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ADDITIONAL NOTES ON PATTERNED GROUND IN ICELAND WITH A PARTICULAR REFERENCE TO ICE-WEDGE POLYGONS

Abstract

The main types of polygons in Iceland are breifly described and their distribution outlined. Ice-wedge polygons (tundra polygons) were recently discovered in the interior of the country. They occur both in subsoil (glacial and fluvial sediments) and in the loessial humus soil cover. The lower limit of the loessial soil polygons is about 300 m lower than the limit of those formed in the subsoil. At least for some types of ice-wedge polygons the climatic conditions necessary for their formation are probably not quite as severe as hitherto assumed.

INTRODUCTION

In a compilatory report on patterned ground in Iceland (Thorarinsson 1951), written at the request of H. W:son Ahlmann, then president of the Commission for the Study of Periglacial Action, it was stated that a lot had been written about periglacial phenomena in Iceland but no student had so far devoted to them the systematic and thorough study which was needed. This statement still holds true.

During the 12 years that have passed since that paper (Thorarinsson 1951) was written some scientists from abroad have visited Iceland and studied periglacial phenomena, but no one has stayed there long enough for a comprehensive survey of these phenomena or for a deep penetration into the problems involved. The main contributions have come from French geomorphologists. P. Bout visited Iceland in 1950 and 1953 and wrote a book on the geomorphology of the country (Bout 1953) dealing partly with periglacial phenomena (op. cit. pp. 53—82). A French expedition spent two months of the summer of 1954 in the highland NE of Hofsjökull, studying *inter alia* the patterned ground of this area (Bout, Corbel, Derruau, Garavel et Péguy 1955). A German specialist on cryopedology, E. Schenk, visited Iceland twice in 1959. He was especially interested in the „thufur" problem but to the writer's knowledge he has not yet published the results of his studies. Some members of the

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numerous „expeditions" of British university students to Iceland have paid attention to periglacial phenomena without adding much new to our knowledge. At the moment a student of Carl Troll in Bonn, Do Jong Kim from Seoul, is working on a general survey of the patterned ground in Iceland, but his studies are far from completed. The present writer's studies of periglacial phenomena during these 12 years have been very sporadic but during travels through the country for other purposes he has now and then been able to make some observations on which the short paper here presented is essentially based.

INFLUENCE OF ELEVATION AND BEDROCK STRUCTURE

In the above mentioned compilatory paper the writer arrived at the following main classification of Iceland's patterned ground on bare soil:

„Low level coastal areas and valley bottoms:

All polygons shallow („floating"), with gravel margins, usual diameters 20—80 cm. Well sorted throughout. Gradually merging into

Inland plateaux at 400—800 m levels:

Polygons usually relatively shallow and sorted, with gravel margins. Usual diameters 60—200 cm, tending to increase with altitude.

The basalt plateaux at about 600—1 000 m levels:

Polygons usually deep („anchored") and sorted, with block margins. Usual diameters 2—10 m." (Thorarinsson 1951, p. 147).

Since this paper was compiled the writer has traveled a lot through the plateau basalt areas of Iceland and found anchored polygons with block margins even on low level coastal plains and valley bottoms (Thorarinsson 1953). In some places, such as near Teigarhorn in Berufjördur on the E coast small floating polygons with gravel rings were found within the large anchored ones (fig. 1). A sorting of the material within anchored polygons is also found at higher levels (pl. 1). The writer's impression is that anchored polygons on low levels are not formed nowadays and thus are „fossil", but as to their age he has no well founded opinion, although it seems to him most likely that they date back to the time of ice recession from these areas.

The explanation of the fact that anchored polygons on low levels are mainly limited to the plateau basalt areas and that even at higher levels anchored polygons are much more common within these areas than within those of the Palagonite Formation, must mainly be sought for in the different structure of the bedrock. The writer also wants to stress the fact that although the above quoted classification is on the whole approximately correct the size of the polygons varies within great limits both in the low and the high level areas. Thus a field of floating polygons with an average diameter of 80 cm and gravel margins occurs at nearly 900 m height in the Kerlingafjöll area, and miniature polygons (diam. 10—15 cm) are found at all altitudes. But small floating polygons (pl. 2) are no doubt by far the most common ones on the lowland areas, especially where the bedrock is mainly palagonite breccia such as in the environments of the capital Reykjavík, where one finds all stages between small fissures forming a polygonal pattern and polygons with gravel accumulation in the marginal fissures. The small

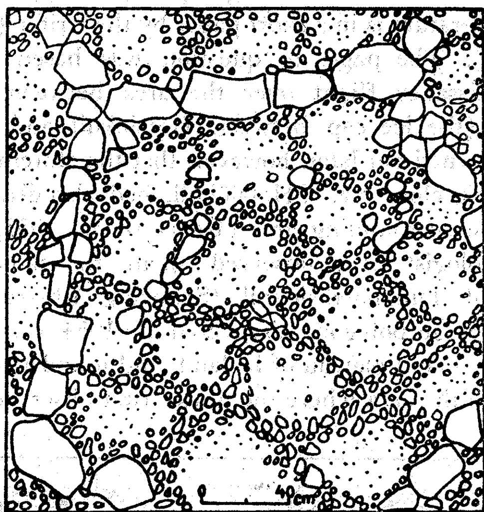

Fig. 1. Small floating polygons within big anchored ones near Teigarhorn in Berufjördur Altitude 35 m. Drawn from the author's photograph, taken Aug. 6, 1953

floating polygons are very often found on patches where the wind has eroded away the loessial soil cover leaving only a thin bottom layer of loessial soil. A mixture of that soil and the underlying coarse material of till or terrace gravel facilitates the formation of patterned ground as the loessial soil is very susceptible both to frost action and contraction by drying. Well sorted floating polygons may be found in patches which have been deprived of their thick loessial soil cover only twenty years or so ago.

A member of the French 1954-expedition has suggested that the relatively high frequency of polygons in SW Iceland has something to do with great seismic activity within that area. The writer found nothing to support that suggestion.

Nonsorted polygons are on the whole rare in Iceland except those which represent the embryonal stage of sorted ones. Pl. 4 shows nonsorted polygons, perhaps more correctly characterized as circles, in the area N of Tungnafellsjökull, at an altitude of about 800 m. The writer found nonsorted polygons with an average diameter of about 1.5 m, in a sandy till on Kringilsárrani, 700 m above sea level, within an area from which the ice has receded since 1890.

ICE-WEDGE POLYGONS

The first reference to ice-wedge polygons („tundra polygons") in Iceland in the literature is in a short paper by the writer (Thorarinsson 1954, pp. 38—39). The paper in question was based on observations during a reconnaissance flight over the area between Hofsjökull and Tungnafellsjökull (the ice cap between Hofsjökull and Vatnajökull) in August 1954. It turned out later, however, that the aforementioned French expedition, camping close NE of Hofsjökull, had also discovered this type of polygons in the surrounding area (Bout *et al.* 1955, pp. 492—493). An Icelandic geologist also observed them the same summer west and north-west of Tungnafellsjökull (Scheving Thorsteinsson 1956, p. 37). The ice-wedge polygons discovered in 1954 were all within the highest part of the inland plateau of Iceland, and found at altitudes between 700 and 800 m. In the area where the writer first observed them, at Hrey-

Fig. 2. Net of ice-wedges on Sprengisandur, Central Iceland

Altitude 750 m. Drawn from author's photograph, taken Aug. 26, 1954 siskvísl nearly midway between Hofsjökull and Tungnafellsjökull they were mainly tetragonal. The polygons studied by the French expedition NE of Hofsjökull were mainly hexagonal and such are they also in the neighbourhood of Tungnafellsjökull. They are especially well developed on some flat gravel covered areas near the mouth of Nýidalur, where they form hexagons somewhat elongated with an average diameter of 10—15 m. In this area the cover of humus soil is very thin or quite absent and the polygons stand out very clearly as the troughs separating them are covered by yellow moss (pl. 5). The width of the troughs is 20—40 cm and a section dug through such a trough by members of an excursion of Swedish geologists guided by the writer through this area in August 1962, revealed that the filling in the trough was sorted coarse gravel, but the narrowing crack beneath was filled mainly with sand (fine- to medium).

The ice-wedge polygons in the area between Hofsjökull and Vatnajökull are formed in a subsoil of mainly fluvial and glacifluvial origin and consisting dominantly of sand, fine gravel and coarse gravel. Occasionally they also occur in till. These subsoil polygons seem to be confined to areas more than 650 m above sea level and therefore their geographical distribution is restricted to the highest parts of the inland plateau (fig. 5). The southernmost place where I have found these subsoil polygons well-developed is on the flat summit area of the mountain Fóstrufell close NE of the Iceland Glaciological Society hut at Jökulheimar. These polygons are at an elevation of about 200 m. Their average diameter is about 15 m. The subsoil in which these polygons are formed is fluvioglacial. The fines are medium to coarse sand with scattered pebbles and irregular layers of gravel. On top is a thin cover of well sorted coarse gravel (pl. 6) underlain by nearly pure sand.

The separating troughs are 30—40 cm wide at the surface and their filling is sorted coarse gravel down to about 30 cm depth. The fissure can be traced downwards about 80 cm (fig. 3).

Besides in the subsoil ice-wedge polygons also occur in the thick cover of loessial humus soil which is a very common type of soil in Iceland, especially within the neovolcanic areas. The areas covered by loessial soil are mainly below the 500 m level, as the soil cover at higher altitudes, where formerly existing, has to a great extent been removed by wind erosion. In typical loessial soil the writer has found ice-wedge polygons down to about 400 m level in the southern part of the country. In a somewhat more coarse grained eolian soil of the type found in the vicinity of the most active tephra producing volcanoes such polygons were found at a still lower level, down to about 300 m above sea level. They are very well--developed on the grass covered area still remaining on the southernmost part of Búdarháls, along the river Tungnaá. Their average diameter is there about 20 m.

In northern Iceland ice-wedge polygons in loessial soil have been found down to about 320 m altitude, southwest of the waterfall Réttarfoss in the river Jökulsá á Fjöllum and also north of lake Mývatn. The polygons at Réttarfoss have an average diameter of about 15 m. They were discovered on aerial photos by an Icelandic geodesist, S. Pálsson, who drew the writer's attention to them. In this connection it may be mentioned

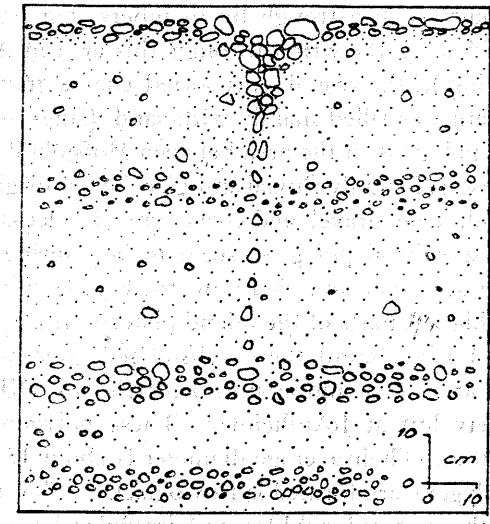

Fig. 3. Section through an ice-wedge (see pl. 6)

that nets of ice-wedges have recently been found in Sweden in studies by aerial photos (Rapp *et al.* 1962, p. 188; cf. also Lundqvist 1962, pp. 31—33). No doubt further field surveys and a detailed study of aerial photos will lead to the discovery of frost fissure polygons in many places not shown on the map (fig. 5).

Fig. 4 shows a part of a net of ice-wedge polygons close southwest of the Iceland Tourist Association hut in Hvítárnes, southeast of Langjökull, at an altitude of 420 m. It also shows a section through a separating fissure going down to the underlying till (cf. also pl. 7). When dug on August 4 there was still an ice layer, 10 cm thick, at 90 cm depth. Many of the tephra (ash) layers in the section are easily identified in spite of great disturbance due to cryoturbation. The many tephra layers that have up to now been identified and dated in Icelandic soils may prove very useful for detailed cryopedological studies and especially for the climatic-historic aspects of the problems involved. To mention an example, we find that in the lowland areas of Iceland the extensive tephra layers H_3 and H_4, both from Hekla, deposited during the Postglacial warm period, and covering about 2/3 of the country, are very little disturbed by cryoturbation, whereas layers from the Subatlantic Time are much disturbed.

The polygons in Hvítárnes (cf. pl. 7) are Type A and Type B polygons according to the classification of Drew and Tedrow (1962), and so are all the loessial soil polygons observed by the writer in Iceland.

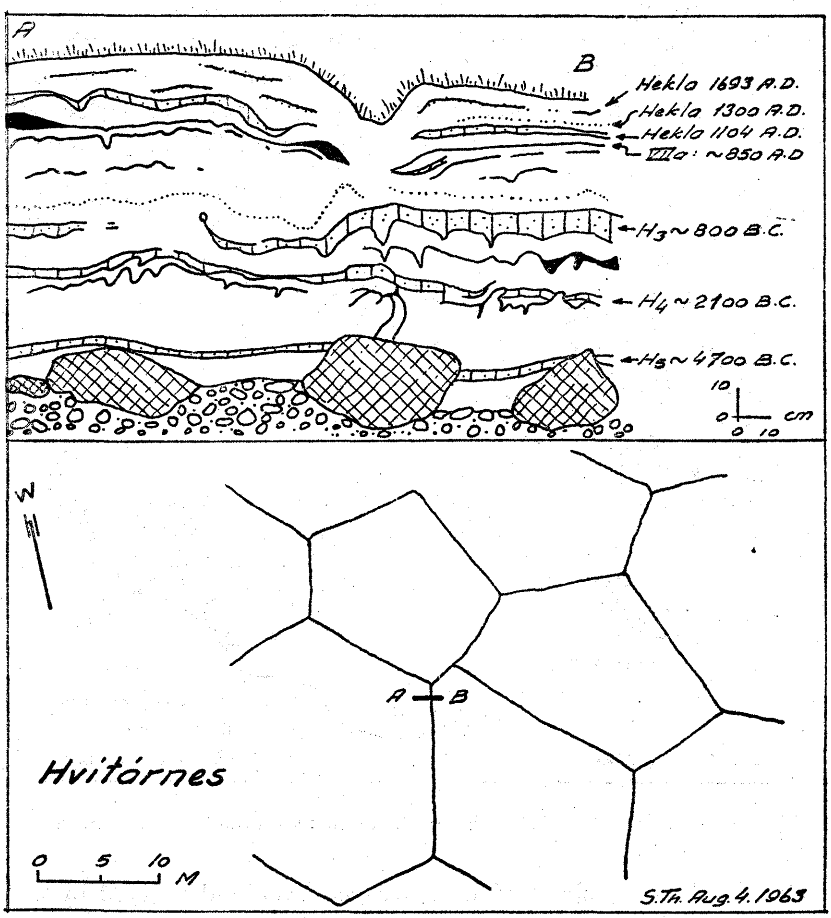

Fig. 4. Net of ice-wedge polygons in Hvítárnes, Central Iceland, and section through a bordering fissure (see pl. 7)

As to the age of the ice-wedge polygons in Iceland it seems unlikely that the subsoil polygons could have formed under the climatic conditions prevailing during the last few decades. Where the ground is bare of humus soil and continuous vegetation carpet, the frost is now thawed out nearly every summer up to at least 800 m altitude. It is also unlikely that they formed during the Postglacial Warm Period, and as the inland ice in all probability did not recede from the area between Hofsjökull and Vatnajökull until the Postglacial Warm Period had begun, it seems most likely that the subsoil ice-wedge polygons were formed during cold periods of the Subatlantic Time, and mainly during the „Little Ice Age'', ca. 1500—1900 A.D., during which periods the bare ground above the 650 m level may have been more or less permanently frozen.

If the polygons were formed mainly during the time of the inland ice recession one would expect to find them also at lower levels, where the ice recession dates farther back in time, but real fossil ice wedges at low levels are hitherto only found in one place, east of Ellidaár in Reykjavík,

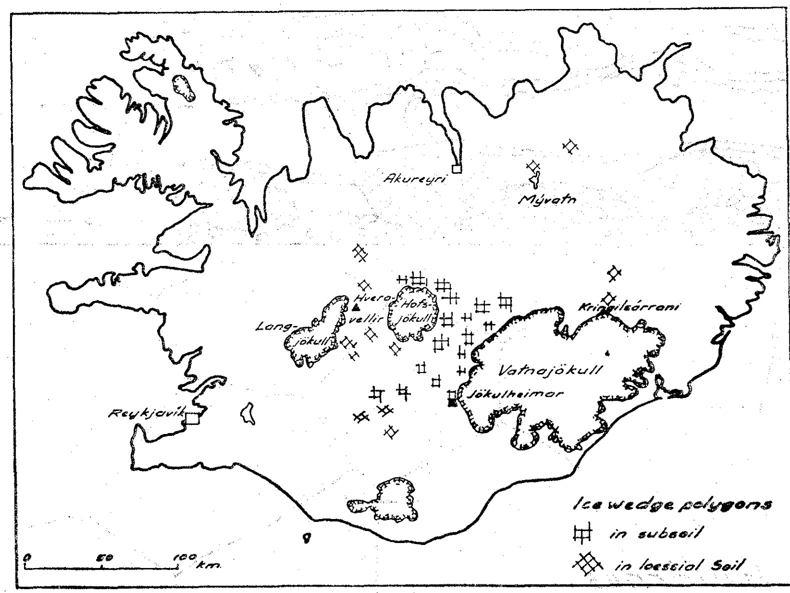

Fig. 5. Distribution of ice-wedge polygons in Iceland as known at present

in deltaic sediments about 15 m above sea level, and covered by a thick layer of similar sediments (pl. 9). They were discovered in 1963 by a young geologist, K. Saemundsson.

As to the ice-wedge polygons in loessial soil there is no doubt that those, now visible at the surface, are of recent age. It has been proved with the aid of dated tephra layers that the upper part of the loessial soil cover, in many cases down to more than 1 m depth, has been deposited since the arrival of man 1100 years ago (Thorarinsson 1961), and the frost fissures going through this soil (cf. fig. 4) cannot be old. That contraction due to low temperatures is the most important factor forming these polygons seems obvious enough (cf. also Dylik 1963). In the Hvítárnes area, 420—450 m above sea level, the writer has looked in vain for new contraction cracks whereas in Kringilsárrani north of Vatnajökull at an elevation of about 650 m there are quite fresh contraction cracks forming a net of polygons about 15 m in diam. (pl. 8). Thus the lower limit for the formation of ice--wedge polygons in loessial soil under the climatic conditions now prevailing seems to be somewhere between 450 and 650 m in altitude, whereas the limit for the formation of ice-wedge polygons in the coarse subsoil material is probably about 300 m higher up. The lower limit for the formation of the loessial soil polygons seems to be about the same as that for the formation of palsas or even somewhat lower. This limit is fairly close to the mean annual 1 °C isotherm (cf. Thorarinsson 1951) but of course it is not the average temperature as such that is the determinating factor. Temperature conditions during the winter and the thickness and duration of the snow cover are probably the decisive factors. Unfortunately we know far to little about the climate in the interior of Iceland. Not until the summer of 1962 did a weather station operate in the interior, at Hveravellir, altitude 600 m. Another station started operating at Jökulheimar, altitude 674 m, in 1963. These stations are inactive during the winter but there are plans for making at least one of them permanent, working throughout the whole year, as a better knowledge of the climate in the interior is urgently needed for many reasons.

At the moment we can state that a considerably more severe climate is needed for the formation of ice-wedge polygons in the subsoils of Iceland than for their formation in the loessial soil. A more thorough and detailed study of the regional distribution of these two types of polygons together with an increased knowledge of the climate in the interior of the country could make fossil polygons of the types described more precise climatic indicators than they now are. In the writer's opinion a closer study of the climatic conditions necessary for the formation of ice-wedge polygons will probably reveal that these conditions are not as severe as has hitherto been generally assumed.

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Photo by the author, Sept. 7, 1958

Pl. 1. Anchored polygons at Mjólkárlón, western Iceland
Altitude 220 m

Photo by the author, June 22, 1962

Pl. 2. Small floating polygons near Svalthúfa on the south coast of Snaefellsnes
Altitude 30 m

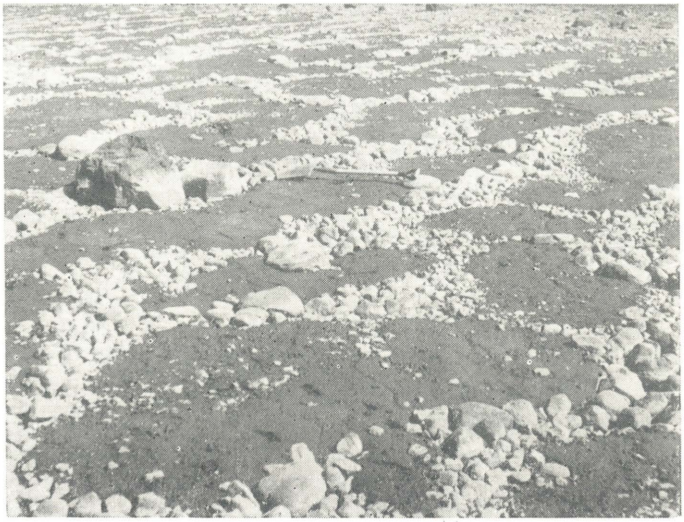

Photo by the author, July 14, 1956

Pl. 3. Polygons east of Hermundarfell in Thistilfjördur, northern Iceland

Altitude 40 m. Length of spade 105 cm

Photo by the author, July 24, 1962

Pl. 4. Nonsorted polygons north of Tungnafellsjökull

Altitude 800 m

Photo by the author, July 24, 1962

Pl. 5. Ice-wedge polygons in Nýidalur, west of Tungnafellsjökull

Altitude 800 m

Photo by the author, Sept. 16, 1962

Pl. 6. Ice wedge northeast of Jökulheimar, Central Iceland

Altitude 720 m

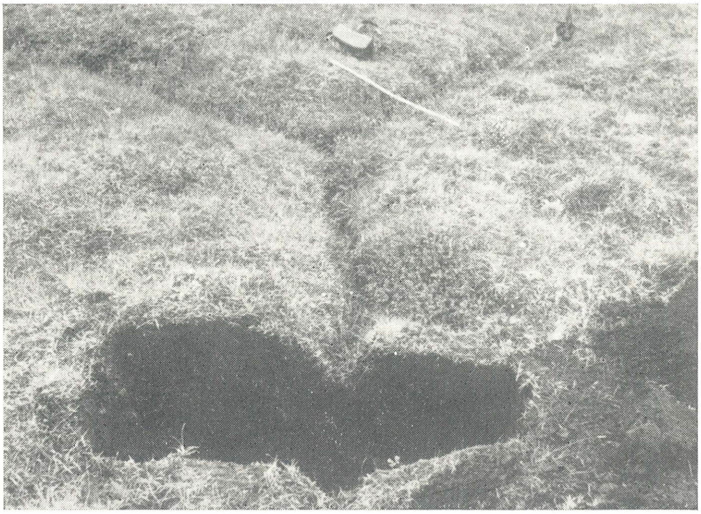

Photo by the author, Aug. 4, 1963

Pl. 7. Pit dug through a bordering fissure of ice-wedge polygons in Hvítárnes (see fig. 4)

Photo by the author, Sept. 6, 1962

Pl. 8. Loess-soil polygons in Kringilsárrani, Central Iceland

Initial stage. Altitude 650 m

Photo by the author, Aug. 28, 1963

Pl. 9. Fossil ice-wedge in delta sediments at Ellidaárvogur near Reykjavík

Altitude 10 m. Length of pen 14 cm