



Almahata Sitta meteorite – numerous individuals and lithologies

The fall and discovery of numerous fragments of the Almahata Sitta meteorite in the desert of N Sudan has significantly deepened our knowledge concerning the formation, structure and life cycle of asteroids [1].

Almahata Sitta - classified as a polymict ureilite - does not only contain small clasts of different meteorite lithologies but consists of individuals of a growing number of different meteorites: various types of ureilites, numerous enstatite chondrites, a number of ordinary chondrites, even a carbonaceous chondrite (a Bencubbinite) and a unique and new meteorite lithology with an affinity to Rumuruti chondrites have been classified earlier [1] and investigated by magnetic means [2-4,8]. Despite the official information of about means 2-3 kg total mass (or even more?) existing, the major limitation for performing more detailed research on this unique material was the very limited access to these extraordinary samples.

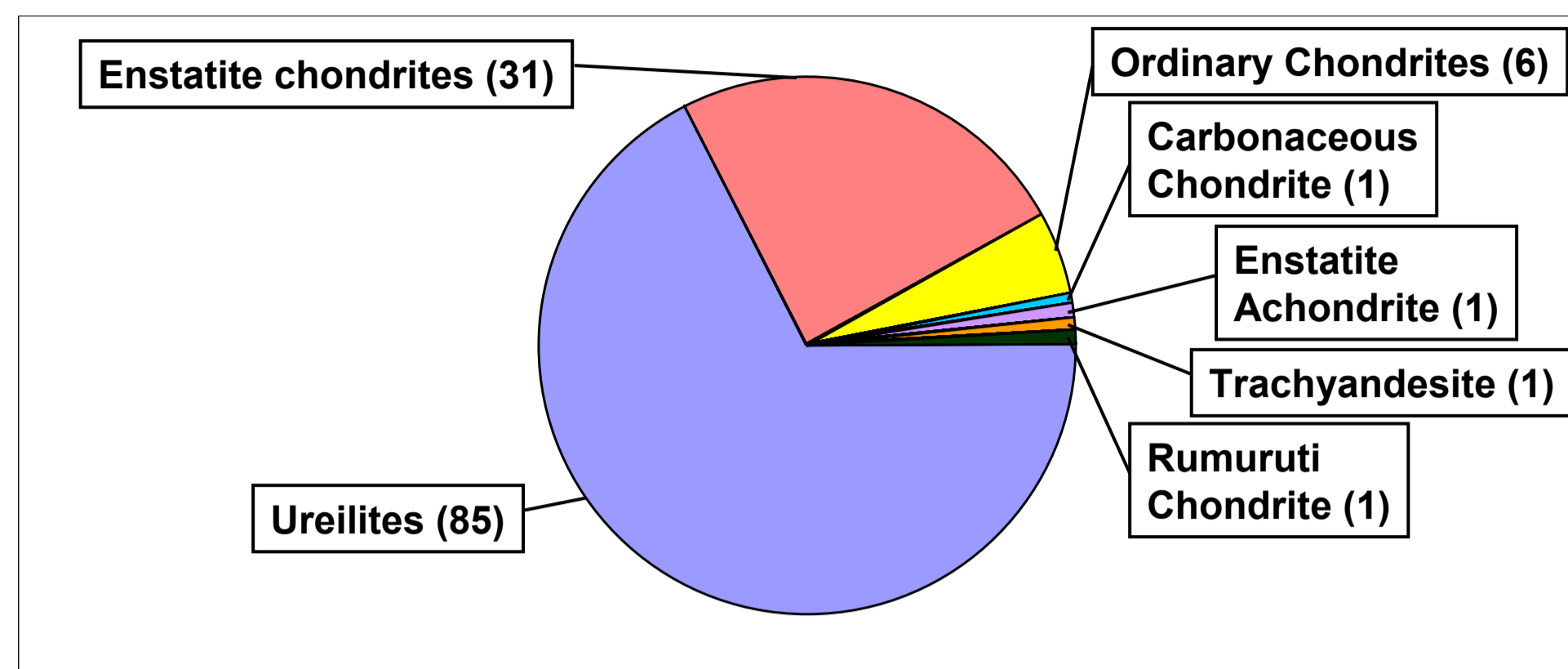


Figure 1: a statistical overview of all so far known and classified individuals of the Almahata Sitta meteorite fall. One can be sure that more different, new and unknown lithologies will be identified in near future.



Figure 2: Typical Almahata Sitta meteorite in finding position, North Sudan desert [from internet].

Recently however, due to the efforts of one of our contributing authors (S.D.) a significant and growing number of new individuals of the Almahata Sitta meteorite could be made accessible for our projects: sample set MS-MU-001–028.

Results and classification of Almahata Sitta MS-MU-001–011 have been reported in [1]. Amongst various types of ureilites and enstatite chondrites (see table 1,2), more fascinating new and unique meteorite individuals could be identified such as an enstatite achondrite or a trachyandesite [5-7]. It becomes obvious that the Almahata Sitta meteorite is unlike anything seen before.

Classification of meteorites by magnetic susceptibility (MS) is a well established method in the meantime [9,10]. A large set of Almahata Sitta samples was classified by MS [2-4,8], first results on the new sample set MS-MU 001–028 have been reported in [11,12].

Almahata Sitta (AS) – new and unique meteorite types

Ureilite MS compilation

MS-MU-011

Trachyandesite [5,6]

Oxygen-isotopy: related to Ureilites, first (rapidly crystallized) rock from UPB crust?

Phases (Raman-S.)
Feldspar (plagioclase) dominating and no glass, pyroxene, graphite, spinel (chromite?)

MS classification
MS value (3.66/3.32) is lower than for all other AS individuals studied [8]. MS is typical for terrestrial intrusives and is in the range of Martian nakhlites.

MS-MU-012

Ureilite [7]

Unbrecciated ureilitic feldspar-olivine-pyroxene rock

Phases (Raman-S.)
Pyroxene, graphite, olivine, metal (kamacite?), troilite, plagioclase

MS classification
MS of 5.37 is one of the highest values of all studied AS individuals and of all ureilites, in the range of severely shocked and brecciated ureilites.

MS-MU-019

Enstatite Achondrite [7]

Enstatite and metal rich achondrite, likely unique type of meteorite

Phases (Raman-S.)
Enstatite (very Fe-poor endmember), metal (iron), graphite, troilite, olivine

MS classification
MS of 5.46/5.38 is much higher than for all known aubrites/enstatite achondrites (average 3.79). NWA 8173/10271 do have similar characteristics.

Table 1a summarizes the MS values (average values of several samples each) of all known ureilite falls and (b) provides a statistical evaluation of the MS values of all investigated ureilite lithologies of the Almahata Sitta meteorite fall, see [2,3] and table 2 below. h: high shock. In (b) MS values of the unique trachyandesite (related to ureilites) are given for comparison.

Sample	Source	MS
Novo Urei	[9]	4.96 +/- 0.09
	[10]	4.91 +/- 0.11
	This study	4.97 +/- 0.02
Haverö	[10]	5.13 +/- 0.03 h
	This study	5.16 +/- 0.02 h
Jalanash	This study	4.94 +/- 0.02
Dyalpur	[10]	4.90 +/- 0.08 h

AS lithologies	Classification	MS
AS Ureilites (14)	Coarse-grained (cg)	4.80 +/- 0.03
AS Ureilites (7)	Fine-grained (fg) Various textures	4.96 +/- 0.03
AS Ureilite (1)	Pla-Ol-pyx	5.18 +/- 0.05
AS Ureilite (1)	Fg, metal-sulfide rich	5.26 +/- 0.03
AS Trachyandesite (1)	Related to ureilites	3.43 +/- 0.05

Almahata Sitta – "Rosetta" Stone of Space

Tab. 2a: Magnetic classification of Almahata Sitta MS-MU 001 - 010

Sample	Classification	Log MS (in 10 ⁻⁹ m ³ /kg)
MS-MU-001	Ureilite (fine-grained)	4.93 Ureilite
MS-MU-002	Enstatite chondrite EL 3	5.26 EL or EH
MS-MU-003	Enstatite chondrite EL (brecc.)	5.43 EL or EH
MS-MU-004	Ureilite (fine-grained, vgs)	5.03 [Bart.] Ureilite
MS-MU-005	Ureilite (coarse grained)	---
MS-MU-006	Ureilite (coarse grained)	---
MS-MU-007	Enstatite chondrite EL 6	5.30 / 5.13 EL or EH
MS-MU-008	Ureilite (coarse grained)	---
MS-MU-009	Enstatite chondrite EH 4/5	5.33 EL or EH
MS-MU-010	Ureilite (coarse grained)	---

Tab. 2b: Magnetic classification of Almahata Sitta MS-MU 011 - 020

Sample	Classification	Log MS (in 10 ⁻⁹ m ³ /kg)
MS-MU-011	Trachy-Andesite (rel. to Ureilites)	3.66/3.32/3.32 Unique
MS-MU-012	Ureilite (feldspar-olivine-pyroxene)	5.37/4.99 Unique
MS-MU-013	Ordinary chondrite (H 5, L/LL)	5.17/5.14 H 5
MS-MU-014	Ureilite (coarse-grained)	4.90 Ureilite
MS-MU-015	Enstatite chondrite (EL 6)	---
MS-MU-016	Ureilite (coarse-grained)	4.83 Ureilite
MS-MU-017	Ureilite (coarse-grained)	5.20 Ureilite
MS-MU-018	Ureilite (fine-grained, metal rich)	5.17/5.35 Unique
MS-MU-019	Enstatite achondrite (metal rich)	5.46/5.38 Unique
MS-MU-020	Ureilite (coarse-grained)	5.01 Ureilite

Important note: EL, EH and petrologic subtypes cannot be discriminated and classified by MS alone.

Tab. 2c: Magnetic classification of Almahata Sitta MS-MU 021 - 028

Sample	Classification	Log MS (in 10 ⁻⁹ m ³ /kg)
MS-MU-021	Ureilite („unique texture“)	5.12 Ureilite
MS-MU-022	Ureilite (coarse-grained)	5.02 Ureilite
MS-MU-023	Enstatite chondrite (EL 3)	5.16 EL or EH
MS-MU-024	Enstatite chondrite (EL 6)	5.29 EL or EH
MS-MU-025	Ureilite (fine-grained)	4.95 Ureilite
MS-MU-026	Enstatite chondrite (EL 6)	5.21 EL or EH
MS-MU-027	Ureilite (fine-grained)	4.82 Ureilite
MS-MU-028	Ureilite (variable texture)	4.95 Ureilite

Tab. 2a-c: Magnetic susceptibility of Almahata Sitta sample set MS-MU 001-028. Abbreviations: n.a.: not available; class.: classification [after 5-7]; MS – specific magnetic susceptibility: log MS in 10⁻⁹ m³/kg; ur: ureilite, fg fine-grained, cg coarse grained, vgs variable grain size; tex.: texture. Errors in log MS values are +/- 0.02. [Bart.: value provided by R. Bartoschewitz 2015].

A new category in MetBull database?

As a consequence of the unique and extremely important findings on the Almahata Sitta meteorite - numerous individuals of different lithologies: we propose to introduce a new sub-category in the Meteoritical Bulletin Database in order to officially report these new meteorites.

References

- [1] Horstmann M., Bischoff A., 2014. Chemie der Erde, 74/2, 149-183, and references herein.
- [2] Hoffmann V., et al., 2011. Meteor. Planet. Science, 46, 1551-1564.
- [3] Hoffmann V., et al., 2012. ACM, Niigata, #6346.
- [4] Kaliwoda M., et al., 2013. Spectroscopy Lett., 46, 141-146.
- [5] Bischoff A., et al., 2011. Meteor. Planet. Sci. 48, A60 (abstract).
- [6] Bischoff A., et al., 2014. PNAS 111/35, 12689-12692.
- [7] Bischoff A., et al., 2015. Metsoc Conf., abstract.
- [8] Hoffmann V., et al., 2014. Hayabusa 2014.
- [9] Macke R., 2012. PhD Thesis.
- [10] Rochette P. et al., Meteor. & Planet. Sci., 43/2008, 959-980, and Meteor. & Planet. Sci., 44/2009, 405-427.
- [11] Hoffmann V.H. et al., 2015. Paneth Coll., #0046.
- [12] Hoffmann V.H. et al., 2015. Hayabusa Conf., Tokyo.

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