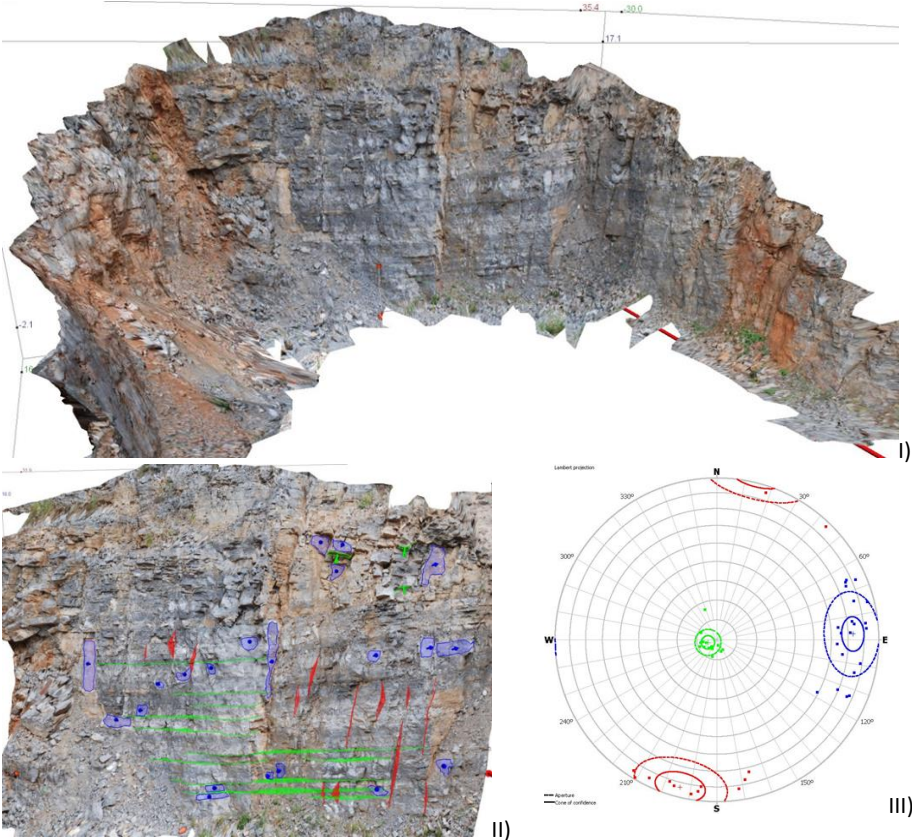


Digital Photogrammetry in Rock Engineering

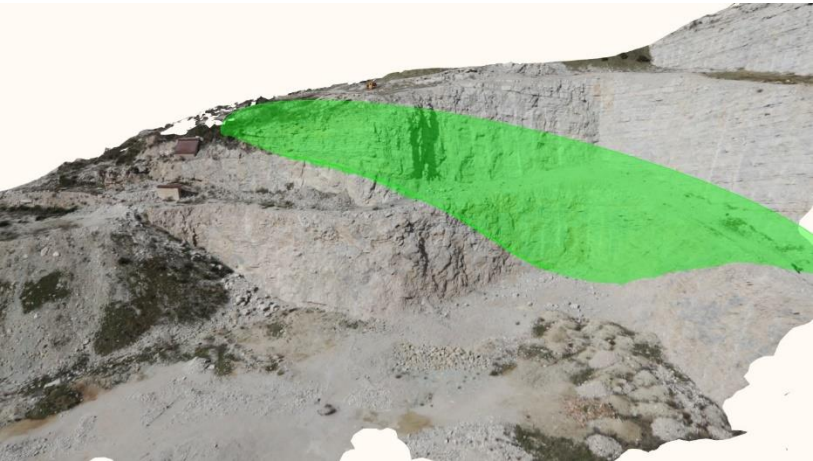
The Croatian Geological Institute combines terrestrial and/or aerial digital photogrammetry to create and interpret 3D photorealistic models. ShapeMetriX3D system (3GSM GmbH, Austria) is used for the metric acquisition of rock and terrain surface from a photorealistic 3D model. Geological boundaries and faults, as well as all other planes that must be deterministically defined in space, can be mapped. For further stochastic analyses, the system enables mapping of discontinuities in rock masses (determination of orientation, persistency and normal spacings). The following analyses are conducted on the data collected by digital photogrammetry and processed by the ShapeMetriX3D system:

- 1) one-dimensional variable statistics (persistency and normal spacing of discontinuities, areas and volumes);
- 2) statistical analysis of circural data (e.g. strike of the discontinuity);
- 3) statistical analysis of spherical data (e.g. poles - normal vectors of the discontinuities).

More reliable delineation of dominant discontinuity sets, better categorization of rock masses, estimation of IBSD (In-situ Block Size Distribution) and more reliable differentiation of statistically homogeneous units in rock engineering in the study area are all made possible by data collected in this way in combination with traditional mapping methods. In addition, the ShapeMetriX3D system's Fragmenter module can be used to calculate the BBSD (Blast Block Size Distribution) in quarries and the RBSD (Rockfall Block Size Distribution) on natural slopes. The most significant benefit of these methods is the ability to collect a large volume of data for more reliable statistical analyses, as well as the accuracy and precision of geometric parameters and the ability to map difficult-to-reach areas without vegetation (steep cliffs and high slopes). In institute we also combined drone imagery (UAV photogrammetry) for fragmentation analysis of 3D models of rock piles with Fragmenter software (3GSM GmbH, Austria) and describing empirical data by the frequency size distribution of naturally and artificially fragmented material.



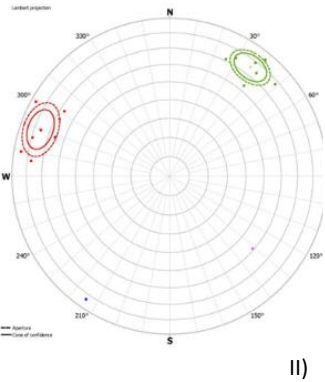
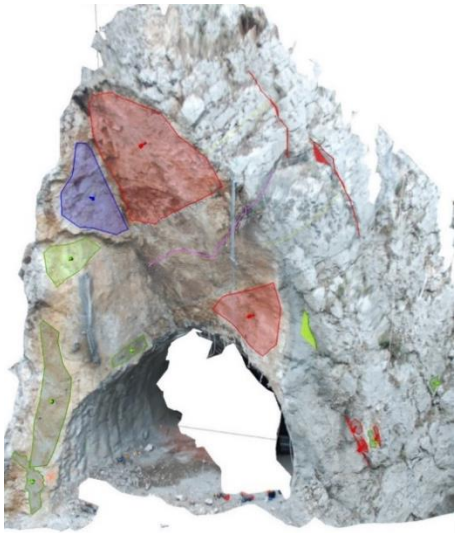
I) 3D model of the Apatish quarry on Northern Velebit (created using the ShapeMetriX3D system); II) mapping of discontinuity sets using the ShapeMetriX3D system; III) diagrams of the poles of the normals of the delineated sets of discontinuities (Lambert projection of equal surfaces).



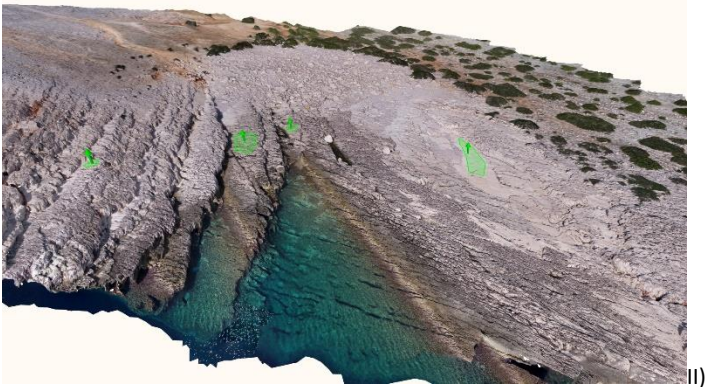
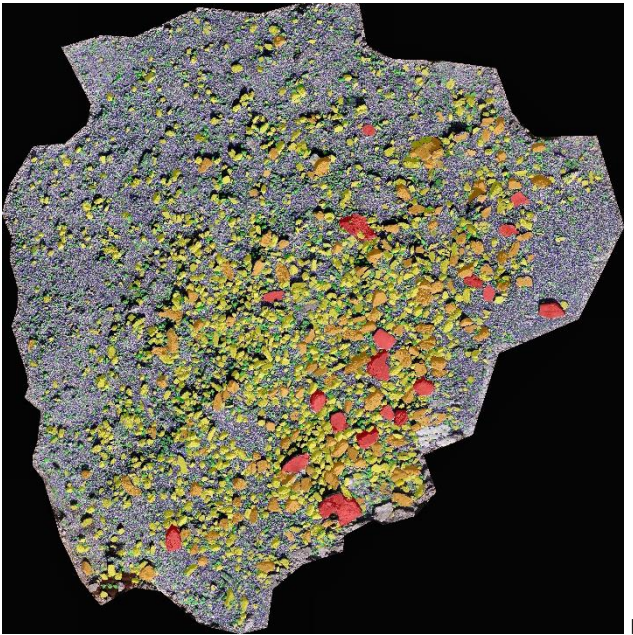
Transgressive boundary in the „Klis-Kosa“ quarry at the discordant contact of Upper Jurassic - Lower Cretaceous limestones and Paleogene breccio - conglomerates.



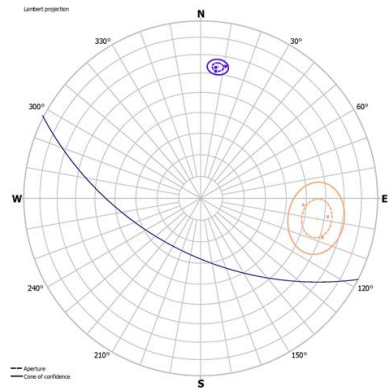
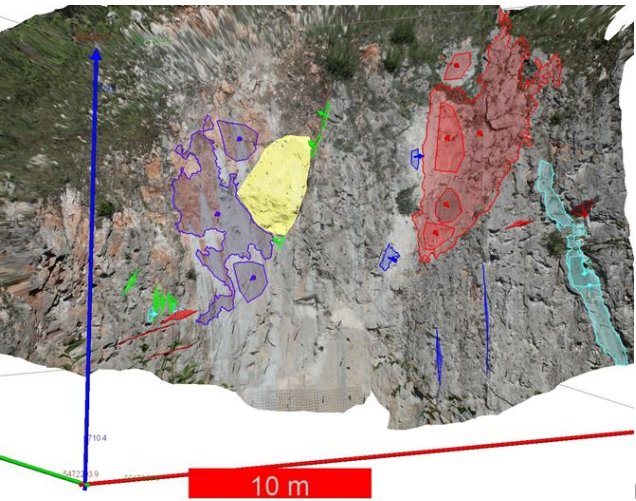
Slope on the eastern side of the quarry "Klis-Kosa" in the Upper Jurassic - Lower Cretaceous limestones with indicated faults related to block instabilities - wedges.



I) Rock fall on the portal of the tunnel's southern pipe in the Celevec river canyon at Demir Kapija (created with the Shapemetrix3D system); II) diagrams of the poles of the normals of the delineated sets of discontinuities on the tunnel's entrance (Lambert projection of equal surfaces).



I) Distribution of limestone fragment size of storm deposits on Mana island (Fragmenter; 3GSM GmbH); II) bedding plane in the vicinity of storm deposits (ShapeMetriXUAV; 3GSM GmbH).



I) 3D model of a section of the Gornje Draževce cut on the railroad track M202 ZAGREB GK - RIJEKA with a marked estimated volume of an unstable block and sets of discontinuities in orthographic projection; II) diagram of the poles of the discontinuity normals that form the wedge at the rock fall location (Lambert projection of equal surfaces).