Diabasic/basaltic shergottites NWA 480/1460 and NWA 5029: magnetic properties indicate launch-pairing. V.H. Hoffmann[1,2], T. Mikouchi[3], R. Hochleitner[4], M. Torii[5], M. Funaki[6], [1]Dept. Geosciences, Univ. Tuebingen, Sigwartstr. 10, 72076 Tuebingen, Germany; [2]Dept. Geo.-Env. Sciences, Univ. Munich, Germany; [3]Dept. Earth Planet. Sci., Univ. Tokyo, Japan; [4]Mineralogical State Collection Munich, Germany; [5]Dept. Geosph.-Biosph.-Syst. Sci., Okayama Univ. Sci., Japan; [6]NIPR, Tokyo, Japan. Email: hoffmann.viktor@gmx.net

Introduction:

Northwest Africa 480 with a main mass of 28gr was found in Marocco in 2000 [1]. In 2001 Northwest Africa 1460 (70.2 gr) was acquired in Marocco and appears to be paired with NWA 480 [2]. Both stones are almost completely fusion crusted and are basaltic shergottites. Northwest Africa 5029 is a small, unpaired 14.67gr partly fusion-crusted stone which was found in Marocco in 2003 and classified as a basaltic shergottite [3] (diabasic–mafic-intermediate shergottite [4]). NWA 480/1460 and NWA 5029 are very similar in mineralogy and texture [3, 4]. In our poster we present results of our studies on the magnetic signature of the three Martian meteorites.

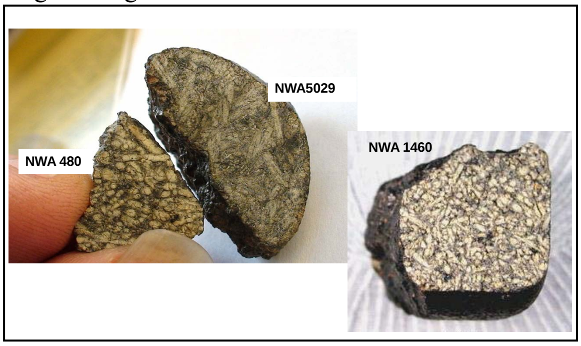

Fig. 1: NWA480 (©The Earths Memory), NWA1460 (©N.Oakes) and NWA 5029 (©The Earths Memory).

Samples and investigations:

For our investigations of the magnetic properties several chips of NWA 480 (plus fragments) and NWA 1460 (both most likely paired) were used. First magnetic data of NWA 480/1460 have been published by [5], whereby NWA 1460 corresponds to the sample of this study. Additionally we used several chips and fragments of the type mass (~1.4gr) as well as a PTS of NWA 5029 for the magnetic experiments.

The opaque minerals have been investigated and characterized qualitatively by optical microscopy and quantitatively by EMPA (Cameca SX100, Univ. Munich) with respective standards and matrix correction.

Measurements of natural remanent magnetization (NRM) and stability tests were carried out on a 2G Cryogenic Magnetometer with attached AF demagnetization (NIPR), maximum AF field was 100mT (in x/y/z direction). Laboratory tests of isothermal remanent magnetization (IRM) in -300mT and +1T fields (in z direction, Pulse Magnetizer MMPM10, NIPR) and its stability were performed in order to check type and quality of NRM, for example to exclude or control "magnetic contamination" (for example by hand magnets).

Kappabridges KLY 3 (NIPR, DG) and MFK1-FA (DG) (both AGICO) were used for determining magnetic susceptibility and its anisotropy.

Low and room temperature experiments of IRM (5T max. field) were done with an MPMS XL5 at Okayama University of Science on small fragments (ZFC: zero field cooling, FC: field cooling).

High field thermomagnetic runs (magnetization (H_{ext} = 0.4 T) were done in a vacuum of about 1 Pa, temperature range was 40-800°C, heating rate 12°C/min., at Kochi University.

Results:

The NRM of NWA 480/1460 is most likely of terrestrial origin, dominated by an IRM which might be due to remagnetisation by the use of hand magnets already in field by the nomads. The NRM of NWA 5029, however, could be attributed to impact shock related processes on Mars, eventually resulting from the last and ejecting event, representing a shock remanent magnetization (SRM). The magnetic susceptibility (MS) values of the three stones are in the range which was found by [6] for Martian meteorites, and typical for diabasic/basaltic shergottites. The degree of anisotropy of magnetic susceptibility (AMS) is quite low in all cases (P between 1.071 and 1.090) despite the high degree of shock which should be reflected by the AMS. In the low-temperature range all three samples show essentially identical behaviour: two magnetic transitions are detected in the range of 40-60K (ilmenite and/or chromite) and at 120K (magnetite) in both FC and ZFC IRM curves.

Fig. 2: Distribution of the opaque phases in NWA 5029 (magn. 200x). Magnetite – ilmenite (lamellae) and iron-sulfide (pyrrhotite?).

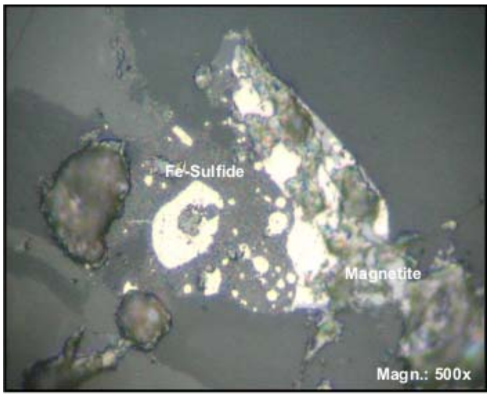

Fig 3: Complex intergrowth of iron-sulfides (pyrrhotite?), partly molten, and magnetite.

Discussion and conclusions:

The magnetic remanences (NRM) in these shergottites are carried by nearly stoichiometric magnetite (Fe_3O_4) with a Curie-temperature (T_c) of about 575°C.

(a)

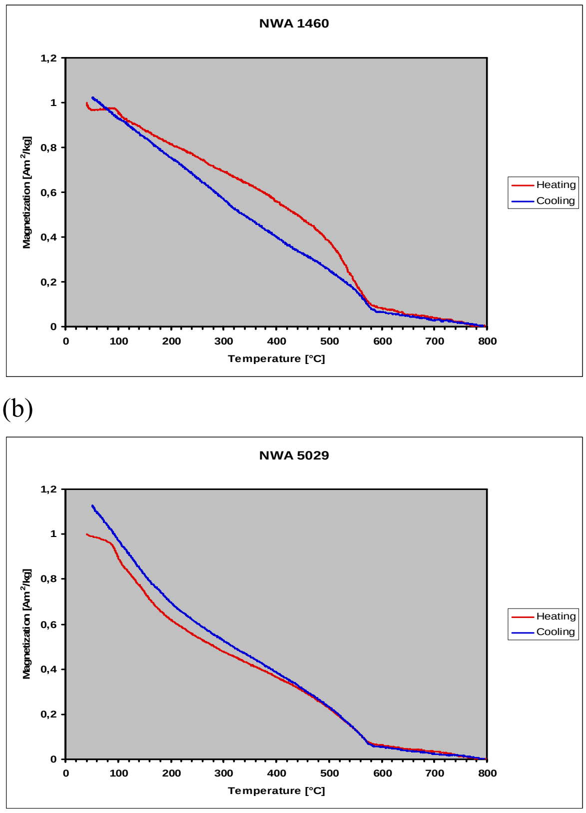

Fig. 4: Thermomagnetic curves of (a) NWA1460 and (b) NWA 5029, respectively. For details see text.

In agreement with other data, magnetite is apparently exsolved (magnetite with ilmenite lamellae), that is, high-temperature oxidized titano-magnetite. Minor effects are related to substituted magnetite with a T_c of about 525°C. Fe-sulfides such as monoclinic pyrrhotite (Fe_7S_8) could not be detected. The magnetic signature and texture of all three stones is very similar which leads to our hypothesis that the three rocks are very likely launch paired. We can conclude that the high-temperature oxidation occurred on the surface of Mars either during the primary formation processes or as a result of shock (at least 35 GPa) from the event which ejected the meteorites from the Mars surface into space.

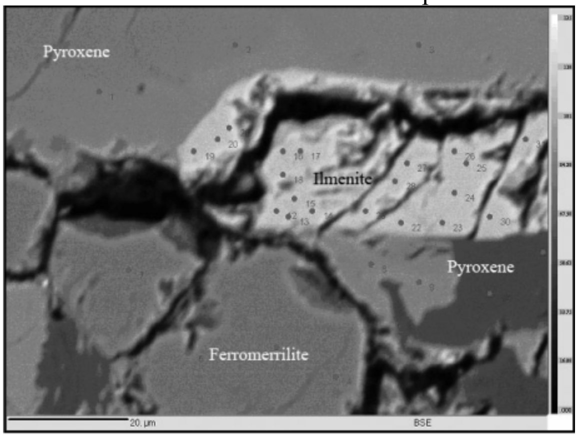

Fig. 5: NWA 5029: SEM backscatter image with EMPA measurement points.

	Ferro-merrilite	Ilmenite	(Titano-) Magnetite	Chromite	Pyroxene 1	Pyroxene 2
FeO	4.46	46.44	66.54	32.77	25.35	33.87
MnO	0.18	1.02	0.41	0.02	0.65	0.83
P_2O_5	43.62	0.06	0.01	0.02	0.02	0.01
Na_2O	1.01	0.02	0.02	b.d.	0.10	0.07
Al_2O_3	0.03	b.d.	1.71	5.34	0.86	0.60
CaO	48.56	0.09	0.24	0.70	14.26	9.27
MgO	1.78	0.09	0.32	1.45	7.92	5.45
SiO_2	0.11	0.24	0.33	0.19	42.91	41.13
TiO_2	0.05	46.35	24.44	1.35	0.92	0.84
Cr_2O_3	0.02	0.40	1.09	55.48	0.35	b.d.
	99.82	94.71	94.02	97.32	93.34	92.07

Tab. 1: Elemental composition of the investigated opaque phases (incl. pyroxene, phosphate) of NWA5029. The element data are consistent with the results of the magnetic experiments. The low sums are due to the fact that all iron is calculated as divalent.

Acknowledgements:

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References:

[1] Barrat J.A. et al., 2002. Meteor. Planet. Sci., 37: 487-499. [2] Irving A. and Kuehner S., 2003. Lunar Planet. Sci. Conf., XXXIV, #1503. [3] Mikouchi T., Barrat J.A., 2009. 72nd Ann. Meteor. Soc. Meeting, #5344. [4] Irving A., 2011. http://www.imca.cc/mars/martian-meteorites.htm. [5] Rochette P. et al., 2005. Meteor. Planet. Sci., 40/4: 529-540. [6] Rochette P. et al., 2009. Meteor. Planet. Sci., 44: 405-427.