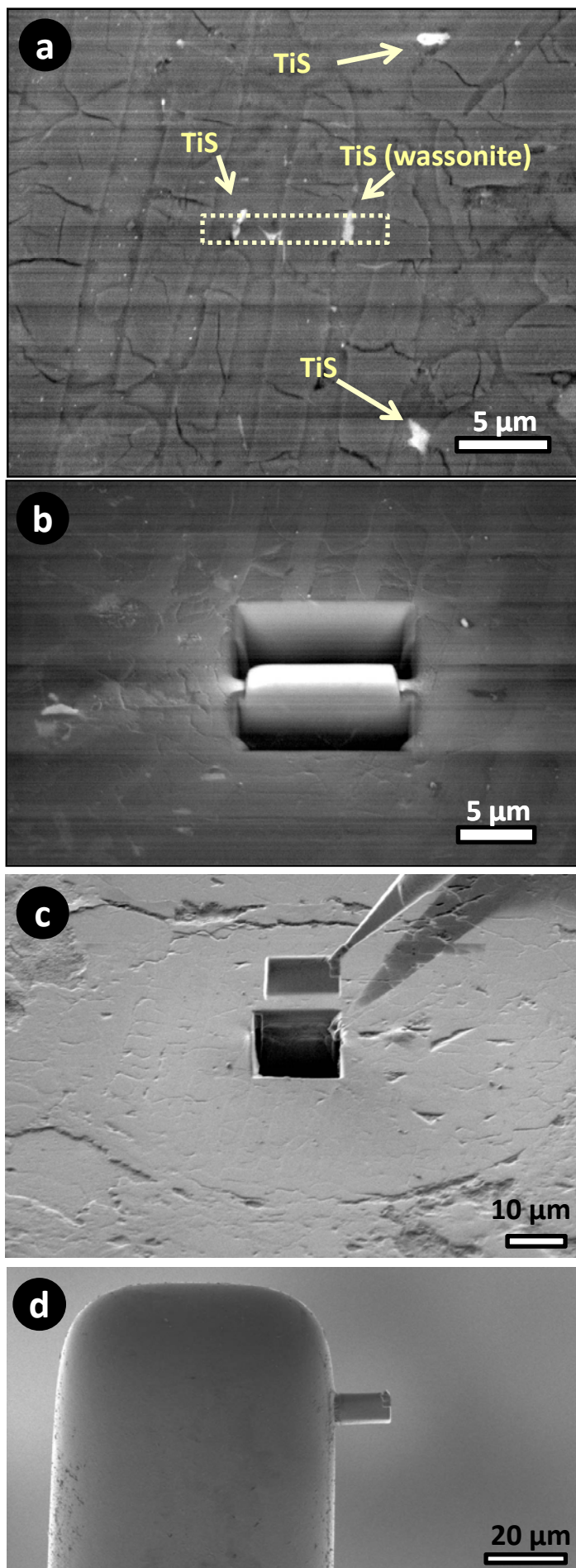


Figure 2: Focused-ion beam (FIB) extraction procedure of wassonite grains from the BO chondrule. (a) A BSE image of the boxed area in Fig. 1d.

A rectangle with broken line including two wassonite candidate grains is the targeted area of FIB extraction. **(b)** 52° tilted ion image after front and back-excitation by focused Ga-ion beam. The target area was protected by C and Pt. coatings. **(c)** SE image of the FIB section lift-out using a tungsten needle. **(d)** The FIB section attached to a TEM grid. **(e)** A SE image of the FIB section before further thinning. The image clearly shows the barred olivines/mesostasis boundaries. **(f)** A BSE image after thinning to 90 nm thickness. Unfortunately, a TiS grain on left was almost completely sputtered away.

We used the dual beam FIB instrument at the NASA JSC (FEI: Quanta 3D-FEG) to extract, *in-situ*, a cross section of the barred olivine chondrule including two TiS grains (Fig.2a). The FIB section was prepared using a 30 keV focused Ga ion beam. Deposition of a ~3 μm thick C-and Pt- strips protecting the chosen ROIs was followed by the ion beam milling of an ~2 μm thick section (Fig. 2b). The section was extracted and then attached to a OMNI half TEM grid with C (Pt) deposition (Fig. 3c and 3d). After mounting on the TEM grid, the section was thinned down to 50 nm thickness (Fig. 2e and 2f). (This thinning process unfortunately sputtered out one of the TiS grains, but the other remained and identified as wassonite grain#1 later in the series of TEM analysis.) The whole section had dimensions of about 5 μm in height and 10 μm in width.

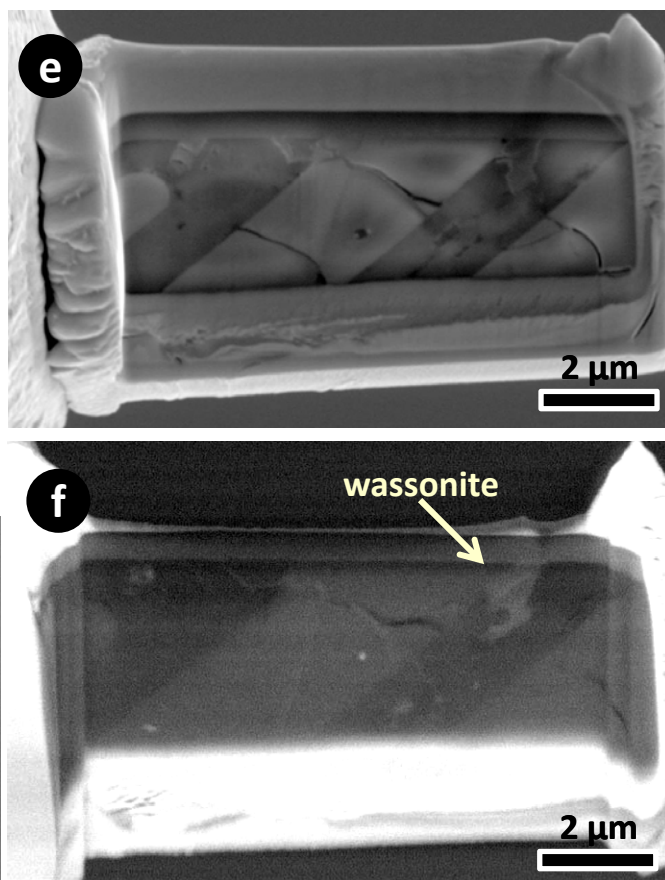


Figure 3: Wassonite elemental x-ray mapping. A bright field Scanning transmission electron microscope (STEM) micrograph (right) showing Wassonite grain in dark contrast. EDX spectra of Wassonite grain is shown in left. Series of nanoscale elemental x-ray (k-line) maps of the same region show that Wassonite grain is chemically uniform but the surrounding material has various compositional differences.

