TRANSIENT HIGH-TEMPERATURE PROCESSING OF SILICATES IN FULGURITES AS ANALOGUES FOR METEORITE AND IMPACT MELTS. J. Parnell, S. Thackrey, D. Muirhead, A. Wright, Dept. of Geology, University of Aberdeen, Aberdeen AB24 3UE, U.K., (J.Parnell@abdn.ac.uk).

Introduction: Fulgurites are appreciated as having value in the interpretation of melts formed during meteorite evolution, re-entry, and meteorite impact [1-4]. They represent the product of fossil lightening strikes in sediments or rock, and as such reflect transient very high temperatures applied to a silicate mineralogy. Their formation involves extreme reducing conditions, that are inherent from the >2000K temperatures involved, and in some cases enhanced where the target contains organic compounds [2]. This makes them especially interesting to compare with reduced meteorites, including enstatite chondrites and ureilites.

Petrographic studies have been undertaken on a fulgurite from sands in the Sahara desert, where fulgurites are well developed [5,6]. The starting material was thus quartz-rich sand with resistant heavy minerals such as zircon.

Objectives included:

(i) Assessment of melt heterogeneity.

(ii) Identification of neoformed minerals characteristic of the reducing environment.

(iii) Relationships between mineralogy and structures produced by devolatilization.

(iv) Indications of melt temperature.

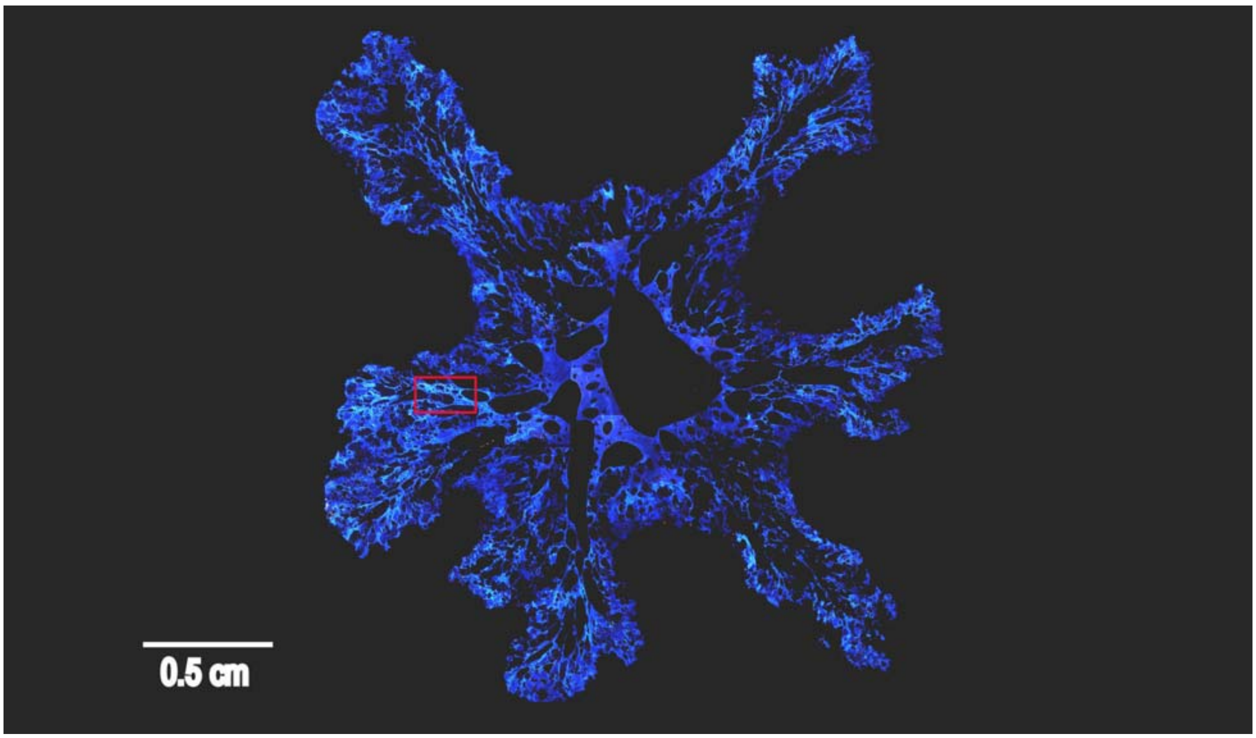

Fig. 1. Composite cathodoluminescence image of a Sahara fulgurite in cross-section. Red square highlights region of Figure 2.

Petrography: The fulgurite, which is 26mm at its widest point (Fig. 1), is composed of heterogeneous silicate melts. There are three predominant melt compositions; K-feldspar (25%), quartz (65%), and zirconium-rich silicates (10%). Figure 2 shows the typical melt flow textures exhibited in the sample and also the gradational nature of melt compositions. Melt flow is more intense in the branches of the fulgurite, demonstrated by the stretching of vacuoles. The composition of melt varies radially. The core of the fulgurite is more silica-rich (darker colours) with the composition changing to a more K-feldspar/zirconium-rich melt (lighter colours) in the branches. This variation could be due to a number of reasons, including melt processes, vaporisation and condensation of silicates in the core, quenching processes, and devolatilization processes. The branches intercept the core of the fulgurite at angles between 54˚ and 79˚ in 2-D cross-section, possibly reflecting the most efficient way to dissipate energy. Unmelted grains of the host sediment occur embedded into the outside of the fulgurite. These grains commonly show a unique extinction pattern where the crystal structure has been slightly deformed. Partially melted grains can also be observed within the melts (Fig. 3), suggesting that host sediments were incorporated during radial growth of the fulgurite.

Neoformed silicides: The predominant neoformed mineral phase in the melt is iron silicide (Fig. 4). Preliminary measurements suggest that these have a 1:1 stoichiometric composition. Iron silicides are also described from other fulgurites [2,4] and indicate extreme reducing conditions. Similarly, iron silicides occur in the most reduced meteorites, enstatite chondrites [7], ureilites [8,9], and achondrites [10], but are not known to form in other terrestrial environments. The silicides occur particularly lining vacuoles (Fig. 4). Loss of oxygen during devolatilization leaves a relatively reduced liquid and enhances formation of metallic silicon and silicon-iron alloys such as the silicides [11]. The crystallization of mineral phases on the free surface of glass is observed elsewhere, e.g. spinel growth on the exterior of micrometeorites, meteorite fusion crusts, and on impact glass droplets [12].

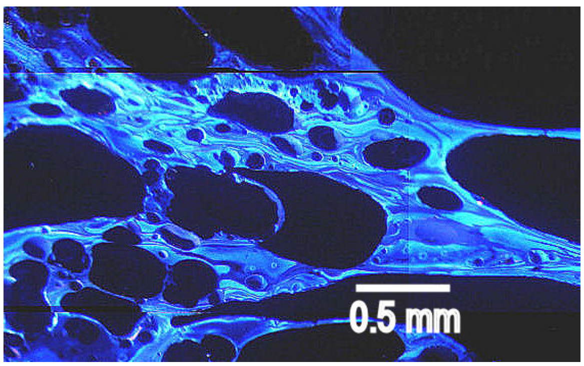

Fig 2. Close-up cathodoluminescence image of the internal flow structure in Sahara fulgurite, highlighting variation in melt composition.

Melt temperature: There are two indicators of melt temperature, the occurrence of iron-silicon alloys and zirconium-rich melts. The existence of liquid silicon and Zr silicates implies temperatures above 2000K and 2800 K respectively [2, 13]. With the presence of unmelted grains embedded into the edge of the fulgurite, cooling must have been remarkably rapid. The temperature gradient would have been extreme. Zirconium silicate melts occur less than 1mm away from unmelted quartz grains. Where within glass, iron silicides have a spherical shape, indicative of complete melting. Some silicide species are dispersed in stringers, comparable to iron/silicon-rich spheres in glass produced by experimental impact-induced metal-silicate partitioning and seen in natural lunar glass fragments [14].

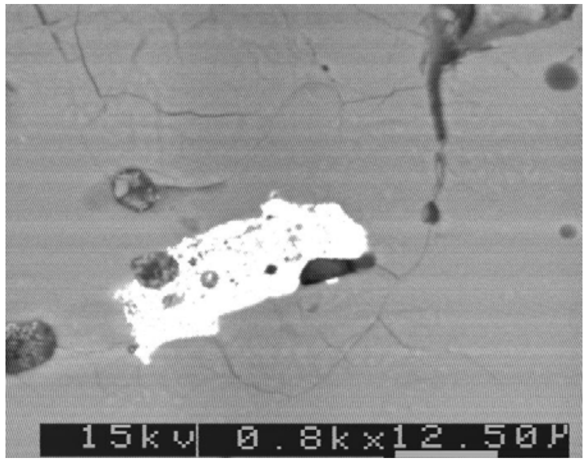

Fig. 3. Partially melted zircon grain amoungst Si-rich melt.

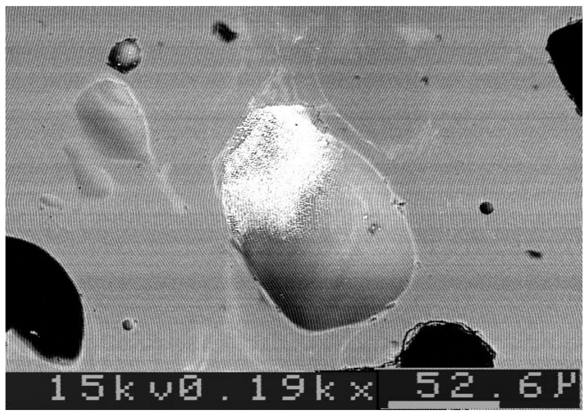

Fig. 4. Iron silicides (bright, under SEM) are particularly associated with surfaces of vacuoles.

References: [1] Weeks R.A. et al. (1980) *J. Non-Cryst. Solids*, 38/39, 129-134. [2] Essene E.J. & Fisher D.C. (1986) *Science*, 234, 189-193. [3] Wasserman A.A. et al. (2002) *LPSC* XXXIII, abs. 1308. [4] Cardona M.R. et al. (2006) *Bol. Mineral.*, 17, 69-76. [5] Sponholz B. et al. (1993) *The Holocene*, 3, 97-104. [6] Navarro-Gonzalez R. et al. (2007) *Geology*, 35, 171-174. [7] Lin Y. & El Goresy A. (2002) *Meteoritics Planet. Sci.*, 37, 677-599. [8] Keil K. et al. (1982) *Am. Mineral.*, 67, 126-131. [9] Ikeda Y. et al. (2000) *Antarct. Meteorite Res.*, 13, 177-221. [10] McCoy T.J. et al. (1999) *Meteoritics Planet. Sci.*, 34, 735-746. [11] Wasserman A.A. et al. (2001) *LPSC* XXXII, abs. 2037. [12] Margolis S.V. et al. (1991) *Science*, 251, 1594-1597. [13] Singh B.P. et al. (2002) *Ceramics Int.* 28, 413-417. [14] Rowan L.R. & Ahrens T.J. (1994) *Earth Planet. Sci. Letts.*, 122, 71-88.