HARALD SVENSSON *
Copenhagen

VALLEY FORMATION INITIATED BY ICE WEDGE POLYGONAL NETS IN TERRACE SURFACES

Abstract

Based on observations of present-day valley formation through thermokarst processes in river terraces of Spitsbergen, some mainly fossil valleys (gullies) in marine terraces of the Varanger peninsula are analysed. Their connection with a fossil pattern of ice-wedge polygons is still visible, and the formation of the valleys was evidently initiated by thermokarst processes in the polygonal furrows.

A more developed, dry valley pattern in another former periglacial area situated in southern Sweden is also discussed. The valleys are situated in a raised coastal area and formed in loose material, mainly sand.

The former presence of a well-developed polygon pattern in ice-rich permafrost (evidenced by distinct crop markings due to former ice-wedge polygons) is considered as the basic factor for the morphogenetic interpretation of the valleys Meltwater, collecting in flat depressions and polygon furrows, started a thermo-erosive process and initiated the valley formation.

When the gullies had developed and were growing deeper, the amount of water present may have increased by the seeping of interpermafrost water from taliks connected with the adjacent river. The presence of icings further contributed to the development of the flat valley bottoms.

Résumé de l'auteur

A partir d'observations de la formation de vallées actuelles par des processus thermokarstiques sur les terrasse fluviatiles du Spitzberg, quelques vallées (ravins) essentiellement fossiles creusées dans les terrasses marines de la péninsule de Varanger sont analysées. Leur connection avec un réseau fossile de polygones de fentes de gel est encore visible. La formation de ces vallées débuta d'une manière évidente par des processus thermokarstiques dans les dépressions polygonales.

Un réseau mieux développé de vallées sèches, situé dans le sud de la Suède, soit dans un autre domaine qui fut autrefois périglaciaire, est également discuté. Les vallées sont situées dans une région côtière soulevée et formées dans des matériaux meubles, principalement des sables.

La présence antérieure d'un réseau polygonal bien développé dans un pergélisol riche en glace (montré clairement par des marques distinctes dans les champs, dues à des traces de polygones de glace) est considérée comme le facteur de base pour l'interprétation morphogénétique de ces vallées. L'eau de fonte rassemblée dans des dépressions plates et dans les dépressions polygonales, a commencé un processus d'érosion thermique qui a débuté la formation des vallées.

Quand les ravins se sont développés et se sont encaissés, la quantité d'eau présente a pu augmenter par le drainage des eaux interpermafrost depuis les taliks connectés avec la rivière voisine. La présence d'icings a contribué plus tard au développement des fonds plats des vallées.

During the field meeting in northern Scandinavia in 1979 some examples of active thermokarst processes were demonstrated but only in bog areas and as collapse features in palsa bodies.

However, there is — both in northern and southern Scandinavia — some

* University of Copenhagen, Geographical Institute, Haraldsgade 68, DK-2100 Copenhagen.

erosional features that may confidently be interpreted as traces of thermokarst processes, once acting in polygonal nets and causing valley formation.

To get a view of the present formation of this type of valley let us for a moment leave the Scandinavian mainland and turn to another area of the Norden countries, Spitsbergen.

THERMO-EROSIONAL VALLEY FORMATION IN A TERRACE SURFACE OF THE ADVENTFJORD DISTRICT, SPITSBERGEN

In aerial photographs, vast nets of active ice-wedge polygons are visible in many coastal or valley areas of Spitsbergen. Usually the patterns are outlined by systems of linear depressions (SVENSSON, 1969, 1978).

On terrace surfaces melt-water sometimes collects and is led through the polygonal net to the edge of the terrace (Pl. 1). The angled character of the polygonal pattern is still visible in the course of the rivulets.

Field examination shows clearly this process of valley formation. The valley is being carved out by thermo-erosive processes and widened by mass movements in the thawed material (Pl. 2).

SHORT VALLEYS PRODUCED BY THE MELTING OF ICE-WEDGES IN AREAS OF THE VARANGER PENINSULA

In some raised deltas and beach terraces of northern Norway, fossil nets of ice-wedge polygons are clearly outlined by vegetation, which grows more densely in the furrows of the pattern (SVENSSON, 1962, 1964; MAACK, 1967). The frontal part of the terrace surfaces is in some places cut by gullies or short valleys (Pl. 3), which seem to have a connection with the polygon system. In some cases the influence is quite clear, as the gully starts in a polygonal furrow (Pl. 4).

The „cut-up" appearance of the terrace is interpreted as the result of thermo--erosive processes starting with the melting out of ice wedges which run more or less perpendicularly to the front, followed by the activity of the seasonally collected melt (and rain) water in the polygon furrows. The process may also have been influenced by wave action, but probably the outline of the gullies was fixed when the ground ice disappeared due to the climatic change.

The formation of the short valleys was not definitely finished with the vanishing of permafrost, but it is clear that the erosion was most active during the melting of the ground ice. The fossilization of that part of the net that was not eroded caused an infilling of material in the wedges resulting in ice-wedge casts. Possibly these fossilized wedge systems could also act as subsurface drainage, leading water to the floor or sides of the gullies. Such water-seeping is seen in fossil ice-wedge systems in cultivated areas of southern Sweden. Later the valleys were influenced by fluvial erosion and mass movements which have widened the valleys especially at the front of the terrace (Pl. 5). However, in many cases the original dependence on an ice-wedge net is still visible in the valley pattern.

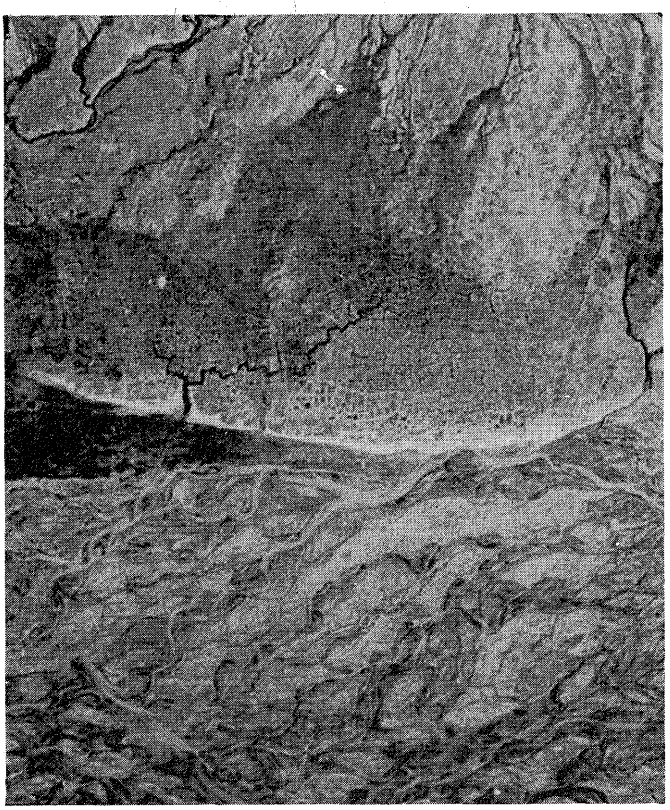
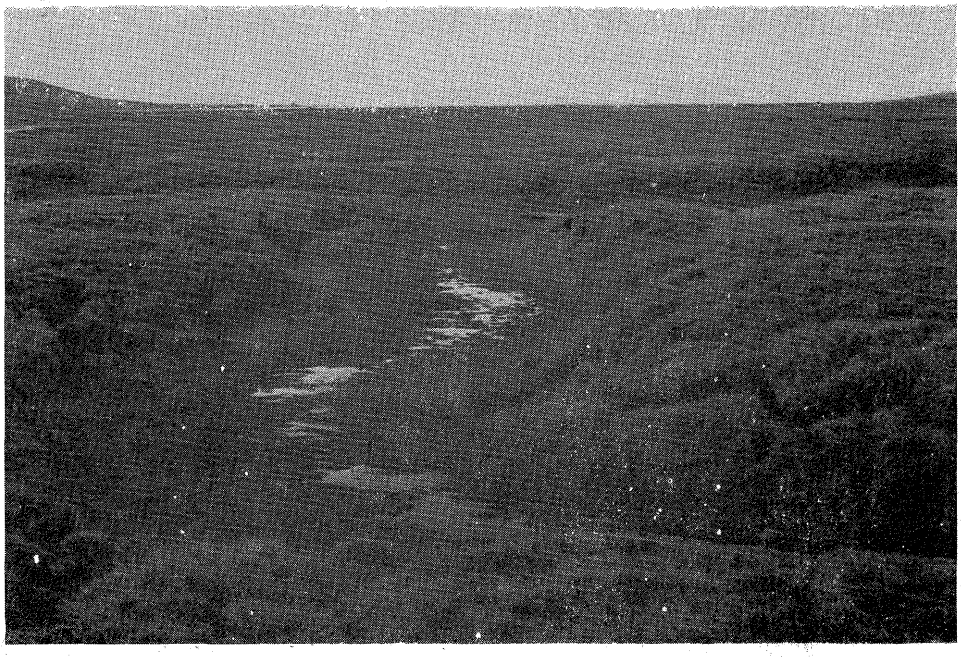


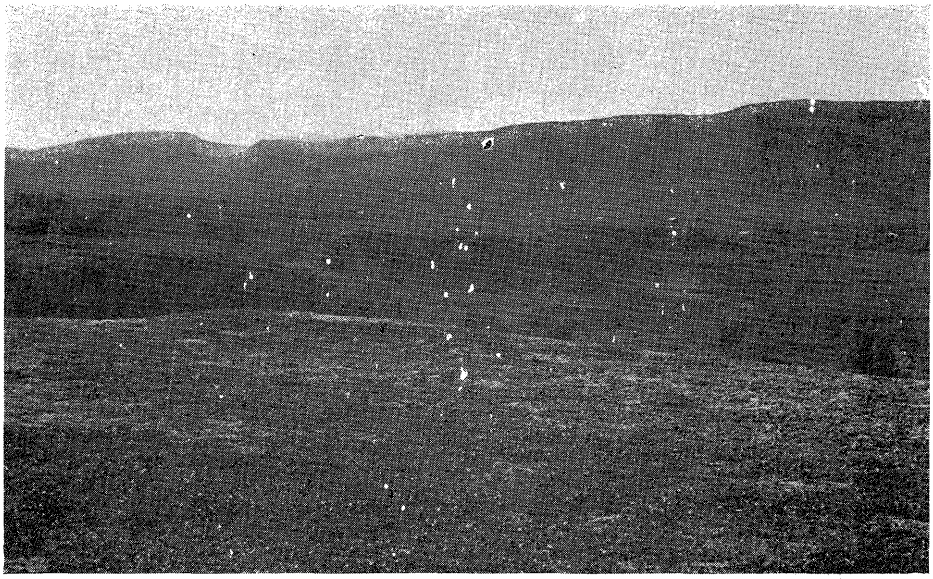
Photo: Norsk Polarinstitut

Pl. 1. Aerial photograph of part of the Advent valley

On the terrace bordering the present flood plain a small branched stream valley is developing from the furrows of the polygonal net. Approx. scale 1 : 15000



Pl. 2. Part of the valley system of Pl. 1 (at the junction of the two branches)



Pl. 3. The frontal part of a raised terrace cut by gullies. The inner part of Kongsöfjord

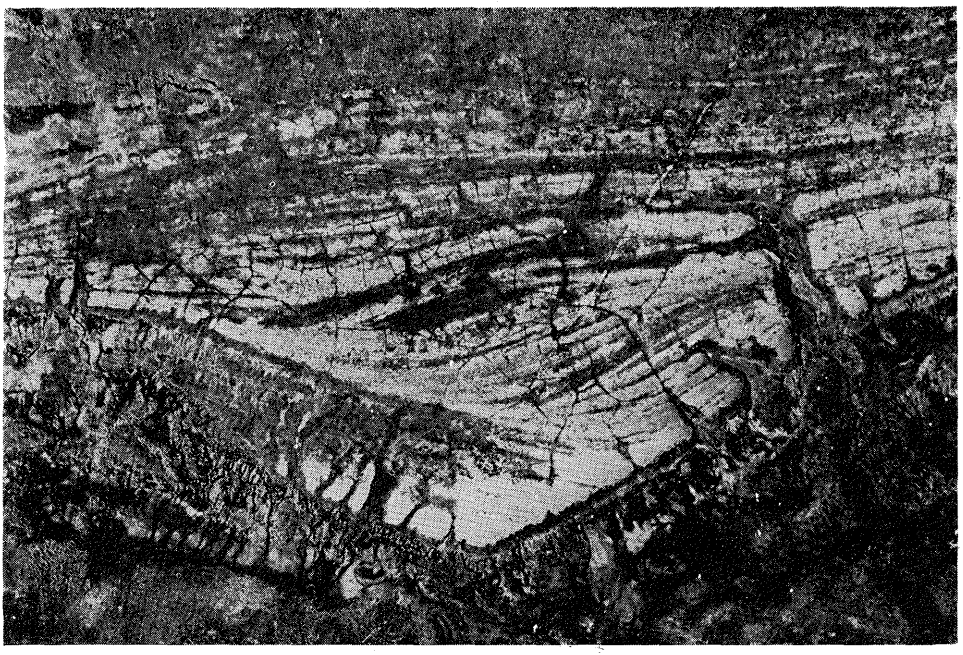


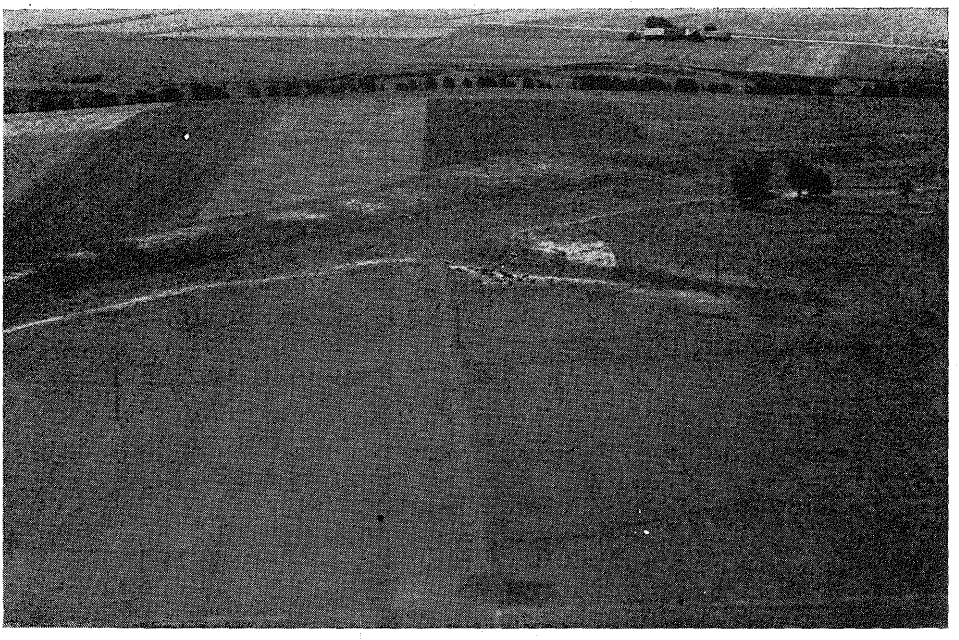
Photo : Fjellanger-Widerøe A/S

Pl. 4. Aerial photograph of a raised beach terrace with a fossil net of polygon lines, reformed into gullies in the terrace front. The northeastern part of the Varanger peninsula. Approx. scale 1:5500

Pl. 5. View across of a short valley in the frontal part of a terrace surface

Photo: Statens Lantmäteriverk

Pl. 6. Three fossil valleys in the Laholm plain, south of the river Lagan, the Swedish west coast. Approx. scale 1:35000



Pl. 7. Aerial view of part of valley No. 3 in Pl. 6. In the fields fossil ice-wedge polygons show in the vegetational pattern

FOSSIL VALLEY SYSTEMS IN SOUTHWESTERN SWEDEN

In a cultivated area of the Swedish west coast, the Laholm plain, there exist valleys that have no function in the present drainage system. Some of them have a short (gully) course ending in a terrace front. Others are branched, maximally 7—8 m deep and nearly 1000 m long (Pl. 6). The ground consists of sand, but in their deeper parts the valleys reach clay beds. The bottom sections of the valleys are flat.

Only during periods of rapid snow melt while the ground is still frozen, is water seen in the valleys. Fluvial erosion is of no significance and most of the year the valley floor is dry. The ground water level reaches, however, very close to the valley bottom, and in some of the valleys the ground water is drained through a ditch or by a pipe. There is no doubt that the valleys are fossil and were formed during other drainage conditions than those existing to-day.

After the deglaciation of the area, the plain was raised above sea level and the surface surrounding the valleys (Pl. 6) is situated 30—35 m above present sea level. During periods of Late Glacial time (esp. the Younger Dryas) the coastal plain constituted a periglacial area. The former arctic environment is evidenced by vast areas of fossil ice-wedge polygons (SVENSSON, 1974). The polygon nets are not outlined by a micro-relief of furrows in the surface as seen in the northern areas, but can be observed especially after dry seasons as vegetation pattern, crop marks (Pl. 7).

The valleys have no connection with some sort of basin that may earlier have had its outlet through the valleys. They start imperceptibly on the plain surface. The water must have collected under special conditions, quite different from to-day. Considering their geomorphological characteristics and the presence of a fossil ice-wedge net, one may justifiably relate the valleys to the former existence of permafrost in the area.

In flat surfaces underlain by permanently frozen ground the surface water could not percolate, but collected in the furrows of the ice-wedge polygons and was led further through a deep furrow system (*cf.* the Spitsbergen model of present periglacial valley formation). The water started thermokarst processes that caused thawing in the bottom and flanks of the furrow.

As mentioned above, there is ground water present close to the bottoms of the valleys. Supplied by springs, it could have contributed to the valley formation in periods of extreme high ground water level after the permafrost had disappeared.

However, springs were possibly active also in the permafrost stages. The valleys are situated close to the present river Lagan, so that after the valleys were established by thermo-erosive processes, river bed taliks or interpermafrost water may have fed springs in the sides of the valleys and supplied water contributing to the further development of the system. During this stage of formation,

the bottoms of the valleys were for a long period of the year covered by icings which stored water and also contributed to the development of the flat valley floor.

CONCLUSIONS

The valleys from the Varanger peninsula and the Swedish west coast treated above are mainly fossil. Morphogenetically, they correspond to the now active valley formation by thermo-erosive processes in permafrost areas, here exemplified by the beaded stream system in the Advent valley area. Evidently the valleys are to be interpreted as a type of periglacial valleys.

The difference in shape: short valleys in the marine terraces of the Varanger area and well-developed „Dellen" systems in the Laholm plain, might depend on the preconditions for thermokarst processes, e. g. kind of material and ice content or on size of catchment area for melt water and ground water. For the marine terraces a possible reduction of the valley system by wave action may also be considered. Especially in the case of dry valleys of the Laholm plain, interpermafrost water and icings may have actively contributed to their development.

The fossil valleys discussed in this paper can be attributed to ice-wedge polygons still appearing in their relict state (as furrows and crop marks). Possibly dry valleys in other areas of former permafrost environment, where the polygon pattern is no longer visible, may have the same origin.

The Norden countries offer good possibilities of comparing periglacial features passing from their active state in Spitsbergen (or Greenland) via fossil forms still unaffected by man in Iceland and northern Scandinavia, to fossil forms fragmented by human activity or masked by vegetation in southern parts of Norden.

References

MAACK, A., 1967 — Fossil ice-wedge polygons in the Kunes and Båtsfjord area. Polygonal ground and solifluction features. *Lund Stud. in Geogr.*, ser. A, 40.

SVENSSON, H., 1962 — Note on a type of patterned ground on the Varanger peninsula, Norway. *Geogr. Ann.*, 44.

SVENSSON, H., 1964 — Aerial photographs for tracing and investigating fossil tundra ground in Scandinavia. *Biul. Peryglacjalny*, 14.

SVENSSON, H., 1969 — Permafrost på Spitsbergen. *Forskn. och Framst.*, 1969: 8.

SVENSSON, H., 1974 — Distribution and chronology of relict polygon patterns on the Laholm plain, the Swedish west coast. *Geogr. Ann.*, 55 A.

SVENSSON, H., 1978 — Ice wedges as a geomorphological indicator of climatic changes. *Danish Met. Inst. Climatol. Papers*, 4.