MAGNETIC SIGNATURE OF E-CHONDRITIC LITHOLOGIES OF ALMAHATA SITTA AND COMPARISON WITH NEUSCHWANSTEIN (EL6). V.H. Hoffmann[1,2], R. Hochleitner[3], M. Kaliwoda[3], M. Torii[4], M. Funaki[5], T. Mikouchi[6], [1]Dept. Geosciences, Univ. Tuebingen, Sigwartstr. 10, 72076 Tuebingen, Germany; [2]Dept. Geo.-Env. Sciences, Univ. Munich, Germany; [3]Mineralogical State Collection, Munich, Germany; [4]Dept. Geosph.-Biosph.-Syst. Sci., Okayama Univ. Sci., Japan; [5]NIPR, Tokyo, Japan; [6]Dept. Earth Planet. Sci., Univ. Tokyo, Japan. Email: hoffmann.viktor@gmx.net

Introduction: Almahata Sitta (AS) was the first case ever that a (~ car-sized) asteroid (2008 TC_3) was detected and remotely studied in near-Earth space (oct. 6th, 2008), found to be on a collision course with our planet, and after the witnessed fall (oct. 7th, 2008) many meteoritic fragments were found in North Sudan. All details concerning this unique event are published in a special volume of Meteoritics & Planetary Science (2010) [1]. Magnetic properties of AS (ureilitic lithologies) and Raman data of the opaque phases are reported in [2,3]. Almahata Sitta was classified as a polymict ureilite. Later is was found that Almahata Sitta represents a complex breccia consisting of many different meteorite types, such as ordinary chondrites, unique new chondrite types and various enstatite chondrites [4].

The aim of our investigations is to compare mineralogy/chemistry/petrology and specifically the magnetic signature of E chondritic lithologies of AS with the properties of known E chondrite falls such as Neuschwanstein. A main focus of any magnetic studies of meteoritic material has to be on the effects of terrestrial alteration: the Almahata Sitta samples under study have been found in 7 and 10/2009, respectively, between ½ and 1 year after the fall [4,5]. Also fusion crust effects on the magnetic signature can be investigated very well under such excellent conditions.

The famous Neuschwanstein (NSS) meteorite fall happened in 2002 (April 6) at the S-Bavarian-Austrian border. Three individual stones (1750 gr (NSS1), 1625gr (NSS2) and 2843gr (NSS3)) have been found in July 2002, May and June 2003, respectively [6]. Neuschwanstein was classified as an EL6 chondrite [7]. In the meantime a number of studies have been performed on NSS 1 and 2 material investigating mineralogy/petrology, chemistry, petrophysics/magnetism and other properties [8,9,10].

Samples and investigations

Several chips/slices (partly purchased from S. Haberer/Freiburg) and PTS of a number of E chondritic lithologies of Almahata Sitta were investigated within this study. Neuschwanstein (NSS) samples (Mineralogical State Collection, Munich (MSCM)) consist of a profile taken from a full slice through the centre of NSS2 (77mm in length, 14 oriented subsamples, see [5]). Samples of the fusion crust on both sides have been included in our magnetic experiments.

The following magnetic parameters have been investigated, for all details concerning the techniques and instrumentation we refer to [2]: Natural Remanent Magnetization (NRM), Isothermal Remanent Magnetization (laboratory) and stability, magnetic susceptibility and anisotropy, IRM low-temperature experiments, thermomagnetic experiments up to 800°C (vacuum). Additionally we performed optical microscopy (polarized light), SEM/EDX (qualitative), Electron Microprobe Analysis (quantitative) and Raman Spectroscopy.

Results and interpretation

Magnetic susceptibility (MS) data of all known EL6 falls, several NSS1/2 and two AS EL6 (IMR) samples (MS150) are shown in fig. 1. The NSS2 value represents a mean value of 10 sub-samples of the profile (excluding rim). E-HL6 is the mean value of all reported E-HL6 falls (1/2012) of 5.46 (log E-9 m^3/kg). Generally, MS of the E-HL falls is characterized by a very homogenous distribution and very low scatter. Both AS samples, however, show significantly lower values which is probably an effect of terrestrial oxidation (MS150-2 has some rustiness already).

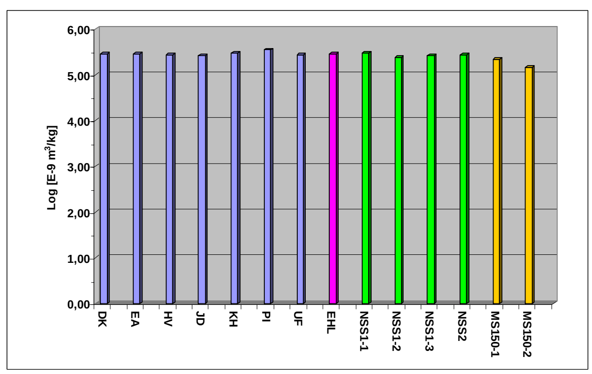

Fig. 1: Magnetic susceptibility of all known E-HL6 falls. Data are taken from [5,8,11].

The room temperature magnetic properties of MS150 (EL6-IMR) are dominated by Curie-temperatures (T_c) of ~700-710°C, ~210°C and ~120°C which can be attributed to a near-kamacite phase (6.3% Ni, 1.5% Si [4]) and cohenite, the origin of the 120°C phase is not clear yet (fig. 2). At low-T (space conditions) daubreelite was found showing a T_c of ~-150°C. NSS2 magnetic mineralogy is characterized by the presence of kamacite (T_c ~ 760°C), sometimes cohenite (T_c ~ 215°C), as well as daubreelite and troilite at low-T (fig. 3) which confirms the results of earlier studies on NSS1 [8].

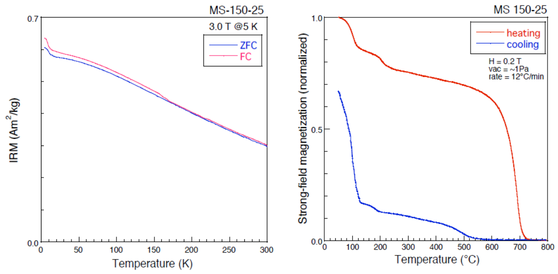

Fig. 2: (a) Low-T IRM experiment of AS sample MS150, (b) thermomagnetic curve (magnetization) of the same fragment.

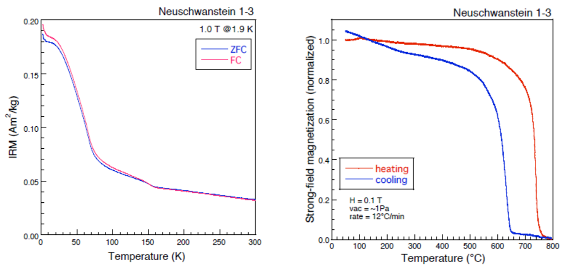

Fig. 3: (a) Low-T IRM experiment on a subsample of NSS2, (b) thermomagnetic curve (magnetization) of the same fragment.

It should be noted that the T_c of ~760°C of NSS2 is higher than expected for a 6 wt% Ni kamacite. It was suggested by [8] that the metal in NSS might consist of a mixture of a 6 wt% Ni kamacite and a low-Ni phase.

Fig. 4 provides IRM (-300mT / +1T field) values of the whole NSS2 profile, and includes results of 3 NSS1 chips together with the 2 AS MS150 samples. IRM intensity of the AS samples is higher than those of NSS, presently we cannot provide a substantiated explanation for that. Differences in the metal content or shock stage (MS150 was classified as EL6 IMR) might play an important role. Sub-samples NSS 1.1/1.2 and 5.13/5.14 belong to the rim/fusion crust, and show alteration effects. Generally, the measured IRM values reveal larger scatter than the magnetic susceptibility data.

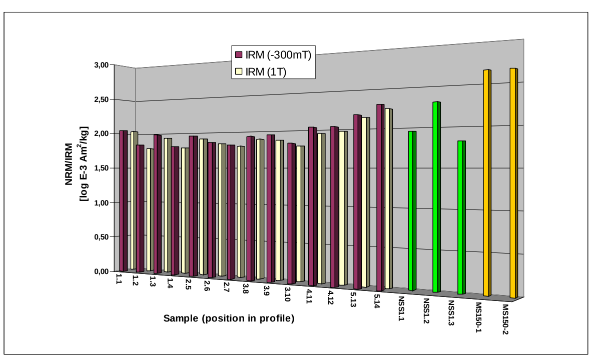

Fig. 4: Results of IRM (-300mT, +1T) on the NSS2 profile and comparison with NSS1 and AS MS150 data (data taken from [5,8,11]).

First SEM/EDX element mapping results obtained on MS150 confirm the presence of a very complex magnetic phase composition: we could detect kamacite, alabandine, keilite, daubreelite, troilite and schreibersite (fig. 5).

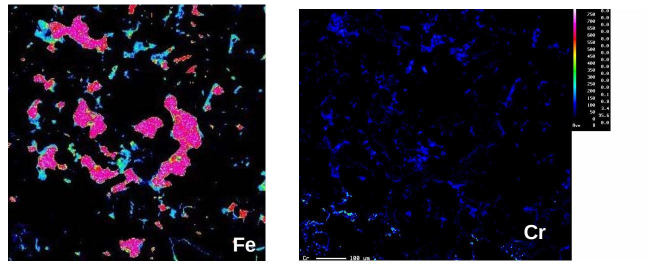

Fig.5: First element mapping results obtained on AS MS150: (a) Fe, (b) Cr distribution.

We can conclude that our first studies on these materials show quite a good agreement of the magnetic properties of the Almahata Sitta E-chondritic sample MS150 (EL6-IMR) with other EL6 falls such as Neuschwanstein.

In near future more E chondritic lithologies of Almahata Sitta will be and included in our database.

References

[1] Asteroid 2008 TC_3 - Almahata Sitta meteorite. Special Volume Meteoritics & Planet. Sci., 45/2010. [2] Hoffmann V. et al., Meteoritics & Planet. Sci., 46/2011, 1551-1564. [3] Kaliwoda M. et al., Spectroscopy Letters 2011, in press. [4] Bischoff A. et al., Meteoritics & Planet. Sci., 45/2010, 1638-1656. [5] Hoffmann V. et al., Antarctic Meteor., XXXIV/2011, 25-26. [6] Bischoff A. and Zipfel J., 2002. LPSC XXXIV, 2002, #1212. [7] Oberst J. et al., Meteoritics & Planet. Sci., 39/2004, 1627-1641. [8] Kohout T. et al., Geophysica 46/2010, 3-19. [9] Zipfel J. et al., Meteoritics & Planet. Sci., 45/2010, 1488-1501. [10] Hochleitner R. et al., Meteoritics & Planet. Sci., 39/2004, 1643-1648. [11] Rochette P. et al., Meteoritics & Planet. Sci., 43/2008, 959-980.

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