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Rockfall hazard assessment of nearly vertical rhyolite tuff cliff faces by using terrestrial laser scanner, UAV and FEM analyses

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Nearly vertical rhyolite tuff cliff faces are located in NE-Hungary representing rock fall hazard in the touristic region of Sirok. Larger blocks of the cliff have fallen in recent years menacing tourists and human lives. The rhyolite tuff, that forms the Castle Hill was formed during Miocene volcanism and comprises of brecciated lapilli tuffs and tuffs with intercalating ignimbritic horizons. The paper focuses on the 3D mapping of cliff faces and modeling of rock fall hazard. The topography and 3D model of the cliff was obtained by using GNSS supported terrestrial laser scanner and UAV. With imaging techniques of UAV a Triangulated Irregular Network (TIN) model was developed that contained triangles with 5-10 cm side lengths. GNSS supported terrestrial laser scanning allowed the observation with a resolution 1-5 cm of point spacing. The point clouds were further processed and with the combination of laser scanner and UAV data a 3D model of the studied cliff faces were obtained. Geological parameters for rock fall analyses included both field observations and laboratory tests. The lithotypes were identified on the field and were sampled for rock mechanical laboratory analyses. Joint- and fault system was mapped and visualized by using Rocscience Dip. EN test methods were used to obtain the density properties of various lithotypes of rhyolite tuff. Other standardized EN tests included ultrasonic pulse velocity, water absorption, indirect tensile strength (Brasilian), uniaxial compressive strength and modulus of elasticity of air dry and of water saturated samples. GSI values were denoted based on filed observations and rock mass properties. The stability analyses of cliff faces were made by using 2D FEM software (Phase 2). Cross sections were evaluated and global factor of safety was also calculated. The modeled displacements were in the order of few centimeters; however several locations were pinpointed where wedge failure and planar slip surfaces were identified as major cliff stability hazards. These were associated with the major joint systems dissecting cliff faces. This research have proved that the combined methods of field surveying, imaging techniques, data processing and FEM modelling with rock mechanical laboratory analyses allowed the identification of major rock fall hazards even at areas which are difficult to access.