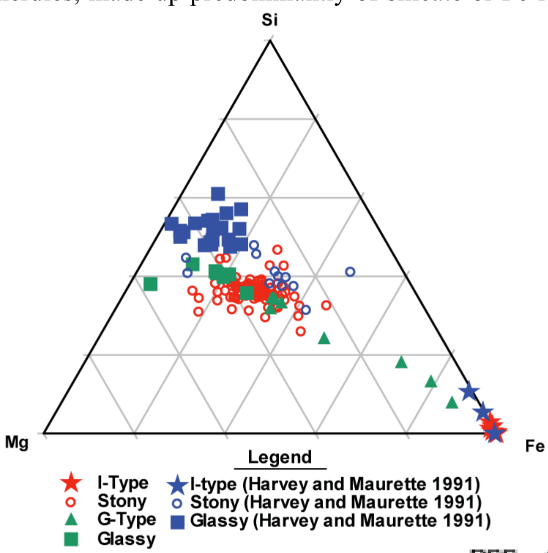
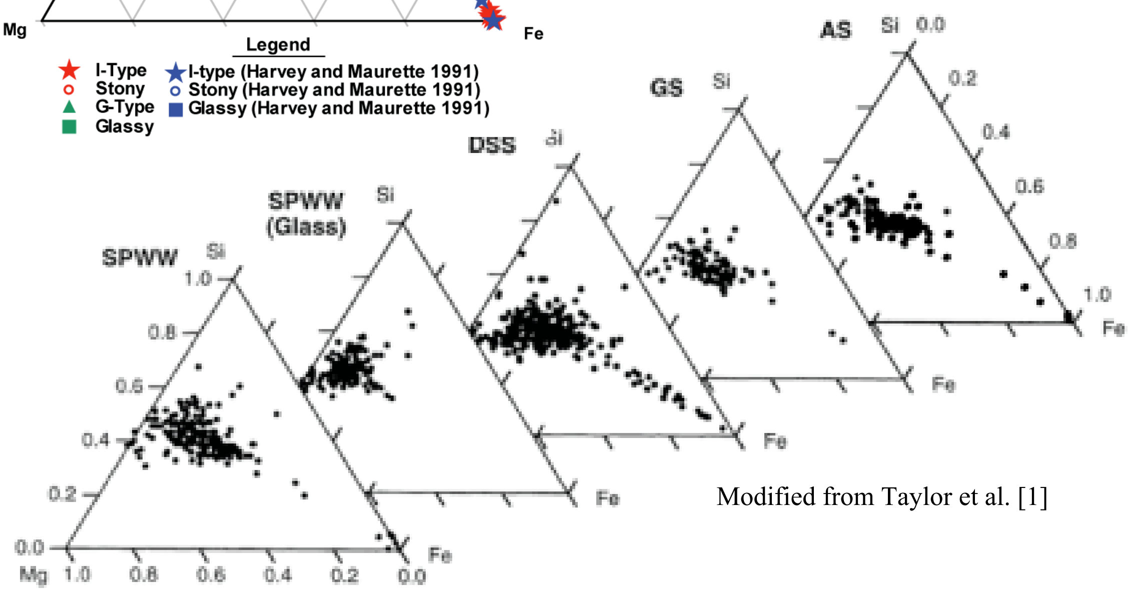
THE PETROGRAPHY AND CHEMISTRY OF COSMIC SPHERULES FROM LEWIS CLIFF, ANTARCTICA.

S. S. M. Hui[1], M. D. Norman[1], R. P. Harvey[2], [1] Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia, [2] Department of Geological Sciences, Case Western Reserve University, Cleveland, Ohio, USA

Introduction: Micrometeorites are meteoritic particles less than 1mm in size found in the deep sea, sediments, swamps and the ices of Antarctica. Cosmic spherules are a group of micrometeorites that have experienced the greatest amount of heating from entering the Earth's atmosphere. We have classified 120 spherules from the Lewis Cliff Ice Tongue Moraine deposit based upon their petrography and major element compositions determined by electron microprobe, and we have measured bulk trace element abundances on 71 of these by laser ablation ICPMS.

Petrography: There are many similarities in textures between the different cosmic spherule collections. The variety of textures is consistent with those described by Taylor et al. [1] and provide a basis for classification. There are two main types of cosmic spherules, made up predominantly of silicate or Fe-Ni oxide. The silicate spherules consist of spinel, olivine and interstitial glass with a variety of internal structures which vary according to the degree of heat alteration. The iron-rich spherules consist of metal oxide (Fe-Ni), sometimes with a preserved glassy Fe-rich cap, or more rarely a silicate/iron dendritic mix.





Modified from Taylor et al. [1]

Composition: Previously, Harvey and Maurette [2] had collected and analysed 35 spherules from this location for major element compositions. Their results are comparable with our results (Fig. 1, AS) and also to the range of major element compositions seen in cosmic spherules from the Deep Sea (DSS), South Pole Well Water (SPWW) and Greenland (GS) (Fig. 2).

Major element compositions of the silicate spherules are distinguished from most terrestrial compositions by their high MgO (25-40 wt.%) and low Al_2O_3 (2-7 wt%) content. Total Fe expressed as FeO shows a very broad range from 5-58 wt% in the bulk spherules. In combination with the melt textures, major element compositions provide strong evidence for an extraterrestrial origin of these spherules. Refractory lithophile trace elements (i.e. Zr, Nb, Sr, Ba, REE, Th) have near-chondritic absolute and relative abundances. In contrast, volatile lithophile and chalcophile trace elements (i.e. Rb, Cu, Zn, Ga, Ge) are strongly depleted to levels near the detection limit. Siderophile elements (Ni, Co, Pt) are also strongly depleted in the silicate spherules compared to chondritic abundances.

Iron-rich spherules (I-types) have major and trace element compositions that are almost complementary to those seen in the silicate-dominated spherules. The iron-dominated spherules are enriched in siderophile elements (P, Cr, Fe, Co, Ni, Ru, Rh, Pd, W, Pt) and depleted in all the other elements analysed for this study.

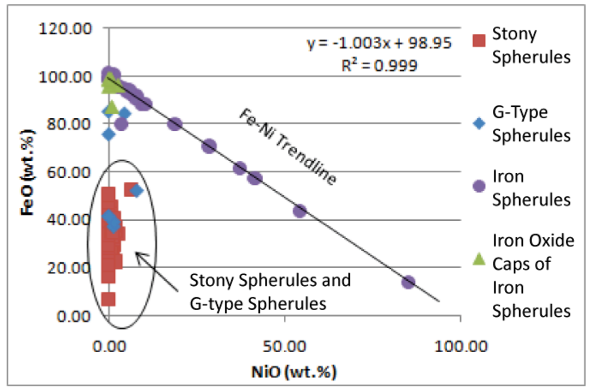
Model of Formation: A study by Love and Brownlee [3] illustrates a number of factors involved in determining whether a micrometeorite will make it to the Earth's surface. The dominate factors are velocity, particle size and angle of entry which not only determine whether or not a particle can reach the surface of the Earth but also how much alteration a micrometeorite may experience.

Cosmic spherules have experienced strong atmospheric heating. The internal textures seen in stony cosmic spherules reflect the different heating regimes. This is fairly well established by experimental melt experiments [4, 5] and isotope studies [6, 7].

Stony Spherule Precursors: Overall**,** stony spherules are most similar to chondrites in chemistry and for this reason are thought to have originated from them [8]. In particular we found that the major and trace elements best match those of CM and H chondrites. This is consistent with the results of previous studies [1, 8]. The depleted volatile element signature is a clear sign that these spherules experienced fairly significant if short heating sequences during atmospheric entry. Since our samples came from glacial moraine it is possible that these depletions are due to terrestrial leaching. However, given the well-preserved fine-grained textures and likelihood that Rb would be introduced by the formation of clays during weathering, the volatile-element depletion is probably a result of strong heating during atmospheric entry.

There are a small number of stony spherules, however, that do not match the chondritic compositions and may have originated from other precursors. The asteroid Vesta has been suggested to be another possible source cosmic spherule material [9]. In our collection, 15 spherules out of 120 have a number of element abundances that exceed the average stony spherule abundance for our collection by 1.5x the interquartile. These spherules could be from materials that are not chondritic in origin or reflect large variability in spherule chemistry.

Iron Spherule Precursors: The origins of the iron-dominated spherules are controversial. One proposal, suggested by Brownlee et al. [10] appears to be the best explanation for our results. I-Type spherules can be located within silicate spherules, sometimes close to the edge of the silicate host forming a nipple. We interpret this as evidence for the formation, migration and possibly separation of an immiscible iron-rich core during melting. Additional evidence comes from the clear enrichment of siderophile elements in the I-Type and complementary depletion in silicate spherules. We also find that in I-types have an excellent (R^2=0.99) negative correlation with Fe and Ni (Fig. 2). This has been suggested as evidence for a common precursor that underwent successive stages of melting, silicate-iron immiscibility, oxidation and fragmentation [11].



Summary: We have completed major and trace element analyses of 120 cosmic spherules from the Lewis Cliff region of Antarctica. This increases the number of previously studied spherules from this locality by about a factor of four. This region can now be considered among the better studied groups.

Out data suggests that the majority of stony cosmic spherules originated from material that was chondrite-like in chemistry and acquired textures through various degrees of heating. The I-type spherules, on the other hand are likely to have been the reduced metallic cores of stony spherules that have separated mid-flight.

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