RELICT ICE-WEDGE POLYGONS
revealed on aerial photographs from Kaltenkirchen, northern Germany

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On aerial photographs polygonal patterns are detected in cultivated fields due to vegetational contrasts. In a section through the ground the structure and composition of the material were studied. The outline of the ice-wedge cast is very faint, but the existing structure and soil qualities are sufficient to make the polygonal network show on the ground surface. The season of the year and the external conditions at the time of photographing are of great importance for a distinct reproduction of the pattern in the aerial photograph.

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Introduction

In the Nordic countries, the surface patterns of fossil ice-wedge polygons are revealed by aerial photographs in two ways: (1) as a micro-topography, and (2) as a vegetation contrast on the surface.

(1) On the original, i.e. uncultivated, ground surfaces in northern Scandinavia and in Iceland, the polygonal pattern is delineated by furrows and is sometimes also strengthened by natural vegetation (Friedman et al. 1971, Maack 1967, Rapp and Annersten 1969, Rapp and Clark 1971, Svensson 1963a, and Öhrngren 1967).

(2) In cultivated areas of southern Sweden and in Jutland, Denmark, the polygons show up on aerial photographs on account of vegetational contrasts in the fields during the growing season (Svensson 1963a, 1964, and 1974). These contrasts mirror different degrees of vitality or growing rate of the plants, and to ensure the best possible picturing of the polygonal network from the air, the 'near infrared' spectral band is best suited because of its sensitivity to differences in foliage reflectance (Christensen, 1974, and Svensson, 1974).

As a continuation of the investigation and mapping of polygonal ground in western Jutland, where vast areas of polygonal patterns have been observed on aerial photographs (fig. 1), it was of methodical interest to try to follow geographically the periglacial zone (outside the last glaciation) southwards into northern Germany (Schleswig-Holstein), using aerial photographs as a detecting tool.

In an earlier paper (Svensson 1972), it has been demonstrated how sensitive to the external conditions the polygonal markings are. The clearest delineation seems to occur in vegetational stress situations (especially after dry periods in the spring).

In examining the aerial photographs that were kindly made available by Hansa Luftbild (January 1972) and the Department of Geography at the Kiel University (November 1972), no aerial coverage from periods with appropriate external conditions could be found. On a few aerial photographs from an area about 30 km north of Hamburg, however, some polygon-patterned fields were observed and were later visited for ground studies.

Occurrence and characteristics of the polygonal pattern

The aerial photographs in which the pattern was observed were taken on 5 May 1970 and cover a small area near Kaltenkirchen. The pattern occurs in fields of bright grey tones (fig. 2) and is delineated as a somewhat brighter network against the field background.

In the fields different crops were grown. The polygonal pattern often disappears at a field boundary due to the fact that the adjoining field had recently been ploughed or carried a different vegetation than the polygon-patterned field. The lines forming the pattern revealed on the aerial photograph are not contour-sharp and may more correctly be regarded as zones, 1-3 m wide. The form of the individual polygones varies, as does also the size. The lenghts of the polygon sides range from a few metres to about 30 m.

The ground surface of the locality in fig. 2, as in other polygon localities in the vicinity, is quite even. The height is about 30 m a.s.l.. Geographically, the area belongs to the outwash plains outside the margin of the last glaciation (Würm). The ground mostly consists of sand. When the Kaltenkirchen area was visited at the end of October 1972, no polygonal markings were detectable in any of the patterned fields on the aerial photographs from 1970.

Observations in sections of the ground

Based on experience from polygon-patterned fields in Jutland and southern Sweden, it seems safe to classify the pattern as a relict, periglacial, ice-wedge network

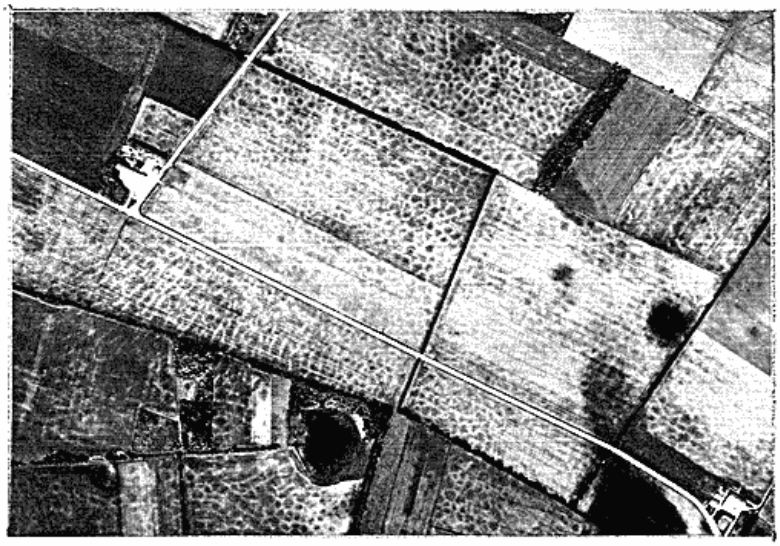


Fig. 1. Polygonal network near the village of Astrup, Jutland. Aerial photograph of May 28, 1070, by Landinspektørernes Luftfoto, Copenhagen. Approx. scale 1:6000.
Fig. 1. Vegetationsmönster av polygoner nära Astrup, Jylland. Flygbilden fotograferad av Landinspektørernas Luftfoto den 28maj 1970. Ungefärlig skala 1:6000.

recorded by vegetation. In some of the vast gravel pits in the Kaltenkirchen area, ice-wedge casts could also be seen.

It was, however, of interest to establish whether the patterns in the actual fields really were underlain by pseudomorphs of ice-wedges and, if this was the case, what details characterized the infillings. As no polygon markings could be seen on the surface of the field, there were no chances of finding the point for digging a test pit exactly in a polygon line. At the boundary of a field with very diffuse polygons and at a distance of 180 m from another field with a very distinct polygonal network, there was a hole made by a bulldozer (possibly in probing the ground for an airport project).

After cleaning one of the walls, a disturbance could be traced (fig. 3a) at a depth of 40-70 cm, i.e. 60-90 cm below the surface of the field, as 20 cm of the top soil had been removed. On the right-hand side of the ice-wedge (just to the left of the folding rule) there was, however, a vertical contour separating stratified bright sand to the right from structureless brown sand within the area of the disturbance. There was a slight difference in the textural composition, the stratified sand being more uniform. Another characteristic of the stratified sand was the bending down of the originally horizontal strata inwards against the disturbed section.

On the left-hand side the contour was also indistinct. Only some down-bending strata in the bright sand (to the upper left in fig. 3 a) could be seen. In general, there was a vertical difference of 10-15 cm (lower to the left)

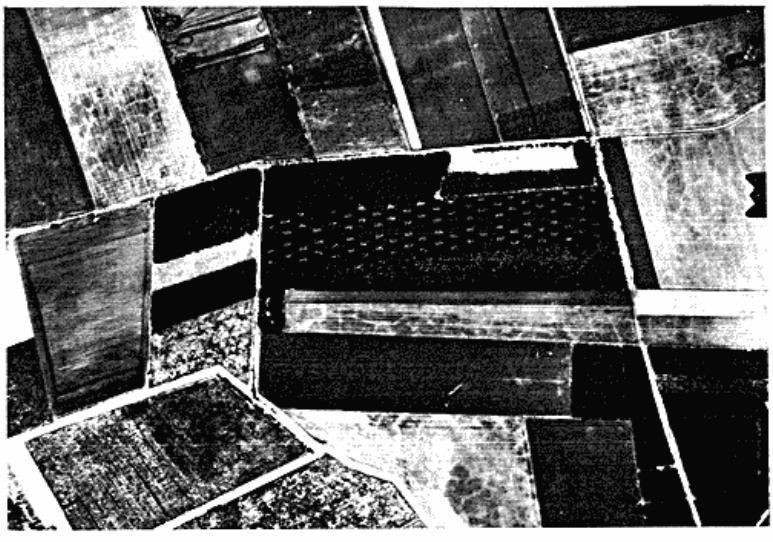


Fig. 2. Polygonal patterns in cultivated fields at Heidmoor (Kaltenkirchen), West Germany. Aerial photograph of May 5, 1970, by Hansa Luftbild, Münster. Approx. scale 1:6000. Freigegeben durch den Regierungspräsidenten in Münster/Westfalen unter der Nummer 4 L 841 (4670).
Fig. ;. Polygonmönster i odlade fält vid Heidmoor (Kaltenkirchen) Västtyskland. Flygbilden fotograferad av Hansa Luftbild, Münster. Ungefärlig skala 1:6000.

between the stratification planes on the side of the disturbance, indicating a vertical movement in the ground section.

On the whole, the contours of the structureless disturbance were so faint that it was open to considerable doubt whether the vertical section contained an ice-wedge cast at all. However, a study of the horizontal section exposed at the bottom of the pit revealed details that indicated the true ice-wedge-polygon origin.

To begin with, the indications were not so clear. In fig. 3 a no delineation of an ice-wedge zone is observable at the bottom level. Deepening the pit by 10 cm and cleaning the bottom (fig. 3 b) revealed a contour on the left-hand side. After a further deepening of 10 cm, a contour showed up also on the right-hand side (fig. 3 c).

That no clear delineation appeared during the two first stages of the digging was due to the above-mentioned vertical displacement in the section. Not until surrounded by the same parent material on both sides (bright sand) did the infilling take on the contours.

With continued deepening (fig. 3 d-f), the ice-wedge zone became still more distinct at the bottom level. At the same time, the width of the infilled zone gradually narrowed. At a depth of 170 cm the zone was still 10-15 cm wide. Probing further down with the spade showed a faint wedging out. The contours at the horizontal bottom level remained very distinct.

In the contour on the left-hand side of the ice-wedge zone at the bottom level, an irregularity (b-d) occurred that during the deepening of the pit at first gave the impression of being an adjoining ice-wedge zone. However, this irregularity disappeared again with depth and was probably the result of a local setting due to thermo-karst processes in the fossilization of the ice-wedge zone.

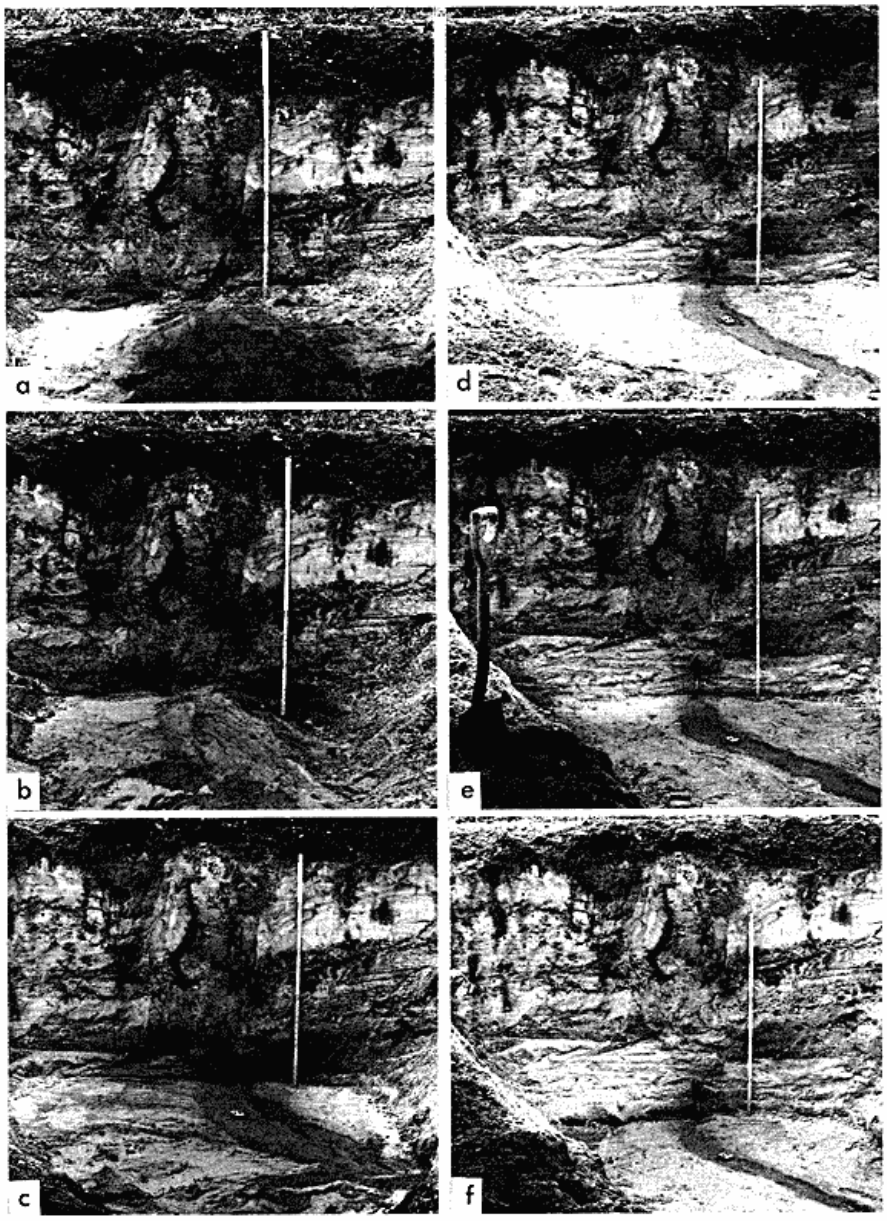
In the horizontal section inside the ice-wedge zone, some thin bands (1-2 mm) parallel to the zone were traceable. These bands were coloured by precipitated humus and/or iron hydroxide and represented probably an original structure of the ice-wedge, i.e. fissures opened up by thermal cracking during the period of active ice-wedge formation. Such ice-walled fissures, usually filled with hoar-frost and vein ice (melt-water) which give rise to the foliated structure of an active ice-wedge, may primarily also have been (partly) filled with soil material from above (cf. the sand-wedge formation, Péwé 1959). In the fossilization of the ice-wedge by thermo-karst processes, causing movement from the sides and infilling from above, the result will mostly be a structureless pseudomorph. However, in the lower parts of an ice-wedge. where the infilled zone is narrow and the movements in the parent material are not so intense, primary structures from the ice-wedge formation, such as thin fissures, may avoid total destruction.

Of the soil samples from 50, 70, and 120 cm depths (fig. 4) only the intermediate sample (fig. 4 b) shows significant differences between the inside and the outside material of the wedge. Characteristic for this sample is also its higher contents of finer fractions inside the wedge, which is due to the fact that the infilling has occurred from the sand bed at the side of the wedge (10-20 cm higher up in the section).

In the polygon areas in southern Sweden, the polygon pattern stands out in dry periods of the growing season because of the more favourable moisture conditions in the ice-wedge zone than in the side soil (Svensson 1964, and 1966). This fact is, in its turn, due to a clear difference in soil fractions, the infilled material being definitely finer than the soil at the side of the wedge. However, contrary to the area investigated in Sweden, all the present samples did not show such significant differences. The more intense precipitation of iron hydroxide in part of the wedge zone indicates, however, a higher permeability of the ice-wedge pseudomorph. This fact is due to the higher degree of porosity in the structureless infilling than in the undisturbed strata beside the wedge.

Conclusions

1. The delineation of the polygons is caused by differences in the field vegetation.
2. The vertical section contains a faintly contoured, ice-wedge cast. The down-bending stratification on the sides of the infilling is an indication of the ice-wedge origin.
3. The fossilization of the ice-wedge was combined with a differential setting in the ground.
4. The horizontal section clearly shows an infilled ice-wedge zone with a slightly bending course. This zone is very distinct: (a) when it is outlined in homogeneous sand and (b) because of the colouring by precipitated material (humus and iron hydroxide).
5. In the horizontal section, the original, foliated structure of the active ice-wedge could be traced as thin veins of primary infillings.
6. The different structural and textural composition found in the polygon line and in the side soil influences the growing conditions and thereby the vegetational pattern (crop marks).
7. It is very likely that ice-wedge casts may be overlooked because of their indistinct contours when studied in vertical, fresh sections of gravel pits with high walls, offering no possibility of studying horizontal sections of the relict ice-wedge pattern with its often sharper contours.



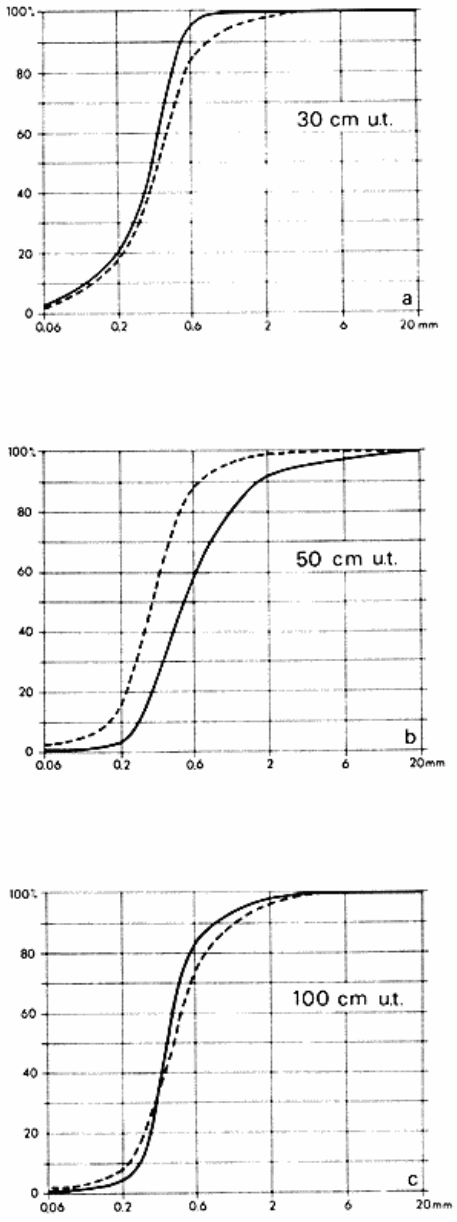


Fig. 3. Section through the ground near Heidmoor, West Germany. In the sequence the pictures (a-f) each represents a deepening of 8-10 cm in relation to the preceding one. (The folding rule is 100 cm long). At the horizontal bottom level, a distinct ice-wedge zone is gradulally appearing (c-f).

Fig. 3. Vertikalsnitt genom marken nära Heidmoor. I serien (a-f) motsvarar varje bild en fördjupning av 8-10 cm i förhållande till föregående. (Tumstocken är 100 cm.). I det horisontella bottenplanet framträder succesivt (c-f) en iskillszon.

Fig. 4. Textural composition of soil samples at depths of 30,50, and 100 cm (a-c) respectively. The continuous line represents soil samples outside and the dashed line soil samples inside the ice-wedge cast.

Fig. 4. Materialsammansätning i jordprover från resp. 30, 50, och 100 cm (a-c). Den heldragna linjen motsvarar jordprov utanför och den streckade linjen innanför konturen av den fossila iskillen.

RESUME

Fossila iskilspolygoner är av paleogeografiskt och paleoklimatiskt intresse, eftersom de indikerer tidigare periglaciala områden och ger möjlighet att bedöma tillsvarande perioders klimat. För att avgöra förekomst och bestämma utbredning av de fossila polygonnäten är flyfotografier ett utmärkt hjälpmedel. I de nordiska länderna får polygonerna sin markering på två sätt, (1) genom grunda fåror eller (2) såsom vegetationslinjer i markytan. Den senare typen finner man i Jylland, där polygonmönster framträder i flygbilder över odlade fält på grund av differenser i växtbetingelser, speciellt under torrperioder.

Såsom en fortsättning på studier av iskilspolygoner i Jylland

och för att pröva metodiken har nordtyskt bildmaterial analyserats. Ett stort flygbildsmaterial från Slesvig-Holstein har analyserats utan att polygonmönster påträffats. Endast i en mindre bildserie, specialfotograferad för flygplatsbygget vid Kaltenkirchen, observerades spår av polygonnät. Området kontrolleredas sedan i fält och upplysningar inhämtades hos lantbrukare beträffande odlingsförhållanden och grödor vid tiden för flygfotograferingen. Vidare detaljstuderades vertikalsnitt i marken, varvid störningar och strukturer i materialet (glacifluvial sand) observerades, vilka entydigt bestämmer företeelsen till ett nät av fossila iskilspolygoner. Att det övriga genomgångna flygbildsmaterialet från geografiskt likartade områden ej uppvisade några polygonmönster har sin förklaring i att bilderna fotograferats vid olämplig tidpunkt på året och/eller efter perioder med riklig nederbörd. I jordartsstrukturerna kan fortfarande detaljer (t.eks. sprickor) spåras från den ursprungliga iskilsbildningen under stadier av permafrost. Vidare kan processer vid fossiliseringen rekonstrueras.

REFERENCES

Christensen, L. (1974): Crop-marks revealing large-scale patterned ground structures in cultivated areas, southwestern Jutland, Denmark. Boreas 3, 1974. pp. 153-180.

Friedman, J.D., Johansson, C.E., Oskarsson, N., Svensson, H., Thorarinsson, S. and Williams, R.S. (1971): Observations on Islandic polygon surfaces and palsa areas. Photo interpretation and field studies. Geogr. Ann. 53A, pp. 115-145.

Maack, A. (1967): Fossil ice-wedge polygons in the Kunes and Båtsfjord area. Lund. Stud. in Geogr. Ser. A. Nr. 40. pp. 41-57.

Péwé, T. (1959): Sand-wedge polygons (tesselations) in the Mc Murdo Sound region, Antarctica. A progress report. Amer. Journ. of Sci. 257. pp. 545-552.

Rapp, A. and Annersten, L. (1969): Permafrost and tundra polygons in northern Sweden: in Péwé, T., ed., The periglacial environment. Past and present, pp. 65-91. Mc Gill-Queens Press, Montreal.

Rapp, A. and Clark, M. (1971): Large nonsorted polygons in Padjelanta National Park, Swedish Lapland. Geogr. Ann. 53A. pp. 71-85.

Svensson, H. (1963a): Tundra polygons. Photographic interpretation and field studies in North-Norwegian polygon areas. Norges Geol. Unders. Nr. 223. pp. 298-327.

—(1963b): Some observations in West-Jutland of a polygonal pattern in the ground. G.T. 62. pp. 122-124.

—(1964): Fossil tundramark på Laholmsslätten. Sveriges Geol. Unders. Ser. C. Nr. 598. pp. 1-29.

—(1972): The use of stress situations in vegetation for detecting ground conditions on aerial photographs. Photogrammetria 28. pp. 75-87.

—(1974): Distribution and chronology of relict polygon patterns on the Laholm plain, the Swedish west coast. Geogr. Ann. 55A. pp. 159-175.

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Péwé, T. (1959): Sand-wedge polygons (tesselations) in the Mc Murdo Sound region, Antarctica. A progress report. Amer. Journ. of Sci. 257. pp. 545-552.

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