Comparing the magnetic signatures of Neuschwanstein (EL6) and E-chondritic lithologies of Almahata Sitta (polymict ureilite).

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Introduction:

The famous Neuschwanstein (NSS) meteorite fall occurred in 2002 (April 6) in south Bavaria at the border to Austria. Three individual stones have been found in July 2002, May and June 2003 with a mass of 1750 gr (NSS1), 1625gr (NSS2) and 2843gr (NSS3) [1,2]. Neuschwanstein was classified as an EL6 chondrite [3,4]. In the meantime a number of studies have been published on NSS 1 and 2 material investigating mineralogy/petrology, chemistry, petro-physics / magnetism and other properties [5,6,7].

Almahata Sitta (polymict ureilite) was the first case ever reported that a small 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 observed fall (oct. 7th, 2008) many meteoritic fragments were found in North Sudan. All details concerning this fascinating und unique object are published in a special volume of Meteoritics & Planetary Science (2010), with some more publications in 2011 [8]. Almahata Sitta was classified as a polymict ureilite. Later is was found that Almahata Sitta represents a complex breccia containing many different meteorite types, such as ordinary chondrites, unique new chondrite types and various Enstatite chondrites.

The aim of our investigation is to compare mineralogy/chemistry/petrology and magnetism of both meteorites. Our specific interest was on the terrestrial alteration effects: Neuschwanstein 2 was found about 13 months after the fall, the Almahata Sitta samples about half a year after the fall (to our best knowledge). Additionally, fusion crust effects to the magnetic signature can be investigated very well under such excellent conditions.

Samples and investigations

A full slice of Neuschwanstein 2 (Mineralogical State Collection, Munich) was prepared and a profile across the slice sub-sampled for this investigation (… oriented individual samples). Samples of the fusion crust on both sides were included in our magnetic experiments. 2 small chips and a number of PTS of E chondritic lithologies of Almahata Sitta were investigated in parallel and with the same experimental setup in order to compare the magnetic signature. Additionally, selected magnetic parameters have been obtained on all Enstatite chondrites of the Mineralogical State Collection, Munich, to widen the existing databases of magnetic susceptibility of stony meteorites [9].

The following magnetic parameters have been analyzed, for all details concerning the techniques and instrumentation we refer to [10, 11, 12]: 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), Electron Microprobe Analysis (quantitative) and Raman Spectroscopy.

Fig. 1: Full slice of Neuschwanstein 2 and sub-sampled profile as it was used for our investigation.

Results and interpretation

The room temperature magnetic behavior of NSS 2 is dominated by kamacite in all samples except fusion crust and a 1-2 mm thick zone where clear alteration effects could be detected. NRM, IRM and MS show a very homogenous distribution along the whole profile (i.e. throughout the whole volume of the meteorite. The low-T experiments can simulate space conditions and are requested in order to understand magnetization processes and the magnetic record obtained in space, i.e. on the parent body (bodies) of NSS and Almahata Sitta, respectively. The signal is characterized by the presence of daubreelite, troilite and a still unknown magnetic phase.

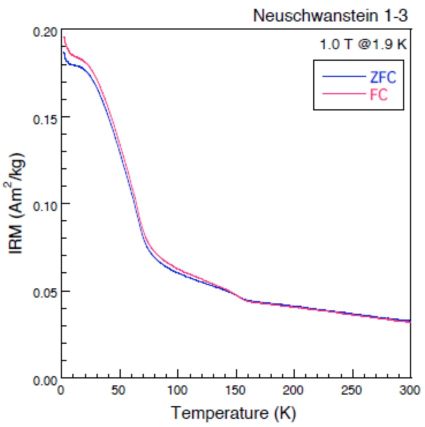

Fig. 2: Low-T IRM experiment on a NSS 2

subsample: the signature is dominated by troilite, daubreelite and an unknown phase with a transition a very low T.

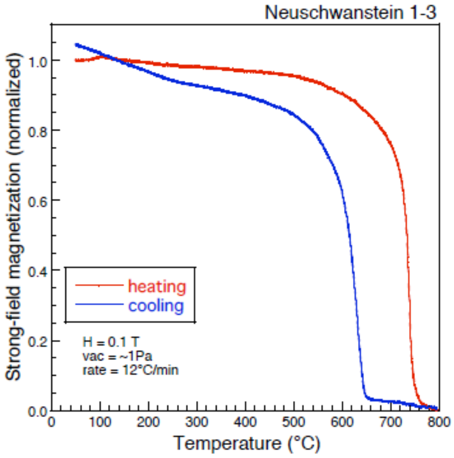

Fig. 3: Thermomagnetic curve on a NSS 2 subsample: Heating curve shows kamacite with a Curie temperature of about 760°C, indicating a very low Ni content.

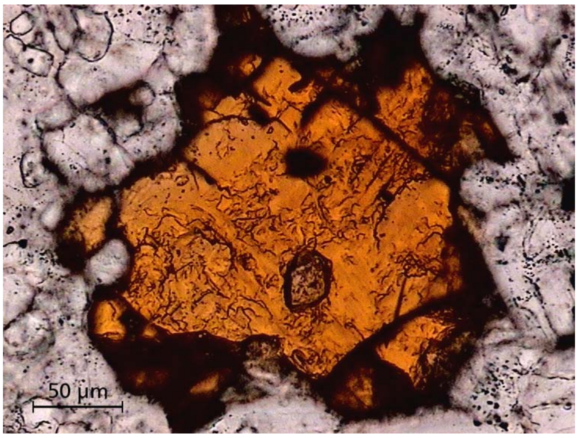

Fig. 4: Polished section of NSS 2 shows Alabandin (MnS) as a typical phase of Enstatite Chondrites.

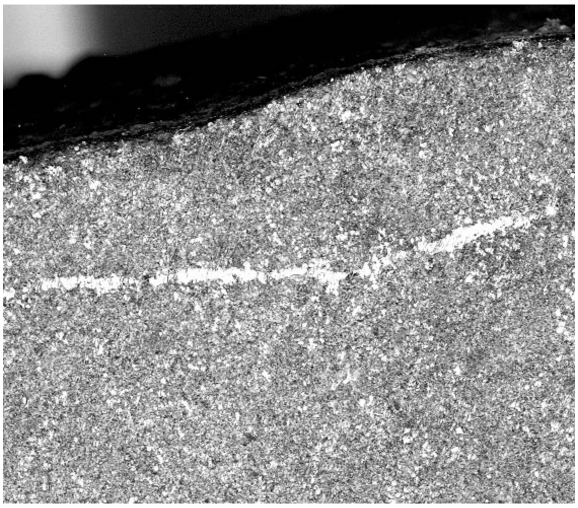

Fig. 5: Large metallic vein (Kamacite) in Neuschwanstein 2.

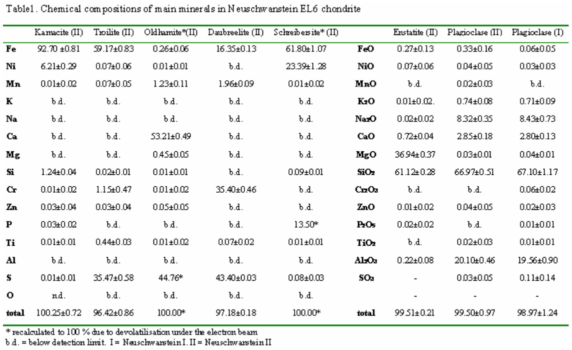

Table1. Chemical compositions of main minerals in Neuschwanstein EL6 chondrite

	Kamacite (II)	Troilite (II)	Oldhamite*(II)	Daubreelite (II)	Schreibersite* (II)		Enstatite (II)	Plagioclase (II)	Plagioclase (I)
Fe	92.70 ±0.81	59.17±0.83	0.26±0.06	16.35±0.13	61.80±1.07	**FeO**	0.27±0.13	0.33±0.16	0.06±0.05
Ni	6.21±0.29	0.07±0.06	0.01±0.01	b.d.	23.39±1.28	**NiO**	0.07±0.06	0.04±0.05	0.03±0.03
Mn	0.01±0.02	0.07±0.05	1.23±0.11	1.96±0.09	0.01±0.02	**MnO**	b.d.	0.02±0.03	b.d.
K	b.d.	b.d.	b.d.	b.d.	b.d.	**K_2O**	0.01±0.02.	0.74±0.08	0.71±0.09
Na	b.d.	b.d.	b.d.	b.d.	b.d.	**Na_2O**	0.02±0.02	8.32±0.35	8.43±0.73
Ca	b.d.	b.d.	53.21±0.49	b.d.	b.d.	**CaO**	0.72±0.04	2.85±0.18	2.80±0.13
Mg	b.d.	b.d.	0.45±0.05	b.d.	b.d.	**MgO**	36.94±0.37	0.03±0.01	0.04±0.01
Si	1.24±0.04	0.02±0.01	0.01±0.01	b.d.	0.09±0.01	**SiO_2**	61.12±0.28	66.97±0.51	67.10±1.17
Cr	0.01±0.02	1.15±0.47	0.01±0.02	35.40±0.46	b.d.	**Cr_2O_3**	b.d.	b.d.	0.06±0.02
Zn	0.03±0.04	0.03±0.04	0.05±0.05	b.d.	b.d.	**ZnO**	0.01±0.02	0.04±0.05	0.02±0.03
P	0.03±0.02	b.d.	b.d.	b.d.	13.50*	**P_2O_5**	0.02±0.02	b.d.	0.01±0.01
Ti	0.01±0.01	0.44±0.03	0.01±0.02	0.07±0.02	0.01±0.01	**TiO_2**	b.d.	0.02±0.03	0.01±0.01
Al	b.d.	b.d.	b.d.	b.d.	b.d.	**Al_2O_3**	0.22±0.08	20.10±0.46	19.56±0.90
S	0.01±0.01	35.47±0.58	44.76*	43.40±0.03	0.08±0.03	**SO_3**	-	0.03±0.05	0.11±0.14
O	n.d.	b.d.	b.d.	b.d.	b.d.		-	-	-
total	100.25±0.72	96.42±0.86	100.00*	97.18±0.18	100.00*	**total**	99.51±0.21	99.50±0.97	98.97±1.24

* recalculated to 100 % due to devolatilisation under the electron beam
b.d. = below detection limit. I = Neuschwanstein I. II = Neuschwanstein II

Tab. 1: Chemical composition of the most important phases in the Neuschwanstein EL6 chondrite.

Electron microprobe analyses (EMPA) and Raman spectroscopy results are in good agreement with the findings of the magnetic experiments (magnetic phase analysis) on both meteorites [details of the magnetic signature of Almahata Sitta are found in 10].

However, one major outcome of our studies is as follows: in order to be able to understand and interpret the results of the magnetic phase analyses correctly, additional experiments on well defined synthetic/natural equivalent materials of rare magnetic phases such as daubreelite, troilite, alabandin or Fe-silicides (Almahata Sitta) are urgently required.

References

[1] Oberst J. et al., Meteoritics & Planet. Sci., 39/2004, 1627-1641. [2] ReVelle D. et al., Meteoritics & Planet. Sci., 39/2004, 1605-1626. [3] Bischoff A. and Zipfel J., 2002. LPSC XXXIV, 2002, #1212. [4] Zipfel J. et al., LPSC XXXIV, 2002, #1640. [5] Kohout T. et al., Geophysica 46/2010, 3-19. [6] Zipfel J. et al., Meteoritics & Planet. Sci., 45/2010, 1488-1501. [7] Hochleitner R. et al., Meteoritics & Planet. Sci., 39/2004, 1643-1648. [8] Asteroid 2008 TC_3 - Almahata Sitta meteorite. Special Volume Meteoritics & Planet. Sci., 2010. [9] Rochette P. et al., Meteoritics & Planet. Sci., 43/2008, 959-980. [10] Hoffmann et al., Meteoritics & Planet. Sci., 2011, in press. [11] Kaliwoda et al., Spectroscopy Letters 2011, in Press. [12] Hoffmann et al., this issue.

Acknowledgements

We are very thankful to Addi Bischoff (Univ. Münster) for providing the Almahata Sitta samples and PTS used in this study. Magnetic experiments were partly performed under the Cooperation Contract with Kochi University (10B033).