A Study of The Thermal History of Antarctic Micrometeorites by Thermoluminescence: A First Look.

F. Sedaghatpour[1], J. Craig[1], and D. W. G. Sears[1,2]. [1] Arkansas Center for Space and Planetary Sciences, and [2] Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701, USA

Introduction: Extraterrestrial particles collected terrestrially with sizes less than 1mm are called micrometeorites (MMs) [1]. Micrometeorites constitute the majority of the mass accreted to the Earth from space [1, 2] and have an origin from asteroids, the Moon, Mars and comets [1, 3]. The main sources for these materials are the south polar ice cap [4,5] and the stratosphere [6]. The compositions, mineralogy, and textures of micrometeorites [7], specifically of Antarctic micrometeorites (AMMs), have been reported [8, 9]. Micrometeorites, which are melted or partially melted, are mostly reported as highly unequilibrated material. They are more similar to carbonaceous chondrites by having lower content of Ni and S, and a different oxygen isotopic composition [9]. The study of micrometeorites has shown that unmelted micrometeorites are mostly similar to CI, CM , CO, and CV.

Thermoluminescence (TL) is uniquely successful in evaluating the thermal history of extraterrestrial materials, including ordinary chondrites [10], CM, CV [11], and CO chondrites [12]. We here report our first TL study of Antarctic micrometeorites collected at Cap Prudhomme.

Experimental: Seven particles with sizes between 100-160 μm were included in our initial study. Three were cosmic spherules (CS) and the rest were scoriaceous micrometeorites (SC). Individual samples were placed in a copper pan in the TL instrument and their natural TL measured by applying a temperature ramp up to 500°C. They were then exposed to a 200 mCi ^{90}Sr beta source for 3 minutes and their induced TL measured. Following measurement of their TL properties, the particles were imaged and analyzed by a Philip Model XL30 ESEM with EDX attachment under high vacuum running at 10 and 20 keV.

Results: There was no detectable natural TL in any of our micrometeorites. Induced TL was below the detection limit for four of our particles, although modifications to our equipment are being undertaken in an attempt to improve this. However, strong induced TL signals were detected for three, designated SC2, CS3, CS2. Their glow curves exhibited two peaks (~380 and ~175°C) characteristic of chondritic meteorites. Fig.1 shows scanning electron images and induced TL glow curves for these three particles. Incomplete EDX analysis of these micrometeorites suggests that these are essentially chondritic. There was no evidence for extensive corrosion or that we were analyzing fusion crust. (For comparison, a micrometeorite not included in this study consisted of almost pure hematite.)

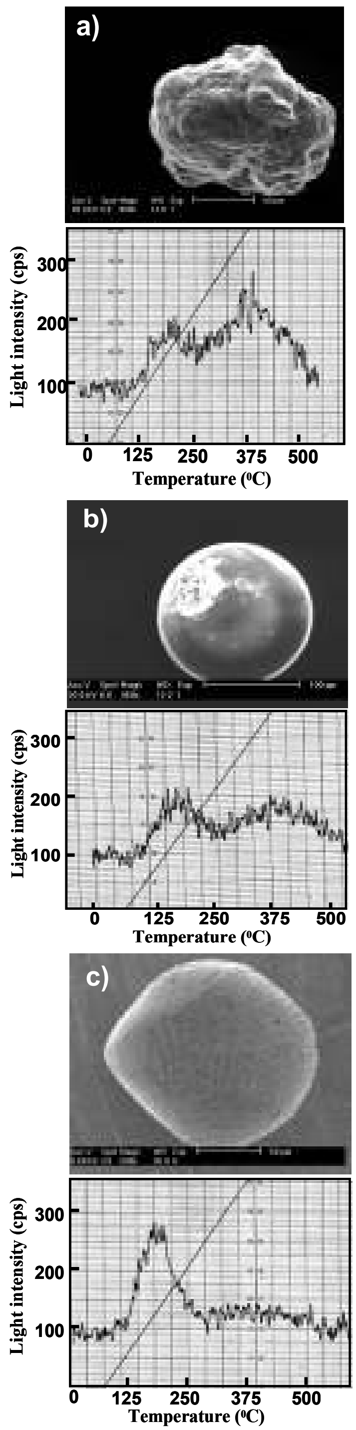

Fig.1 Scanning electron images and induced TL glow curves of a) scoriaceous , SC2, b) cosmic spherule, CS3, and c) cosmic spherule MMs, CS2. These particles show a variety of significant induced TL signals. The diagonal line is a monitor of the heating ramp.

Discussion: We were not surprised that these tiny samples had no measurable natural TL since this would have been drained during atmospheric passage. The presence of a measurable natural TL signal would have indicated a long terrestrial age, many thousands of years. After this time environmental radiation could have caused a build-up in signal. We are not aware of any potential corrosion product that would have measurable TL signal, presumably because such minerals tend to be iron-rich, and Fe tends to be a luminescence quencher.

Of great interest is the presence of a relatively strong induced TL signal. CI and, with one exception, CM chondrites, do not produce a measurable induced TL signal because Fe-rich, hydrated minerals and amorphous materials do not have the crystalline structure with the appropriate lattice defects or impurity atoms. The anomalous CM chondrite is MAC87300 – which has several paired fragments – which is metamorphosed and therefore has been slightly recrystallized [13]. On the other hand, CO or CV chondrites show a wide range of strong induced TL signals depending on their metamorphic history [11, 13].

Fig.2 shows the induce TL glow curves for some metamorphosed and unmetamorphosed CO and CV meteorites compared with our results for MMs. In passing, we mention that the induced TL properties of these micrometeorites do not match those of ordinary chondrites. Instead, two of the present micrometeorites (SC2 and CS3) have induced TL properties most closely resembling MAS87300 and the low metamorphic grades of CO and CV chondrites while the third (CS2) has induced TL properties resembling the metamorphosed CO and CV chondrites. In as much as four of our micrometeorites showed no induced TL, they resemble CI and normal CM chondrites.

The question that arises is whether the crystals we are detecting in SC2, CS3 and SC2 are extraterrestrial or were formed by dehydration and crystallization during atmospheric passage and only coincidentally resemble slightly metamorphosed CM, CV and CO chondrites. We are strongly inclined to the conclusion that induced TL properties are extraterrestrial and these three micrometeorites are related to CM, CV or CO chondrites. (1) We think atmospheric passage was too short-lived and cooling was too rapid to cause these effects. (2) If these properties were induced by atmospheric passage, the four micrometeorites which showed no induced TL would have had a measurable signal.

Conclusion: In short, based on this first look we think it is possible that four of our micrometeorites are related to CI and normal CM chondrites, SC2 and CS3 are related to weakly metamorphosed CM, CV and CO chondrites and CS2 is related to more strongly metamorphosed CO or CV chondrites.

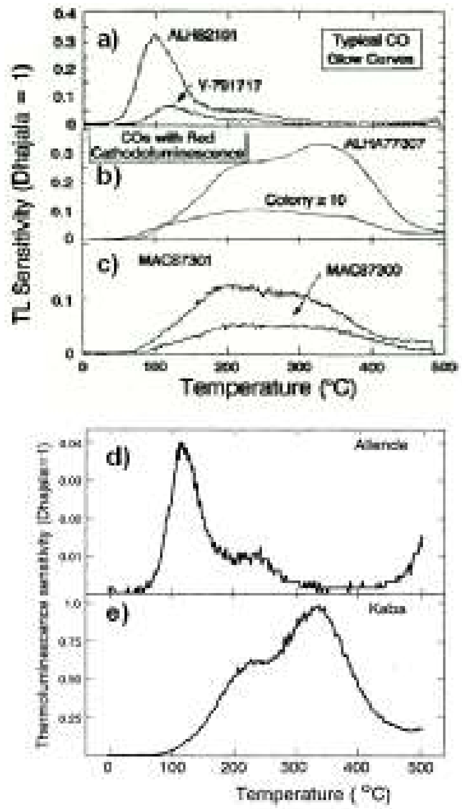

Fig.2 Representative glow curves for carbonaceous chondrites. a) ALH82101 as an example of a metamorphosed CO chondrite, b) ALHA77307 as an example of an unmetamorphosed CO, c) MAC87300, an example of a metamorphosed CM chondrite, d) Allende, a metamorphosed CV chondrite, and d) Kaba, an unmetamorphosed CV chondrite [11 & 13].

References: [1] Love, S. G. and Brownlee D. E. (1993), *Science* **262**, 550. [2] Brownlee, D. E. (1981), "*The Sea 7*", Wiley and Sons, p. 733. [3] Bradley, J. P. *et al*. (1988), "*Meteorite and Early solar system*" U. .Arizona Press, 861. [4] Maurette, M. *et al*. (1986), *Science* **233**, 869. [5] Maurette, M. *et al.* (1991), *Nature* **351**, 44. [6] Brownlee, D. E. (1985), *Ann. Rev. Earth Planet. Sci.* **13**, 147. [7] Taylor, A. *et al.* (2000), *MAPS* **35**, 651. [8] Gounelle, M. *et al.* (2005), *MAPS* **40**, 917. [9] Michel-Levy, M. C. *et a.l* (1992), *Meteoritics* **27**, 73. [10] Sears, D.W. *et al.* (1980) *Nature* **287**, 791. [11] Guimon *et al*. (1995), *Meteoritics* **30**, 707**.** **[12]** Keck, B.D. et al. (1987), *GCA*, **51**, 3013. [13] Sears, D. W. et al. (1991), *NIPR* **4**, 319.