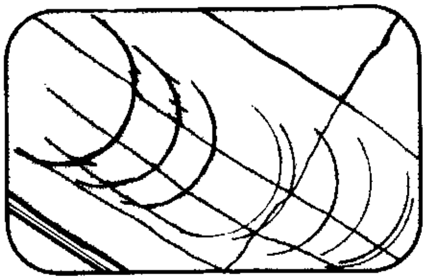

Glacial Striae and Crescentic Marks in Nepean Sandstone near Ottawa

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Summary
An outcrop of Nepean Sandstone (Cambro-Ordovician) at Kanata, 21 km west of Ottawa, containing a unique concentration, diversity and distribution of glacial striae and crescentic markings has been partly removed by highway construction, leaving the north sloping stoss end and part of the top surface. Two sets of striae are preserved. The main set, indicating ice flow toward the south-southwest across the Ottawa Valley, is transected by short, deep, west-east striations indicating a late and final ice flow downvalley to the east. East-trending striations are seldom observed in the Ottawa Valley.

Crescentic markings variously termed gouges, scours, scars, or pluckings, are on the northern stoss slope, concave up-ice toward the north. On average, these are 25 cm across, about 5 cm broad and 1 to 2.5 cm deep. They become progressively less crescentic and less concave away from the stoss slope and change to fine, hairline fractures on the more polished top surface, becoming convex up-ice toward the southern end of the outcrop. The change in crescentic form from north to south along the outcrop clearly represents a differential impingement of ice and its contained boulders over the surface of the outcrop.

Introduction
In 1975 while mapping geological features ahead of the advancing Queensway (Billings, 1975), we noted an outcrop of Nepean Sandstone with an unusual concentration and diversity of glacial markings.

The outcrop at Kanata, 21 km west of Ottawa (Fig. 1) on the north side of the Queensway, about 2 km west of Eagleston Road, has been partly destroyed. The photographs and diagrams in this paper illustrate the progressive distribution, on one small outcrop, of different kinds of glacially-induced crescentic markings and fractures.

The outcrop, of 500 m^2 with a maximum vertical height of 1.5 m, consists of horizontal orthoquartzitic sandstone. The surface, except where glacially polished at the southern end, is pitted with chalky-white pits set within the more vitreous quartzose groundmass. The pits, according to Prest, "represent a concretionary, in-place growth of carbonate derived from the surrounding carbonate-poor groundmass. In places on nearby outcrops, bedding planes may be seen passing from the groundmass through the concretions which are commonly 2 to 3 cm diameter." (V.K. Prest, pers. comm. 1985).

The Markings
The Kanata outcrop displays two sets of glacial striae as well as concentric scars, pluckings, and fractures that are both concave and convex up-ice, that is, toward the north.

The striae consist of a prominent N-S set and a less prominent W-E set (Figs. 2–6). The more prominent N-S set, with striations trending from 197° to 232°, indicates a southward flow of ice. The less prominent W-E set, which is clearly the younger, indicates an eastward flow of 85° to 90°. Eastward-trending striations have not been reported near Ottawa but are recorded in the Chalk River area (Gadd, 1962), while a southeasterly flow is reported in the Pembroke-Renfrew area (Gadd, 1980). Little, if any, relationship exists on the Kanata outcrop between the length, width, and depth of the striae — the longest striae are commonly the most narrow and the most shallow.

The term crescentic marking is used here to cover the many common words used at different times, by different authors to describe crescentic marks, markings, scars, scours and gouges, and lunate, semicircular, hyperbolic, sagittate, chatter and chattering marks, and friction cracks in many different rocks. A simplification has recently been presented by Prest (1983).

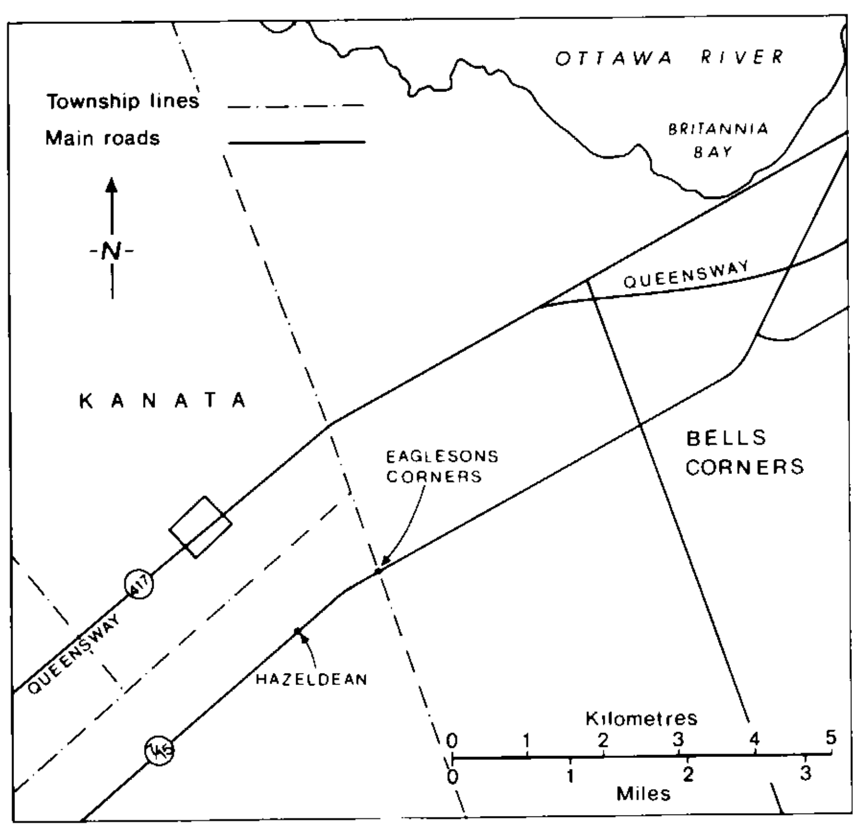

Figure 1 *Location indicated by rectangle*

Figure 2 *Crescentic fracture scars, concave up-ice (the reverse crescentic fractures of Prest, 1983, p. 34), transected by N-S striae. Surface slopes north toward the observer. Note later W-E striae particularly in centre and left*

Figure 3 *Seven concave up-ice fractures and scars or pluckings one above the other. Rock surface slopes north (bottom of photograph) at 10°. N-S striae trending between 190° and 215°. W-E striae absent. Note N-S joint parallel to striae, and in background joint scarp representing either frost-heaving or seismic disturbance (cf. Basham and Adams, 1984, Fig. 5). Frost-heaving is less likely as both near and distant blocks appear to be solid bedrock*

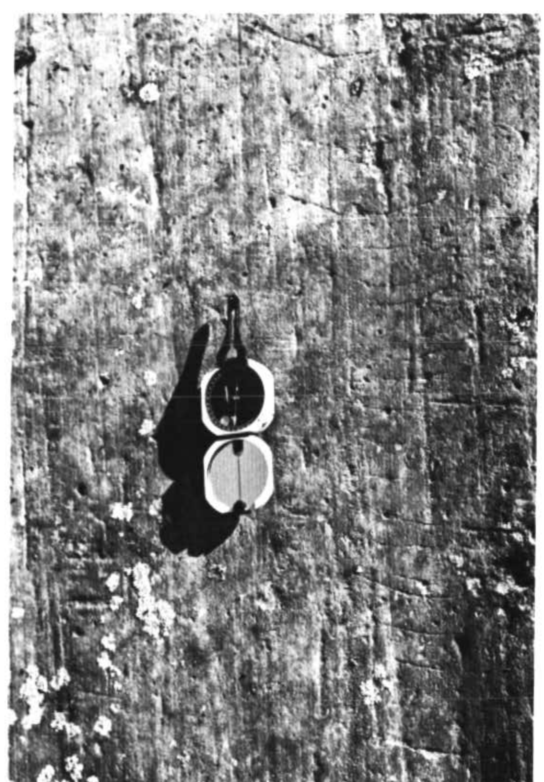

Figure 4 *Relief indicated by coin (centre right). N-S striae (north at left) on rock surface sloping at 5° toward the observer. Note later W-E striae and virtual absence of crescentic fractures*

Figure 5 *Striae (north at bottom of photograph) trending 180° to 200° on surface sloping 3° north. Crescentic fractures at right-angles to the N-S striae are slightly convex up-ice. A few later W-E striae are visible*

The more numerous and more obvious crescentic scars are concave up-ice. The rock was plucked, either by the original ice or by subsequent frost action. The scars average 25 cm across, are about 5 cm broad, and are astride the N-S striae (Figs. 2 and 3). The depths in the central deepest parts of the concavities vary from 1 cm to 2.5 cm. The primary fracture in most of the scars dips slightly in the direction of ice movement (Figs. 2 and 7B), and was at one time thought to follow bedding (J.A. Donaldson, pers. comm. 1976). Bedding surfaces could not, however, be detected by us either along or near the primary fracture. Gilbert (1906) postulates a much steeper primary, concoidal fracture dipping in the direction of ice movement (Fig. 7A). Supporting and opposing observations as to the direction of dip of the primary fracture are summarized by Embleton and King (1975).

Convex up-ice fractures occur only on top toward the southern polished end of the outcrop (Fig. 6) and consist of fine, hairline fractures closely stacked one inside the other, becoming smaller southward but with a definite up-ice relationship to the N-S striae (Prest, 1983). The convex up-ice fractures at Kanata are vertical or dip steeply down-ice to the south in agreement with observations by Ljunger (1930), Okko (1950) and Gilbert (1906). However Lahee (1912), Harris (1943) and Dreimanis (1953) record dips as low as 60° down-ice (see also Fig. 20 in Prest, 1983).

Convex up-ice fractures are, according to Harris (1943), best developed in hard, brittle rocks as at Kanata. Lahee (1912) counted 60 separate fractures per linear inch. The fractures usually become smaller in the down-ice direction (cf. Fig. 6) and invariably, as at Kanata, closer together so that the number of fractures times length of fractures is constant.

Conclusions

Both Harris (Fig. 7C) and Ljunger (Fig. 7D) attempted to reconstruct the stress field that might have produced crescentic, glacial fractures. Ljunger postulated convex and concave fractures developing on opposite sides of a cone of compression with the convex fractures formed ahead (up-ice) of the concave ones. Such a distribution, however, is the reverse of our findings. Moreover, at Kanata, the two sets of fractures are more than 20 m apart (Fig. 8).

The progressive distribution of crescentic fractures and scars: concave up-ice to the north on the sloping northern stoss end with a gradation through intermediate to convex up-ice fractures on the upper horizontal southern surface appears to represent a slope impingement phenomenon (V.K. Prest, pers. comm. 1985).

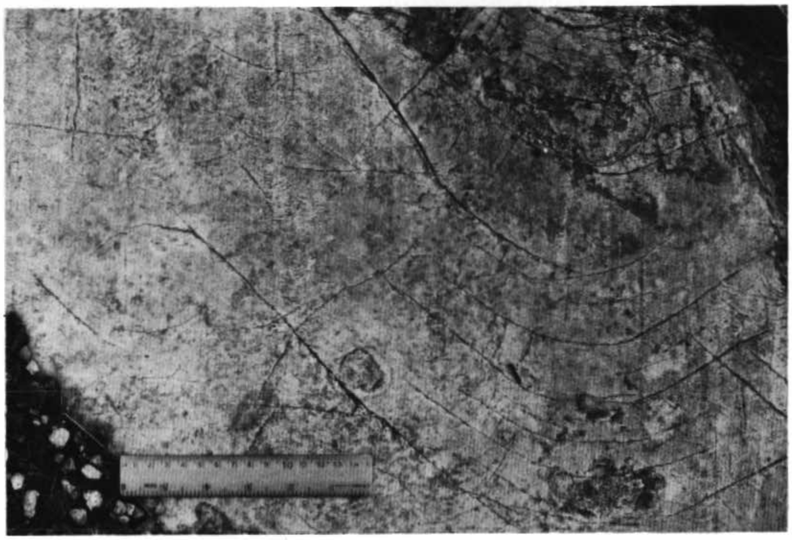

Figure 6 *Flat, polished surface showing one large and several smaller sets of crescentic fractures, convex up-ice. North is at the bottom of the photograph, part of which is illustrated in Prest (1983, p. 33). N-S striae trending 197° with one at the upper left at 215°. The smaller fractures are bisected by pitted striae indicative of the bouncing or chattering of glacially-held fragments. Notice the incipient N-S, W-E jointing developed on the left, and the incipient NW-SE, NE-SW jointing elsewhere. (cf. Trainer, 1973)*

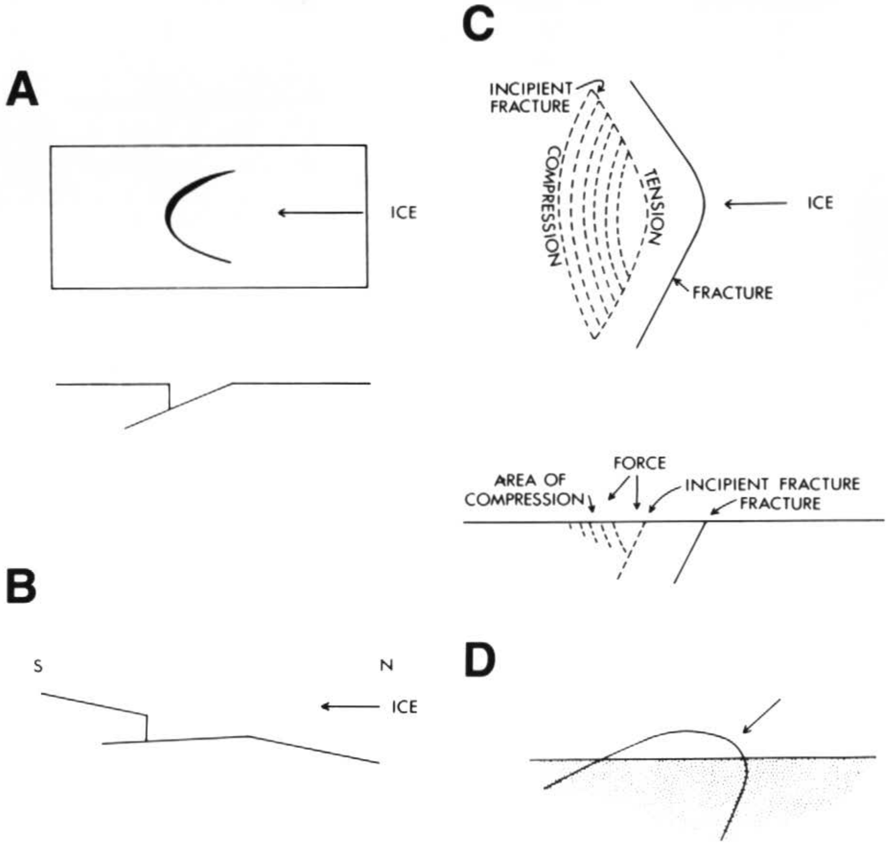

Figure 7 ***A)*** *Plan and section of a concave up-ice scar (after Gilbert, 1906, p. 305);* ***B)*** *Section through a concave up-ice scar on stoss face at Kanata (also see Figs. 2 and 3);* ***C)*** *Plan and section of "forces" that produce convex fractures (from Harris, 1943, p. 250);* ***D)*** *Section showing the theoretical relationship between concave fracture (left) and convex fracture (right) (according to Ljunger, 1930, p. 290)*

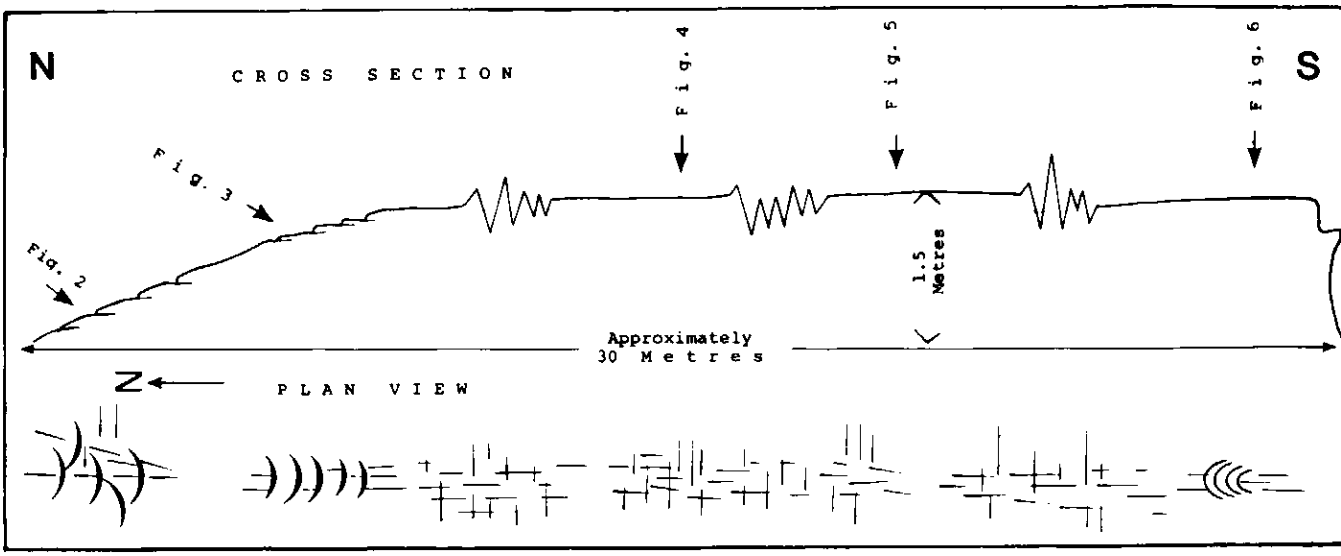

Figure 8 *The progression from concave up-ice fractures, through a zone (of about 8 m) lacking crescentic fractures, to convex up-ice fractures. Note N-S and W-E striae. The approximate camera positions of Figs 2 to 6 are indicated*

Acknowledgements

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