EVIDENCE FOR A SINGLE UREILITE PARENT ASTEROID FROM A PETROLOGIC STUDY OF POLYMICT UREILITES.

Hilary Downes[1] and David W Mittlefehldt[2], [1]Lunar and Planetary Institute, Houston, Texas, USA (Downes@lpi.usra.edu) [2]NASA/Johnson Space Centre, Houston, Texas, USA.

Introduction: Ureilites are ultramafic achondrites composed of olivine and pyroxene, with minor elemental C, mostly as graphite [1]. The silicate composition indicates loss of a basaltic component through igneous processing, yet the suite is very heterogeneous in O isotopic composition inherited from nebular processes [2]. Because of this, it has not yet been established whether ureilites were derived from a single parent asteroid or from multiple parents. Most researchers tacitly assume a single parent asteroid, but the wide variation in mineral and oxygen isotope compositions could be readily explained by an origin in multiple parent asteroids that had experienced a similar evolution. Numerous ureilite meteorites have been found in Antarctica, among them several that are clearly paired (Fig. 1) and two that are strongly brecciated (EET 83309, EET 87720). We have begun a detailed petrologic study of these latter two samples in order to characterize the range of materials in them. One goal is to attempt to determine whether ureilites were derived from a single parent asteroid.

EET 87720: The initial announcement [3] described this ureilite as a "cataclastic aggregate", implying that it is a polymict breccia. Subsequent studies [4,5] have shown that it contains numerous ureilitic clasts that have been shocked to different extents, as well as rare albitic plagioclase grains, nearly pure forsterite (Fo98) and nearly pure enstatite (En98). Dark inclusions have also been reported. This meteorite has been recognized as a regolith breccia [6] because of its solar wind implanted noble gases. It has a cosmic-ray exposure age of 8.9 Ma [7]; therefore it is not apparently paired with any other known ureilite. Although EET 87720 shows petrographic similarities to polymict ureilite EET 83309 found only 15 km away, the latter has a cosmic-ray exposure age of 46.8 Ma [7].

In thin-section this sample contains large (8-10mm) ureilite clasts that have experienced strong shock metamorphism that has formed a mosaic texture. This material appears to be the major component of the meteorite. Some thin-sections contain only a single mosaic-textured clast and hence resemble monomict samples. Compositional scans reveal that, in some large clasts, an original poikilitic texture is preserved, with rounded olivine crystals typically 1000 microns in diameter surrounded by pigeonite. These large clasts are surrounded by a matrix of much finer-grained material that is dominated by individual mineral clasts, up to 1500 microns in diameter, mainly comprising olivine and subordinate pigeonite. Many of these clasts do not have mosaic texture and thus were spared the shock metamorphism that affected the large clasts. Clasts of plagioclase are occasionally found.

EET 83309: Some sections of EET 83309 also contain individual ureilite clasts up to 2 mm in diameter, both shocked and unshocked, and smaller lithic clasts of uncertain origin. The matrix is composed of sub-angular to rounded grains of ureilitic olivine and pigeonite, with a small proportion of non-ureilitic clasts.

Mineral compositions: Electron-probe analyses of the cores of olivine clasts in the brecciated regions of EET 87720 fall precisely on the well-established correlation between Fe/Mg and Fe/Mn (Fig. 1) [6]. The constituent ureilitic olivines show an extremely wide range, from Fo75.0 to Fo96.4. They include Fe/Mg and Fe/Mn (molar) values that are slightly higher and slightly lower than those found within all other analysed ureilites. While is is possible that some of the observed variation is due to the well-known reduced rims found on ureilitic olivines, we have only analysed cores of clasts. However, the most Mg-rich olivine reported here may be from a section cut through a rim or be a rim fragment. This sub-angular clast is cut by metal veins and contains numerous disseminated metal inclusions. Its composition is similar to olivine cores in the strongly reduced ureilite ALH 82130. Nevertheless, the entire range of ureilitic olivine can be found in a single thin-section and the range of olivine compositions is slightly more extensive than the range in monomict ureilites. Pigeonite core average mg#s range from 76.6 to 89.2, similar to the range for all monomict ureilites.

Interpretation: The range of olivine and pyroxene compositions can be interpreted as circumstantial evidence that ureilites originated from a single parent asteroid. However, it is possible that the regolith represented by EET 87720 may have received a wide variety of ureilitic material from numerous impactors. This possibility is suggested by the rare occurrence of non-ureilitic material such as low-Mn olivines that are probably derived from chondritic impactors (Fig. 1). Significantly, the distribution of olivine compositions in the brecciated region of this single polymict ureilite (Fig. 2) is closely similar to the distribution reported for all ureilites [1,6]. This similarity in distribution is unlikely to have come about if monomict ureilites represent separate parent asteroids, as random impact events on multiple bodies are unlikely to result in the assembly of a single object that has a similar compositional distribution. Therefore we consider that the ureilitic material present in samples such as EET 87720 was more likely formed on a single parent asteroid, and we predict that this holds for all polymict ureilites. These objects may have formed either by gardening of an intact parent asteroid, or by disruption and reassembly prior to ejection of the meteorite.

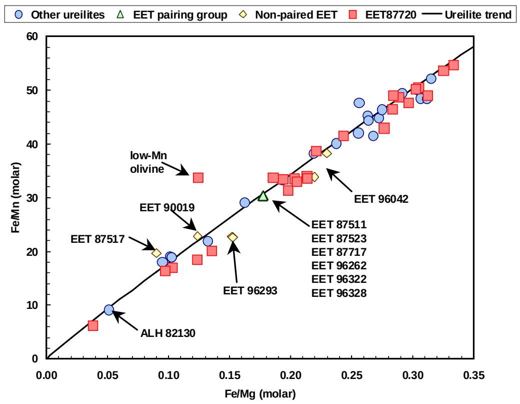

Fig. 1. Fe/Mn vs Fe/Mg (molar) of olivines from ureilites. The range in olivine core compositions from EET 87720 is wider than the range shown by core compositions of monomict ureilites. Several other Antarctic samples are clearly paired. Ureilite correlation line from [6].

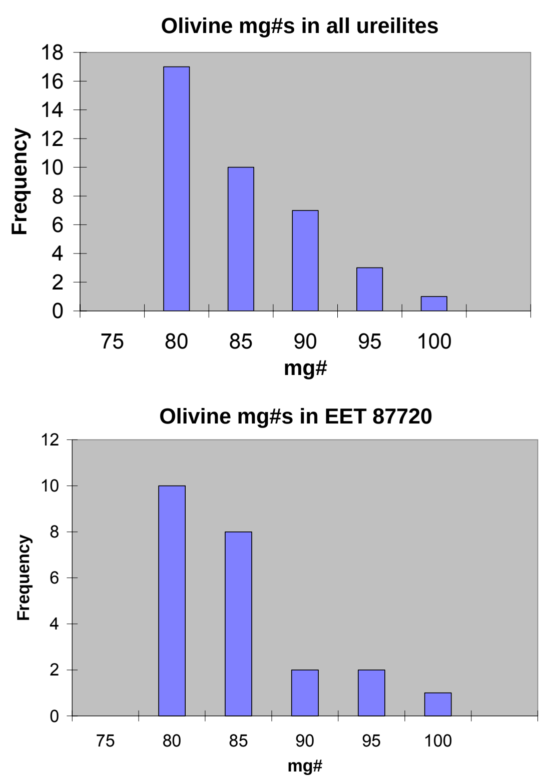

Fig 2. Histograms showing the similarity of distribution of olivine mg#s in clasts in EET 87720 (lower panel) compared with the distribution of olivine mg#s in monomict ureilites (upper panel).

References: [1] Mittlefehldt D W, McCoy T J, Goodrich C A and Kracher A 1998. In: Planetary Materials, RIM 36, 4-1 – 4-195. [2] Clayton R N and Mayeda T K (1988) GCA 52, 1313-1318. [3] Schwarz C and Mason B 1989. Antarctic meteorite newsletter 12 (3) 15. [4] Warren P and Kallemeyn G W 1991. LPS 22, 1467-1468. [5] Guan Y and Crozaz G 2001. MAPS 36, 1039-1056. [6] Goodrich C A, Scott E R D and Fioretti A M 2004. Chemie der Erde 64, 283-327. [7] Rai V K, Murty AVS and Ott U 2003. GCA 67, 4435-4456.