FAMENIN, IRAN ORDINARY CHONDRITE 2015 FALL: NON-DESTRUCTIVE ANALYSIS.

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Famenin fall event: On the early morning of June 27, 2015 (~08:30 local time), Mr. Reza Salimi heard an object hit the roof of his house in Famenin, Hamedan Province, Iran [1]. Upon investigation, he found that a small meteorite had punctured his flat, concrete roof. The broken stone was immediately recovered as two large fragments of about 220 g each and several smaller pieces. Over the following days, additional scattered fragments from the hammerstone were recovered bringing the total mass to nearly 700 g [1].

Externally, the meteorite has a fusion crust which varies from glassy black to a dull reddish-brown. Broken surfaces show a light grey interior with a number of dark clasts and an abundance of sharply-defined chondrules up to several mm in diameter. A 24 g fragment of the shattered stone was typed by Pourkhorsandi et al. at CEREGE as an H/L (3.8/3.9) chondrite on the basis of magnetic susceptibility, electron microprobe, petrographic and geochemical data [1]. Here we report on bulk petrophysical properties and other non-destructive petrographic analyses of a fresh “hammer” main fragment and several sub-fragments of the June, 2015 Famenin fall.

Methods: We use laboratory-based X-ray computed tomography [e,g 2] to quantitatively investigate the bulk volume and internal density distribution of Famenin meteorite fragments. *In situ* micro-XRD is used to investigate minerals and textures in the broken surface and fusion crust of the meteorite.

X-ray imaging was performed using one of three medical laboratory CT scanners (GE eXplore speCZT; GE Locus Ultra; Bruker Skyscan 1172 microCT) at Western University and the University of Oslo. Scan parameters consisted of 80 - 120 kV (peak) applied energies for multiple separate radiograph images over a full 360° rotation. These acquisition parameters permit volume resolutions of between 12 and 154 μm per voxel depending on peak energy and sample size. Beam hardening was corrected using a custom calibration for the speCZT and voxel greyscale values were corrected to Hounsfield Units [2]. Image and volume analysis using 3D isosurfaces was performed with *MicroView* software. Magnetic susceptibility [e.g, 3] was measured using a Sapphire Instruments SI2b susceptibility meter.

In situ mineral identification and textural analysis [5, 6] were performed using a Bruker D8 Discover diffractometer, operating with Co Kα radiation (λ = 1.78897 Å) at 35 kV and 45 mA and a nominal incident beam diameter of 300 μm [4].

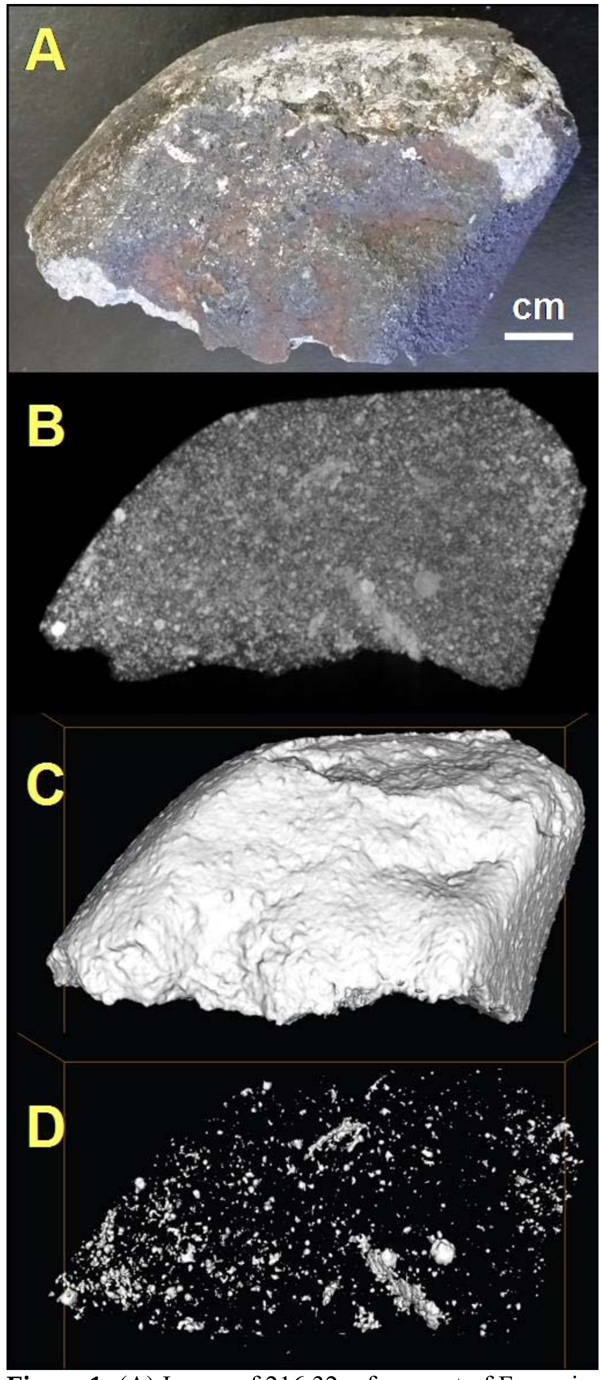

Figure 1: (A) Image of 216.32 g fragment of Famenin; Maximum intensity projection (MIP, B) of radiodense material within the fragment; (C) Micro-CT isosurface rendering yielding bulk volume (Table 1); (D) Isosurface chosen for high voxel HU values >15000 to illustrate ~metallic content of the main fragment, including vein-filling metal.

Petrophysical properties: Micro-CT reconstructions of the 216 g Famenin main fragment and two subfragments reveal distinct chondrules, widely disseminated mm-sized metal and sulphide grains as well as what appear to be vien-filling metal and sulphide (Fig 1). Several 4 to 6 mm wide subrounded darker radiodensity regions are also present within the main fragment; these may represent unusually large, metal-free clasts or chondrules.

Meteorite bulk volumes derived from isosurface definition of the 3D reconstructions provide a bulk density of 3.22 g/cm3 for the main fragment and 3.30 and 3.18 g/cm3 for the subfragments (Table 1), consistent with an L chondrite classification [5]. Mass-based magnetic susceptibility for the two subfragments is log χ = 5.29 and 5.17 (log of E-9 SI units), slightly higher than that found in the type specimens (5.09) by [1], and is more consistent with H chondrites [3].

Famenin fragment	Mass (g)	Bulk Volume (cm3)	Bulk density (g/cm3)	Magnetic susceptibility (log *X*)
Famenin main	216.32	67.12	3.22	--
Famenin a	4.843	1.469	3.30	5.29
Famenin b	1.906	0.599	3.18	5.17

Table 1: Petrophysical properties of Famenin fragments.

Micro-XRD investigation: Non-destructive *in situ* analysis of selected regions on the broken surface of various pieces of the meteorite (Fig. 2) have revealed major phases forsterite (Fo), enstatite (En), kamacite (Kam), troilite (Tro), pyrrhotite (Po) and possibly plagioclase (Pl). XRD shows kamacite and troilite in close association, and also abundant pyrrhotite. These observations are consistent with unequilibriated ordinary chondrites [7]. The presence of plagioclase suggests that at least parts of this meteorite have undergone limited thermal metamorphism [7].

References:
[1] Pourkhosandi et al. (2015) Meteoritical Bulletin no. 104. [2] Edey, D.R. et al. *LPSC XV* Abstract #2616; [3] Rochette et al. (2003) *MAPS 43*, 251-268; [4] Flemming, R.L. (2007) *Can. J. Earth Sci. 44*, 1333–1346; [5] Britt D.T. and Consolmagno G.J. (2003) Meteoritics & Planet. Sci. *38*, 1161-1180; [6] Bramble, M.S. et al. (2015) *Am. Mineral. 100*, 1899-1911; [7] Brearley, A.J. and Jones, R.H. (1998) *Rev. Min. 36*, 398pp

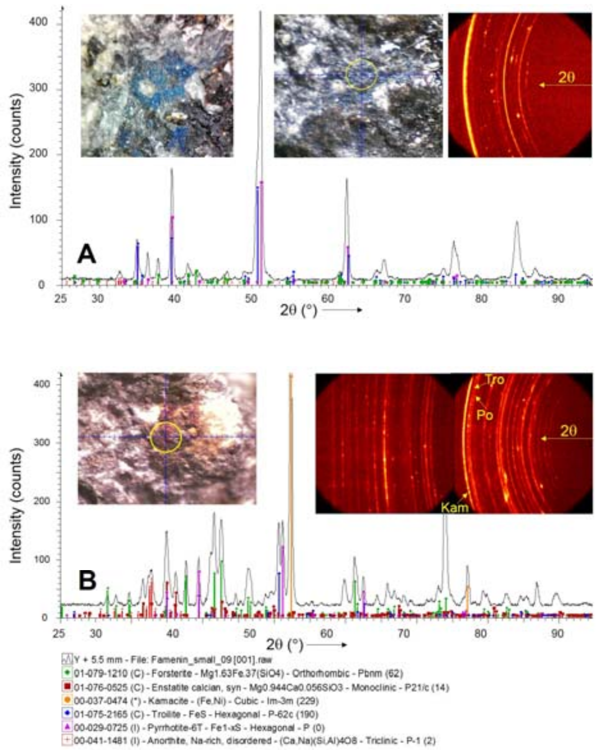

Fig. 2. µXRD patterns from selected areas of Famenin. (A) Intense blue area on 'hammer' piece, near fusion crust (see photomicrograph in upper left and context image in upper middle). This is identified as pyrrhotite and troilite, which are exhibiting a 'peacock ore'-like tarnish, likely associated with the fireball event. Pyrrhotite and troilite appear as homogeneous rings in GADDS 2D image (upper right), indicating grain size < 5 µm, while silicates exhibit large diffraction spots, indicating coarser grain sizes (> 20 µm) [6].
(B) Rusty area (see context image in lower left) showing all major phases Kamacite appears as spotty rings, indicating a 10-20 µm grain size. The kamcite and troilite patterns are well resolved rings. Silicates show a bimodal grain size distribution, with coarse and fine grain sizes occurring together. In both locations, slight streaking of silicate diffraction spots (e.g. olivine) indicates that the meteorite has undergone some shock. Notes: Yellow circle on context photos indicates nominal beam diameter of 300 µm. Horizontal arrows show increasing 2 theta. Kam=kamacite, Tro=troilite, Po=pyrrhotite.