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Towards a geomechanics classification of folded layered rock masses

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Several schemes have been proposed in the last decades to account for the effects of structure and alteration of rock masses on their geo-mechanical properties. Among these, the Geological Strength Index (GSI) turned out as the most effective to account for complex geological conditions, including heavily fractured, heterogeneous (e.g. flysch-like) or tectonically disturbed rock masses. It is well known that folding has a direct impact on the type and degree of fracturing. Nevertheless, no classification scheme has been developed to introduce explicitly the effects of folding and associated fracturing on rock mass strength and deformability. In this perspective, we carried out an exploratory study aimed at establishing relationships between outcrop-scale folding and GSI in layered carbonate rock masses, exceptionally well exposed in a quarry near Bergamo (Lombardia, Southern Alps). A N-S trending, 350m long and 115m high benched rock face exposes a complete cross section of a sub-horizontal inclined fold involving Lower Jurassic cherty mudstones (Moltrasio Lms.) and marly limestones successions (Domaro Lms.). The main fold has an axial surface moderately dipping to the north and is characterised by polyharmonic folds at scales of metres to tens of metres. The site was documented by producing a digital outcrop through a high-resolution terrestrial photogrammetric survey from distances ranging from 70 to 130 m (18 camera stations, 395 pictures), using RTK GNSS measurements for camera station geo-referencing. Data processing by Structure-from-Motion (SfM) techniques resulted in detailed point clouds covering the entire slope with a cm-scale accuracy. In order to establish relationships between lithology, folding styles, and geomechanical properties of folded rock masses we performed a detailed structural analysis at 25 survey stations spread over all the different fold sectors. These surveys include: lithology, bedding attitude and thickness, brittle structures (e.g. flexural slips, faults, shear fractures and extension veins) and related kinematic indicators. Field data were complemented with the analysis of the RGB-rendered point cloud to characterize local fold geometry (wavelength, interlimb angle), fracture spacing and trace length. At each survey location, an independent estimation of the GSI has been carried out in the field and correlated to the different measured structural and rock mass descriptors. These parameters add better constrains to the relative effects of rock type (intact rock strength and bedding thickness), fold geometry and associated structures on rock mass geometry and weathering, providing inputs to a modified GSI scheme for folded rocks.