# REFRACTORY INCLUSIONS IN THE EATON BRASS PSEUDOMETEORITE?

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**Introduction:** In 1931, a farmer was tending to his field in Eaton, Colorado, when he heard a faint humming noise over his shoulder. Shortly thereafter, a small metallic object impacted the soil nearby. In the following weeks, the material was examined by Harvey Nininger, arguably the foremost expert in Meteoritics at the time. After hearing the accounts of this incident, Nininger concluded that the testimonies were consistent with that of an observed meteorite fall. There was only one aspect of this fall that puzzled Nininger: the object was an alloy of Cu, Zn, and Pb. Out of an abundance of caution, Nininger would not publish his findings until he had amassed enough evidence to support the possible identification of a Cu-rich meteorite. Years later, the identification of native Cu metal in the Garnett H4 meteorite fall [1] provided Nininger with enough precedent to propose that the Eaton object represented a new type of Cu-rich meteorite [2]. This conclusion was, of course, met with skepticism, and the subsequent (and only) study of the Eaton "meteorite" 30 years later argued that the object was most likely a pseudometeorite composed of artificial brass, based on its major element composition and the lack of corresponding Cu-Zn alloys in the meteoritic record [3].

The two conclusions for the Eaton object's provenance differ primarily on philosophical grounds; Nininger would not discount the possibility of the Eaton object's extraterrestrial origin based solely on its unusual composition, whereas others argued for a terrestrial, artificial origin based on compositional similarities with Muntz brass alloys [3]. However, neither perspective provides conclusive evidence for either an extraterrestrial or terrestrial origin—only that the Eaton object was (a) unlike known meteorite components of the time and (b) that it shares some compositional similarities with artificial alloys [3]. The following 50 years have borne witness to an exponential growth of knowledge and analytical techniques in the field of Meteoritics, as well as in the diversity of the meteoritic record itself. Recent identification of small (<10 µm) Cu-Zn alloy nuggets in chondrites [e.g., 4-5] merits further investigation into the origin of the Eaton object. Ca-aluminosilicate clasts identified in the Eaton object [3] may provide the best opportunity to conclusively determine its provenance, but no data is available for the mineralogy or chemistry of these clasts.

**Methods:** A polished section of the Eaton pseudometeorite was obtained from the ASU Buseck Meteorite Collection. The texture and mineralogy of its largest silicate clast was first determined by EDS semiquantitative spot analyses and elemental mapping at the LPI SEM Facility. EMPA data were collected for individual mineral phases at ARES NASA JSC.

**Preliminary Results & Discussion:** The Eaton pseudometeorite contains one silicate clast approximately 200 µm in diameter and is roughly circular in cross section. This small inclusion hosts an enigmatic diversity of mineral phases: grossular, nepheline, altered Ce-monazite, altered thorianite, perovskite, and sodalite. Grossular is the most abundant phase, with interstitial nepheline (± sodalite), and perovskite. Altered Ce-monazite and thorianite are present as ~20-50 µm inclusions composed of aggregates of ~1 µm crystals and are texturally associated with one another. The majority of the clast is mantled by a 10-50 µm thick ZnO rim that has visibly altered silicates along the clast's margin.

The mineralogy of the silicate clast in the Eaton pseudometeorite provides a valuable opportunity to investigate its provenance. Its mineralogy shares some similarities with that of terrestrial nepheline syenites, which can be used as ceramic fluxes for metal casting. However, neither grossular nor perovskite are phases associated with nepheline syenites, but both are common constituents of some CAIs [e.g., 6], along with nepheline and sodalite. Few reports of monazite are found in the meteoritic record, but its rare occurrence has been associated with metasomatism or hydrothermal activity [7]. Such a mechanism may also explain the pervasive alteration throughout the Eaton silicate inclusion and the lack of $PO_4$ in altered monazite, as S-rich, acidic fluids have been found to dissolve phosphates, leaving residual REE- and Th-rich sulfates [e.g., 8-9]. Alternatively, the low EMPA totals for REE,Th-rich phases may be attributable to their uneven surface textures.

The two potential origins for the silicate clast within the Eaton object should be discernable with isotopic measurements relevant to CAIs, namely oxygen isotope and $^{26}$Al-$^{26}$Mg isotope systematics. In situ oxygen isotopic ratios along the CCAM fractionation line and/or excess $^{26}$Mg would provide strong evidence that the silicate inclusion is extraterrestrial and formed early in solar system history (i.e., an altered CAI); thus, the major brass component surrounding the silicate inclusion would also necessarily be extraterrestrial. Future work will investigate the isotopic composition of Eaton's silicate clast and provide more definitive evidence for its origin.

**References:** [1] Nininger H. H. (1941) *Pop. Astro.* 49:326-329. [2] Nininger H. H. (1943) *Pop. Astro.* 51:273-280. [3] Buseck P. R. et al. (1973) *GCA* 37:1249-1254. [3] Author G. H. (1996) *LPS XXVII*, Abstract #1423. [4] McCanta M. C. et al. (2008) *GCA*, 72:5757-5780. [5] Bischoff et al. (2011) *Geochemistry*, 71:101-133. [6] MacPherson G. J. (2003) *Treatise on Geochem.*, 1:201-246. [7] Liu Y. (2016) *EPSL*, 451:251-262. [8] Cui H. et al. (2020) *Geology* 48:145-148. [9] Kim E. & Osseo-Asare K. (2019) *Hydrometallurgy*, 113-114:67-78.