Harald Svensson
Lund

AERIAL PHOTOGRAPHS FOR TRACING AND INVESTIGATING FOSSIL TUNDRA GROUND IN SCANDINAVIA

NORTHERN SCANDINAVIA

The extreme north of Scandinavia was largely mapped (on a scale of 1 : 200 000 or larger) before aerial photography was widely used in map-making. Recently aerial photography has been used in the land areas within the Arctic Circle for complementary mapping and for making new maps. In addition, aerial photographs have been taken of parts of the area for prospecting and planning new roads. Nevertheless, aerial photographic coverage of the extreme north of Scandinavia for civil use is still lacking over large regions.

The available photographic material has, however, proved to be extremely valuable for geological and physical geographical studies. By means of such photographs a ground phenomenon unknown to Scandinavia in its surface form, i.e. the large-scale type of patterned ground called tundra polygons or ice-wedge polygons, has been identified.

The evidence on which this paper is based has been obtained by the interpretation of aerial photographs followed by ground inspection in the extreme north of Norway, in southern Sweden and in western Denmark (v. the bibliography). With the aid of aerial photographs Rapp, Gustafsson & Jobs (1962) investigated interesting ice-wedge polygons within an area of the Inner Scandes; these are dealt with in greater detail in an article in this Bulletin (Rapp & Rudberg 1964).

Owing to its characteristic geometrical form the polygon ground can easily be seen as a pattern in vertical photographs (pl. 1). As, however, the areas in question in northern Norway do not seem to contain recent permafrost[1] the ground formations have been obliterated by erosion (pl. 2) in some cases so that the pattern so typical of recent tundra ground does not appear or is only visible in occasional meshes. This can make

[1] This is particulary the case in the lower lying areas. In some of the higher situated areas perennial *tjäle* may occur. It has not yet been possible to make test excavations to the required depth in all places.

it difficult or impossible to observe and reconstruct the tundra pattern from the ground perspective.

In the areas investigated in northern Norway, the pattern in the ground surface is reproduced by thicker vegetation in the polygon lines. This in turn is due to the fact that the polygon lines consist topographically of depressions which protect vegetation on the wind-swept surfaces (pl. 3).

The depressions are usually shallow, only a few decimetres in depth, and then usually do not appear stereoscopically on account of the fact that the vegetation in the furrows levels out the profile. The furrows can, however, reach a considerable depth locally — as much as 1.5 metres has been observed. In these deeper formations the furrows also usually contain a type of vegetation that requires moisture and in that case are reproduced in another grey tone in the photograph.

When the furrows lead to the edge of a terrace, they have sometimes caused erosion and have been deepened into small valley formations which dissect the steep slope of the terrace.

The vertical perspective naturally makes the aerial photograph an important instrument for determining the type of the ground pattern and its regional distribution. The affinity to certain types of terrain and irregularities in occurrence can also be determined in the photograph without field work that requires a great deal of time.

The polygonal patterns appear most clearly in exposed surfaces which are poor in vegetation, where the vegetation of the polygon lines contrasts with the surrounding ground. With increasing ground vegetation the possibility of identifying the ground pattern becomes less and less. The tetragonal pattern occurs clearly inside the reindeer enclosure (pl. 4), where the vegetation has been trampled down and become withered, while the pattern outside the enclosure shows less clearly in the untouched vegetation.

Where the ground is covered by forest, which is only the case in lower lying and sheltered areas, old polygonal patterns can be perceived more seldom on aerial photographs. Even in such cases, however, the photograph can give guidance. As already mentioned, the type of terrain can be determined, e.g., terrace or raised delta and beach areas can be localised. On account of the fact that the polygonal pattern usually occurs in such a milieu, the reconnaissance work in the field can be limited and the field study directly applied to suitable areas.

For the study of the third dimension in the polygonal pattern (pl. 5), it is sometimes of interest to find gravel-pits, cuttings or steep terrace slopes, the surface of which contains the pattern. Aerial photographs are a good guide in this connection.

SOUTHERN SCANDINAVIA

As regards conditions in the southern part of Scandinavia, here air photography has been carried out in connection with the new map of Sweden. Aerial photographs on scales of up to 1 : 20 000, in certain special cases on still larger scales, have thus become accessible for scientific use. In the case of Denmark also good new photographs exist. A usual scale of picture in the Danish photography is 1 : 10 000.

In geographical and geological investigations the scale often limits the possibilities of getting information from aerial photographs. When it is a question of identifying large scale polygonal ground, as in the actual case, identification is, however, often possible even on small scale air photographs on account of the pattern effect.

For more detailed studies reference should be made to large scale photographs or enlargements. The Scandinavian aerial photos are usually of such a quality that they can easily bear very considerable enlargement.

In the southern part of Scandinavia periglacial phenomena are known from studies in gravel-pits (Nörvang 1939, 1942; Johnsson 1956, 1959, 1963). On account of the actual occurrences of these relict forms of frozen ground, it has been of interest from the aspect of methodical photographic interpretation to investigate whether there is a possibility of identifying the surface form of this type of ground on aerial photographs.

In these southern parts of Scandinavia one must expect for several reasons to encounter considerably greater difficulties in identification than in the northern areas described above. This is mainly due to the fact that the areas which are liable to be tested are open regions, that is to say, as a rule areas that are cultivated and have been so for a long time. It must therefore be expected that with the cultivation of these areas a ground pattern composed of furrows after collapsed ice-wedges will gradually have been effaced or eliminated. In addition, on account of the southern location a polygonal pattern may possibly not have got the same clear and profound formation originally as in the regions of the far north.

On aerial photographs of an area of the coastal plain on the west coast of Sweden indications of a large scale polygonal ground pattern were first observed. No traces of the pattern are, however, to be found in the ground surface.

It became apparent, however, last summer that on the cultivated fields a pattern occurs in the growing crop. This pattern is composed of plants growing higher and denser (pl. 6).

Under the even surface of the fields it can be seen that these lines contain ice-wedges usually more than 1.5 metres deep. In the sandy subsoil

these ice-wedges show up in marked contrast both in longitudinal and vertical sections (pl. 7).

The clearness of the registering of the pattern depends upon the type of vegetation in the field and its stage of growth (thickness, height, etc.). In order, that the lines of the pattern should get a continuous formation thick and relatively high vegetation such as a field of corn is required. By comparison with air photographs taken of one and the same area but in different years, it is thus possible to establish the fact that the pattern is missing from one of the fields where it was in an earlier year on account of the fact that now other crops are being grown (e.g. root crops).

In such comparisons it has also been noted that the pattern within the coastal area in question with its sandy soil shows up particularly well in aerial photographs taken after periods of early summer drought.

Thus it has proved possible with the assistance of aerial photographs not only to identify, but also to map the extent of the polygon ground, in spite of the fact that the direct source of the pattern no longer appears on the surface itself. The pattern is literally subcutaneous and is composed of ice-wedge lines. It is, however, due to the vegetation that the polygonal pattern is registered in the aerial photograph and can be perceived and interpreted.

With this registering of the polygonal pattern in the ground surface it is no longer absolutely necessary to have recourse to any available gravel--pits for the study of the vertical character of the polygon ground (dimension, stratigraphy, etc.). Test excavations can be made exactly at the place where the pattern seems to have specially interesting characteristics and where detailed studies are wanted.

It has not been possible to check the indications of polygonal ground in the Danish photographic material by means of test excavations, as the pattern could not be observed in the ground at the visit of the area. The pattern has, however, a clearly polygon character and corresponds to a high degree with the pattern from the Worcestershire Avon that Shotton (1960) considered to be ice-wedge polygons.

References

Johnsson, G. 1956 — Glacialmorfologiska studier i södra Sverige. *Medd. Lunds Univ. Geogr. Inst.*, Avh. 30.

Johnsson, G. 1959 — True and false ice-wedges in Southern Sweden. *Geogr. Annaler*, vol. 41.

Johnsson, G. 1963a — Periglacial phenomena in Southern Sweden. *Geogr. Annaler*, vol. 44.

Johnsson, G. 1963b — Periglacial ice-wedge polygons at Hässleholm, southernmost Sweden. *Svensk Geogr. Årsb.*, vol. 39.

Lundqvist, J. 1962 — Patterned ground and related frost phenomena in Sweden. *Sveriges Geol. Unders.*, Ser. C, No. 583.

Nörvang, A. 1939 — Stenringe och frostspalter i Danmark. *Naturhist. Tidende.*, Aarg. 3.

Nörvang, A. 1942 — Frostspalter i Jylland. *Medd. Dansk. Geol. Foren.*, Bd. 10.

Rapp, A., Rudberg, S. 1960 — Recent periglacial phenomena in Sweden. *Biuletyn Peryglacjalny*, nr 8.

Rapp, A., Rudberg, S. 1964 — Studies on periglacial phenomena in Scandinavia, 1960—1963. *Biuletyn Peryglacjalny*, nr 14.

Rapp, A., Gustafsson K., Jobs P. 1962 — Iskilar i Padjelanta? *Ymer*, 3.

Shotton, F. W. 1960 — Large scale patterned ground in the valley of the Worcestershire Avon. *Geol. Magazine*, 5.

Svensson, H. 1962a — Note on a type of patterned ground on the Varanger peninsula, Norway. *Geogr. Annaler*, vol. 44.

Svensson, H. 1962b — Ice-wedges in fossil tundra polygons on the Varanger peninsula. *Svensk Geogr. Årsb.*, vol. 38.

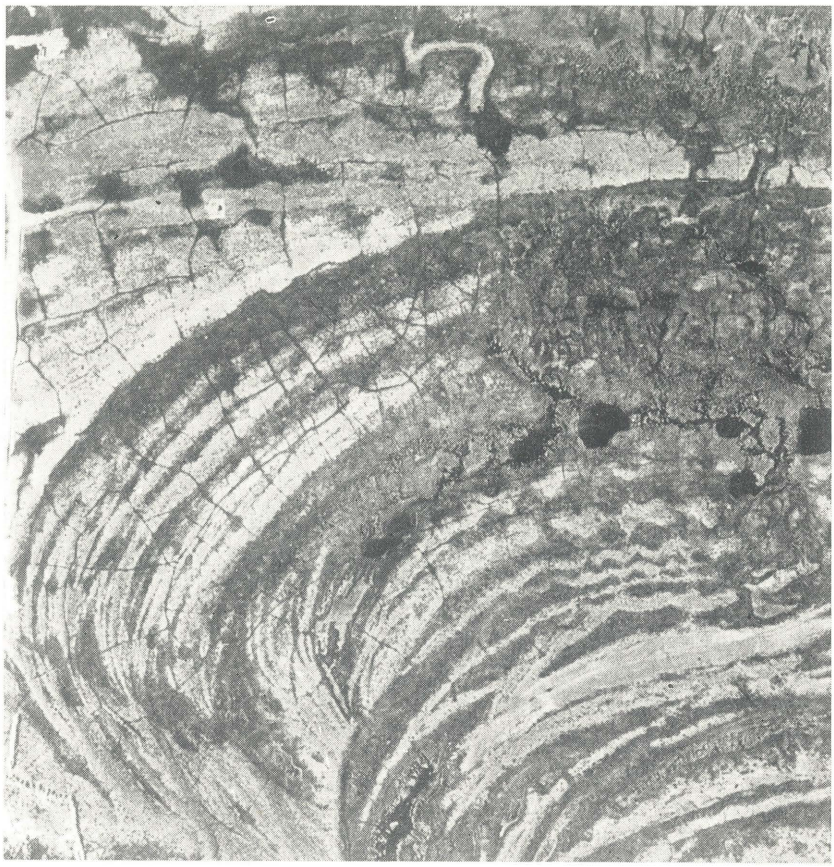
Svensson, H. 1962c — Ett mönster i marken (summary: A pattern in the ground). *Svensk Geogr. Årsb.*, vol. 38.

Svensson, H. 1963a — Tundra polygons. Photographic interpretation and field studies in North-Norwegian polygon areas. *Norges Geol. Unders.*, Årbok 1962.

Svensson, H. 1963b — Några iakttagelser från palsområden. Flygbildsanalys och fältstudier i nordnorska frostmarksområden (summary: Observations on palses. Photographic interpretation and field studies in North-Norwegian frozen ground areas). *Norsk Geogr. Tidsskr.*, B. 18, 5—6.

Svensson, H. 1963c — Some observations in West-Jutland of a polygonal pattern in the ground. *Geogr. Tidsskr.*, B. 62, Köbenhavn.

Svensson, H. 1963d — Iskilspolygoner på Laholmsslätten. *Svensk Geogr. Årsb.*, vol. 39.



Pl. 1. Ice-wedge polygons in a raised shore terrace, the Varanger peninsula

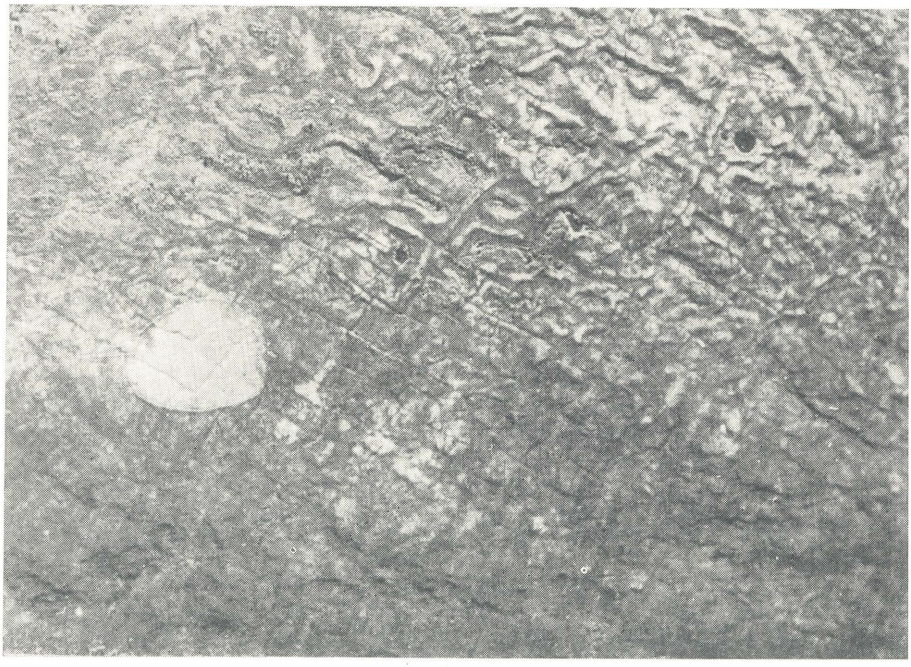
Appr. scale 1 : 5000. Widerøes flyveselskap A/S, Oslo

Pl. 2. An eroded polygonal pattern in an area of raised beaches, the Varanger peninsula

Appr. scale 1 : 3500. Wideröes flyveselskap A/S, Oslo

Photo by H. Svensson, 13/7, 1962

Pl. 3. Polygonal lines in the area of pl. 1



Pl. 4. A tetragonal pattern in a mountain slope

The light coloured field is a reindeer enclosure. The Tana district. Appr. scale 1 : 7000. Widerões flyveselskap A/S, Oslo

Photo by H. Svensson, 13/7, 1962

Pl. 5. Ice-wedge in the gravel pit of pl. 1 (top left). The ice-wedge is coloured by iron precipitation

Photo by H. Svensson, 18/6, 1963

Pl. 6. Lines of higher corn (barley) indicate the position of a former network of tundra polygons, Halland, Southern Sweden

Photo by H. Svensson, 30/9, 1963

Pl. 7. Longitudinal section of an ice-wedge line

The figure shows two horizontal levels of the test hole, to the right 85 cm and to the left 50 cm under the surface of the cornfield