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Genesis and related slope stability analyses of the Turtle Mountain anticline (Alberta, Canada)

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The aim to this study is to improve the general understanding of the Turtle Mountain anticline and its fracturing pattern as well as evaluating the implications of these latter two features in potential rock slope failures.
Turtle Mountain anticline is located in southwest Alberta in Canada and is part of the Livingstone Thrust sheet of the Foothills. The Foothills forms the eastern part of the Canadian Rockies which are located in the easternmost part of the Canadian Cordillera. The study area became well known when a 30 Mm3 rock avalanche of massive limestone and dolostone known as the Frank Slide, affected the eastern mountainside of Turtle Mountain on April 1903.

This study focuses on the structural features of the anticline, comprising the characterization of the fold geometry and formation mechanism and the related fracturing pattern using HR-digital elevation model combined with detailed field survey. The investigations allow describing the anticline as an eastern verging box-fold with multiple hinges that merges at depth. Field evidences revealed the expression of both flexural slip and tangential longitudinal strain folding mechanisms involved in the development of the fold. A simple 3D geological model based on geological profiles across the mountain allows improving the geometrical comprehension of the core of the anticline as well as the visualisation.

Ten discontinuity sets are identified in the study area. The local variations of the sets are estimated in order to separate the study zone into homogenous Structural domains.

Referring to the different tectonic phases affecting the region, the potential origin of the detected fractures is interpreted based on kinematic relationships between fractures. It results that the origin of the four major discontinuity sets is attributed to the folding phase. Except the bedding plane and a pre-existing joint set, the other discontinuity sets are interpreted as resulting of post-folding deformations.

The conduction of a Rock mass condition analysis allows pointing out the influence of the fold geometry revealing a general decrease of the Rock mass strength with the proximity of the axial surface of the anticline. It illustrates the importance of the high fracturing density of the hinge area on the weathering of the mountain. A predictive modelling of the GSI (SVR by Matlab) completes and supports this analysis.

Using field and remote sensing techniques, the deformation modes of the crown area of the mountain are characterized by analysing the large open back cracks. It illustrates the control of the fold related fractures in the cracks geometry and allows highlighting four main deformation sectors. Due to the opening of the cracks, the cumulative displacement of the top of the mountain reaches at least 10% at present day.

A slope stability analysis of a localized portion of the mountain using both field measurement and numerical modelling (UDEC) illustrates the failure mechanisms involved in the control of the slope stability. The volume calculation of potentially unstable rock compartments is constrained using the Sloping Local Base Level (SLBL) method.

Globally, this study highlights that the fold related fracturing plays an important role in the destabilization of the mountain. Indeed, due to its homogenous spatial distribution in the study area as well as its geometrical configuration, its constitutes an important predisposing factor leading to potential present day rock slope failures.