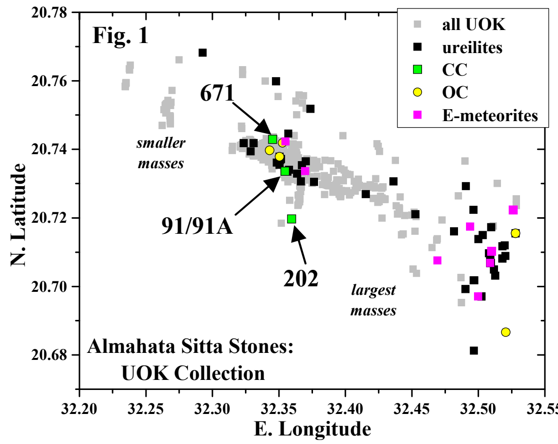
THE ALMAHATA SITTA POLYMICT UREILITE FROM THE UNIVERSITY OF KHARTOUM COLLECTION: CLASSIFICATION, DISTRIBUTION OF CLAST TYPES IN THE STREWN FIELD, NEW METEORITE TYPES, AND IMPLICATIONS FOR THE STRUCTURE OF ASTEROID 2008 TC_3. C. A. Goodrich[1], A. M. Fioretti[2], M. Zolensky[3], M. Shaddad[4], D. K. Ross[5], I. Kohl[6], E. Young[6], N. Kita[7], T. Hiroi[8], M. G. Sliwinski[7] and P. Jenniskens[9]. [1]Lunar and Planetary Instititute, USRA, Houston TX 77058 USA (goodrich@lpi.usra.edu); [2]CNR – Istituto di Geoscienze e Georisorse, I-35131 Padova, Italy; [3]ARES, JSC, Houston TX 77058 USA; [4]Dept. Astronomy, Univ. of Khartoum, Khartoum 11115 Sudan; [5]UTEP/Jacobs-JETS/NASA-JSC, Houston TX 77058 USA; [6]UCLA, Los Angeles CA 90095 USA; [7]Wisc-SIMS, U. Wisconsin, Madison WI 53706 USA; [8]Brown Univ., Providence RI 02912 USA, [9]SETI Inst., Mountain View CA 94043 USA.

Introduction: The Almahata Sitta (AhS) polymict ureilite fell in 2008 when asteroid 2008 TC_3 impacted over Sudan [1,2]. It is the first meteorite to originate from an asteroid that had been tracked and studied in space (with spectral classification) before impact [1,2], and provides a unique opportunity to correlate properties of meteorites with those of their parent asteroid.

More than 700 monolithologic stones from the AhS fall were collected. Of those previously studied, ~70% were ureilites and ~30% were chondrites [3,4]. It has been inferred that 2008 TC_3 was loosely aggregated and porous and disintegrated in the atmosphere, with only its most coherent clasts falling as stones [1,2,4-6].

However, understanding the structure of this atteroid is limited by incomplete study of the heterogeneous stones, and the loss of most of the mass of the asteroid [4]. The University of Khartoum (UOK) AhS collection contains over >600 AhS stones with find coordinates [1,7]. We are studying this collection [10,11] to determine: 1) the proportion of ureilitic to various non-ureilitic stones; 2) the distribution of types of stones in the strewn field; and 3) the compositional and physical structure of 2008 TC_3. We report on 61 new stones, including a unique sample that may represent the bulk of the material lost from 2008 TC_3.

Classification: We studied polished sections from 61 previously unclassified UOK stones (Table 1) by SEM and EMPA. Oxygen isotope analysis, FIB/TEM, and reflectance spectroscopy were conducted on some. Approximately 56% are coarse-grained ureilites, 21% are fine-grained porous ureilites, and 21% are non-ureilites, similar to previously studied UOK stones. Compared with non-UOK AhS stones, our studies show lower proportions of non-ureilites and fine-grained porous ureilites (Table 1). The non-ureilites were three OC (two H4-5 & an LL3-4), five EC (EH & EL of various types), two unique E-meteorites, and three unique C1-C2 (previously the only known CC from AhS was a C_B [3]). The distribution of these types in the strewn field (Fig. 1) suggests a possible concentration of E-meteorites among the largest masses at the east end. The three CC were found in a limited range of latitude. These observations will be tested with the remaining UOK collection.



C1-C2 Lithologies: AhS 91 (paired with 91A) is a friable breccia [11], consisting of a C1 lithology (phyllosilicates, bruennerite, dolomite, magnetite, fayalite, ilmenite, phosphate, pyrrhotite, pentlandite) that contains ~10 µm to 3 mm-sized clasts of ureilitic olivine, pyroxenes and plagioclase from a range of ureilite types, as well as chondrules and metal (OC and EH compositions) that do not belong to the C1. The bulk oxygen isotope composition of the C1 material plots along CCAM with $\Delta^{17}O$ = ~1.8‰ (Fig. 3), similar to a CC-like clast in the Nilpena polymict ureilite [14]. In situ (SIMS) oxygen isotope analyses from one fragment of AhS 91 (Fig. 2,3) confirm the ureilitic provenance of several mineral clasts, and show that three chondrules could be derived from OC, while one (area 5) may be related to primitive CC. Oxygen isotopes of a bruennerite grain in the C1 show $\Delta^{17}O$ = ~2.3‰ with large mass-dependent fractionation. Reflectance spectra of 91A (chips and powders) are relatively flat and dark (reflectance ~0.03-0.05) in the 0.7-2.6 µm range, and show a 2.7 µm band due to water of hydration in phyllosilicates. Compared with spectra of CC from RELAB, they are most like CM but lack the 0.7 µm band of phyllosilicates typically seen in CM.

AhS 671, found ~1400 meters from AhS 91A (Fig. 1), is a similar breccia, except that the CC lithology shows partial dehydration of serpentine to fibrous olivine. Its bulk oxygen isotope composition has slightly lower $\delta^{18}O$ and $\Delta^{17}O$ (~1.6‰) than 91A (Fig. 3). This could be due to minor terrestrial weathering, which is seen in a 0.5 µm band in reflectance spectra of 671. Cr isotopes of 91A and 671 [15,26] show that they are unlike any previously known CC.

AhS 202 is an extremely magnetite-rich rich C2 unlike any known CC [10]. Magnetite compositions are consistent with CI but oxgyen isotope compositions are in the range of CR or CM (Fig. 3).

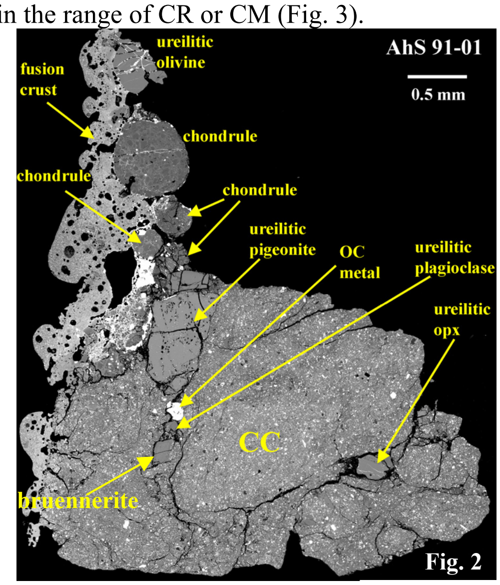


Fig. 2

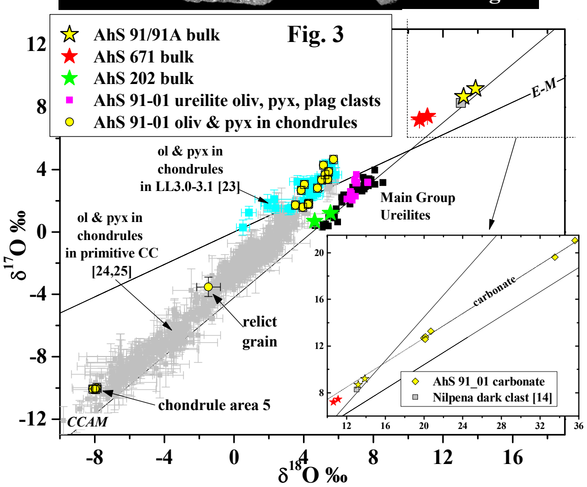


Fig. 3

Unique Enstatite Meteorites: AhS 38 is an unusual E-meteorite with a fine-grained (~10 µm), equilibrated texture. It contains forsterite (~25%), enstatite, diopside, metal (0.9% Si), niningerite-alabandite and troilite. It has similarities to MS-MU-019 and-036 from AhS [12,13], as well as Itqiy [16], but with significant olivine. AhS 60 has a coarse-grained, lineated texture of rounded enstatite grains (up to 6.5 mm long but internally mosaicized), minor forsterite, and ~20% interstitial metal (~3% Si). It may be an annealed impact melt rock analogous to Portales Valley [17,18].

Discussion: This work shows that the diversity of AhS stones is even greater than thought [3,4]. So far, both UOK and non-UOK stones show a dominance of E-meteorites among non-ureilites. This may be due to studying mainly the larger stones from the east end of the strewn field. A concentration of E-material could be inherited from the asteroid, or due to greater strength. A high abundance of E-material in AhS overall would be different from typical polymict ureilites [19]. These uncertainties can only be resolved by classifying the remaining UOK stones.

Stones 91/91A and 671 are the first AhS samples to consist of both ureilitic and chondritic material. They show an intimately mixed breccia of C1 material, several ureilitic lithologies, and other chondritic lithologies, which suggests that they represent well gardened regolith. Their highly friable nature suggests that they could represent the bulk of the material that was lost from 2008 TC_3. If so, ureilitic regoliths could contain a significant component of dark, CC-like material similar to Vesta and Psyche [20-22], possibly masking the ureilitic signature in remote reflectance spectra.

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Table 1. Classification of AhS Stones	# stones	coarse ureilite	fine-grained, porous ureilite	metal-sulfide-rich ureilite	other type of ureilite	non-ureilite
UOK this work	61	55.7%	21.3%	1.6%		21.3%
UOK previous [7]	19	63.2%	15.8%			21.1%
non-UOK [3,12,13]	111	32.4%	28.8%	1.8%	1.8%	35.1%