SIR,

Transition from shear moraines to rock glaciers

Several authors have discussed the origin of rock glaciers and stated that they are of glacial origin, in other words, a stagnant glacier which had become debris-covered (Brown, 1925; Outcalt and Benedict, 1965). The fact that rock glaciers may formerly have been active ice glaciers would seem rather well established by Brown (1925). Miners tunneling into a rock glacier in the San Juan Mountains of Colorado exposed a central core of ice, which Brown concluded to be of glacial origin.

If an ice glacier can in time evolve into a rock glacier, the question then arises of how it becomes so ladened with superglacial debris. In many cases the inactive or stagnant glacier may become covered by rock falls from the surrounding slopes.

However, the possibility exists that the glacier may be responsible for its own surficial cover. If the glacier's terminus is stationary (a condition which would favor the formation of shear moraines), shear moraines may develop. As the glacier slowly retreats a succession of shear moraines may form up-valley, producing what is referred to as a rock glacier.

It is known that many rock glaciers possess arcuate ridges in their terminal areas. Wahrhaftig and Cox (1959) stated that these ridges form when the basal shear of the rock debris exceeds the internal friction of the material. However, Wahrhaftig and Cox believed rock glaciers to consist of debris cemented with interstitial ice, and not old glacial ice covered by debris. For those rock glaciers which are indeed old glaciers covered by debris these arcuate ridges may well be a series of shear moraines.

A photograph in the paper by Outcalt and Benedict (1965) shows debris bands in the ice of a rock glacier. These debris bands may well be shear planes which would be one mechanism for obtaining a surficial mantle on the ice body.

This idea is put forward only as a theory and certainly not as a rule of formation for rock glaciers.

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SIR,

Geographic orientation of wave-ogive systems

Investigations of wave ogive systems on glaciers have led to a wide variety of postulated mechanisms of formation for these surprisingly uniform phenomena. A widely accepted mechanism is the seasonal-ablation–plastic-deformation hypothesis of Nye (1958). An annual process is untenable for some slow moving polar glaciers. Hughes (1971, in press) proposed an alternative ablation hypothesis; a differential-ablation–longitudinal-compression model that operates on north-flowing polar glaciers to account for ogives on some Antarctic alpine glaciers. Holdsworth (unpublished) rejected ablation as a causative factor and postulated a Biot (1960) type stress-induced buckling instability as a wave initiator.

My own studies have thrown some doubt on the validity of the Nye model and have shown that probably as many south-facing as north-facing ogive systems exist in the extreme southern latitudes for which Hughes' model was proposed. Ogive systems figured in the literature have an overwhelming preponderance of facings toward the equator with a very weak secondary mode in the opposite direction. This apparent geographical control is somewhat disquieting to the writer, who favours the stress initiation model of Holdsworth.

The excellent photographs of Post and LaChapelle (1971) are of value to this writer's cause. Their illustrations of pairs of ogive systems originating from separate ice falls with different orientations (their figures 68 to 70) suggest that there is no simple geographic control. The illustrations also show interference between coalescing ogive systems, strongly suggesting a stress-dependent mechanism of formation and supporting the principle of Holdsworth's model of stress initiation.

The author issues a plea for information that members might possess regarding the orientations of ogive systems at sites of initiation, and particularly regarding the occurrence of multiple interfering ogive trains.

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