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Digital structural interpretation of mountain-scale photogrammetric 3D models (Kamnik Alps, Slovenia)

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From the earliest days of geological science, mountainous terrains with their extreme topographic relief and sparse to non-existent vegetation were utilized to a great advantage for gaining 3D insight into geological structure. But whereas Alpine vistas may offer perfect panoramic views of geology, the steep mountain slopes and vertical cliffs make it very time-consuming and difficult (if not impossible) to acquire quantitative mapping data such as precisely georeferenced traces of geological boundaries and attitudes of structural planes. We faced this problem in mapping the central Kamnik Alps of northern Slovenia, which are built up from Mid to Late Triassic succession of carbonate rocks. Polyphase brittle tectonic evolution, monotonous lithology and the presence of temporally and spatially irregular facies boundary between bedded platform carbonates and massive reef limestones considerably complicate the structural interpretation of otherwise perfectly exposed, but hardly accessible massif.

We used Agisoft Photoscan Structure-from-Motion photogrammetric software to process a series of overlapping high-resolution (∼0.25 m ground resolution) vertical aerial photographs originally acquired by the Geodetic Authority of the Republic of Slovenia for surveying purposes, to derive very detailed 3D triangular mesh models of terrain and associated photographic textures. Phototextures are crucial for geological interpretation of the models as they provide additional levels of detail and lithological information which is not resolvable from geometrical mesh models alone. We then exported the models to Paradigm Gocad software to refine and optimize the meshing. Structural interpretation of the models, including mapping of traces and surfaces of faults and stratigraphic boundaries and determining dips of structural planes, was performed in MVE Move suite which offers a range of useful tools for digital mapping and interpretation. Photogrammetric model was complemented by georeferenced geological field data acquired along mountain trail transects, mainly using the MVE Field Move software application.

In our experience, vertical aerophotos were sufficient to generate precise surface models in all but the steepest mountain cliffs. Therefore, using existing vertical photoimagery (where available) is a very cost-effective alternative to organizing shooting campaigns with rented aircraft. For handling reasonably large models (cca 3 x 3 km, up to 10 million triangles), a low-end computer workstation with mid-range professional 3D graphic card is sufficient. The biggest bottleneck is the photogrammetric processing step which is time-consuming (10s of hrs) and has large RAM requirements, although those can be offset by dividing models into smaller parts. The major problem with geological modeling software like Gocad or Move is that it at present does not handle well projecting of phototextures. Whereas Photoscan-generated orthophotos can be vertically projected onto mesh models, this results in unacceptable distortions and gaps in subvertical or overhanging parts of the mountain cliff models. A real 3D UV texture mapping method, such as implemented in Photoscan, would be required to realistically model such areas.

This limitations notwithstanding, digital geological mapping of photogrammetric models of mountains is a very promising, cost- and time-effective method for rapid structural interpretation and mapping of barren mountainous terrains, particularly when it is complemented by field measurements and observations.