Impact Melts in Ordinary Chondrites

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Objective

Evidence suggests the Moon was submitted to a period of heavy meteorite bombardment 3.9 billion years ago. This leads to the query of whether or not other inner Solar System planetary bodies experienced a similar phenomenon. Since samples of Mars are rare and there are no known samples of Mercury or Venus, we instead turned to meteorites of asteroidal origins to conduct our study.

Source: http://ie.microsoft.com/testdrive/Performance/AsteroidBelt/Default.html

By studying brecciated (impacted) ordinary chondrites (stony meteorites) we can determine whether or not the asteroid belt experienced heavy bombardment and, vicariously, the rest of the inner Solar System. This research provides further information on the development of our Solar System and may also influence the study of the origins of life, as the earliest traces of life on Earth correlate to the proposed period of bombardment.

Methods

Using the Antarctic meteorites database we sorted through ordinary chondrites in the museum's possession for those that had a mass of over 500g.

Picture by Virginia Power

Picture by Virginia Power

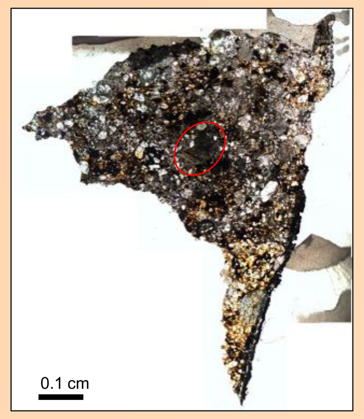
These meteorites were then examined for evidence of brecciation. Twelve were selected for further study.

Large white breccia clast inside of meteorite

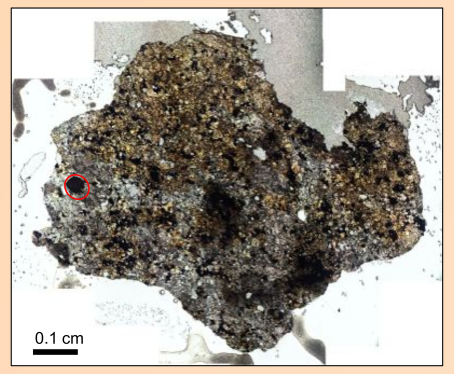
Thin sections were made for each sample, which were then photographed underneath an Olympus BX61 Motorized Research Microscope in plain, cross-polarized, and reflected light. By comparing the images we chose at least one location within eight of the thin sections that could be a potential melt clast. Melt clasts are created at the time of impact due to the heat of friction. This makes them the best points to date when looking for the age of the collision.

Meteorite Thin Sections

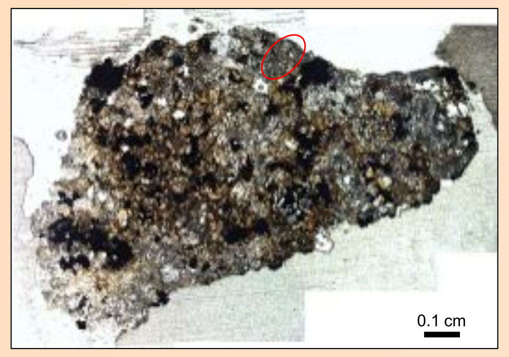
(Suspected melt clasts circled in red)



MET 01002



MET 01004



QUE 99012

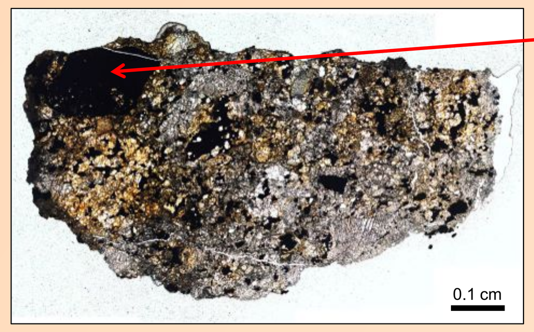
PRE 95400

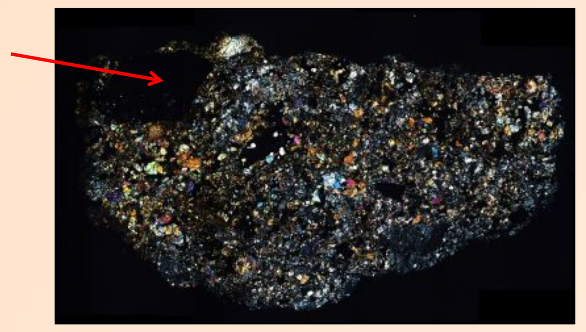
PCA 02070

PCA 02071

PCA 02072

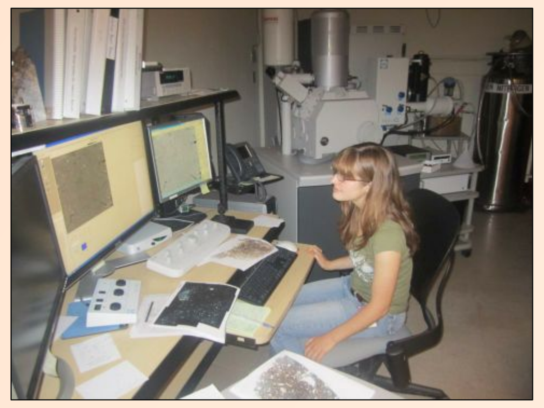
Potential melt clast in meteorite MET 01052 in plain, reflected, and polarized light, respectively.





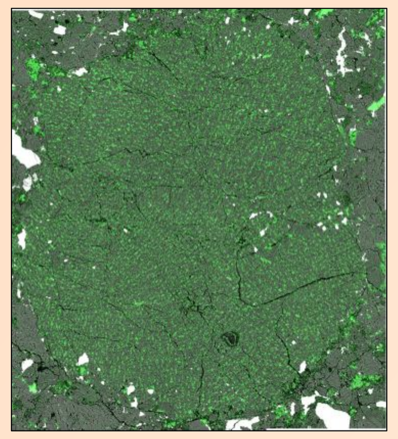
Melt shows up dark in plain and polarized light, but light gray under reflected light, distinguishing it from metal.

An FEI Nova NanoSEM 600 Variable Pressure Field Emission Scanning Electron Microscope (SEM) was then used to closely examine the suspected melt clasts. The Energy Dispersive Spectrometer (EDS) of the SEM was used to obtain elemental composition data of individual minerals within the clasts. This gave us the additional information need to decide if the breccia clasts contained melt material.

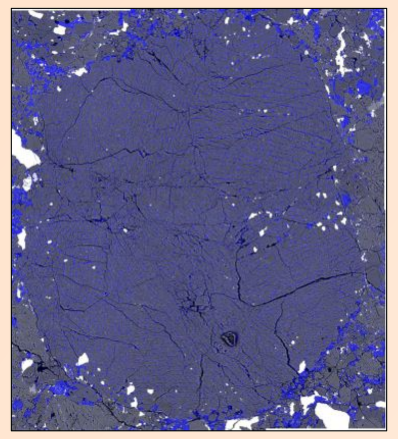


SEM Individual Element Maps of PRE 95400

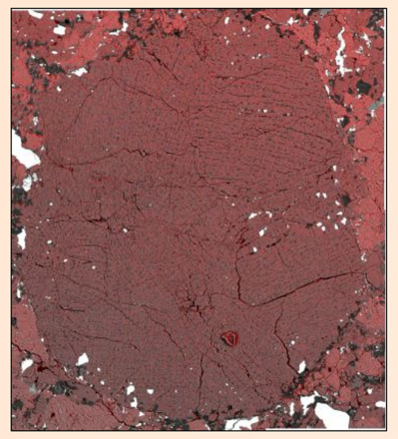
(Overlaid on backscatter electron image)



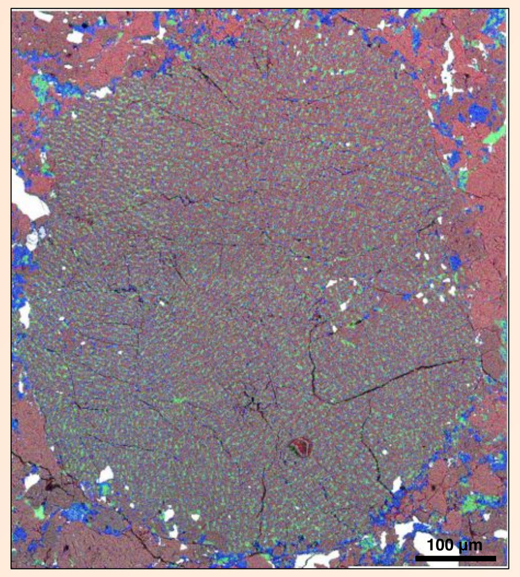
Calcium



Aluminum



Magnesium



Composite image of PRE95400 with all three elements

Acknowledgements

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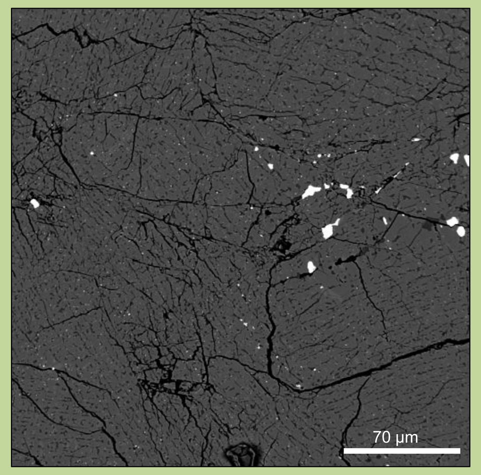
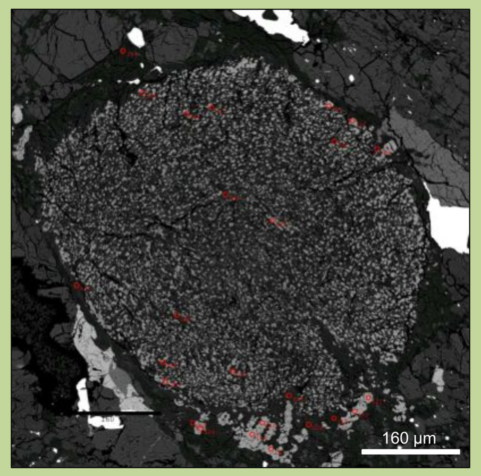
Results

The melt clasts were further examined using the JEOL 8900R Electron Microprobe in the Department of Mineral Sciences. These were identified optically and then analyzed at several points to reveal the combination of minerals present. Our clasts typically contained plagioclase feldspar, pyroxene, olivine, and a combination of these concluded to be melt material.



Close up of melt clast with characteristic striated pattern in the sample of PRE 95400



Melt clast with probed points marked in red in sample of MET 01004

Average Mineral Compositions as Determined by Electron Microprobe in PCA 02071, Clast 1

SiO2	CaO	Na2O	MgO	TiO2	FeO	Al2O3	K2O	Total	Mineral
55.95	1.18	0.04	31.32	0.06	10.03	0.29	0.01	98.88	Pyroxene
39.12	0.38	0.04	42.74	0.04	16.91	0.14	0.01	99.37	Olivine
47.76	4.40	0.77	24.79	0.18	12.40	5.28	0.17	95.75	Melt

After all our examinations, both optical and mineralogical, had been concluded, we were left with nine identified melt clasts in eight meteorites.

Future Work

The meteorites chosen in our study will be sent to Dr. Barbara Cohen at NASA Marshall Space Flight Center where she will perform ^{40}Ar -^{39}Ar age dating on the melt clasts. If there is an age spike at 3.9 billion years our study will have lent further evidence to the heavy bombardment theory.

Meanwhile, researchers at the Smithsonian NMNH will continue to look for brecciated chondrites greater than 500g. These will also be thin sectioned and examined in hopes of finding more melt clasts. As additional qualified samples are identified and age dated, researchers hope to provide a more accurate picture of the impact age distribution.