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SIR,

The origin of waves on rock glaciers

Lowenherz and others (1989) have applied to rock glaciers the well-known theory of incipient folding in layered beds subject to transverse compression (e.g. Lliboutry, 1987, p. 325-28). As they suspect, they have missed an important process, because they could not have read my publications on the subject (Lliboutry, 1955, 1956, 1961, 1965, 1986; the latter being the only one in English and the most complete of all).

Observations on rock glaciers of different ages show that their surfaces evolve from a flat surface of unsorted material to a patterned ground, where most clasts are aggregated in parallel furrows and on edge, the bulges between being mostly silt. It is only when a final stage has been reached that all the fine material has been washed out from the surface, and the rock glacier deserves its name. (The names "rubble glacier", or "glaciar de escombros" in Spanish, used by Corte, would be better.) Moreover, in the average, more sloping parts of rock glaciers, longitudinal furrows are often found, and this could be explained by no compression. Transverse, arcuate furrows are found only near the front, where the surface slope is gentle.

Outwash is due to melt water from winter snow, and this occurs in spring, a period when very few observations (as ours) have been made. This is unfortunate, because it is the time when soils are active. In semi-arid zones, where rock glaciers form, it is only in spring that soils are water-saturated. They thaw at the surface every afternoon. Water drains readily into the furrows without silt, and remains in the intestitial silty bumps. Nocturnal freezing swells the silt, and squeezes the clasts into the furrows. Moreover, over the furrows the snow cover is thicker and disappears from these later. Both effects enhance the development of furrows with coarse material only. Note that streamlets flowing from the rock glacier have clean water. The silt is transferred to a deeper horizon where it remains. Total outwash of the fine material should occur only after a climatic change, when summer rains become frequent.

Therefore, a "cryonival" process triggers the formation of waves on rock glaciers. This should also govern their spacing, rather than the vertical viscosity profile in the creeping material. For the time being, the subject deserves further field studies on *young* rock glaciers and *in spring* rather than mathematics!

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21 January 1990

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ERRATUM

Vol. 35, No. 121, p. 314, Fig. 4

The author has drawn attention to an error in the left-hand part of Figure 4. The following is the correct illustration.

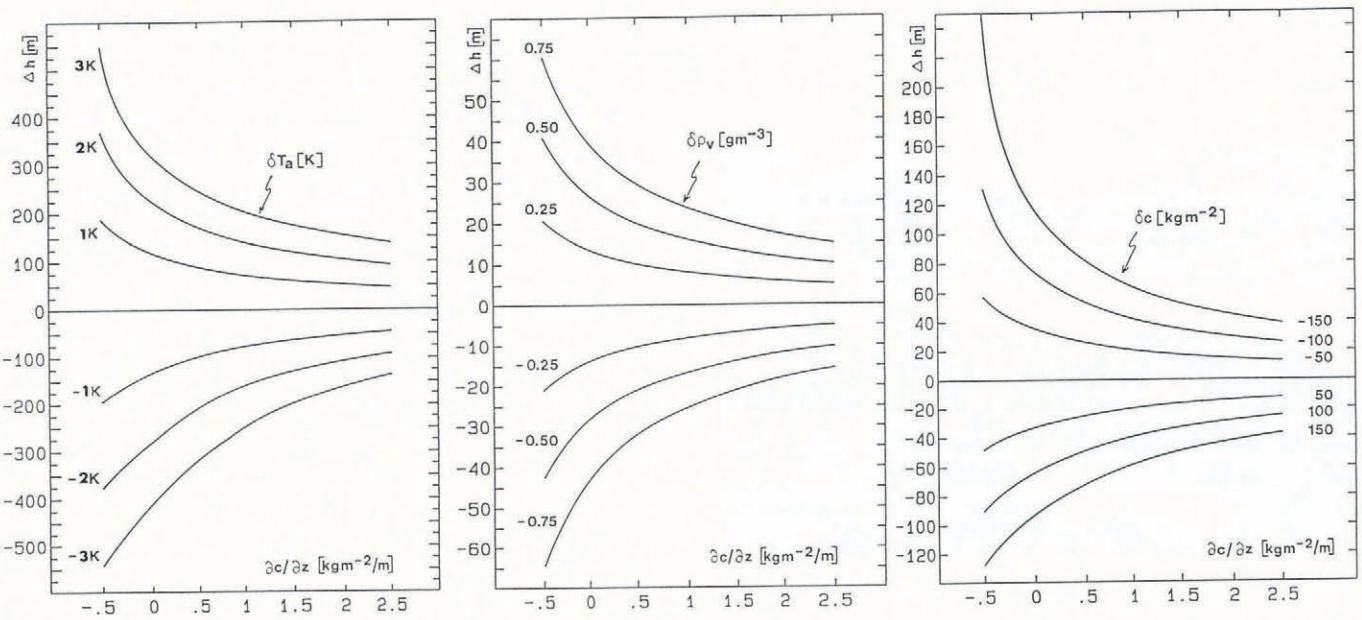

Fig. 4. Altitudinal shift of the equilibrium line versus the gradient of annual accumulation for perturbations of air temperature δT_a (left), absolute humidity $\delta \rho_v$ (center) and annual accumulation δc (right).

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