MICROSPHERULES AS PROXIES FOR LIGHTNING STRIKES

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Introduction: Microspherules may be found in trace amounts throughout the geologic record and on planetary surfaces owing to high-temperature processes, such as the atmospheric entry of cosmic dust or impacts. In addition, lightning strikes may produce melt droplets, derived from the target rock, that are quenched to form microspherules. The prevalence of lightning as a climatic phenomenon suggests that the abundance of lightningogenic microspherules may not be insignificant, though this will be influenced by the local geography in the geologic past. Here, we present microspherules thought to form from melt droplets ballistically sprayed from the discharge zone.

Spherule textures and compositions are likely to be dependent on their formation mechanism and are thus signatures of environmental, climatic and geological processes. Detecting microspherules in the geological record gives clues as to the prevalence of lightningogenic spherules and aids in palaeoenvironment modelling.

Methods: Fine-grained sediment was collected from the granitic summit of Pikes Peak, Colorado, USA. The sediment was sieved through a 500 µm mesh and spherical particles were picked from the <500 µm fraction under a binocular microscope. The microspherules were mounted in an epoxy stub and polished using alumina powder. The polished blocks were analysed using a Hitachi TM4000Plus scanning electron microscope (SEM) at Imperial College London with energy-dispersive spectroscopy (EDS).

Results: 33.28 g of sediment <500 µm was separated from a total mass of 230 g and searched, yielding 37 spherules. Rounded silica grains were also picked, though under closer inspection, showed sub-spherical shapes and translucency under light, compared to the transparency of the glassy spherules. The spherules are predominantly homogeneous, with smooth surfaces and glassy internal textures. The size range of the spherules is 180-330 µm. Vesicles are rare and where present, are small (<25 µm) and occur close to the surface. Some spherules have curved pits on their surfaces, <2 µm in width and 20-40 µm in length.

Most spherules are silicate-dominated with Na (Na/Si<0.50) and Ca (Ca/Si<0.26), and minor Mg (Mg/Si<0.10) and Al (Al/Si<0.04). One spherule, predominantly composed of Na-silicate glass and 210 µm in diameter, is embedded in a sediment grain with calcitic and feldspathic components. Two spherules have composite morphologies: one comprises two spherules of similar size (246 µm and 179 µm) connected at a high contact angle with a small difference in the backscatter signal, whilst another shows three hemispherical surface protrusions, 20 µm, 40 µm and 70 µm in diameter, on a 255 µm spherule. An anomalous spherule in the collection has a blocky surface texture and equigranular interior, and is composed of Fe (>18 wt%) and O (>39 wt%).

Discussion: We suggest a lightningogenic origin for the Pikes Peak microspherules. The sampling locality represents a prime target for lightning strikes on rocky surfaces. With its high topographic prominence and isolation among the Colorado Fourteeners, Pikes Peak has the highest ground stroke density in Colorado, with >19 strikes per km^2 annually [1]. Furthermore, the summit has a low vegetation cover, exposing the bare rock surface. These factors may contribute to a high spherule production rate, reflected in the recovery statistic of 16/100 g for the total sediment processed and 111/100 g for the <500 µm fraction.

The broadly feldspathic compositions points toward a genetic relationship with the underlying granite and may be due to the lower melting point of felsic minerals. Other formation mechanisms are discounted due to the non-chondritic elemental spectra and absence of local volcanism or impacts; the occurrence of a spherule embedded in a feldspathic sediment grain suggests the observed spherules are not contaminants. The discovered Fe-rich spherule is interpreted as an I-type micrometeorite, and is likely composed of magnetite or wüstite.

The lack of vesicles may indicate formation within a saturated vapour plume, similar to spherules thought to be from an Antarctic touchdown event [2]. The high abundances of Na, a volatile element, support this conclusion. The occurrence of composite particles and spherules with protrusions also indicate that the particles formed in a material-saturated environment, either as quench products from a melt or as condensation products. Alternative explanations for the scarcity and small size of vesicles are the low atmospheric pressure at >4,000 m or the low indigenous volatile content of the feldspathic minerals in the granite.

Implications: The features of these microspherules and their comparison to other collections – collected in geologically diverse localities [3] – may shed light on the signatures of formation environments preserved within microspherules, such as atmospheric parameters. This is important for climatic modelling in addition to understanding the prevailing exposure conditions of planetary surfaces in the past. The discovery of a micrometeorite gives an indication as to the frequency of cloud-to-ground lightning strikes, given a steady cosmic dust background flux.

References: [1] Vogt B. J. and Hodanish S. J. (2016) *Applied Geography* 75:93-103. [2] van Ginneken M. et al. (2021) *Science Advances* 7:eabc1008. [3] Boyd M. R. et al. (2022) *85th Annual Meeting of the Meteoritical Society*, Abstract #6224.