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A full-3D laser-scan mapping of a hypogene cave: a morphogenetic study of Märchenhöhle, Austria

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In contrast to "common" caves, formed by corrosive action of gravity-driven waters, hypogene caves owe their existence to deep-seated waters rising toward Earth's surface. Hypogene caves commonly exhibit a peculiar macro-, meso-, and micromorphology. It has long been perceived that these morphological forms may provide information on the specific processes of cave formation. Deciphering this information is hindered by the fact that elements of solutional cave morphology are difficult to document and quantify. In this work we used a z+f Imager 5006i terrestrial laser scanner in order to generate a full-3D representation of the inner surface of a hypogene cave; the resulting high-resolution mapping will be used as a basis for detailed morphogenetic study of the cave.

Märchenhöhle (cadastre# 1742/17) is located at the southern margin of the Northern Calcareous Alps, near Eisenerz (Steiermark, Austria). This 135 m-long cave occurs near the crest of a limestone ridge at ca. 1500 m a.s.l., some 900 m above the valley floor. The cave consists of several near-isometric chambers separated by relatively narrow openings. The lower parts of cave walls are coated with a mammillary calcite crust (cave clouds). Above this crust the internal surface of the cave exhibits a wealth of peculiar smaller-scale corrosional features (e.g., funnel-shaped chambers with flat roofs, cupolas, cup-shaped pockets on inclined walls, etc.).

Terrestrial laser scanning offers the possibility to acquire three-dimensional data of complex shapes in short time with up to sub-cm resolution. To achieve high accuracy and complete coverage, scanning from different positions is necessary. This requires accurate co-registration of the single scans. In contrast to other geomorphologic applications of terrestrial laser scanning, an absolute georeference was not necessary in this case.

The scanning campaign, carried out on July 23, 2010, consisted of eleven scan positions and yielded a 3D point cloud containing 1.35*109 points all together. The individual scans were coarsely registered using coded targets. In order to handle this huge amount of data properly, a sophisticated 3D filtering and thinning process was applied reducing the number of points to approximately 15 million point while preserving as many details as possible. These data were used as input for fine co-registration using an ICP algorithm, and subsequently, merging and homogenization of the point cloud. On this level, first analysis steps were performed (e.g., horizontal profiles). Furthermore, the merged point cloud was triangulated (approx. 10 million triangles) and resulted in the final three-dimensional model of the internal surface of the cave. This model is the base for numerous three-dimensional geomorphologic analyses, covering both the overall shape of the cave and small corrosional features.