

INTERDEPENDENCE BETWEEN GLACIER EROSION AND GEOLOGICAL FEATURES

By M. ARENILLAS,

(Cátedra de Geología aplicada, E.T.S. de Ingenieros de Caminos, C. y P. Madrid, Spain)

E. MANTINEZ DE PISON,

(Departamento de Geografía, Universidad Complutense, Madrid, Spain)

and A. SAMARTIN

(Cátedra de Estructuras, E.T.S. de Ingenieros de Caminos, C. y P. Santander, Spain)

ABSTRACT. A strong relationship between the shapes of glacier excavation and some specific structures of the bedrock seems to exist in all the cases observed by the authors. Important examples of this kind include present and Quaternary glaciers in the Iberian Peninsula, the Alps, and the Peruvian Andes. A preliminary mathematical model has been developed, a brief description of which is given in this paper. Within the framework of this model the above interdependence can be interpreted. In this way the excavation mechanism that occurs in stationary glaciers can be explained without requiring the use of more sophisticated theories implying quite complex morphological phenomena. Suggestions for further studies are also made.

CHARACTERISTICS AND ORIGINS OF THE DEBRIS AND ICE, MATANUSKA GLACIER, ALASKA

By D. E. LAWSON

(U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire 03755, U.S.A.)

ABSTRACT. The physical characteristics of the ice and debris of the Matanuska Glacier, Alaska (lat. $61^{\circ} 47'$, long. $147^{\circ} 45'$) and their consistent variation in a vertical stratigraphic column of the glacier indicate multiple origins for both. The two zones of ice recognized in the glacier are the upper englacial zone, which comprises the bulk of the glacier (est. 300 m thick), and the thin (3 to 15 m thick) basal zone, which contains an estimated 97% of the sediment transported in the glacier. The physical characteristics of the ice and the quantity and mode of distribution of debris in it define two ice facies in each zone. The englacial zone consists mainly of the debris-poor (0.002 volume per cent) diffused facies. White coarse-bubbly ice and blue coarse-clear ice (2 to 10 cm diameter) comprise most of this facies. The bubble-rich banded facies (debris bands) contains abundant debris (25 to 50 volume per cent), varies in lateral and vertical extent, and occurs randomly in the diffused facies.

The basal zone consists of the upper dispersed and lower stratified ice facies. The dispersed facies is characterized by a uniform distribution of debris (mean content of 3.8%) and thickness of 0.2 to 2.0 m. The upper contact is planar and marked by the change in debris content; the lower contact with the stratified facies, resulting mainly from the onset of debris stratification, large increase in debris content (mean of 25 volume per cent), and decrease in ice grain size (typically <4 mm diameter), is sharp and irregular. Ice of the stratified facies is clear to black in color and generally free of bubbles. Stratification results from the alternation of debris-laden and debris-poor layers of ice of variable thickness and extent. Subfacies, which represent different distributions of sediment in these layers, include: (1) the solid subfacies of distinct layers of sediment that contain ice as an interstitial component only and may show sedimentary structures; (2) the discontinuous subfacies of ice which contains aggregates, lenses, and particles of sediment aligned sub-parallel to basal-zone stratification and which exhibits debris streaming; and (3) the suspended subfacies of ice which contains particulate suspensions of sediment without preferential orientation.

The debris in each facies is poorly sorted to very poorly sorted and generally polymodal. Fine-grained sands and silts tend to be concentrated in the diffused and stratified facies; coarse-grained sediments occur in the dispersed facies. Gravel clasts are round to sub-round in the stratified facies, very angular to angular in the englacial zone, and mixed but mostly angular in the dispersed facies.

Debris of individual facies and subfacies, excepting the solid subfacies, is size-limited. This limited range of particle sizes and their distribution in a given ice facies or subfacies indicate that the glacier entrains and thus transports sediment in distinct textural sub-populations.

Pebbles are oriented with respect to the local direction of glacier flow in ice of the basal zone. The mean axis, derived from measurement of the trend of the *a*-axis of prolates and direction of dip of the *ab* orientation plane of blades and disks, is parallel to the local direction of ice flow and plunges up-glacier. Individual pebbles, however, lie sub-parallel to debris stratification and are not imbricated in the direction of ice flow. The regional pattern of mean axes orientation is consistent and a deposit found with little disturbance of the debris would inherit an ice-flow-oriented pebble fabric.

The oxygen-isotope values measured in ice of the basal and lower englacial zones show two trends. The $\delta^{18}\text{O}$ values decrease with depth from the upper sample of the diffused facies to the base of the dispersed facies, whereas they increase sharply by more than 4‰ below the top of the stratified facies. The diffused-dispersed facies trend agrees with previous isotope analyses of temperate glaciers and indicates this ice originated in the accumulation area. Characteristics of the debris of the dispersed facies suggest it was mainly incorporated sub-glacially.

Radiocarbon dates of wood (515 ± 75 B.P.; 350 ± 75 B.P.) taken from ice of the stratified facies and the abnormally large $\delta^{18}\text{O}$ values of that ice are evidence of a different origin unrelated to the source and formation of ice of the diffused and dispersed facies. The stratified facies originated predominantly by subglacial freezing of isotopically-enriched melt waters, possibly surface-derived, to the glacier sole. The bubble-poor fine-grained ice, thickness, characteristics of individual strata, diverse texture of the debris, stratification, rounded pebbles, and presence of undisturbed sedimentary structures in the debris of this facies support this conclusion. The location and extent of the area of freeze-on and the rates of ice formation and sediment entrainment beneath the glacier are probably variable. These variations are suggested by local differences in the thickness of this facies, the lack of continuity, variation in thickness and extent of individual strata, and the disparity in the radiocarbon ages of wood taken from about the same height in this ice.