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PROCESSES OF SLOPE FORMATION: RECENT QUANTITATIVE  
STUDIES IN CANADA

BY

P. J. WILLIAMS

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## Processes of slope formation: recent quantitative studies in Canada

by

P. J. WILLIAMS, Ottawa

**Zusammenfassung.** Die direkte Messung der Schuttbewegung ist grundlegend für Untersuchungen über Hangentwicklungsprozesse. Die vorliegende Betrachtung versucht, eine möglichst vollständige Übersicht über derartige Arbeiten der letzten 10 Jahre zu geben. Genaue Analysen schließen notwendig die Betrachtung anderer Phänomene ein, die nicht direkt mit der Hangformung zu tun haben. Artikel zur Hangentwicklung finden sich in geologischen, agrarwissenschaftlichen, technischen u. a. Zeitschriften. Daraus ist nur eine Auswahl behandelt worden. Das Hauptkriterium für die Auswahl war: entweder die sofort erkennbare Beziehung der Arbeit zur Frage der Hangformung, oder daß der Artikel ein spezielles Beispiel genau behandelte.

**Summary.** The direct measurement of rates of movement of material is fundamental in studies of slope formation processes. This review gives as full a coverage as possible of studies of this type in the last ten years. Detailed analysis, however, usually involves consideration of other phenomena, which may not even be particularly associated with slopes. Relevant papers are found in journals in the fields of geology, agriculture, civil engineering and elsewhere. Only a selection of such papers has been included. The main criterion is that the article be of immediate significance in studies of slope formation, or alternatively that it be an example of subject matter relevant in specific cases.

**Résumé.** La mesure directe de la vitesse de déplacement des matériaux est fondamentale pour l'étude des processus de formation des versants. La présente récapitulation s'efforce d'inclure toutes les études à ce sujet effectuées au cours de la dernière décennie. Cependant, l'analyse détaillée nécessite habituellement la prise en considération d'autres phénomènes qui n'ont pas de relation étroite avec la formation des versants. On trouve des articles et communications pertinentes dans les revues de géologie, d'agriculture, de génie civil et ailleurs. On n'a examiné ici que les articles ayant une importance directe pour l'étude de la formation des versants ou bien ceux qui concernent un cas précis.

### *Determination of Amounts of Movement*

A continuing programme (BARNETT 1966) of observations on solifluction slopes and scree is being carried out in Baffin Island. The displacement of wooden and aluminium pegs and painted stones is recorded, and displaced

material is trapped on sacking. Blocks moved up to 25 m/yr (81 ft/yr) on one scree. Solifluction lobes showed movements of a few centimetres per year. GARDNER (1966, 1967) has made visual observations in the Lake Louise district (Rocky Mountains) of various movements, noting time of occurrence. Photographic recording techniques were also used. Avalanches and rock falls show a maximum soon after midday; furthermore, there is a substantial overall peak in early July.

WILLIAMS (1966) described a study of solifluction movements, involving measurement of movement relative to depth. He recorded the deformation of tubes inserted in the ground with special probes (WILLIAMS 1962). Surface movements of 10 cm/yr (4 in./yr) occurred on an 8- to 10-degree slope. RUDBERG (1963) comments briefly on observations of stakes and painted stones, indicating mass movements are less pronounced on Axel Heiberg Island than in Scandinavia.

Several studies have been made by engineers of landslides in clays in the temperate regions. CONLON (1966) gives volumes of material displaced, and also a detailed study of processes and geomorphological conditions involved in such a slide. A study of the landslide topography in the Meikle Valley of Northern Alberta, and of the processes involved in slope failures, was made by NASMITH (1964). BRAWNER (1960) gives information on quantities, nature and causes of movement of material involved in 18 landslides in British Columbia. One huge landslide moved 1 in. or so a month in association with small changes in height of the water table.

Observations of the type described generally require several years and there are several such studies underway but not yet described in publications. B. G. THOM of McGill University is investigating slopes in Saglék Fjord, Northeast Labrador; J. T. GRAY is studying rock faces and talus slopes in Central Yukon, determining movement by lichenometry and surveying methods. Several types of instrumentation are involved in a study, directed by J. A. ELSON, of slopes in the Montreal region. Similar studies of slopes outside the Arctic region are being carried out by L. CURRY and others of the University of Toronto. On Devon Island rates of movement and the associated environment are being investigated by R. H. KING of the Institute of Northern Studies, University of Saskatchewan. J. P. JOHNSTON of Carleton University uses surveying methods to determine rates of movement of up to 25 cm/yr (10 in./yr) in rock glaciers. Dendrochronometric and lichenometric methods are also used.

#### *Studies of Special Situations in Formation of Slopes*

MATTHEWS & MACKAY (1963) used ball and wire devices to measure the creep at the base of snow layers on slopes. Displacements of 60 to 90 cm (2 to 3 ft) occur in one winter with maximums of 12 cm/week (5 in./week). Pressures of up to 0.4 kg/sq cm (6 p. s. i.) were recorded in the base of the snow, tangential to the ground surface, by use of pressure transducers (MACKAY & MATTHEWS 1967).

The role of ground ice in causing slumps and local slope retreat of up to 5 m/yr (15 ft/yr) is considered in detail by MACKAY (1966). Studying similar

features, LAMOTHE and ST-ONGE (1961) observed 10 m (33 ft) of slope retreat in one summer.

Soil erosion by water, resulting from agricultural practices, is a slope forming process dependent on the activities of man. A fairly detailed summary account is given by RIPLEY, KALBFLEISCH, BOURGET & COOPER (1961). A bibliographic review of Canadian investigations was prepared by WILLIAMS (1963).

### *Studies of Slope Forms and Lithology*

Though not directly concerned with quantitative studies of slope formation, the following articles are included as examples of recent geomorphological studies having relevance in this respect. ST-ONGE (1959) concluded from a study on Ellef Ringnes Island of topography over gypsum, that this rock is specially resistant to erosion under periglacial conditions. ST-ONGE (1964, 1965) gives account of nivation and slope erosion in the same locality, in relation to slope angle and lithology. The effects of stress release on the stability of slopes composed of shales previously heavily consolidated by the weight of ice or overlying deposits, is considered in detail by PETERSON and co-authors (1958, 1960), and by SCOTT & BROOKER (1968). Both geological and engineering techniques of analysis are used. The polygenetic nature of valley slope profiles measured in Labrador is described by TWIDALE (1959). Glacial and periglacial processes are important while stream erosion plays little part.

### *Studies of Processes not Restricted to Slopes*

Wind erosion is discussed in a publication for farmers (Dept. of Agriculture 1966). BISAL (1960) developed a relationship between raindrop size and velocity, and sand splash from experimental observations.

The effects of freezing and thawing and wetting and drying on aggregate size (an important factor in wind erosion) were investigated by SILLANPAA & WEBBER (1961), and HINMAN & BISAL (1968). BISAL & HSIEH (1966) showed relationships between moisture content and erodability of soil by wind.

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