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JOINT PATTERNS AT THE HEADSCARP OF THE 1965 HOPE SLIDE

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ABSTRACT

Joint patterns around the headscarp of the 1965 Hope Slide were examined in detail during July and August, 1988. An unbiased line mapping method was used to investigate the fabric of the greenstone involved in the rock avalanche. Three dominant sets of joints were identified in the greenstone and are believed to have played an important role in the failure mechanism. The three sets of joints (J1, J2 and J3) have average dips and dip directions of 45°/270°, 85°/300° and 80°/020° respectively. J1 appears to have been the main basal plane of translation of the detached mass. The vector of movement suggests that the 1965 event did not slide in the direction of true dip of J1 but down an apparent dip surface that daylighted in the slope. At present rockfalls are most common where tension cracks are prevalent in the headscarp. Seepage was noted on the rupture surface suggesting that water pressures may have played an important role in detachment.

INTRODUCTION

Early in the morning of January 9, 1965, a rock avalanche with an estimated volume of 47 x 10^6 m^3, descended the southwest slope of Johnson Peak, located southeast of Hope, approximately 160 km east of Vancouver, British Columbia (Fig. 1,2). The slide, which is Canada's largest known historical landslide, buried a section of British Columbia Highway No. 3, three vehicles and their four occupants.

A study conducted shortly after the slide by Mathews and McTaggart (1969) listed the following as possible contributing factors:

- the existence of planes of weakness within, or at the margins of, felsite sheets that are exposed on the rupture surface;
- a general parallelism between the rupture surface and the felsite sheets;
- weakness of the rock mass due to a slight schistosity;
- serpentinization along some of the joints;
- the occurrence of two minor earthquakes with magnitudes 3.2 and 3.1 earlier the same morning.

In a detailed analysis of the available seismic data, Wetmiller and Evans (in press) suggested that, although the earthquakes may have triggered the slide, the incipient instability of the slide mass was the dominant factor.

The 1965 slide was not a unique event since it involved the failure of part of the scar created by a prehistoric rock avalanche of similar size which occurred approximately 9700 years B.P. (Mathews and McTaggart, 1978). In addition, open cracks in the headscarp of the Hope Slide and trench-like, or sackūng features adjacent to the slide scar have been reported, both of which may indicate limited slope deformation (Wetmiller and Evans, in press; Sather, 1988; Mollard and Janes, 1984).

Although the potential of a third rock avalanche from the flanks of Johnson Peak poses an ongoing hazard to any development in the valley below, no detailed study of the rock mass has been undertaken. In an effort to better understand the failure mechanisms of the prehistoric and the 1965 events, together with the significance of the possible slope deformation features noted above, mapping of the rock mass was carried out at the headscarp of the 1965 slide and adjacent Johnson Ridge during July and August, 1988 (Fig. 1, 3). This report presents a preliminary interpretation of these data.

GEOLOGICAL SETTING

The general geology in the vicinity of the Hope Slide consists of late Paleozoic Hozameen Group rocks, which are intruded by felsite sheets (Mathews and McTaggart, 1969, 1978). The Hozameen Group consists of four units: ribbon chert, greenstone, limestone and argillite. These rocks were affected by two episodes of metamorphism in the Late Paleozoic or Triassic, and in the Late Cretaceous. Intrusion of a tonalite body occurred during Cretaceous time or later (McTaggart and Thompson, 1967). The 1965 slide involved the greenstone unit of the Hozameen Group.

Jointed greenstone predominates around the headscarp of the slide. Felsite sheets of varying orientations are found in the greenstone in the slide area. The tonalite/greenstone contact is not exposed, but can be traced on the ridge at the eastern margin of the study area. The nature of the tonalite was not investigated in detail.

ROCK MASS STRUCTURE

A line mapping method (Herget, 1977) was used to measure and record the rock fabric of the greenstone in a study area outlined in Figure 3. Traverses were made between survey stations M1 to M6 (Fig. 3). The study area was restricted because of safety considerations in the headscarp area and on the rupture surface itself.

Rock mass fabrics representative of the greenstone in the study area are given in Figure 4 (A,B). The pole concentrations in Figure 4 indicate that three well developed sets of joints are present. The first set (J1) has an average dip direction of 270° and a dip of 45°. This dip is slightly steeper than the slope angle of approximately 40° which existed in this part of the slope prior to the 1965 rupture. The second joint set apparent in Figure 4 (J2) has an average dip direction of 300° and dips steeply at 85°, and a near third set (J3) has a near dip direction of 20°, dipping approximately 80°.

A portion of the northwest margin of the slide may have experienced shear and/or tensile displacement along a pre-existing tectonic shear zone. This is evident by the remains of cemented breccia that is still attached to the headscarp cliff.

A few contacts between felsite intrusions and greenstone occur at the base of the precipitous headscarp, but their orientations show marked variation. Contact dip angles vary between 30° and 80°, generally dipping into the slope along the southwest margin and sub-parallel to the slope at the northwest margin. Observations made while flying over the slide confirm that the felsite/greenstone contacts in the lower portion are also sub-parallel to the slope, as noted by Mathews and McTaggart

(1969, 1978). Here the felsite/greenstone contacts may in fact be strong contributors to the weakness of the rock mass, but their influence appears secondary to that of joints. Felsite intrusions are visible between the study area and the lower portion of the scar, but most are inaccessible for mapping.

RELATIONSHIP BETWEEN ROCK MASS STRUCTURE AND DETACHMENT

A preliminary attempt has been made to relate elements of the rock mass fabric to the detachment of the 1965 event. J1 surfaces are exposed on the rupture surface which suggests that the slide detached in part along this joint set. However, movement could not have taken place in the direction of true dip since J1 does not daylight in the slope in that orientation. The initial direction of movement was probably orthogonal to the slope contours at 230°N (Fig. 4) which is slightly south of the true dip direction of J1 (270°). This suggests that movement took place across the J1 surfaces on a plane of apparent dip and it is noted that this apparent dip plane does daylight in the slope in the vicinity of 230°N allowing translation to take place.

Elements of the headscarp developed parallel to joint sets J2 and J3 as seen as Figure 3.

It was noted that numerous smaller failures of various scales have occurred on cliffs in the Johnson Ridge area. Many of these small failures, again bounded by J1 and J2 joints but with a less well defined northwest margin, have the same configuration as larger scale blocks in the headscarp area of the slide illustrated in Figure 3.

ADDITIONAL OBSERVATIONS

Rockfalls are still occurring at the slide site. It was noted that rocks often started spalling by noon, in response to expansion due to temperature changes. The northwest wall of the slide seems the most unstable. This is also the area of the headscarp, where open cracks are found. Due to inaccessibility and the frequency of rockfalls along the northwest cliff base, no data were collected between the study area and the lower exposures of the slide mass.

Springs are readily identifiable on the lower exposures of the detachment surface in air photographs and while flying over the slide. Seepage is naturally expected from snowmelt between

April and June, but despite the dry conditions in July and August, water continued to seep from these springs. In contrast, only three or four seepage sources were observed in the study area around the headscarp, from which very small volumes of water discharged during the summer months. Johnson Ridge and the headscarp areas are considered areas of groundwater recharge. The observations of groundwater discharge conditions on the slope indicate careful study of climatic records in the several months preceding the 1965 slide will be necessary to estimate appropriate water pressures for analysis.

CONCLUSIONS

This report presents a preliminary interpretation of the data collected by detailed rock structure mapping in the headscarp area of the Hope Slide. Three major sets of joints (J1, J2, and J3) and a pre-existing tectonic shear zone are thought to define the boundaries and the behaviour of the 1965 Hope Slide. J1 (45°/270°) appears to have been the main basal plane along which the slide mass detached. J2 (85°/300°) forms northerly trending elements of the headscarp. East-west trending elements of the headscarp are parallel to J3 (80°/020°) and a pre-existing tectonic shear zone.

The vector of movement suggests that the 1965 event did not slide in the direction of true dip of J1 but down on apparent dip surface which daylighted in the slope. Additional observations indicate that rockfalls from the precipitous headscarp are most common in its northwestern sector where tension cracks are most prevalent. The presence of seepage on the rupture surface suggests that water pressures may have existed in the slope prior to detachment in 1965.

Findings in this report only represent a preliminary evaluation of some of the field data collected in the summer months of 1988. More detailed analyses are underway.

ACKNOWLEDGMENTS

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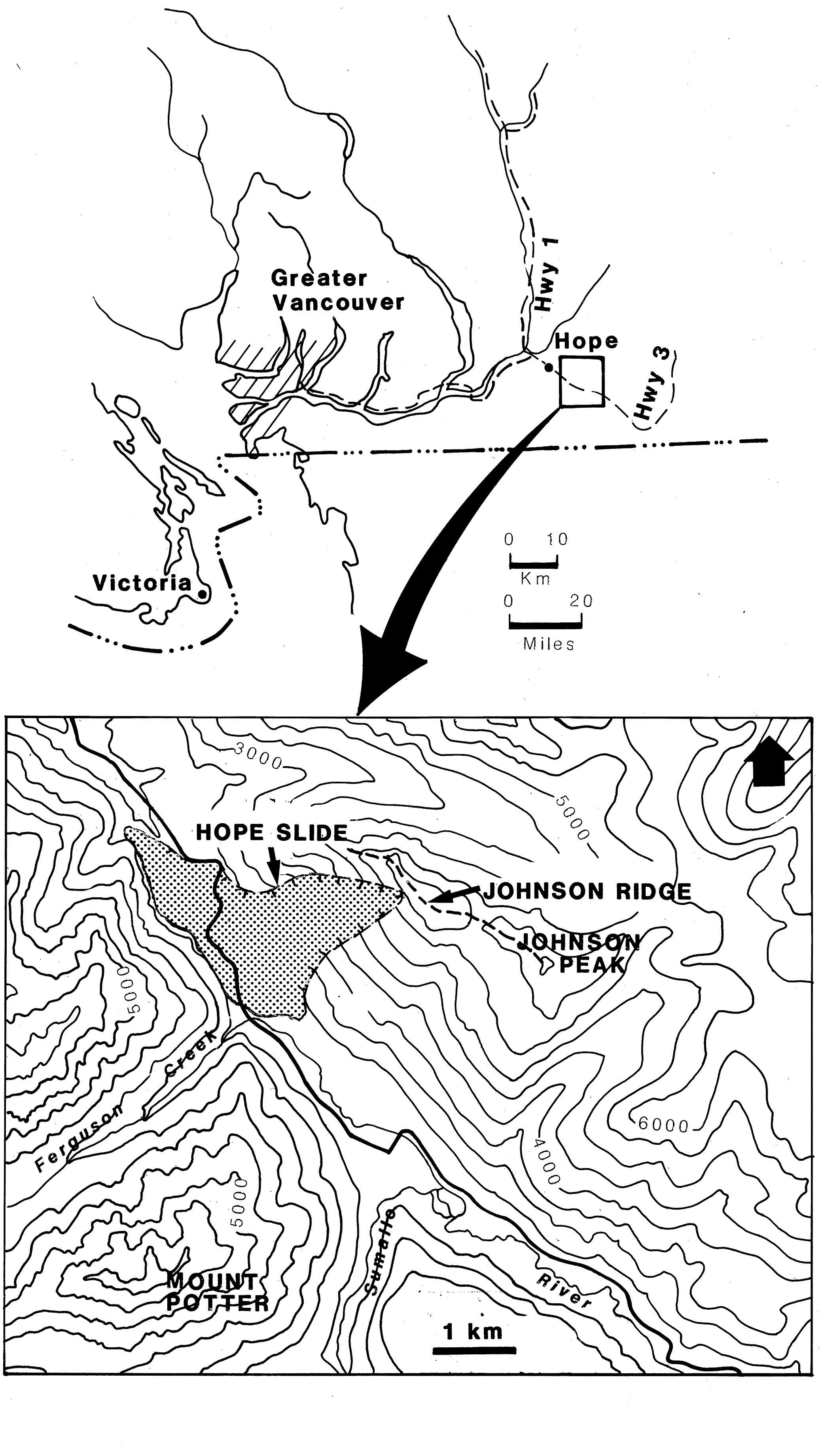


Figure 1: Location map and contour map of the Hope Slide area.

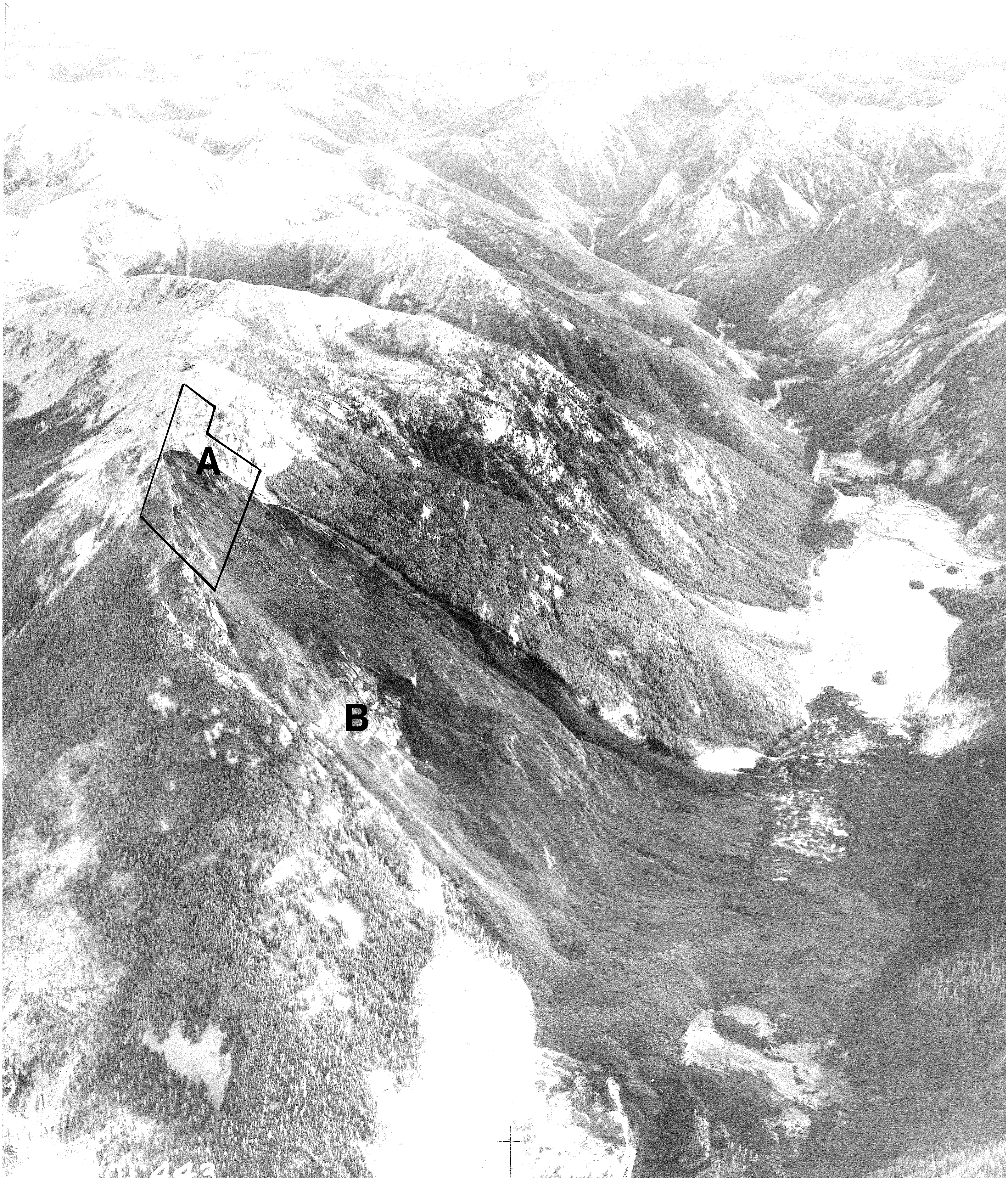


Figure 2: Oblique air photograph looking southeast over the 1965 Hope landslide (B.C. Government Photo, BC(0)443; taken January, 1965). A = study area; B = lower exposure referrred to in text.

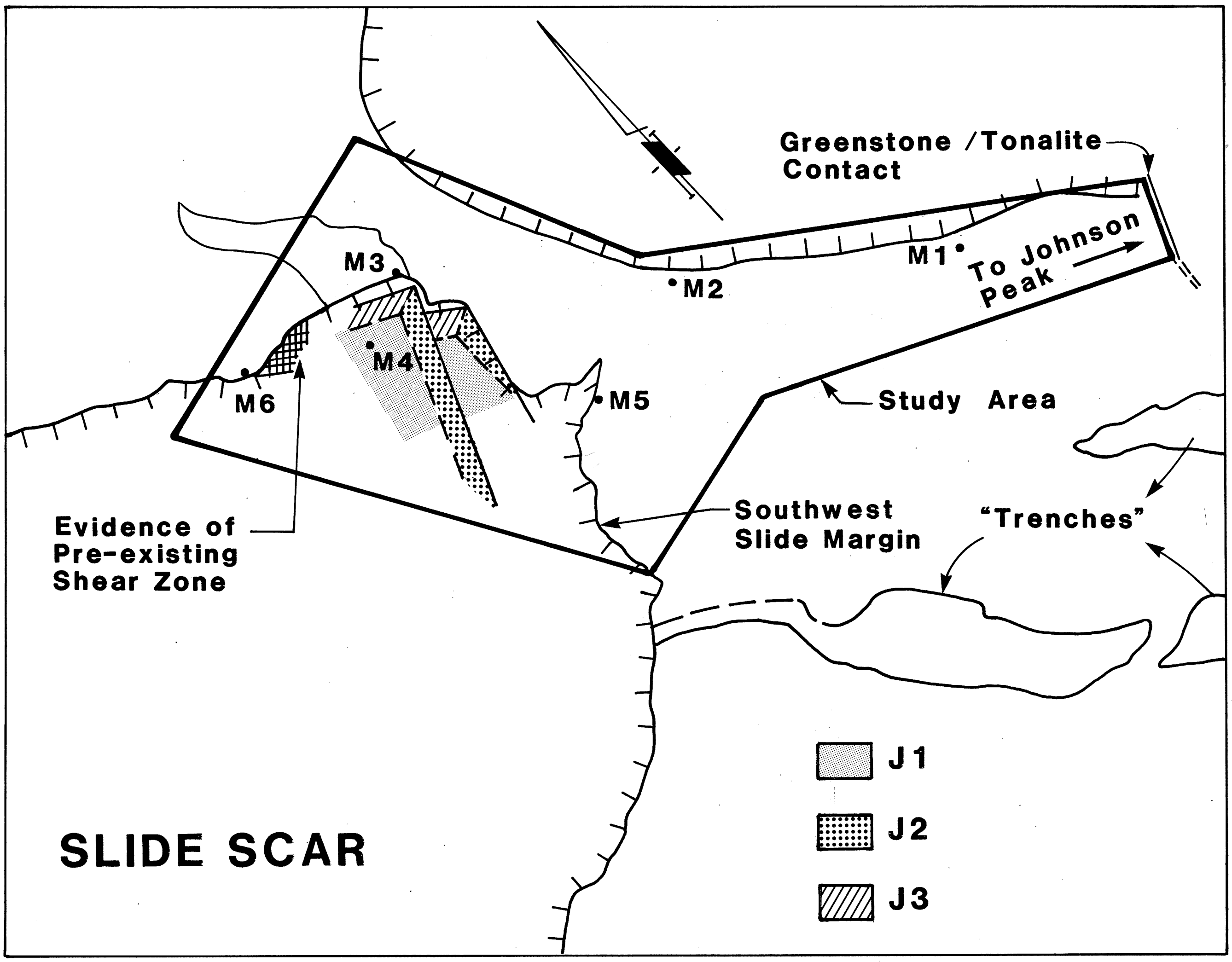
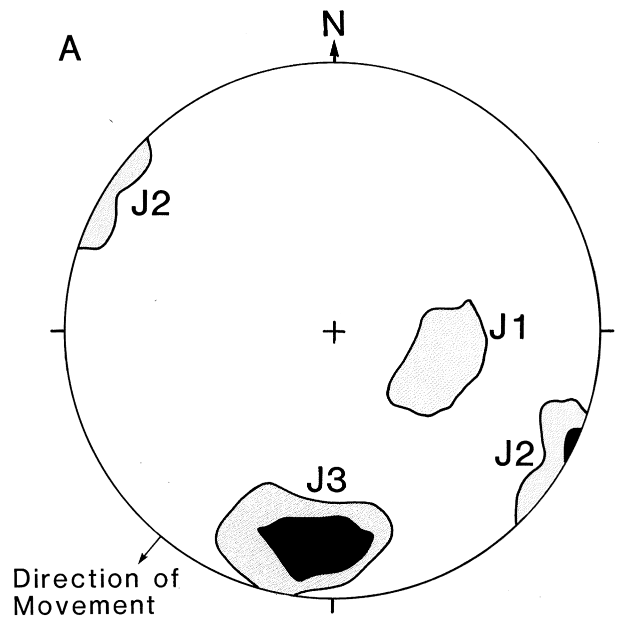


Figure 3: Sketch map showing J1 (45°/270°), J2 (85°/300°), and J3 (80°/020°), and configuration of possible "wedge-shaped" blocks at the headscarp of the Hope Slide (outline of slide traced from enlargement of air photograph BC 5672-100).



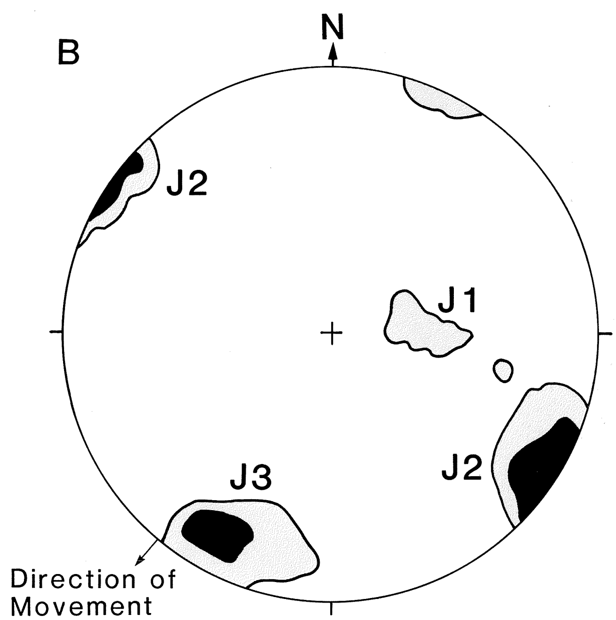


Figure 4: Lower hemisphere equal-area projection of joint data at the Hope Slide. A; joint data (n=88) from Johnson Ridge, adjacent to slide scar. B; joint data (n=106) from northwest part of scar. Pole concentrations indicate three joint sets, J1, J2 and J3 with average dips and dip directions of 45°/270° (J1), 85°/300° (J2), 80°/020° (J3). Direction of movement is assumed to be orthogonal to the slope contours.