MEMIN PROJECT: THE SEARCH FOR SUITABLE PROJECTILE MATERIAL IN MESO-SCALE HYPERVELOCITY CRATERING EXPERIMENTS. I. Domke[1], A. Deutsch[1], L. Hecht[2], T. Kenkmann[2], [1]Institut f. Planetologie, WWU Münster, D-48149 Muenster, Germany (I.Domke@uni-muenster.de), [2]Museum f. Naturkunde (MfN) – Leibniz Institut an der Humboldt-Universität Berlin, D-10115 Berlin, Germany

Introduction: The “MEMIN” (***m**ultidisciplinary* ***e**xperimental and* ***m**odeling* ***i**mpact crater research* ***n**etwork*) project is aimed at a better understanding of the impact cratering process by combining (i) numerical modelling of crater formation, (ii) the investigation of terrestrial craters and (iii) meso-scale hypervelocity impact experiments using well defined target and projectile materials [1]. In the core of this research projects is the large two-stage light gas gun at the Ernst-Mach-Institute (EMI; Efringen-Kirchen, Germany) capable of producing craters in the decimeter-range in quartz sandstone. One sub-project of MEMIN is devoted to investigate the “fate of the projectile”, and comprises questions like mechanical response of the projectile and distribution of projectile matter between the crater and the ejecta that is collected in newly designed catchers. In addition, potential chemical fractionation of the projectile material will be investigated using small samples from different precisely characterized sites in the crater floor. To be successful, the use of well-analyzed projectile material is mandatory in the MEMIN program. Requirements to the projectiles are: (i) mechanical stability during launch and flight, (ii) geochemical homogeneity, (iii) strong chemical differences to the target such that small fragments and – if present – minute condensates of the projectiles can be identified unambiguously, and (iv) presence of elements such as Co, Ni, Cr, PGE that play an important role in natural impactors

Methods: The projectile materials were first characterized by optical and electron microscopy. Major and minor element concentracions were determined by electron microprobe (JEOL JXA 8900M Superprobe; Inst. f. Mineralogie WWU Münster; and JEOL JXA-8500 F; MfN, Berlin). Trace element analysis was performed on a LA-ICP-MS (Element 2, ThermoFisher; Inst. f. Mineralogie WWU Münster) using a 193 nm ArF excimer laser (UP193HE, New Wave Research). Laser repetition rates were 5 Hz using an energy density of ~9 J/cm2. Beam-spot diameters varied between 25-235 µm. In the future, INAA will be used too in order to characterize minute quantities of the target that may contain projectile matter.

Specification of the projectile material: *Steel SAE 4130.* In the MEMIN pilot study, we have used spherical projectiles of the alloyed heat-treatable steel SAE 4130 (German Industry standard material number DIN 1.7218; matrix: Fe - 97 wt.%, Cr - 1.0, Mn - 0.56, Mo - 0.2, Co - 0.15, Ni - 0.08). Problems with textural and chemical heterogenity (Fig. 1) as well as the ubiquitous presence of this material in the recipient of the gun facility was the reason to start a search for better suited projetile matter for the follow-up experiments.

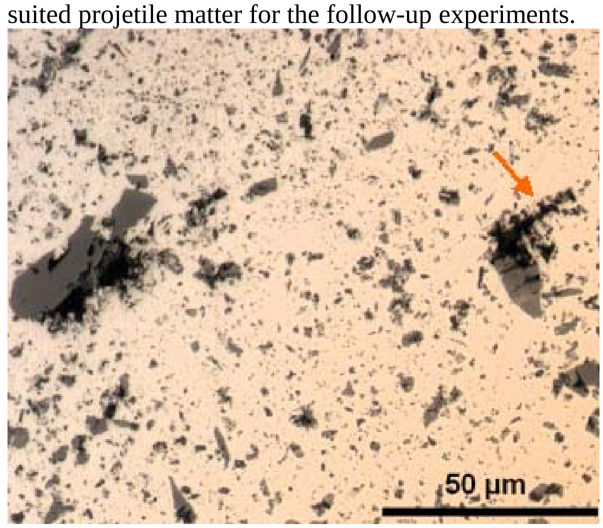

Fig. 1 SAE 4130. The homogeneous matrix is peppered with heterogeneously distributed Si-C-rich domains of various size and composition (Si - 25-70 wt.%, C < 75). Reflected light, // nicols

Steel D290-1. This alloyed steel (Cr – 4 wt.%, Co – 5, Mo - 5) represents good projectile matter as it is very homogeneous at the scale of <10 µm (Fig. 2). D290-1 has in addition, suitable mechanical properties, allowing to turn even small spheres on the lathe that are used in calibration experiments. In general, steel as projectile matter is a good analogue for iron meteorite projectiles.

High concentrations of Cr, Co, W, and Mo in steel projectiles facilitate the detection of projectile material within the crater floor or ejecta. Furthermore, high temperature fractionation of these elements during contact - excavation may occur as their condensation temperatures vary considerably. These elements are well suited for INAA and can be detected in very low concentration within the target material that is a quartz sandstone. However, such steel projectiles are not suited for identifying element fractionation amongst the platinum group elements (PGEs, e.g., [2]). Therefore iron meteorites are evaluated also as projectile material in the cratering experiments.

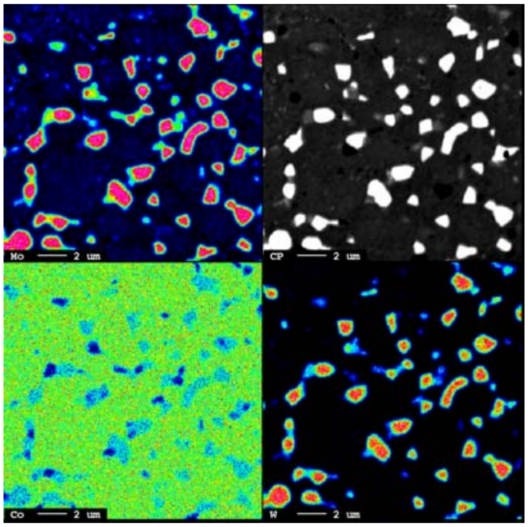

Fig. 2 D290 document the quite homogeneous allocation of up to 2 µm-sized W-Mo-rich phases. JEOL JXA-8500 F, MfN Berlin; acceleration voltage 10 kV; color code: red - high, blue to green – low concentrations

Iron meteorites: We have started to analyze two iron meteorites, *Arispe* (IC [3]), and *Campo del Cielo* (IAB [4]); *Arispe* was selected because of its high PGE content, *Campo del Cielo* because large fresh pieces are easily available.

Arispe is rather coarse-grained (2.9 mm) and shows many micro-fractures. Our LA-ICP-MS results (Table 1) indicate (a) good reproducility for most trace elements but (b) significant inhomogeneities for others.

Campo del Cielo has a Widmannstatten bandwith of 3.0 mm ± 0.6 mm and a rather homogeneous kamcite matrix [4] in which schreibersite and taenite are distributed rather irregularily (Fig. 3). A major setback for the purpose of projectile assembly are the up to cm-sized silicate inclusions (Fig. 4) which, however, can be avoided.

Outlook: Current mechanical tests will help in the selection of appropriate projectile material. The ongoing microchemical characterization will yield a comprehensive data set as basis for fast and accurate detection of projectile matter in the crater and the ejecta, and will help to constrain fractionation effects that have been observed during impactor specification in terrestrial craters [e.g., 2] as well as during previous cratering experiments [e.g., 5,6].

References: [1] Schäfer F. et al. (2006) *ESA SP-612.* [2] Mittlefehldt D.W. et al. (1992) *Meteoritics* 27, 361–370. [3] Scott E.D. (1977) *EPSL* 37, 273 -284. [4] Buchwald V.F. (1975) *Handbook of Iron Meteorites* UCB Press, Los Angeles – London (U.K.). [5] Evans N.J. et al. (1994) *GSA Spec. Pap.* 293, 93-101. [6] Gerasimov M.V. et al. (2005) *GSA Spec. Pap.* 384, 351-366.

Acknowledgments: Special thanks to Jay Piatek, donator of a big slice of the Campo del Cielo meteorite for the MEMIN project, and to M. Ostermann (Bundesanstalt f. Materialprüfung, Berlin) for supporting test samples of steels. We appreciate skillful technical assistance by U. Heitmann and M. Feldhaus (WWU) as well as advice by J. Berndt (LA-ICP-MS, WWU) and K. Born (EMP, MfN). This research is supported by the German Science Foundation DFG (Research Unit FOR-887).

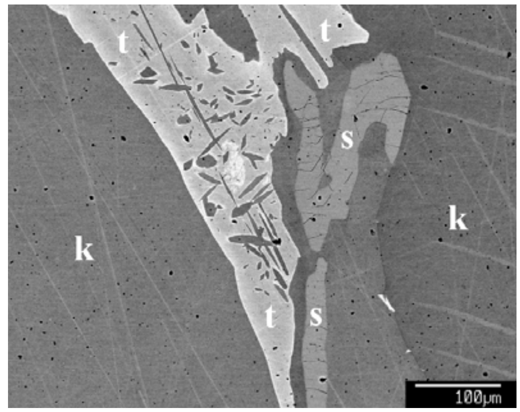

Fig. 3. BSE image of the iron meteorite Campo del Cielo. Schreibersite (s) and taenite (t) in a kamacite matrix (k).

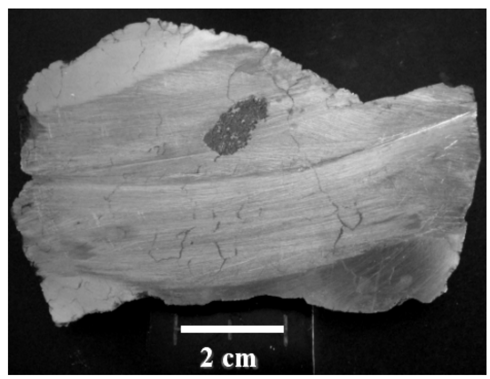

Fig. 4. Fresh cutted surface of Campo del Cielo with a large silicate inclusion (dark grey in the center).

Table 1. Trace elements concentrations in Arispe

Element*)	[ppm]	std. dev.**)
^{52}Cr	35,0	> 20 %
^{53}Cr	32,2	> 20 %
^{59}Co	4340	370
^{63}Cu	124	5,6
^{69}Ga	43,7	5,3
^{72}Ge	159	15,0
^{75}As	5,5	0,70
^{95}Mo	5,11	> 20 %
^{121}Sb	0,18	> 20 %
^{182}W	1,26	0,09
^{197}Au	0,57	0,07
^{191}Ir	12,90	0,54
^{193}Ir	12,90	0,84
^{194}Pt	11,30	0,90
^{195}Pt	11,1	1,1

*)Element concentrations calculated from the corrected counts of the isotope given. **)ppm unless otherwise stated