THE PRIMITIVE CHONDRITE WATONGA (LL3.1): UNUSUAL CLASTS AND THE ACCRETION OF ORDINARY CHONDRITES. J. N. Bigolski[1, 2], M. K. Weisberg[1, 2, 3], D. S. Ebel[2, 3]. [1]Dept. Phys. Sci., Kingsborough College CUNY, Brooklyn, NY 11235, USA. Email: john.bigolski@kbcc.cuny.edu. [2]Dept Earth and Planet. Sci., American Museum of Natural History, New York, NY 10024, USA, [3]Earth and Envi. Sci. CUNY Graduate Center, New York, NY 10016, USA.

Introduction: Primitive meteorites such as unequilibrated ordinary chondrites (UOCs) provide nominal samplings of materials from the earliest history of the Solar System. Their primary components include chondrules that often host fine-grained rims (FGRs), which are accompanied by chondrule fragments, lithic clasts, and metal nodules [e.g. 1–4]. Less common are unusual, in some cases xenolithic, clasts, such as dark inclusions (DIs). Other present but rare objects in UOCs include agglomeratic olivine objects (AOs) and refractory inclusions—calcium-aluminum inclusions (CAIs) and amoeboid olivine aggregates (AOAs)—which are far less abundant than in primitive carbonaceous chondrites (CCs). All of these components are embedded within a fine-grained matrix (< 10 µm particle size) that also occurs in relatively lesser abundance in UOCs than in the least equilibrated CCs [5].
The most primitive (least thermally processed) UOCs show well defined FGRs that formed from dust that accreted onto the surfaces of nascent chondrules and contains microchondrules, mineral and lithic fragments, and to a lesser extent, amorphous material [2, 6–8]. Some exceptional UOCs have been previously shown to contain unusual clasts and refractory inclusion [e.g., 9], a testament to their primitive nature.

Documenting the variety of inclusions in primitive chondrites provides information for constraining conditions and processes in the early Solar System. Watonga, although a type 3.1, has been previously reported to preserve primary features including FGRs [1, 4] and a variety of chondrule types and inclusions. Building upon our previous work, we present a detailed petrologic study of Watonga with attention paid to compound objects, refractory inclusions and other unusual clasts not commonly found in UOCs.

Analytical Techniques: The petrology of 2 thin-sections of Watonga (AMNH 5290-1, -3) was studied in detail. Chondritic components were examined using the JEOL JSM-6390 LV/LGS scanning electron microscope (SEM) with a Quantax 200 energy dispersive X-ray spectrometer at Kingsborough College. Compositional data were collected using the Cameca SX100 electron probe micro-analyzer at the American Museum of Natural History.

Results: Section 1 (Fig. 1a) has a total surface area of ~330 mm, while section 3 (Fig. 1b) has a surface area of ~100 mm. A total of 88 chondrules were documented from the 2 thin-sections of Watonga (Fig. 1). The average chondrule diameter falls within the range of LL UOCs (~740 µm; avg. Φ 1.30).

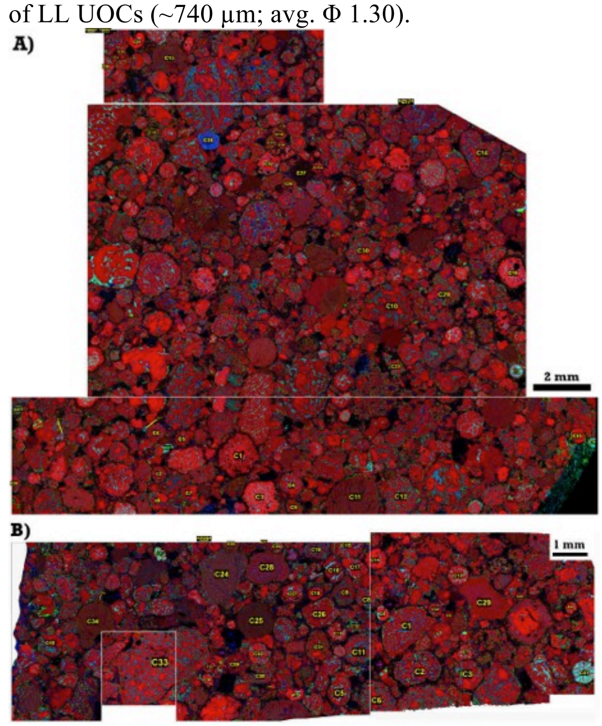

Fig. 1. Mg-Ca-Al (red-green-blue) X-ray maps of 2 thin-sections of Watonga: a) AMNH 5290-1; b) AMNH 5290-3.

Watonga contains exceptionally preserved fine-grained materials; 74 % of all examined chondrules host FGRs, which occur around both type I (MgO-rich, FeO-poor) and type II (MgO-rich, FeO-poor) chondrules [4]. FGRs surrounding chondrules are composed of Fe-rich silicates, although some chondrules have strictly sulfide-rich rims. Chondrule fragments may be completely or partially surrounded by rim material. Watonga also contains several compound objects composed of angular fragments indenting and/or partly embedded within other chondrule fragments, with fine-grained material sandwiched between the contacts of compacted objects (Fig. 2).

Along with the striking diversity of materials in Watonga, the Cr content in ferroan olivine chondrule phenocrysts supports the low petrologic type (3.1) assigned for Watonga (mean Cr_2O_3 0.40 ± 0.20 wt%).

Refractory Inclusions. Both thin-sections of Watonga contain isolated refractory inclusions. A CAI measuring 250 X 200 µm occurs within Watonga that contains numerous anhedral spinel grains overgrown by Ti-bearing diopside. Inclusions of rounded magnesian olivine zoned with FeO increasing toward the edges are found dispersed within the CAI. Troilite is dispersed throughout as a discontinuous "network" of intergrowths between diopside. Rare melilite occur as < 10 µm grains surrounded by diopside.

A spinel-rich AOA also occurs within Watonga (Fig. 3). It consists of nodules of MgAl spinel surrounded by diopside, which are enveloped by forsterite (Fo_{95-97}) (Fig. 3a). Also present with some spinel is Ti-rich Ca-pyroxene and perovskite (Fig. 3b).

Unusual clasts. Other inclusions identified include: a chondrule-like object containing euhedral olivine grains associated with lath-shaped anorthite and a BO clast containing euhedral MgAl spinel included within diopside between the olivine bars.

Discussion: Watonga is a primitive UOC displaying a wide array of components. Compound objects strongly suggest plastic deformation, either due to collisions in space, during rapid hot accretion or impact-induced compaction. The presence of matrix between compound objects, along with the deformation of FGRs [3, 4], suggests chondrite deformation occurred during or after accretion. Since Watonga is shock stage S2, impact heating and pressure may have played only a minor role in its lithification and compaction. Thus, the compound components may be products of hot accretion similar to that proposed for cluster chondrite clasts [10]. Refractory inclusions and unusual clasts, although rare, may support transport and mixing of material from different nebular regions [11].

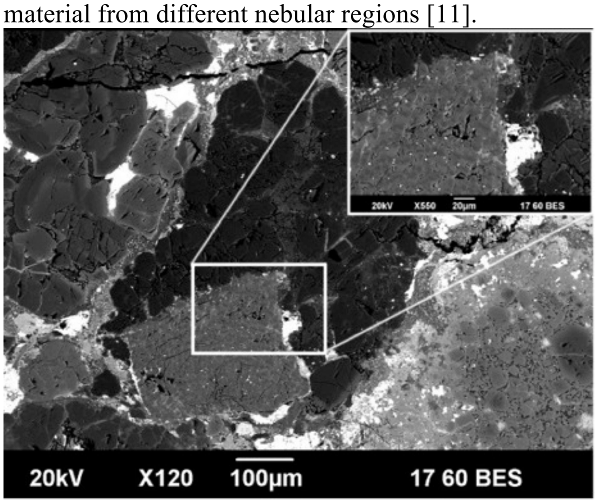

Fig. 2. BSE of a type I chondrule fragment indented by an angular fragment composed of ferroan olivine. The inset shows fine-grained matrix and FeO-rich fine-grained material that closely resembles FGR material, as well as Fe-sulfide, between the two objects.

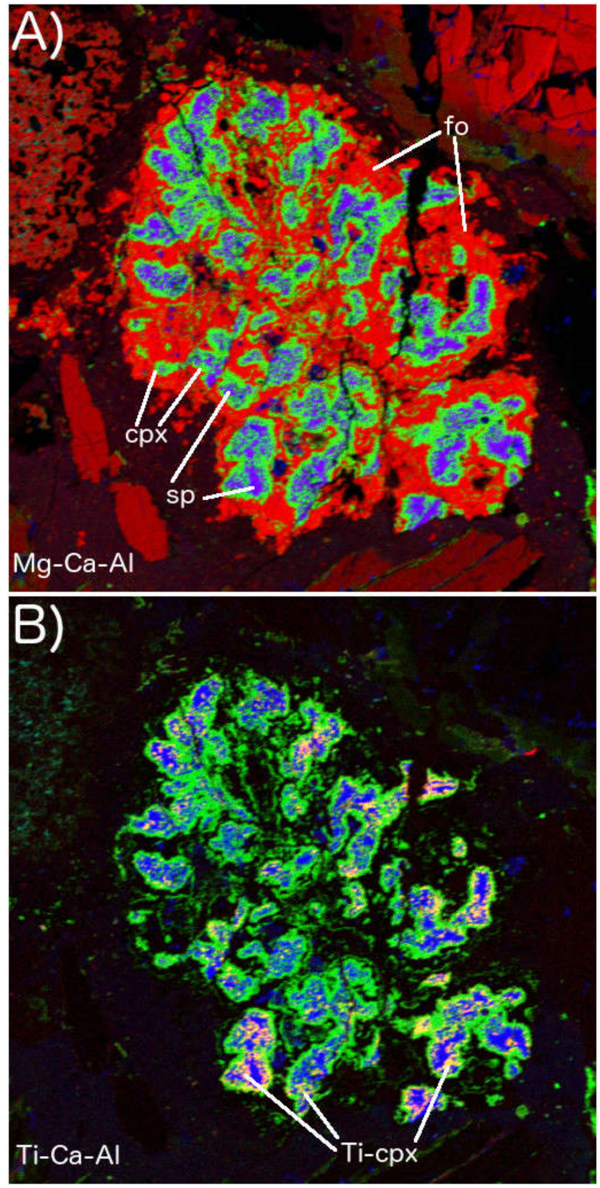

Fig. 3. 512 µm x 512 µm element maps of an AOA: a) Mg-Ca-Al (red-green-blue); b) Ti-Ca-Al (red-green-blue).

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