UNUSUAL PATTERNED GROUND ON DECEPTION ISLAND, SOUTH SHETLAND ISLANDS

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ABSTRACT. The location and site of an unusual example of patterned ground on Deception Island, South Shetland Islands, are described. Hypotheses accounting for the sorting of volcanic ash into concentric bands of contrasting grain-size are discussed. It is suggested that two explanations are necessary: one for the origin of the pattern and another for the preservation of the sorting under present conditions of rill wash and wind erosion. Tentative explanations are made, using arguments based on detailed observations of patterned ground in the South Orkney Islands. Data from recent laboratory experiments in the United States, dealing with the effects of ice in soils under varying conditions, are referred to. There is still some uncertainty as to the precise mechanisms involved in the formation and preservation of this patterned ground.

DURING an excursion on Deception Island in January 1964 an extraordinary type of sorted stone circle (Washburn, 1956) was discovered on the crest of a ridge about 0·5 miles (0·8 km.) south-east of the British Antarctic Survey hut. The ridge is composed of loose volcanic ash of morainic or fluvio-glacial origin capped by a layer of brownish silty material 1–2 m. deep. From the quantity of feathers and organic material contained in this layer it appears to have been frequented by penguins at some time. At the narrowest part of the ridge the superficial deposit has been eroded, exposing the ash, and a miniature col has been formed. At this point the ridge crest lies about 50 m. above sea-level and is only 8 m. across. Within the col there is a roughly oval formation comprising a series of concentric bands of sorted ash, alternately fine and coarse. There are 8 double bands, their breadth varying between 15 and 60 cm., and each band has a fine and a coarse section, making the whole feature from 5 to 7 m. across. The pattern centres upon an ovate mass of fine ash about 1·5 m. in diameter, elongated parallel to the axis of the ridge. Sectioning revealed that the individual bands dip steeply in towards the centre, the angle of dip decreasing with depth. The ash was found to be frozen at a depth of 40 cm., so the structure beneath this can be inferred only from a projection of the upper parts of the bands. Thus the form of the pattern appears to be a series of concentric oval basins of sorted ash separated from each other by a texture contrast so distinct that a knife could be inserted between the fine and coarse bands (Fig. 1). It is apparent from the photographs (Figs. 2 and 3) that some of the bands are discontinuous and also that the gradation of the bands from the centre is from coarse to fine, before the next sharp change to coarse.

Conclusions based on a study of patterned ground on Signy Island,* South Orkney Islands,

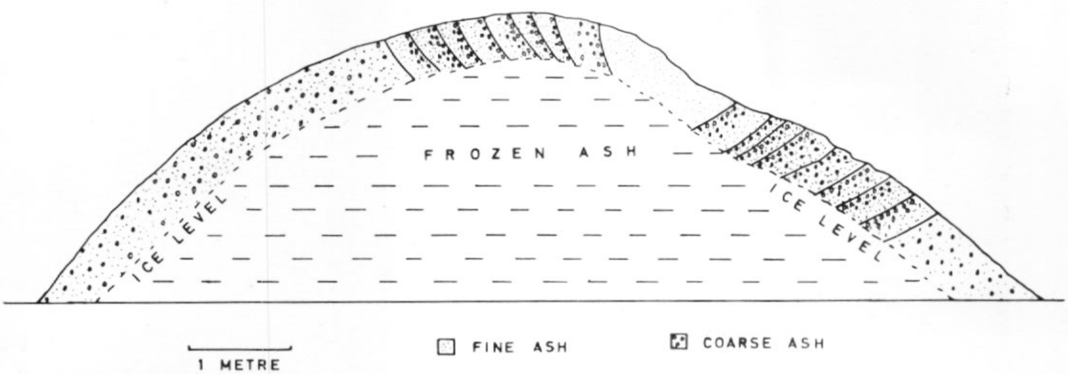

Fig. 1. Diagrammatic cross-section of ridge crest showing pattern. The vertical scale is slightly exaggerated.

* A report on this work, including a quantitative study of frost heave, sorting and solifluction, and a detailed temperature analysis of the active layer, is in preparation.

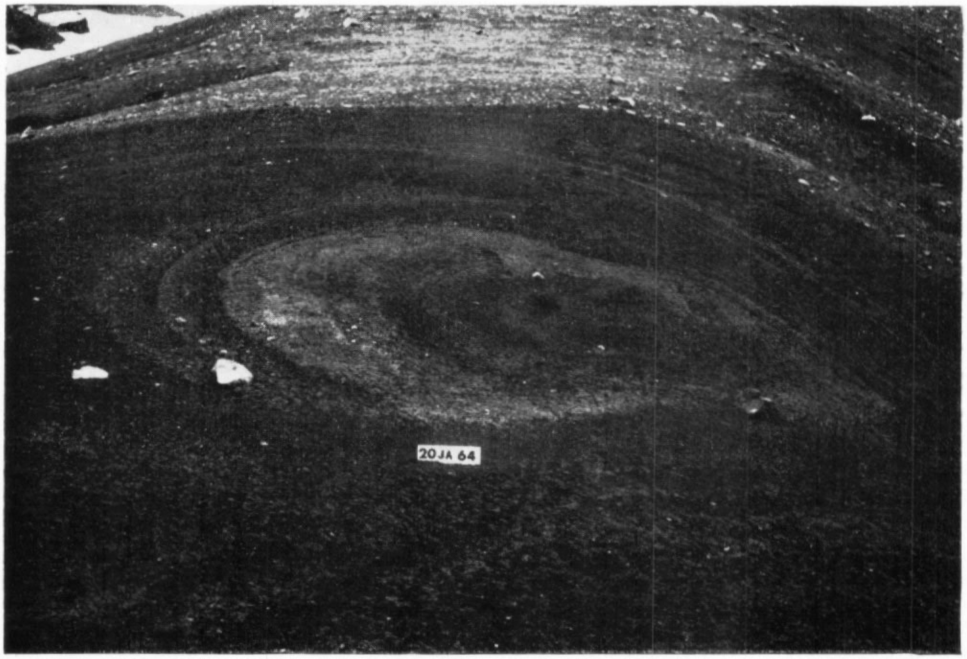

Fig. 2. A general view of the pattern along the ridge. The apparent deformation to the right is an illusion due to the slope angle. The date marker is 20 cm. long. 20 January 1964.

Fig. 3. Detail of the centre bands of the pattern. The date marker is 20 cm. long. 20 January 1964.

suggest that this site is exceptional for any form of sorted circle. The unconsolidated nature of the ash and its upstanding position promote excellent drainage above the permafrost level, a situation which would normally be expected to inhibit patterning processes. From a previous analysis of many sites, an almost level surface with poor drainage or an adjacent water course appears to be essential to the initiation of such features. There seem to be three possible ways of explaining such a phenomenon:

i. A completely different formation process.
ii. A radical change of drainage within the ash since the formation of the pattern.
iii. Some basic difference between this ash and the broken-down quartz-mica-schist material of Signy Island, on which the earlier conclusions were based.

The volcanic nature of Deception Island, giving rise to current thermal activity in this area, necessitates the consideration of a similar process for the origin of the pattern. This may be disregarded immediately, however, as the volcanic ash of the ridge has been re-worked and observations of surface temperatures throughout the sorted bands show a uniform gradient from +1° C at the surface to 0° C at ice level. There is clearly no present thermal influence and no extinct process could account for such marked sorting in an unconsolidated ash undergoing present-day rill wash and wind erosion. A more likely solution is that a periglacial process, similar to that observed on Signy Island, has brought about the anomaly by its action upon a different material. The chemical, physical and mechanical properties of the ash vary widely from those of the mineral soil derived from quartz-mica-schist.

Some re-organization of the drainage may also have occurred, for the ridge was probably once bounded on one or both sides by ice. If exposed to a periglacial climate under such conditions, when the drainage would be impeded by ice and the surface waterlogged in summer, conditions favouring the formation of the patterning would obtain. Once sorting was completed, the freeze–thaw cycles of the present climate could perpetuate the feature, in spite of the removal of the ice and consequent drainage of the seasonally thawed surface of the ridge. This "semi-fossil" explanation would also account for the excessive angle of slope (12°) measured across the pattern. In normal circumstances a sorted stripe, not a circle, would have been formed on such a slope, but if it is assumed that the surface was approximately level at the time of formation, i.e. when bounded by ice, and the ridge has since suffered partial erosion, then the problem does not arise. Support for this theory comes from the pattern itself, where sectioning revealed that the bands of ash dip less steeply at depth. Thus the wider bands found at the surface of the lower and steeper side of the pattern owe their breadth to a shallower dip angle, with the inference that these originally occurred beneath the surface of the formation (Fig. 1).

Although the above account postulates the general conditions under which this pattern was formed, it in no way explains the uniqueness of the repeated concentric sorting. So far as the author is aware no comparable features have been reported elsewhere and, whilst there are theories to account for the sorting of soil and rock debris under periglacial conditions (Corte, 1963), there is no suggestion of a process which might result in a pattern of this nature. Corte has shown experimentally that, with a high soil-water content, small particles may be carried immediately ahead of an advancing freezing plane. He has also found that the lower the specific gravity of a particle the more liable it is to movement. Thus the low specific gravity of the ash, 2·35, would render it more susceptible to such movement than the more common soil composed of quartz-mica particles with a mean specific gravity of 2·8, causing a more efficient sorting of the lighter material.

In a soil overlying permafrost, the onset of winter brings the descent of a freezing plane from the surface. At the same time, with the incoming heat source cut off, the permafrost freezing plane has a tendency to advance upward. Applying Corte's results here, if sufficient ground water is present a concentration of fines may ultimately be expected where the two freezing planes meet, and such a concentration has in fact been reported elsewhere (Corte, 1962*b*). It is exactly at this point where the so-called cryostatic pressure (brought about by ice segregation and expansion in the two approaching freezing planes) is set up, and it is compressed unfrozen material from between these planes which may be forced through weaknesses in the overlying frozen layer to extrude on to the surface (Washburn, 1956,

p. 842 *et seq.*). Formations in which this process appears to be in operation have been sectioned throughout their entire vertical extent on Signy Island. It is therefore possible that successive accumulations of extruded ash, each subjected to further sorting by repeated freeze–thaw action on the surface before being covered by the next outflow, could account for this feature. During his experiments, Corte (1961) induced the movement of glass marbles up to the surface of saturated sand by alternate freezing and thawing. This process would explain the gradation from coarse to fine across the individual bands, after they had lain horizontally across the surface. As a result of the annual thaw, subsidence would occur where the greatest concentration of ice and extrusion of fines had taken place, i.e. in the centre of the pattern, thus causing the basin-like feature.

In order to establish the degree and nature of the sorting, samples were taken from the pattern and subjected to detailed mechanical analysis. A further sample was taken from outside the pattern for comparative purposes. The distribution of grain-size was determined using sieves and a soil hydrometer, and the results are shown in Fig. 4.

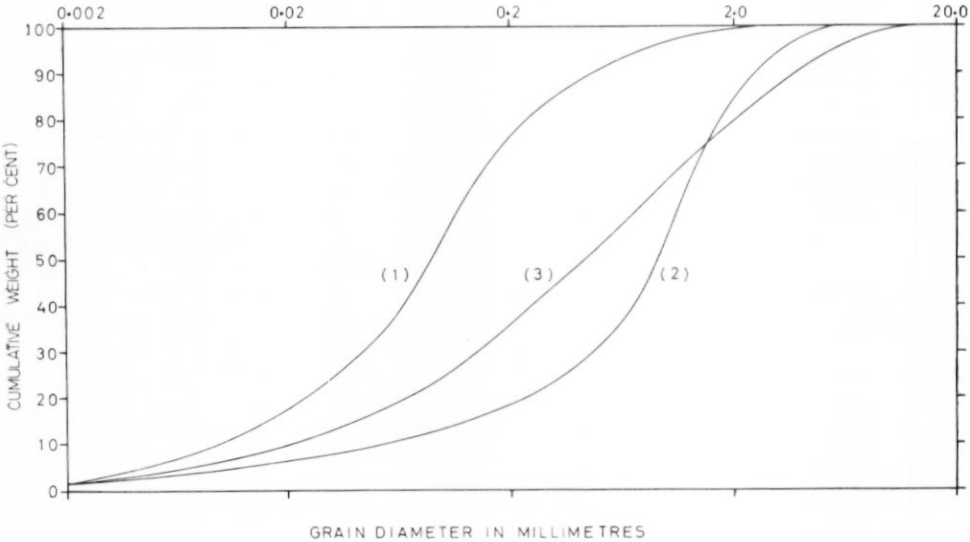

Fig. 4. Comparative grain-sizes of three samples:

1. From centre fines.
2. From coarse band surrounding central fines.
3. From outside pattern.

The difference between the central mass of fines (curve 1) and the coarse band surrounding it (curve 2) is clearly illustrated, with a great preponderance of material finer than 0·5 mm. diameter in the first sample. These two curves are typical of the sample series, showing a pronounced division between fine and coarse across the bands. Samples taken from the frost level revealed similarly distinct sorting, whilst in bands towards the periphery of the pattern the difference was still apparent though not so marked. The sorted bands did not merge gradually with the surrounding unsorted ash but remained quite distinct until the final ring. The sample taken from outside the formation (curve 3) contains a coarser element than the others, but apart from this, the distribution curve lies approximately half-way between them, indicating that it has not been subjected to the sorting experienced by the others. This raises the problem that only a few metres from the most extreme sorting, in an apparently identical environment, no sorting has taken place. This indicates that the cause of the sorting is not due solely to the climatic conditions nor to the nature of the medium, and that some more variable and localized factor has had an over-riding influence. The suggested extrusion through a surface weakness, possibly accentuated by internal thawing and collapse along the crest of the ridge, would certainly account for this influence and also explain why the surrounding surface material contains a coarser element but does not display any sorting.

Once it had been established, the grain-size contrast within the bands would mean that any subsequent frost heave was uneven, and concentrated within the finer fraction. According to Casagrande's (1934) statement, a minimum of 3 per cent of particles smaller than 0·02 mm. is necessary before significant frost heave can take place. This means that even the coarse fraction, with 6 per cent in this class, is liable to some heaving, but owing to the smaller pore space of the fines and to their higher water content (20 per cent by weight, as opposed to 16 per cent in the coarse), ice segregation and consequent heave would occur in the fines to a much greater extent (Taber, 1930; Kretchmer, 1961). Whilst thawing, semi-liquid surface fines have a tendency to flow down the gradient which they themselves have created by upward heaving. It would be expected, therefore, that the fines within this pattern should have flowed out over the coarse part of the bands, with the movement further influenced by the slope angle across the pattern. Although this has happened to a slight extent, the individual bands have maintained their identity to a surprising degree. It would appear then, that there is another process at work counteracting this re-mixing tendency and also counteracting the disturbance of current erosion. A process which maintains sorting in a vertical plane must therefore be sought. Possible differential freezing rates within the fine and coarse parts of the bands might cause some warping of the freezing plane and thus bring about this horizontal segregation (Corte, 1962*a*).

For many years confusion and divided opinion have centred around the origin and mechanics of the numerous forms of patterned ground, the controversy having been brought about to a large extent by the polygenetic nature of these features. So many factors are involved and the balance between them is so precarious that minute environmental variations appear to cause disproportionate changes in the resulting forms. The pattern discussed here well illustrates this fact, and until more is understood about such complicated processes their precise mode of origin remains enigmatic and only suggestions may be put forward to account for their presence.

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