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CORRESPONDENCE

The Editor,

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SIR,

The hydrological significance of rock glaciers

The high central Andes of Argentina (Mendoza y San Juan) are probably depicting the largest area of rock glaciers in the world. Based on a large aerophoto survey of more than 12 000 km², several hundreds of km² of rock glaciers have so far been mapped. A complete paper on all types of rock glaciers is being prepared. At this time I would like to deal with the two most common types of rock glaciers:

(1) True rock glaciers, talus rock glacier type (Spencer, 1900).

(2) Rock glaciers derived from the melting of true glaciers containing an ice core (Brown, 1925; Lliboutry, 1953; Outcalt and Benedict, 1965; Potter, 1972).

I would like to propose using the term *true rock glaciers* for all features resulting from the accumulation of snow and debris below avalanches, shutes and couloirs (Lliboutry, 1961), in talus cones, (Di Colbertaldo, 1946), protalus ramparts (*Hangblockwulst*, in German) (Grötzbach, 1965), which by the motion of the debris and ice, are transformed into tongues of rock glaciers. The ice in this type of rock glacier is believed to be interstitial. However, as previously indicated by Di Colbertaldo (1946) and Lliboutry (1961), the talus cones fed from avalanches contain a structure of layers of snow-ice and debris.

The surface of this type of rock glacier does not show elaborate transversal arches and troughs, nor thermokarst features. This is the classical talus rock glacier described by Spencer (1900) which should be considered the prototype (Johnson, 1974), the "valley-wall type" of Outcalt and Benedict (1965), the "ice-cemented type" of Potter (1972), and the "talus slope type" of Barsch (1969). I would also propose that rock glaciers which are derived from the melting of valley glaciers (Brown, 1925; Lliboutry, 1953; Outcalt and Benedict, 1965; Potter, 1972; Barsch, 1969), should be called *debris-covered glaciers*. Such rock glaciers still retain some features of the valley glaciers which originated them: a tongue shape located at the foot of a cirque, a core of glacier ice, crevasses in the ice below which still may be visible, thermokarst features produced by the massive ice melting below, and in later stages in the rock glacier development, an elaborate pattern of arches and troughs. Since they originate from a glacier, such rock glaciers should be called "debris-covered glaciers".

In our survey of rock glaciers, we observe that this type of debris-covered glacier exhibits several altitudinal "facies" or "patterns" as follows: at the top is the glacier or "non-covered ice facies"; below that is the "thermokarst facies" in which lakes are formed over a thin layer of debris. Further down, as the surficial layer increases, the regolith shows structural patterns of arches and troughs: this is the "structural debris facies". Further down the patterns of the surface material are less pronounced as the rock glacier becomes inactive: this is the "inactive facies". Still further down the rock glacier surface is more rounded and covered with vegetation; this is the "dead stage".

It is obvious that the hydrological behavior of a rock glacier will depend on the methods in which water, snow, ice, or ground-ice can become incorporated and eliminated from the body of the rock glacier. Since we are observing these genetic-morphological differences in these two types of rock glaciers, it is interesting to question whether or not these differences could lead to differences in the hydrological behaviour. In the available literature there is no data on the hydrology of rock glaciers. However, it is proper at this state of the research to look for the factors which should be significant in rock-glacier hydrology: (a) type or genesis of rock glaciers, (b) amount of melting produced below the debris cover, (c) the role of the debris cover as accumulator of either snow or ice (ice could be produced by the refreezing of the melt water at the top of the frozen core of the rock glacier). It is reasonable to assume that the rough surface of the rock glacier, with its boulder material, the very porous cover (sorted), and its elaborate patterns of arches and troughs, is an ideal place for snow to be trapped. In fact this rock glacier cover seems to be a better accumulator than the smooth surface of a glacier.

It is noteworthy that, especially in the eastern Andes, rock glaciers are the dominant feature of the valleys and slopes. Consequently, the hydrology is largely determined by the rock glaciers. During the fall of 1974 and summer of 1975, some qualitative observations on rock-glacier hydrology were made:

(1) True rock glaciers and the debris-covered glacier type carried significant amounts of water which makes them a special subject for research.

(2) Usually the water from the rock glaciers drains underground due to the presence of boulder material.
(3) The rivers fed from rock glaciers are clearer and have more stable run-off than rivers fed from snow or ice.

In the Alps Schweizer (1968, p. 98–105) indicates a significant amount of water coming out of a rock glacier in Braissekar (Sestrière). I would be very glad to know whether such phenomena have been observed in other places, and would appreciate receiving information regarding the ways in which water, snow, ice, ground ice, segregated ice, or interstitial ice, can become incorporated or eliminated from the body of the two types of rock glaciers.

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REFERENCES

Barsch, D. 1969. Studien und Messungen an Blockgletschern in Macun, Unterengadin. *Zeitschrift für Geomorphologie*, Supplementbd. 8, p. 11–30.
Brown, W. H. 1925. A probable fossil glacier. *Journal of Geology*, Vol. 33, No. 5, p. 464–66.
Di Colbertaldo, D. 1946. I Ghiacciai del Canin a del Montasio nel 1946 ad il loro regreso durante l'ultimo ventennio. *Società Monte Lussari, Pubblicazioni Scientifiche*, No. 1.
Grötzbach, E. 1965. Beobachtungen an Blockströmen im afganischen Hindukusch und in den Ostalpen. *Mitteilungen der Geographischen Gesellschaft in München*, Bd. 50, p. 175–201.
Johnson, P. G. 1974. Mass movement of ablation complexes and their relationship to rock glaciers. *Geografiska Annaler*, Vol. 56A, Nos. 1–2, p. 93–101.
Lliboutry, L. A. 1953. Internal moraines and rock glaciers. *Journal of Glaciology*, Vol. 2, No. 14, p. 296. [Letter.]
Lliboutry, L. A. 1961. Les glaciers enterrés et leur rôle morphologique. *Union Géodésique et Géophysique Internationale. Association Internationale d'Hydrologie Scientifique. Assemblée générale de Helsinki, 25–7—6–8 1960. Commission des Neiges et Glaces*, p. 272–80.
Outcalt, S. I., *and* Benedict, J. B. 1965. Photo-interpretation of two types of rock glacier in the Colorado Front Range, U.S.A. *Journal of Glaciology*, Vol. 5, No. 42, p. 849–56.
Potter, N. 1972. Ice-cored rock glacier, Galena Creek, northern Absaroka Mountains, Wyoming. *Geological Society of America. Bulletin*, Vol. 83, No. 10, p. 3025–57.
Schweizer, G. 1968. Der Formenschatz der Spät- und Postglazials in der Hohen Seealpen. Aktualgeomorphologische Studien im oberen Tinéetal. *Zeitschrift für Geomorphologie*, Supplementbd. 6, p. 98–105.
Spencer, A. C. 1900. A peculiar form of talus. *Science*, Vol. 11, No. 266, p. 188.

SIR, *Ice-movement direction from drumlin morphology: comments on the paper by C. P. Gravenor*

A recent paper by Gravenor (1974) raises two points concerning drumlins, first by the use of the term "stoss" in this context and secondly the position of the steep end. Over the years stoss has become synonymous with steep—see, for instance, Gravenor (1953), Blake (1956) and Chapman (1970); *the actual meaning of stoss in relation to streamlined forms, however, is proximal—it does not mean or imply steep.* (Consideration of the general usage of "lee" lends etymological support to this.)

It is, as Gravenor states, generally taken for granted that the stoss is the steeper end and generally points towards the up-stream ice-movement direction; he also states (p. 51) "the acceptance of this general observation is critical in deciphering the ice-movement directions in the Yarmouth area". It must be pointed out that this is only a general observation, not an invariable law. Gravenor therefore assumes that, as the steep end of the Yarmouth drumlins in most cases (55%) is to the south, the ice that moulded them was from this direction—a direction opposite to that suggested by the erratics and till-fabric analysis. He therefore has to postulate two separate glacial episodes: one to account for the erratics and fabric, the other to account for the position of the steep end.

In many cases the stoss is the steeper end but this is not invariable. Charlesworth (1924) noted that there was some divergence of opinion on the position of the blunt and higher end of the drumlin and that in general this was towards the stoss end of the mound. Hollingworth (1931) noted that the steeper end was usually the stoss, although in the Carlisle area there was an apparent reversal of "this general