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Robert Duncan Enzmann
Boston University

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Morphology of Frost Polygons As Related To Ground Slope in Eastern Greenland

ROBERT DUNCAN ENZMANN[1]

Abstract. This paper describes polygonal frost-patterned ground on level terraces, modification of the polygons by solifluction to garlands on slopes of 5° to 35°, modification of the garlands to rock stripes on slopes of 20° to 45°, collapse of stripes into jumbled rock glaciers on slopes of 35° to 60°, or more commonly, modification of stone stripes back through the sequence of stripes and garlands where the slope shallows toward the valley floor. The subsurface structures of eight polygons, two garlands, and two stone stripes were exposed by trenching. The garlands and stone stripes were on a slope lying between a flat-lying raised beach and a very slightly inclined valley floor. The trenching proved the rock-rimmed areas to be three dimensional with limited depth. Within each ring there was a vertical as well as horizontal sorting of soil, sand, and rock fragments, with the finest fractions toward the center.

LOCATION

Patterned ground was observed between the inland mining camp at Mestersvig and the Danish Airfield on the northern coast of Scoresby-Jameson Land on Kung Oskars Fjord. This is the fjord, lying immediately to the north of Scoresbysund, which has been scoured over 1,400 m. below present sea level and is said to be the deepest fjord in the world. The Mestersvig region lies about 60 km. west of the Norwegian Sea and 100 km. east of the Greenland meer de glace or icecap. The area is bounded by 70° to 73° N. Lat. and 22° to 25° E. Long.

CLIMATE

The climate is arctic. Winters are dry; summers are very dry, relatively windless, and warm because of the sheltering effects of the Skeldal Alps. The climate of late winter and spring is very pleasant, leading some to designate east central Greenland as the paradise of the Arctic. The prevailing winds are from the anticyclone in the center of Greenland. The great thaw commences in May and lasts through June. During the last three to five weeks it is impossible for aircraft to operate from the earthen landing strips of Mestersvig, and no ships can move through the southward moving pack ice. The freeze in eastern Greenland takes place in late August or September following snowstorms. If the freeze precedes the snow, many muskoxen die of starvation during the fol-

[1]Department of Geology and Mineralogy, Boston University, Boston, Massachusetts.

lowing months. It is thought that the formerly plentiful caribou of the region may have perished in one season which commenced with heavy sleet and rain followed by a sudden freeze and heavy snows.

Relief and Drainage

Relief is marked with U-shaped valley walls and matterhorns rising to 2,000 m. above valley floors in a youthful topography. The ice-free region has been uplifted at least three times since the last glacial optimum, as attested by marine terraces which are found as much as 120 m. above sea level. The patterned ground discussed herein is associated with a 50 m. terrace.

Geology

The basement is a geosynclinal complex crystallized during the Caledonian revolution under physical conditions of the granulite facies. It is comprised of white-gneisses, granulites, schists, gray-gneisses, and late metavolcanics. Nepheline syneites are associated with the stratigraphically highest members; pegmatites are rare; agmatitic phenomena are common. One orbicular-textured body was discovered near the south filank of the Schuchert Valley Glacier, and orbicular erratics were noted at the snout of this glacier and in other glaciated valleys. Late unmetamorphosed members of the system are more abundant away from the axis of the syncline on the coast of the Norwegian Sea. Late Devonian and Carboniferous sediments lie horizontally above the crystalline series. These are largely red sandstones, grits, shales, and occasionally marls and limestones. Lead-zinc-barite mineralization is widely associated with the limestones. During the Tertiary plateau basalts were poured over the entire region through fissures.

Snow and Permafrost

Snow on flat-lying terrain reaches depths of 5 m. to 10 m. During the winter all of the gorges, some over 100 m. deep, are drifted full of snow; all mountains are blanketed to their tops with snow which persists from fall until the spring thaw. Soil movement and the downthaw of the permafrost commence with the disappearance of the snow cover, wane in midsummer, and cease in the fall. Permafrost is known to depths of about 70 m. in the Mestersvig lead mine.

Composition of Patterned Ground

Compositions vary from pure sand and rock with a high feldspar content to material black with included organic matter. The crystalline granitic fragments are generally rounded. The sandstone fragments are flaggy due to frost splitting.

Location of Patterned Ground Types With Respect to Slope

Stone nets composed of rings, polygons, and irregular shapes are found well-developed on the flat-surfaced 50 m. marine terrace. One hundred measured "diameters" of the polygons averaged between 1 m. and 3 m. Rocks with maximum dimensions of 15 cm. seem to have been moved to the boundaries of the polygons; larger fragments are less easily moved. Within the stone rings there is a lateral gradation from central fine-grained sands to outer coarser materials. Often vegetation is absent within the stone rings, presumably because of the violence of frost stirring.

Stone nets composed of garlands (stone rings and polygons elongated downslope by solifluction) develop on slopes of 5° to 35°. The twenty measured averaged 1 m. to 1.5 m. across slope and 2 m. to 3 m. downslope. Vegetation is rare in garlands; the centers often include areas of fine rock flour.

Stone stripes averaging 20 cm. to 50 cm. in width, 15 cm. to 30 cm. in height, and 3 m. to 20 m. in length downslope, develop on slopes of 20° to 45°. On slopes exceeding 35° stripes tend to form rock glaciers. On gentler slopes soil is common between rock stripes, in which case depressions appear on both sides of a stripe with the stone in the stripe and intermixed soil rising above the depressions. Occasionally small pockets of fine soil are found on stripes, indicating that forces act to concentrate fine as well as coarse materials. The stripes are completely free of vegetation, even lichens.

Occasionally boulders of up to 2 m. surface diameter appear on the terrace and slopes. These apparently have their lower reaches anchored in permafrost, and their upper parts protrude through the zone of active soil movement. Such boulders take no active part in ring formation but do play a passive role by stopping their growth in one direction or by deflecting the downslope migration of garlands on gentle inclines and of stripes on steeper inclines. Where slopes revert to gentler inclinations the stripes merge again into garlands and the garlands into stone rings on the valley floor (Troll, 1958).

Origin of Dimensional Features in the Polygonal Frost-Patterned Ground

Vertical migration and frost heaving. Frost heaving of boulders, cobbles, and pebbles from soils is common in middle and high latitudes. Ice needles form most readily below stones, fed from below by capillarity. They press the mass upward, and then when melting occurs some soil settles behind the stone and the net movement is upward. The larger a rock, to approximately the 15 cm. limit, the faster its relative movement upward through the soil. The writer believes that all vertical sorting within the polygons is due to simple frost heaving. Upward heaving is most marked in the fall and practically nonexistent in the spring.

Vertical sorting. The uppermost soil within the stone rings is exhausted of all stones, pebbles, and coarse sand grains. This is a homogeneous layer of roughly cylindrical shape and is called the *zone of exhaustion*. Below it lies a *zone of vertical sorting* in which larger fragments are more abundant than in the deeper layers. The *subsurface stone boundary* penetrates approximately half way into the zone of vertical sorting. This is also a layer of cylindrical shape. There was no evidence in the trenched polygons of sorting from the center line toward the subsurface stone boundaries in the layer of vertical sorting. The zone of vertical sorting grades downward into a relatively thin *unsorted layer,* which in turn lies directly on the impermeable base of permafrost (Figure 1).

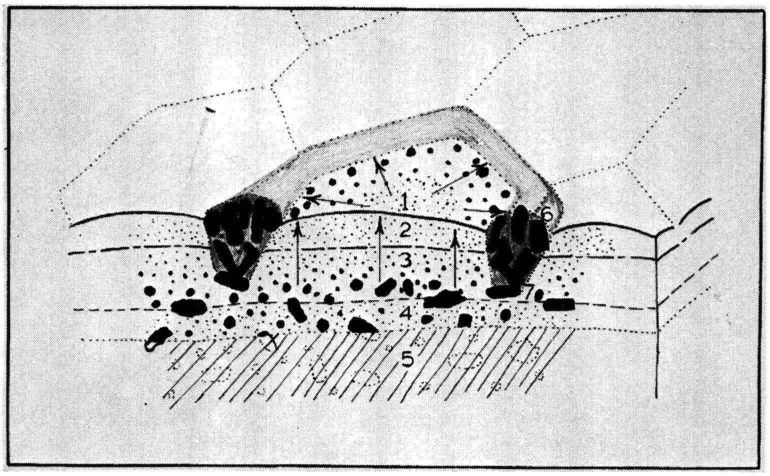

Figure 1. Typical and idealized frost polygon showing: (1) lateral migration and surface sorting, (2) zone of exhaustion, (3) zone of vertical sorting, (4) unsorted zone, (5) impermeable permafrost base (unsorted), (6) stone ring, and (7) subsurface stone boundary.

Radial migration, radial sorting, and hexagonal structure. Large fragments are most abundant in the stone boundaries. Within the boundaries and on the surface of the polygons there is ideally a gradation from fine matter in the centers through coarser and coarser matter toward the stone boundaries. In most rings observed this ideal pattern was interrupted by large fragments recently heaved out on the surface, and by minor stone rings within the

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larger ring. The writer believes that all movement of large fragments is a surface, or very near surface, phenomenon in which fine material is moved toward the center of the rings and coarse material toward the rims. The moving force is the forming and melting of ice needles (Figure 1).

In a single area stone rings, or the open parts of the net, have an average size. In an area where polygons have just started to form, rings below the average diameter seem to be cannibalized and early-formed rings of extra large size are often seen to be crusted on one or several sides by rings of average size. The writer thinks that under ideal conditions the members of a stone net would have hexagonal outlines; however, he has yet to find one perfect hexagon.

Structure of the boundaries or stone rims. The coarsest members are found in the rim. Often there is no fine material whatsoever in the rims, indicating that it was somehow removed. At the surface, flat fragments have a vertical position. The farther below the surface flat members are found, the more they approach a horizontal position. The writer thinks this is because the rim itself is being heaved upward (Figure 1).

Conclusion

The necessary conditions for the formation of stone rings are: (1) an aggregate containing various sized materials, (2) a water saturated zone, (3) a cycle of crystallization and resolution so that larger fragments are differentially moved, and (4) an impermeable base of permafrost or stone which keeps the soil above it water saturated, or an extraordinarily active capillary action which keeps the soil above water saturated. The shape of stone rings is modified by gravity, anchored members, and changes in level of the impermeable base.

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Literature Cited

Troll, Carl. 1958. Structure soils, solifluction, and frost climates of the Earth (Strukturböden, solifluktion, und frostklimate der Erde). Translation by U. S. Army Snow, Ice, and Permafrost Research Establishment, Wilmette, Illinois.

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