

The Heather Hill landslide: an example of a large scale toppling failure in a natural slope

M. A. PRITCHARD AND K. W. SAVIGNY

Geological Engineering Program, Department of Geological Sciences, University of British Columbia,
6339 Stores Road, Vancouver, B.C., Canada V6T 2B4

Received April 6, 1990

Accepted March 5, 1991

This paper is an inquiry into the suspected relationship between toppling and large deep-seated landslides along the Beaver Valley, Glacier National Park, British Columbia. The study area includes the Heather Hill landslide, one of several in the valley, and adjacent slopes that show varying degrees of toppling disturbance. The development of the Heather Hill landslide is simulated using the distinct element method of numerical analysis. The rock mass is modelled using deformable columns whose boundaries represent a coarse approximation of *in situ* discontinuity patterns. An intercalated change in the predominant lithologies and a concomitant change in discontinuity spacings are modelled by varying column thickness and material properties. The analysis confirms that a deep-seated failure surface can develop as a result of the toppling process. The intercalated change in lithologies and the related change in discontinuity spacings account for the curvilinear failure surface and the headscarp position of the Heather Hill landslide. These variables are believed to also control the overall distribution of landslides in the Beaver Valley. The paper demonstrates that the distinct element method provides an effective basis for quantitative analysis of large scale toppling. Many more applications will be needed to refine the geometric and material property generalizations used in this study. Nevertheless, the method appears to offer considerable promise for elucidating problems of rock slope behaviour in both slope engineering and geomorphology.

Key words: toppling, landslide, British Columbia, mountains, numerical modelling, distinct element method.

Cet article présente une étude de la relation possible entre les mouvements de bascule et les glissements profonds dans la vallée de Beaver River, Glacier National Park, Colombie-Britannique. La région étudiée comprend le glissement de Heather Hill, un des nombreux dans la vallée, et les talus adjacents qui exhibent des désordres par bascule à des degrés variables. Le développement du glissement de Heather Hill est simulé par calcul numérique au moyen de la méthode d'éléments distincts. La masse de rochè est modélisée par des colonnes déformables dont les limites représentent une approximation grossière des patrons de discontinuité *in situ*. Un changement intercalé dans les lithologies prédominantes, et un changement concomitant dans les espacements des discontinuités sont modélisés en variant l'épaisseur de colonne et les propriétés du matériau. L'analyse confirme qu'une surface de rupture profonde peut résulter du processus de bascule. Le changement intercalé des lithologies et le changement résultant des espacements des discontinuités expliquent la surface de rupture curvilinéaire et la position de la crête de l'escarpement du glissement de Heather Hill. L'on croit que ces variables contrôlent également l'ensemble de la distribution des glissements dans la vallée Beaver. Cet article démontre que la méthode d'éléments distincts fournit une base efficace pour une analyse quantitative de bascule à grande échelle. Plusieurs autres applications vont être requises pour raffiner les généralisations des propriétés de géométrie et du matériau utilisées dans cette étude. Néanmoins, la méthode semble offrir beaucoup de potentiel pour élucider des problèmes de comportement de talus rocheux tant en géomorphologie que pour la conception de talus.

Mots clés : bascule, glissement, Colombie-Britannique, montagnes, modèle numérique, méthode d'éléments distincts.

[Traduit par la rédaction]

Can. Geotech. J. 28, 410-422 (1991)

Introduction

Toppling is a well-documented mass wasting process than can occur at any scale (de Frietas and Watters 1973). Geomorphologists have reported examples of large scale toppling in natural slopes and have recognized a possible association between the toppling process and some types of sacking (Holmes and Jarvis 1985; Bovis 1982, 1990; Savage and Varnes 1987; Zischinsky, 1966). Geotechnical engineers, although familiar with toppling in engineered slopes, are less acquainted with natural toppling. Available methods of toppling analysis for design applications are limited to small scale engineered slopes. Best known is the limit equilibrium method described by Goodman and Bray (1976). No method of analysis has yet been developed for large scale toppling of natural slopes. The effect of large scale toppling on a rock mass is typically not considered in engineering design, even though variations in discontinuity orientations, hydraulic conductivity, RQD, and shear fabric in rock masses comprising some natural slopes may be a predictable manifestation of toppling.

This paper and a companion paper (Pritchard and Savigny 1990) represent the initial part of a research program with the following objectives: first, to develop a versatile method of toppling analysis and second, to investigate the depth to which toppling influences rock masses comprising natural slopes in mountainous terrain and the mechanical and morphological nature of its effect. Pritchard and Savigny (1990) reviewed the toppling process and alternative methods of analysis, provided a rationale for selection of the distinct element method, and verified the method using three examples of toppling failure. This paper provides a summary of a detailed study of the Heather Hill landslide, one of several in the Beaver River Valley of Glacier National Park, and presents the results of a distinct element analysis where the effect of toppling in development of the landslide is evaluated.

Beaver Valley is the eastern approach to Rogers Pass, British Columbia (Fig. 1), a narrow transportation corridor first traversed by Canadian Pacific Railway (now CP Rail) in 1885. The Trans Canada Highway was built in the 1960s,

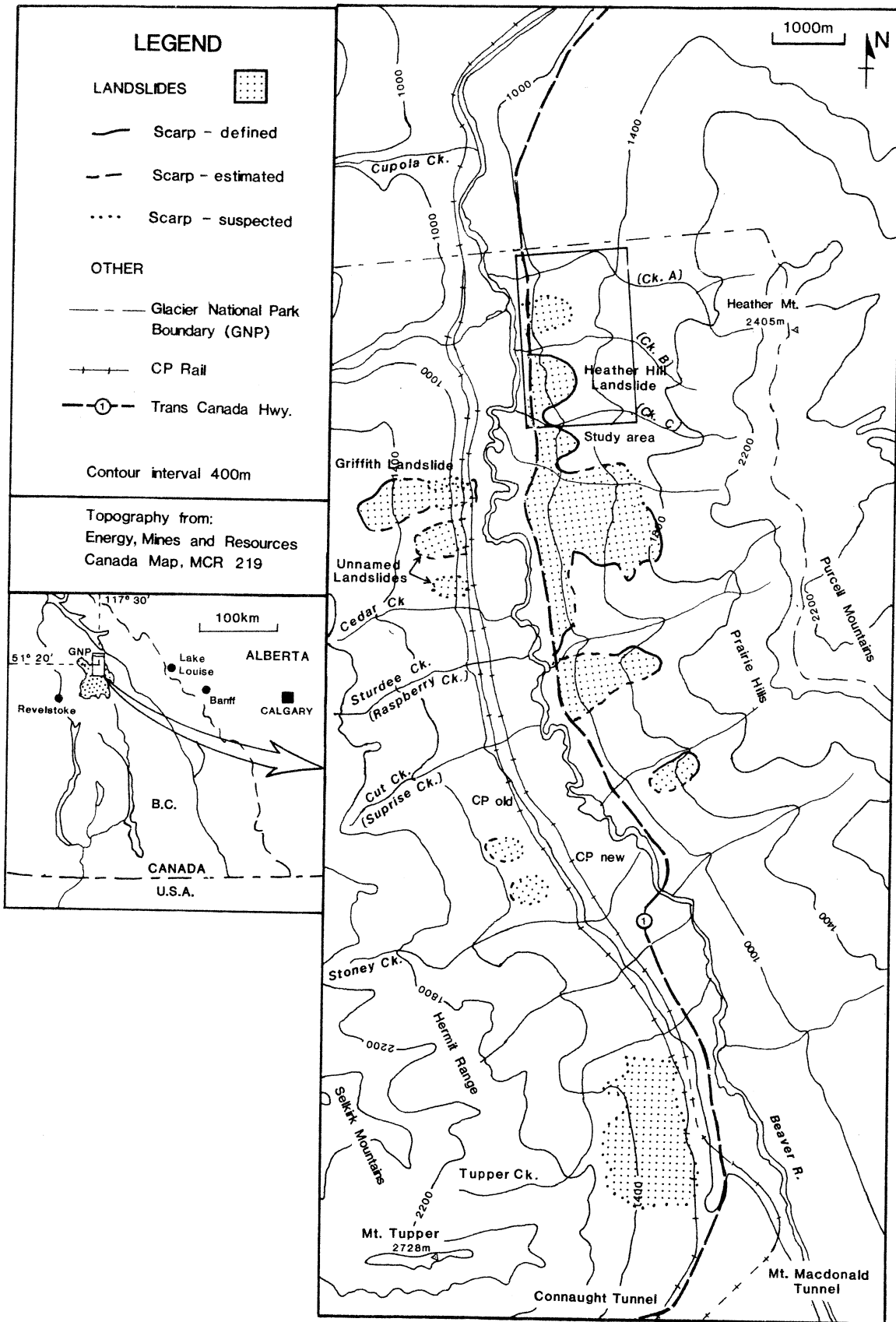


FIG. 1. Topographic map of the Beaver Valley showing locations of deep-seated landslides and study area (after Pritchard *et al.* 1988).

and in the 1980s, CP Rail constructed a second line as part of its larger Rogers Pass grade revision project (Savigny *et al.*, in press).

Large, deep-seated landslides on the Beaver Valley slopes cause maintenance problems on both the CP Rail grade and the Trans Canada Highway (EBA Engineering Consultants