THE STUBENBERG (BAVARIA) ORDINARY CHONDRITE BRECCIA: THE LATEST GERMAN METEORITE FALL

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Introduction: After Neuschwanstein (2002, EL6 [1]) and Braunschweig (2013, L6 [2]), Stubenberg is the latest meteorite fall in Germany [3]. On March 6, 2016 at 21:36 UT a bright bolide was spotted by eyewitnesses and the digital all-sky fireball network. The observations show that the meteorite was fragmented in the atmosphere and the strewn field was calculated for the area around the village of Stubenberg [3]. First fragments of the meteorite were found six days after the fall. Within several weeks of intensive search six meteorite fragments with a total mass of 1473 g were recovered. The largest fragment has a mass of 1320 g. All fragments were found inside the calculated strewn field [3]. Here, the first results are reported based on microscopic studies and microprobe (EPMA) analysis: The Stubenberg meteorite is an LL6, S3 ordinary chondrite breccia.

Methods: For optical microscopy in transmitted and reflected light a ZEISS polarizing microscope (Axiophot) was used. A JEOL 6610-LV electron microscope (SEM) was used to study the fine-grained textures and to identify the different mineral phases. Quantitative mineral analyses were obtained using a JEOL JXA 8900 Superprobe EPMA at the University of Münster, which was operated at 15 kV and a probe current of 15 nA. Natural and synthetic standards were used for wavelength dispersive spectrometry.

Results: Optical inspection of the type specimen clearly shows that the Stubenberg meteorite is brecciated (Fig. 1) and three thin sections (PL16031, PL16032, and PL16033) were prepared from a representative area.

Petrography: Based on the study of the thin sections with the optical microscope the brecciated nature of the Stubenberg is confirmed. In our thin sections only highly-recrystallized fragments (type 6; Fig. 1) were observed which have only very few relic chondrules [3]. Plagioclase (partly >100 µm) and olivine show undulatory extinction, and the olivines show distinct sets of planar fractures (Fig. 1) indicating that the rock is weakly shocked (S3) [4,5]. As opaque phases, metals (kamacite, taenite), troilite, and chromite were observed. Other accessory phases include Cl-apatite and merrillite. Several shock veins cross the meteorite.

Geochemistry: The mean composition of olivine is $Fa_{31.4 \pm 0.3}$ with a compositional range between 30.5 and 32.2 mol% Fa (n = 54). The low-Ca pyroxenes have a mean composition of $Fs_{25.4 \pm 0.3}$ (n = 43) varying between 24.8 and 26.1 mol% Fs and the Ca-pyroxenes have a mean composition of $Fs_{11.2 \pm 2.5}Wo_{41.4 \pm 6.7}$ (n = 7) [3]. Mean plagioclase has An- and Or-contents of 11.1 ± 0.4 and 5.5 ± 1.2 mol%, respectively (n = 42; range An: 10.3-12.1 mol%). Kamacite has mean Ni- and Co-concentrations of 3.9 and 6.1 wt%, respectively (n = 8). The taenite composition is variable, with Ni content varying from 41.9 to 48.2 wt% (average: 44.3 wt%; mean Co: ~1.8 wt%; n = 38).

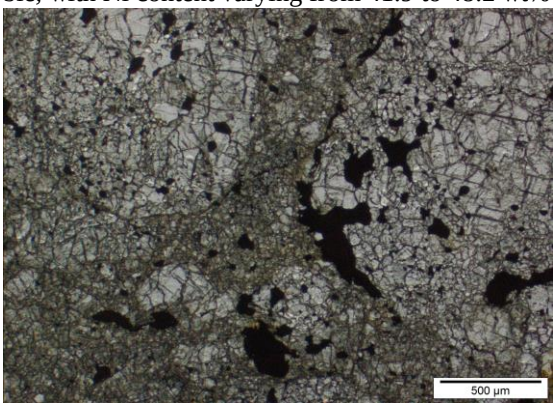

Fig. 1: A transmitted light image from Stubenberg. The brecciation and recrystallization of the fragments are clearly visible.

Conclusions: Stubenberg is a breccia (Fig. 1). The individual fragments are highly recrystallized (Fig. 1) and only a few relic chondrules are still visible in the thin sections. This points to a high metamorphic grade of the fragments within the rock. The large grain size of plagioclase and the homogeneous compositions of olivines and pyroxenes also support this conclusion. These facts clearly indicate that the fragments within Stubenberg are of type 6. Based on the mean olivine and low-Ca pyroxene compositions of $Fa_{31.4}$ and $Fs_{25.4}$, respectively, the rock has to be classified as an LL-group ordinary chondrite breccia. Since no fragments of other petrologic type were observed so far a classification as a LL6 breccia is appropriate. However, Stubenberg does not belong to the quite abundant group of complex regolith breccias among the LL-group ordinary chondrites [6] and is also different from the LL5-6 breccia Chelyabinsk [7]. Based on the undulatory extinction in olivine and plagioclase and the presence of planar fractures in olivine, the chondrite is weakly shocked (S3) [4,5]. Thus, Stubenberg is an LL6, S3 ordinary chondrite breccia.

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