EVIDENCE OF IMPACT MELTING FROM μXCT SCANNING OF TROILITE IN UNGROUPED IRONS DRONINO AND N'GOUREYMA. C. M. Corrigan[1], B. Andrews[1], and T.J. McCoy[1], [1]Smithsonian Institution, National Museum of Natural History, 10th St. and Constitution Ave. NW, Washington, DC 20560, USA (corriganc@si.edu).

Introduction: Of the ~1250 recognized iron meteorites, ~10% do not fit into compositional clusters consistent with the recognized groups and are termed "ungrouped" [1]. Among these, iron meteorite impact melts are exceptionally rare, despite the fact that iron meteorite parent bodies, exposed cores of larger differentiated protoasteroids, must have experienced a violent impact history commensurate with the evidence for frequent impact processes observed on stony meteorite parent bodies. Notable among those that exhibit, or have been interpreted as impact melt features, are Nedagolla [2] and Tucson [3]. In addition, a number of iron meteorites contain anomalously low volatile siderophile element concentrations that have been attributed to impact devolatilization [4]. Here, we present results of a three-dimensional (3D) μXCT study of troilite inclusions in the ungrouped irons N'Goureyma (an observed fall in 1900) and Dronino (a find in 2000) that are suggestive of formation by diapiric rise of troilite through molten or partially-molten metal after impact melting.

Methods: Compositional and textural analyses of Dronino and N'Goureyma were conducted at the Smithsonian Institution (National Museum of Natural History) using the Nova NanoSEM for backscattered electron imaging, the JEOL 8530F+ Field Emission electron microprobe for compositional analyses of constituent minerals, and the GE Phoenix Dual Tube μXCT scanner to create 3D images of two pieces of Dronino (USNM 7203b) and one piece of N'Goureyma (USNM 559a). Compositional analyses were acquired from polished sections USNM 7203b (Dronino) and USNM 559a (N'Goureyma).

Compositions: The average compositions of the metallic host determined by electron microprobe for Dronino (10.5 wt.% Ni) and N'Goureyma (9.3 wt.% Ni) are consistent with published analyses [5,6]. Sulfides are consistent with troilite and rare chromites are near endmember $FeCr_2O_4$. These chromites are particularly attractive targets for planned oxygen isotopic analyses. No daubréelite, phosphates or phosphides were observed.

The high-Ni concentrations of both N'Goureyma and Dronino are consistent with their grouping as non-carbonaceous (NC) meteorites, as confirmed for Dronino [8]. In addition, both meteorites are volatile depleted, with the Ga concentration of Dronino in the range of IVB irons and N'Gouryema having the lowest Ga and second lowest Ge concentration among all iron meteorites - only Nedagolla has a lower Ge concentration.

Troilite textures in two dimensions (2D): Dronino (Figure 1) and N'Goureyma exhibit troilite textures unlike those in other iron meteorites. Sulfide textures in these two meteorites share a number of similarities, and at least one important distinction. The morphology of the sulfide blebs differs dramatically between the large cut faces and smaller perpendicular edges of these slices. On the cut faces, troilite appears in both meteorites as blebs (sometimes containing one or more inclusions of metal), rings, crescent shapes, and elongated ellipses of various dimensions. Textures become increasingly complex in larger sulfide blebs, typically rings with one or more metal inclusions, such as those pictured in [7]. In Dronino, these sulfide particles range up to 5 mm in maximum dimension, while they tend to be significantly smaller in N'Goureyma (1-2 mm). In both meteorites, troilite comprises a few percent of the surface area (estimated by [6] as 2 vol. %). On the smaller cut edges perpendicular to the large faces, troilite typically forms rods, often extending the thickness of the slice, reaching up to 1 cm in Dronino. These features often have bulbous heads on one end, reminiscent of tadpoles, and always at a common end of the rod or tube (Figure 1).

Troilite textures in three dimensions (3D): In three dimensions, the features, all of which show parallel long-axis alignment, either exhibit a bulb-like feature with a long solid tail, or a solid head with a hollow tail filled with metal. The latter would appear as two separate tubes in 2D, but are connected in 3D. We informally refer to these features as tadpoles and jellyfish. In some cases, multiple rods or tubes merge or connect in 3D, often producing complicated branching structures. The end of each inclusion opposite the bulbous head is typically a long, thinning tail that tapers to a point. In some cases, these tails have separated into a set of segments with a common orientation. In all cases, the troilite forms in 3D are on the scale of <1 cm.

Modal determinations from μXCT scans give 6.7% for Dronino and 5.7% for N'Goureyma, substantially higher than the 2% derived by [6] using 2D point counting methods.

Discussion: Texturally, these troilite inclusions strongly resemble diapirs formed when a buoyant liquid ascends through a denser material. The relative densities of troilite (~4.6 g/cm^3) and metal (~7.6 g/cm^3) are consistent with such an interpretation.

The most plausible scenario for the formation of these features is that molten troilite ascended through molten metal. The relatively short, long dimensions of these particles suggest limited ascent distances, as the tails elongate during ascent. We suggest that melting and subsequent cooling occurred rapidly during impact melting, consistent with this inferred thermal history and explaining why such morphologies are rare among iron meteorites. If true, the implication of complete remelting and rapid solidification might explain the absence of a distinct Widmanstätten pattern. [6] attributed this texture in N'Goureyma to sintering at 1000-1200°C, but these temperatures would be insufficient to produce a completely molten system.

Ongoing work will model the diapiric rise of these materials using a range of inferred temperatures, cooling rates, and, importantly, compositions of the melt, particularly the Ni concentration of the metal. An interesting feature of these meteorites is the distinct morphologies of the troilite inclusions, which can be broadly grouped as rods with bulbous heads (tadpoles) and tubes that appear as rings on the cut surface (jellyfish). [9,10] suggest that the initial size and shape of a sulfide bleb prior to ascent has a strong outcome on its post-ascent and solidification morphology. Those inclusions that started as essentially spherical would have formed the elongate occurrences with bulbous ends (tadpoles), and those that were more oblate (with long axis perpendicular to the direction of gravity) would have formed tubes or curtains (jellyfish). After impact melting, but before ascent of these troilite blebs, it would not be surprising to find both spherical and oblate shaped troilite blebs resulting from the dynamic nature of impact melting.

Finally, it is interesting that these seemingly rare morphologies are only found in two ungrouped iron meteorites of unusual composition. Further study of these meteorites is warranted to understand the genetic link between these meteorites, other ungrouped irons, and the iron meteorite groups. Planned oxygen isotopic analyses of chromites might provide one such link.

References: [1] Wasson et al. (1989) *GCA* 53, 735-744. [2] Miyake & Goldstein (1974) *GCA* 38, 747-755. [3] Nehru et al. (1982) *JGR* 87, A365-A373. [4] Kleine et al. (2018) LPSC 49, #1963). [5] Russell et al. (2004) *MAPS* 39, 8 Suppl, A215–A272. [6] Buchwald (1975), *Handbook of Meteorites*, Univ. of California Press, 1418 pp. [7] http://www.meteorites.com.au [8] Bermingham et al. (2018) *EPSL* 487, 221-229 [9] Koh & Leal (1989) *Phyis. of Fluids* 1, 1309-1313 [10] Pozridikis (1990) *J. Fluid Mech*. 210, 1-21.

Figure 1: Photograph of Smithsonian slice of Dronino showing various sulfide features (USNM 7203). Thickness of slice = 2 cm.

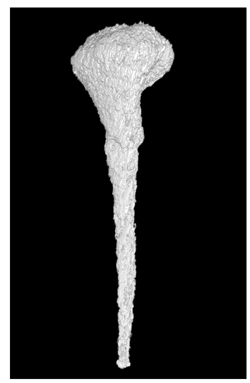

Figure 2 : µXCT scan of Dronino "tadpole"(USNM 7203) scanned at a resolution of 14.996 µm/voxel. Vertical dimension = 10.44 mm.

Figure 3: µXCT scan of Dronino troilite features (USNM 7203) scanned at a resolution of 14.996 µm/voxel. Vertical field of view is 24.0 mm.