**FALL OF THE GRIMSBY H5 CHONDRITE.** McCausland P.J.A.[1], Brown, P.G.[2], Hildebrand, A.R.[3], Flemming R.L.[1], Barker, I.[1], Moser, D.E.[1], Renaud, J.[4], Edwards W.[5] [1]Dept. of Earth Sciences, U. of Western Ontario, London, ON, N6A 5B7 pmccausl@uwo.ca [2]Dept. of Physics & Astronomy, U. of Western Ontario, London, ON, N6A 3K9. pbrown@uwo.ca [3]Dept. of Geoscience, U. of Calgary, Calgary, Alberta Canada T2N 1N4 [4]Renaud Geological Consulting, London, Ontario, Canada, N6H 5L2 [5]Natural Resources Canada, Ottawa, Ontario, Canada K1A 0Y3

**Grimsby fall event:** On the early evening of Sept 25, 2009 (01:03 UT Sept. 26, 2009), a brilliant fireball showing three major bursts was observed over southwestern Ontario and adjacent regions. Several witnesses under the entry path reported sonic booms and some described sound which was simultaneous with the fireball. The event was recorded by a network of automated cameras, radar and infrasound sensors operated by the University of Western Ontario.

The solved trajectory and a peak brightness greater than that of the full moon indicates that a multi-hundred kg object on a 27 degree inclined Apollo-type orbit collided with the upper atmosphere at 21 km/s. Camera records as well as visual reports suggest that several ~kg mass fragments survived to the ground. Darkflight modeling of fragments from the endpoint and major burst locations along the fireball trajectory puts fragments of gram to multi-kilogram mass on the ground to the west and south of Grimsby, Ontario.

A field search was undertaken in the projected strewnfield, along with an effort to raise public awareness of the event. The first recovered individual (Fig. 1) hit the windshield of a parked vehicle and was collected as five fragments on the morning after the fall by A. Garchinski, but remained unrecognized until October 11, 2009. As of December 2009 13 meteorites have been found by search parties and individuals. Fragments are located within a 4 by 8 km strewnfield west of Grimsby; more are expected to the southeast.

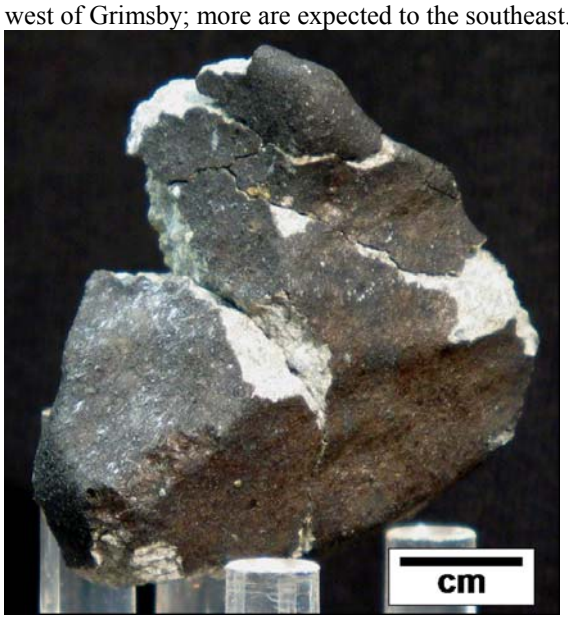


**Figure 1.** Reassembly of five fragments from the 46.1g Garchinski piece of the Grimsby meteorite.

**Recovered meteorites**: Of the thirteen recovered meteorites, eleven are complete or nearly complete individuals, allowing for a ground test of the darkflight modeling predictions. Most fragments have mature fusion crust but two have immature fusion crust representing a probable derivation from late fragmentation. Two individuals show evidence of preferred orientation. Individual masses range from 1g to 69g, giving a total known weight of 215g. Fracture surfaces free of fusion crust reveal a sub-mm chondrule rich matrix with abundant sub-mm flecks of metal and sulphide and occasional large chondrules which exceed 3 mm in diameter. All meteorites except the initially recovered Garchinski individual show some terrestrial weathering of metal (Fig. 2).


**Figure 2.** Grimsby 21.9g fragment "HP-1" upon field recovery with quarter for scale (left); 1.11g complete individual "pjam-2" (top centre); 1.2g complete oriented individual "wing" (top right); and, 22.4g Grimsby "Five" (bottom right).

**Bulk properties:** Bulk density was determined by the Archimedean method [1,2] using 100 µm glass beads as a fluid. Determinations of volumes for six Grimsby meteorites ranging in mass from 21g to 69g provide a bulk density of 3.37±0.03 g/cm$^3$. Grain density for eight fragments was determined by He pycnometry [1,2] (Quantachrome Multipycnometer), giving a mean of 3.62±0.02 g/cm$^3$. Calculated porosities for six fragments are 6.7±0.8%, with no apparent distinction between two "fresh" Garchinski fragments and the other, slightly weathered Grimsby individuals. Magnetic susceptibility [e.g, 3] was measured using a Sapphire Instruments SI2b susceptibility meter for 16 fragments of the Grimsby meteorite, including all five "fresh" Garchinski fragments. Again no distinction was found between the fresh and weathered fragments, giving a mass-based magnetic susceptibility of log $\chi$ = 5.14±0.04 (log of E-9 SI units). These bulk properties are typical for H

chondrites [1,3] and further imply that there is little discernable lithological variation within the Grimsby meteorite thus far.

**Micro-XRD:** In situ micro-XRD [4] was performed on ten locations on a fresh broken surface of Grimsby Five (Fig. 2) using a Bruker D8 Discover diffractometer, operating with Cu Kα radiation (λ = 1.54056 Å) at 40 kV and 40 mA and an incident beam diameter of 300 µm. Diffracted X-ray spot patterns and their integrated analyses indicate the ubiquitous presence of low shock state ~Fo90 olivine and enstatite, kamacite and troilite as well as polycrystalline magnesioferrite spinel in the fusion crust. A large white 3.5 mm chondrule consists almost entirely of ferroan forsterite (Fig. 3).

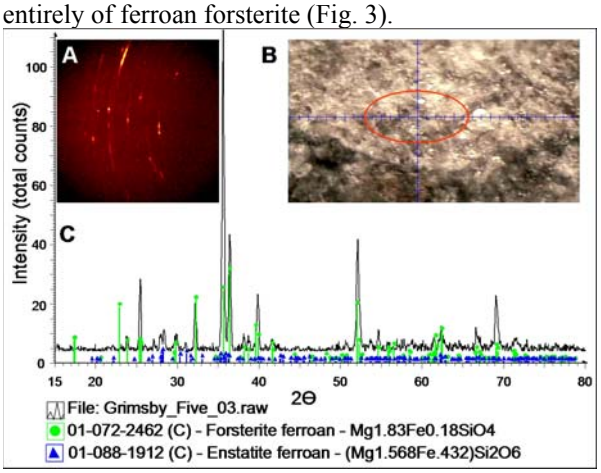


**Figure 3.** Paired two-dimensional detector image of diffracted rays (A) and inline microscope context image (B; 2 mm field of view) of a location within the large white chondrule seen in Grimsby Five (Fig. 2). Integrated X-ray response is plotted as intensity versus 2 Theta (C), with best fit matches from the International Centre for Diffraction Data (ICDD) database. The dominant mineral present is ferroan forsterite, giving bright spots in the 2D pattern.

**Petrography:** Two 0.8 $cm^2$ polished thin sections from the Grimsby HP-1 fragment have been examined so far (Fig. 4). Abundant chondrules and chondrule fragments range in size from 0.03 to 0.70 mm in apparent diameter. Chondrule types include porphyritic olivine, radial pyroxene, finely crystalline orthopyroxene and cryptocrystalline textures. The matrix is variably recrystallized and chondrule rims typically are poorly defined, but feldspar is not well developed. Coarse olivines and pyroxenes show sharp optical extinction, implying a low shock state. In the examined sections, minor Fe-oxide has developed adjacent to the metal and troilite. In SEM backscatter, olivines do not show evidence of zoning, but strings of metal inclusions within some silicate grains, implying a more complex shock history involving annealing of preexisting shock damage [e.g, 5].

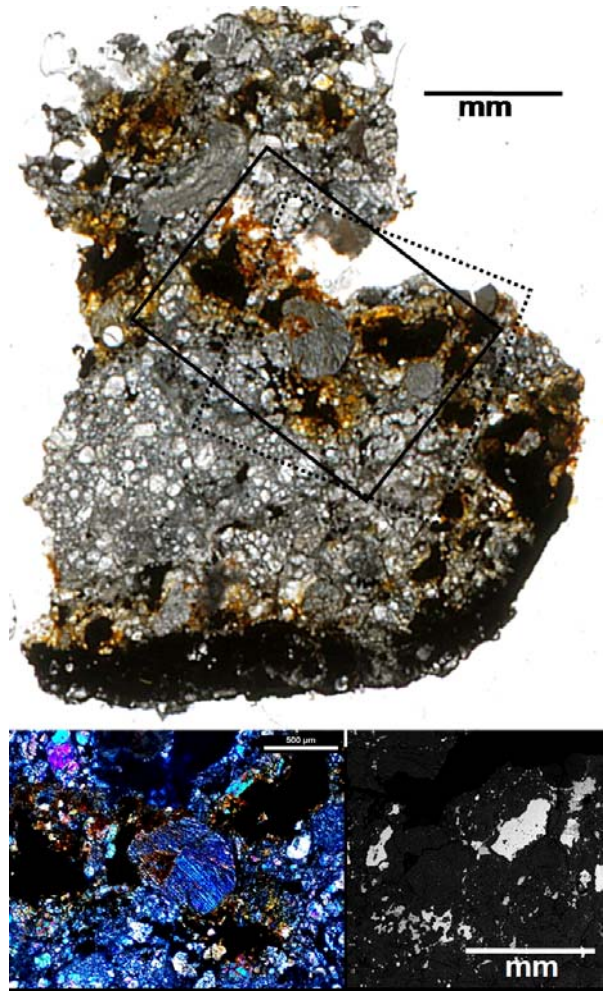


**Figure 4.** Thin section of Grimsby HP-1 chip, in PPL (top, full section), XPL (inset, bottom left) and in SEM backscatter (inset, bottom right). Fusion crust is visible along the bottom and lower right of the PPL view.

**Classification:** Initial EPMA data for olivine in chondrules and matrix are $Fa_{17.8\pm0.4}$, (n=8 grains) and for low Ca pyroxene, $Fs_{15.8\pm1.0}$, (n=5), indicating Grimsby to be an H chondrite [5,6]. From this initial examination, Grimsby is an H5 (S2, W0-1) chondrite.

**Acknowledgements:** We wish to thank the meteorite owners for kindly providing loan of Grimsby fragments for this study. Thanks also are due to the numerous people volunteered for field searching and helped with logistics during the fall of 2009.

**References:** [1] Consolmagno G.J. and Britt D.T. (1998) *MAPS 33*, 1231-1241. [2] McCausland and Flemming *LPSC XXXIX:* Abstract # 1183. [3] Rochette et al., 2003 [4] Flemming R. L. (2007) *Can. J. Earth Sci. 44*, 1333–1346. [5] Brearley, A.J. and Jones, R.H. (1998) *Rev. Min. 36*, 398pp. [6] Van Schmus W.R. and Wood J.A. (1967) *GCA 31*, 747-765.