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TRANSFORMATION OF LANDFORMS AND QUATERNARY DEPOSITS

The greatest changes in landforms and Quaternary deposits have occurred due to the glaciers' recession, as described above. New landforms have appeared. Accumulation landforms appeared in the front of glaciers and around glacier tongues in their marginal zones, i.e. on lowlands and valley floors abandoned by glaciers and in their fore-fields situated below the marginal zones (i.e. beyond the former reach of the glaciers, Figs 10–14). Erosion landforms, apart from pro-glacial river incisions (Fig. 15), prevail on the steep slopes of valleys and mountain massifs. Hence, the recession of the upper parts of glaciers results almost exclusively in erosion landforms, and the recession of the lower parts of glaciers leaves both erosion and accumulation landforms behind (with predominance of the latter).

The following new ice-free landforms have been observed: rocky and rock-and-weathering slopes, valley incisions (cut by glacial waters) of different types (gullies, gorges), and roche moutonnées. The decrease in glacier thickness uncovers nunatak slopes from top to bottom. The continuation of this process leads to the joining of nunataks into new mountain ridges or ranges. Once the ice is gone, these erosion landforms undergo mostly non-glacial denudation-erosion changes, especially if they are located on steep slopes and in significantly inclined upper parts of valleys. However, some of them, especially at the foot of the slope and in the lower parts of valleys, are being covered by new deposits, first of all moraine or glacifluvial deposits, but also talus, weathering and fluvial deposits.

Marginal zones began to appear in the front and around the lowest parts of glacier tongues in the beginning of the 20th century, when the glaciers were the widest (Maps 1, 2). These zones have been expanding due to frontal and lateral recession of glacier tongues ever since. Marginal zones develop from single ice-cored frontal moraine ridges into extensive complexes of different landforms, including intra-marginal sandurs with pro-glacial river beds, kettle holes, kames, eskers and low and narrow ridges of fluted moraines. Landforms of one type are transformed into landforms of another type, e.g. ice-cored moraine ridges into undulated moraine plains.

A particularly clear change was visible in the valley above the lowest part of Gåsbreen glacier due to its shortening in the period 2001–2004. The ice-dammed lake (Goësvatnet) was still there in 2000. However, in 2005, the lake did not exist, and

Fig. 15. Wide bed of the Vinda, which was a large pro-glacial river in the past (during the Little Ice Age) and declined due to Bungebreen glacier's recession. Photo: J. Dudek, 2008

its trough was in an initial stage of fluvial transformation (Ziaja, Ostafin 2007). By 2008, the terraced river bed built of alluvial deposits was formed, with waterfalls on rock outcrops (Figs 11, 13).

Landforms clearly stabilize in places where dead ice was never present or had thawed completely, which is expressed by a large decrease in the rate of landform evolution. This stabilization occurs in some of the smallest marginal zones and along edges of larger ones. However, dead ice is covered by superficial deposits in the majority of the marginal zones' area. The slow thawing of dead ice causes continuous geomorphic transformation and the lowering of marginal zones. The thawing of ice is stimulated by the influx of freshwater and seawater. This leads to the appearance of characteristic ephemeral forms of thaw holes and tongues of mud-flows (Fig. 16).

Of course, the cliffs of tidewater glaciers undergo the quickest of changes, i.e. retreat (Fig. 12). Stormbukta bay as a whole appeared due to the recession of Olsokbreen since 1900 (Wassiliew 1925). The new shore of this large bay is continuously transformed. The sea took 750 m of coastline and 11 ha of land along the northern shore of Stormbukta bay, and removed the coastline inland a distance of 5 to 250 m, mainly due to ablation of dead ice (Figs 12, 17) from 1990 to 2008. This process continues, which is evidenced by mud-flows from the lateral ice-cored moraine to the sea (Fig. 16). However, at a shorter distance to the glacier front, the land has widened by

Fig. 16. Mud-flow due to ablation of the dead-ice core of the Olsokbreen lateral moraine, on the northern Stormbukta coast. Photo: J. Niedźwiecki, 2008

Fig. 17. New northern coast of Stormbukta bay formed after the retreat of Olsokbreen glacier since the 1980s, due to ablation of dead-ice cores in the lateral moraine and sea action. Photo: J. Niedźwiecki, 2008

ca. 100–200 m (9 ha) due to marine accumulation of the former moraine and glacifluvial material from 1990 to 2008 (Map 2, Figs 12, 17, 18). The southern Stormbukta coast experiences the same processes. 2.3 ha was added to the land in a similar way on the eastern coast of the small bay at the front of Körberbreen glacier (Map 1).

The geomorphic transformation of areas devoid of glaciers in a warming climate is much slower (than described above) but noticeable. Changes in some parts of the shoreline are the most visible. Geomorphic sea action along the coast increased considerably (especially during storms) due to a significant shortening of the sea-ice season since the 1980s. Sea accumulation prevails in the bay south of the Palffyodden headland: the beach widens at a rate up to 1 m per year (Fig. 19). The reverse process, sea abrasion, acts on the Tørrflya plain built of Old-Holocene marine deposits: the beach coastline retreats up to 1 m per year, and the cliff behind the beach (cut from above during storms only) – up to 2 m per year (Fig. 20).

The reindeer population, regenerated in the 1990s, is a new geomorphic factor affecting large areas of western Sørkapp Land. There are simply too many reindeer, ca. 170 in 2008, because they are not threatened by any predators. They destroy vegetation and initiate or intensify erosion processes in many places by overgrazing, e.g. river erosion in the Hohenloheskardet valley and wind erosion on the Tørrflya (Fig. 21) and Bjørnbeinflya plains. Small dunes, which were overgrown and stabi-

Fig. 18. New northern coast of Stormbukta bay formed after the retreat of Olsokbreen glacier since the 1990s, due to sea action. Photo: J. Niedźwiecki, 2008

Fig. 19. Results of intensified geomorphic sea action in western Sørkapp Land during a few recent decades: the accumulation coast south of the Palffyodden headland. View to the north. Photo: J. Dudek, 2008

Fig. 20. Results of intensified geomorphic sea action in western Sørkapp Land during a few recent decades: the abrasion coast of the Tørrflya plain, ca. 9 m high, with an uncovered whalebone, in the right. Photo: J. Niedźwiecki, 2008

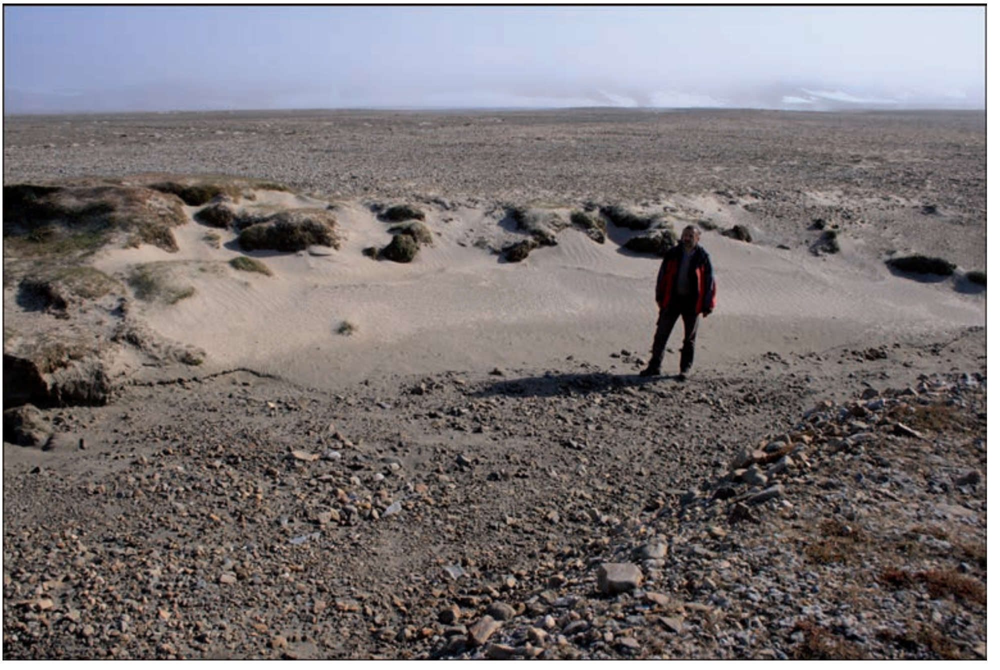

Fig. 21. Destruction of the small dunes, which is a result of damage to the vegetation cover due to overgrazing and trampling by reindeer on the Tørrflya coastal plain. Photo: J. Niedźwiecki, 2008

lized before (Gębica, Szczęsny 1988), have been made mobile by reindeer. Reindeer also impact microrelief on gentle slopes overgrown by tundra by trampling and thus forming so-called cattle terraces, e.g. at the foot of Sergeijevfjellet from the sea-side (Fig. 8).

Karst processes have intensified due to higher air temperatures and larger quantities of flowing water. Rapid development of karst holes was observed on the Olsokflya lowland. The holes were no deeper than 1 m during the summer of 1986. Some of the holes were 1.5–2.0 m deep in 2000, and at least 10–20 cm deeper in 2008. The enlargement of one of them resulted in the collapse of a cave (karst channel) roof just before Trollosen spring, which is a pro-glacial river (Fig. 7). The development of similar karst holes may also be observed above this karst channel.

Smaller changes in landforms include debris-flows on talus and talus-torrent fans as well as a halt in the development of nivation moraines.