The influence of fracture networks on stability and geohazards of the Niagara Escarpment in southern Ontario

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The Niagara Escarpment is a geological feature comprised of highly fractured Ordovician and Silurian shales and carbonates stretching through southern Ontario and parts of the north-eastern United States. Differential erosion of the shale and carbonate strata has generated a steep cliff face bisecting the city of Hamilton, Ontario. Fractures occur throughout the cliff face and result in the formation of loose blocks of rock that are subject to erosion through rockfalls. This presents structural stability issues and an associated geohazard, which is of particular concern due to the proximity of the escarpment to city infrastructure. Previous work has alluded towards the role of geologic fractures in controlling erosion and stability of the Niagara Escarpment, but the causal mechanisms and extent to which these processes operate remains unclear. As such, the aim of this study is to quantify and analyse fracture networks using a combined field and numerical modelling-based approach to understand the distribution and nature of fractures throughout the escarpment, their connectivity, fluid flow properties, and relationship to structural stability. The location, orientation, and aperture of fractures were systematically quantified and documented around Hamilton. Data were plotted and analysed using the software Orient to identify clusters representative of fracture sets and to calculate average fracture set orientations and the respective confidence intervals. Three primary sets of geological fractures were identified including: 1) a near-vertical bedding confined set oriented north-south, 2) a near-vertical bedding confined set oriented east-west and 3) sedimentary bedding planes which have facilitated fracture migration and controlled resultant fracture geometry. Discrete fracture network modelling of these fracture sets in MOVE highlights their high degree of connectivity and indicates that the distribution and nature of these discontinuities are predominant controls on the locations and sizes of rock fragments generated on the cliff face resulting in rockfalls. Moreover, fracture-controlled porosity is a significant contributor to fluid flow throughout the escarpment. We conclude that geologic fractures present a first-order control on the stability of the Niagara Escarpment near Hamilton.