A METEORITE FRAGMENT TRAPPED BETWEEN POSITIVE AND NEGATIVE SHATTER CONES IN A LIMESTONE BLOCK STORED AT THE METEORKRATER-MUSEUM STEINHEIM, GERMANY.

E. Buchner [1,2], M. Hölzel[3,4], M. Schmieder [5,6], M. Rasser[7], J. Fietzke[8] M. Frische[8] S. Kutterolf[8].
[1]HNU – Neu-Ulm University of Applied Sciences, Wileystraße 1, 89231 Neu-Ulm, Germany. E-mail: elmar.buchner@hs-neu-ulm.de. [2]Institut für Mineralogie und Kristallchemie, Universität Stuttgart, Azenberstraße 18, 70174 Stuttgart, Germany. [3]Meteorkrater-Museum Steinheim, Hülbenweg 4, 89555 Steinheim am Albuch, Germany; [4]SCHWENK Zement KG, Werk Mergelstetten, Hainenbachstraße 30, 89522 Heidenheim, Germany; [5]Lunar and Planetary Institute, 3600 Bay Area Blvd, Houston TX 77058, USA. [6]NASA-SSERVI; [7]Staatliches Museum für Naturkunde, Rosenstein 1, 70191 Stuttgart, Germany; [8]GEOMAR Kiel, Wischhofstraße 1-3, 24148 Kiel, Germany.

Introduction: The Miocene ~3.8 km Steinheim Basin impact structure, Germany, is known for its well-developed shatter cones, which occur in Middle to Upper Jurassic sedimentary rocks of the central uplift, the structural crater floor beneath the annular crater moat, target rock fragments in the impact breccia, and in the crater rim domain. The shatter cones are mainly formed in Upper Jurassic limestone (e.g., [1,2]). Rare metals including Fe, Ni, Co, Cu, and Au in metal-rich coatings were previously reported on the surfaces of shatter cones in limestone and claystone, and were interpreted as possible remnants of the Steinheim impactor, altered and redistributed by impact-induced hydrothermal activity [3]. According to [3,4], some of the Fe, Ni, Co-rich particles may represent primary meteoritic matter.

Sample and Sample Locality: A ~1m-sized limestone block with shatter cones, which is stored at the Meteorkrater-Museum Steinheim [1], was investigated. It has been part of the exhibition for ~20 years. Although the exact provenance of this Upper Jurassic (Kimmeridgian-Tithonian) limestone block is undocumented, it is likely that it stems from a limestone megablock forming the eastern morphological crater rim where it was sampled during road constructions in 1997. The block exhibits multiple shatter cone individuals in manifold directions. In 2016, the block exhibited a prominent fracture, along which a part of the limestone block was removed for safty reasons. On a shatter cone surface in the main mass of the limestone block and on a shatter cone surface in the removed part, an approximately 2 cm-sized, light to dark grey fragment of metallic luster became visible, surrounded by a brownish rim zone between the metallic fragment and the surrounding carbonate rock.

Analytical Methods: The metallic fragment was analyzed by SEM-EDS and EPMA on raw sample material and polished thin sections at the University of Stuttgart. Furthermore, LA-ICP-MS spot analyses were conducted at GEOMAR, Kiel, on the same material. Bulk chemical ICP-MS analyses were carried out on a solution made of a 180 µg particle of light and apparently metallic matter at the Institute of Minerology, University of Stuttgart.

Results: Compositionally, the metallic fragment can be subdivided into three portions: 1. A light grey matter of metallic luster, predominatly composed of Fe, Ni (~6-15 wt%), Co (~0.6-0.8 wt%), and minor S and P. Kamacite, taenite, and minor tetrataenite, troilite, schreibersite, and melliniite were identified. This material features elevated Ga, Ge, and PGE concentrations; 2. A dark grey, nonlustrous mass, composed of Fe and S and variable P, Ca, Si, and Al. This mass contains brecciated fragments of troilite, surrounded by Fe-rich oxide phases with variable S content. Nickel, Co, Ga, Ge and the PGEs are enriched, but less abundant than in the light grey, metallic phase; 3. A brownish rim between the metal/sulfide/phosfide mass and the carbonate rock, with variable Fe, Ca, S, P, Si, Al, Mg, and K. Nickel values range from traces up to ~10 wt%. This crust also contains secondary iron oxide, Fe-sulfide, and gypsum.

Discussion: The light grey portion of the metallic fragment contains minerals that are characteristic for various types of meteorites. The bulk chemical composition suggests this material represents portions of an iron or stony-iron meteorite. Platinum group element concentrations are elevated, and internal PGE ratios are meteoritic. Gallium (~40 ppm), Ge (~80 ppm), and PGE values in kamacite match those of IIAB, and IIIAB irons, or of stony-iron meteorites. The dark grey portion with brecciated troilite, a groundmass of highly variable Fe/S, and secondary iron oxide phases can be interpreted as (partly) altered troilite. According to [5], troilite weathering is characterized by S depletion, leading to the precipitation of secondary sulfide and sulfate phases. The brownish crust between the metal/sulfide/phosfide mass and the host carbonate block seems to be a reaction rim composed of secondary phases (iron oxides, secondary Fe-sulfide, gypsum) locally rich in Ni and Co.

The new findings suggest the metallic fragment is most likely a piece of the Steinheim projectile. The position of the meteorite fragment trapped between positive and negative shatter cone faces requires a formation mechanism that allows for the injection of cm-sized, particulate impactor matter into transient open target rock fractures during the impact process. This process is not fully understood yet and will have to be studied in further detail.

References: [1] Heizmann, E. P. J. & Reiff, W. 2002. Der Steinheimer Meteorkrater. 160 pp. [2] Schmieder, M. & Buchner, E. 2013. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften* 164: 503–13. [3] Buchner, E. & Schmieder, M. 2017. *Geological Magazine* (in press, online 2/13/17). [4] Schmieder, M. & Buchner, E. 2009. *Meteoritics & Planetary Science* 44, A185. [5] Al-Kahtiri, A. et al. 2005. *Meteoritics & Planetary Science 8*, 1215–1239.