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Application of remote sensing to topographic maps of polar areas

ABSTRACT: We propose contents of topographic maps for polar areas to be supplemented with such landforms that are easily identified during the analysis of air or terrestial photographs. Such landforms include rock outliers (monadnocks), glacial boundaries, a beach and thick mantles of tundra vegetation. All these landforms create together with fluvial and lake patterns a system of elements that enable location of users and therefore make preparation of other (*e.g.* geological, geomorphological or glaciological) maps possible.

Key words: Arctic, Spitsbergen, topographic maps.

Introduction

Recent studies of a natural environment of polar areas have been generally organized either due to their natural resources or significance in worldwide transformations caused by man. Such investigations usually end with map reports that can be prepared only if topographic maps in sufficiently detailed scales are available. They are badly needed for location of studied phenomena.

Several years ago a map of Quaternary landforms and sediments of the Hornsund Region in South Spitsbergen was prepared (Karczewski *et al.* 1984). At that time only the Norwegian topographic maps at a scale of 1:100,000 (Norge, Topografisk Kart over Svalbard: B12 Torellbreen, 1953, C13 Sörkapp 1947 and B11 Van Keulenfjorden, 1952) and for our work considerably enlarged, were available as a hypsometrical base. Among the advantages of these Norwegian maps were: multi-colored picture (contour lines — brown, water — blue, glaciers — greenish-blue and moraines — black), presentation of some landforms, and location of trapper huts and skerries. On the other hand, the small scale and standard contour intervals of 50 m could not be accepted, as these features made a precise location impossible (*cf.* Birkenmajer 1960, 1964; Karczewski *et al.* 1984).

Several more detailed topographic maps have been published lately for the Hornsund Region of Spitsbergen:

(*i*) Map of the Polish Polar Station in Hornsund at a scale of 1:500 (1984),
(*ii*) Map of the Polish Polar Station in Hornsund at a scale of 1:5,000 (1984),
(*iii*) Topographic map (10 sheets) of the Hornsund Region at a scale of 1:25,000 (1987).

In spite of a precise contour picture, all these maps are only slightly useful for fieldworks as they do not contain any of the landform symbols that are present in the aforementioned Norwegian maps. In polar areas such landforms are indispensible for location of observation sites.

Thus we faced serious difficulties when initiating, in the early eighties, a preparation of detailed geologic-geomorphologic maps of the Hornsund Region. We were restricted to a photogrammetric analysis, namely the photogeologic mapping (Lindner *et al.* 1985, 1989a, b). This mapping is based on analysis of air photos and starts with preparation of a hypsometrical background at a scale of 1:10,000. Then, using the same instrument (Topocart by C. Zeiss—Jena) and without disconnecting the system (*i.e.* air photos — coordinatograph — automatic plotting table) we were able to draw the boundaries of landforms and sediments identified during fieldworks. As the methodology of photogrammetric works has improved, we have already preparated seven maps (Fig. 1) with considerably enriched geologic-geomorphologic data.

Proposed supplementary elements for topographic maps of polar areas

The straightforward nature of our work with photogeologic maps of South Spitsbergen (Fig. 1) encourage us to present a proposal to supplement the topographic maps of polar areas with some extra elements that can be useful when using such maps in the field. These elements should be identified and drawn together with a hypsometrical picture of a studied area. We find it useful if the supplement contains not only rock outliers (monadnocks), glacial boundaries and crevasses, debris and ice-cored moraines, taluses, beaches, but also thick mantle of tundra vegetation (in wet sites), fluvial and lake patterns, and trapper huts.

Rock outliers (monadnocks)

In polar deserts larger rock outliers, and especially their groups undoubtedly create the outstanding and persistent landforms which can easily be recognized and located. On relatively flat and vast coastal plains (Fig. 2), the

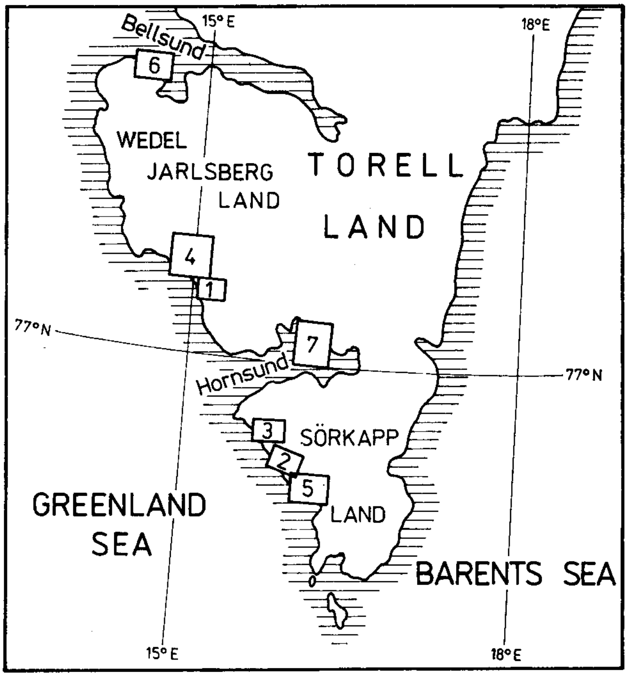

Fig. 1. Location sketch of South Spitsbergen with photogeologic maps at a scale of 1:10,000. 1 — forefield of the Nann and Torell glaciers (Ostaficzuk *et al.* 1980), 2 — forefield of the Bunge Glacier (Ostaficzuk *et al.* 1982), 3 — Slakli Valley Region (Ostaficzuk *et al.* 1986), 4 — interlobal zone of the Torell Glacier (Szczęsny *et al.* 1985), 5 — Hilmarfjellet Region (Szczęsny *et al.* 1987), 6 — forefield of the Renard, Scott and Blomli glaciers (Szczęsny *et al.* 1989), 7 — Treskelen-Hyrnefjellet-Kruseryggen area (Szczęsny *et al.* 1989)

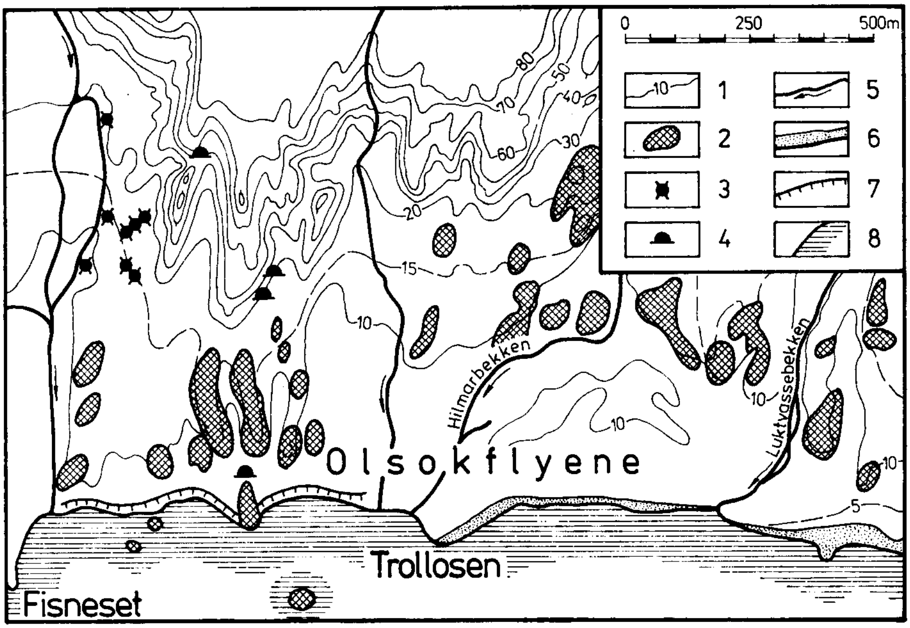

Fig. 2. Olsokflyene, based on the photogeologic map of Hilmarfjellet Region (Szczęsny *et al.* 1987). 1 — contour lines, 2 — rock outliers, 3 — sinkholes, 4 — caves, 5 — streams and lakes, 6 — beach (present storm ridge), 7 — edges, 8 — sea

position of these features indicates relationship between the Quaternary sediments and the bedrock. In the case of Olsokflyene (Fig. 2), such rock outcrops are the predominant features which are defined by one or two contour lines. They occur landwards but also emerge from the sea (skerries) between Fisneset and Trollosen where are accompanied by a rocky seashore with a cliff. Close to some of these inland features there are sinkholes and caves that indicate not only shallow bedrock but also its carbonate composition.

Glacial boundaries

Glacial boundaries are not so persistent as rock outliers, but nevertheless generally form quite stabile zones (Figs. 3—6), which can easily be identified on air photographs. A glacier boundary constitues an important reference line, useful in fieldwork location of older moraines or outcrops of pre-Quaternary rocks. A boundary of the Austre Torell Glacier (Austre Torellbreen) indicates a possible occurrence of a lateral depression between the glacier and the northern slope of the mountain massif (Fig. 3). On the other hand, a boundary

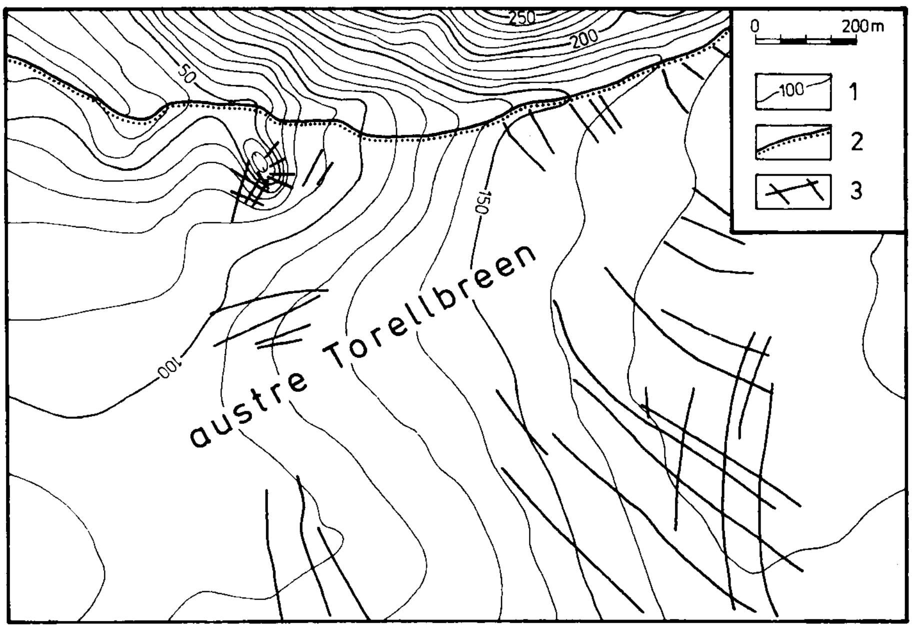

Fig. 3. Fragment of the Austre Torell Glacier (Austre Torellbreen), based on the photogeologic map of interlobal zone of the Torell Glacier (Szczęsny *et al.* 1985). 1 — contour lines, 2 — glacial boundary, 3 — glacial crevasses

of the Raudfjell Glacier (Raudfjellbreen) demarcates the glacier extent and its contact with an immence ice-cored moraine along its snout (Fig. 4). To the north of Bungeleira (Fig. 5) the glacier boundary is not only the glacier contact with terminal, lateral and median ice-cored moraines but also with heaps of ablation till on the glacier surface.

Glacial crevasses

Glacial crevasses are quite important but not long-lasting features in a glacial surface (Figs 3—6). Their development is usually connected with a rugged rock surface underneath the glacier: crevasses generally occur on bedrock elevations or close to ice cliffs of calving tidewater glaciers. In the Austre Torell Glacier, a crevasse system is also connected with occurrence of a huge glacial mill (Fig. 3). Crevasse patterns identified on air or terrestial photographs reflect glacial dynamics and if marked on a topographic map, they enable a choice of most convenient routes.

Debris and ice-cored moraines

Debris and ice-cored moraines comprise the present ice-cored moraines which indicate maximum extents of Spitsbergen glaciers during the Little Ice Age. Ancient terminal and lateral moraines of Holocene and Pleistocene age as well as nival moraines and rock glaciers are also enclosed here (Figs 4—6). All

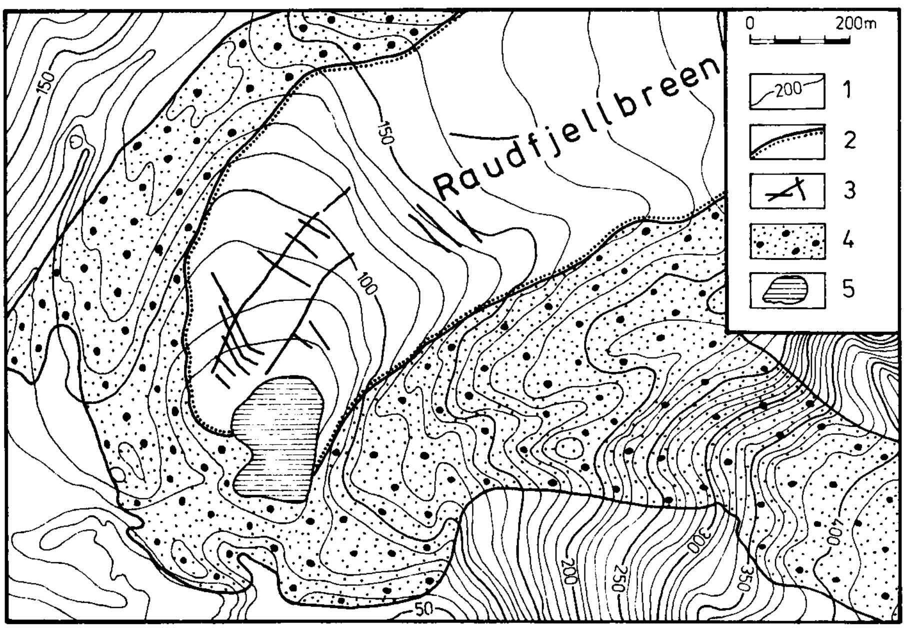

Fig. 4. Snout of the Raudfjell Glacier (Raudfjellbreen), based on the photogeologic map of interlobal zone of the Torell Glacier (Szczęsny *et al.* 1985). 1 — contour lines, 2 — glacial boundary, 3 — glacial crevasses, 4 — debris and ice-cored moraines, 5 — lake

these features are up to several dozen meters high and usually are considerably long and wide. They encircle the Raudfjell Glacier (Raudfjellbreen) and form a complex feature with the coalescing rock glacier in the east (Fig. 4). Ice-cored moraines always contain ice cores, melting of which results in development of

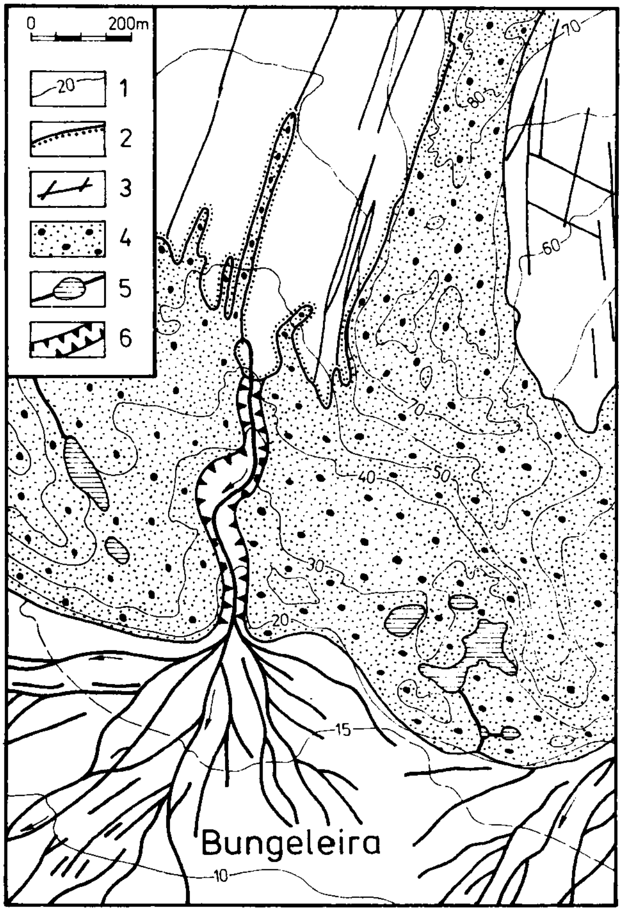

Fig. 5. Fragment of morainal zone of the Bunge Glacier, based on the photogeologic map of forefield of the Bunge Glacier (Ostaficzuk *et al.* 1982). 1 — contour lines, 2 — glacial boundary, 3 — glacial crevasses, 4 — debris and ice-cored moraines, 5 — stream and lake, 6 — gorge

thaw depressions with occasional ponds (Figs. 4—5). Moraines are locally complex features, composed of several overlapping ramparts (*cf.* Fig. 6).

Taluses

Taluses are considerably stabile in polar areas. Their sizes and development strongly depend on lithology of mountain slopes at foot of which they are located (Figs 6—7). At the foot of Gråkallen the taluses are steeper upslope and gently flow down (Fig. 6), whereas at the foot of Jens Erikfjellet they form a system of steep overlapping fans (Fig. 7). Individual taluses can easily be identified in the field. Thus their record on topographic maps is especially significant.

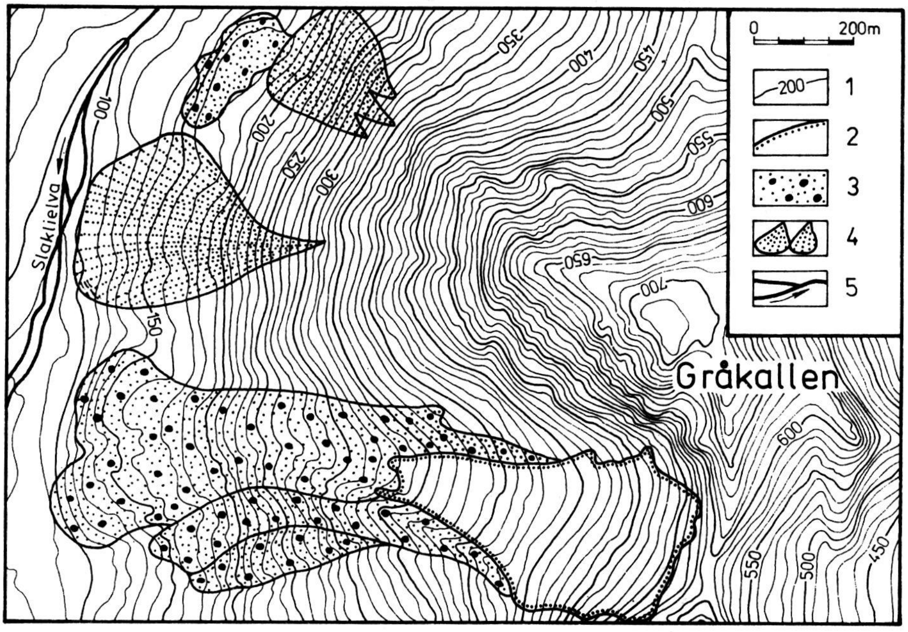

Fig. 6. Fragment of Gråkallen slope, based on the photogeologic map of Slakli Valley Region (Ostaficzuk *et al.* 1986). 1 — contour lines, 2 — glacial boundary, 3 — debris and ice-cored moraines (rock glaciers), 4 — talus, 5 — stream

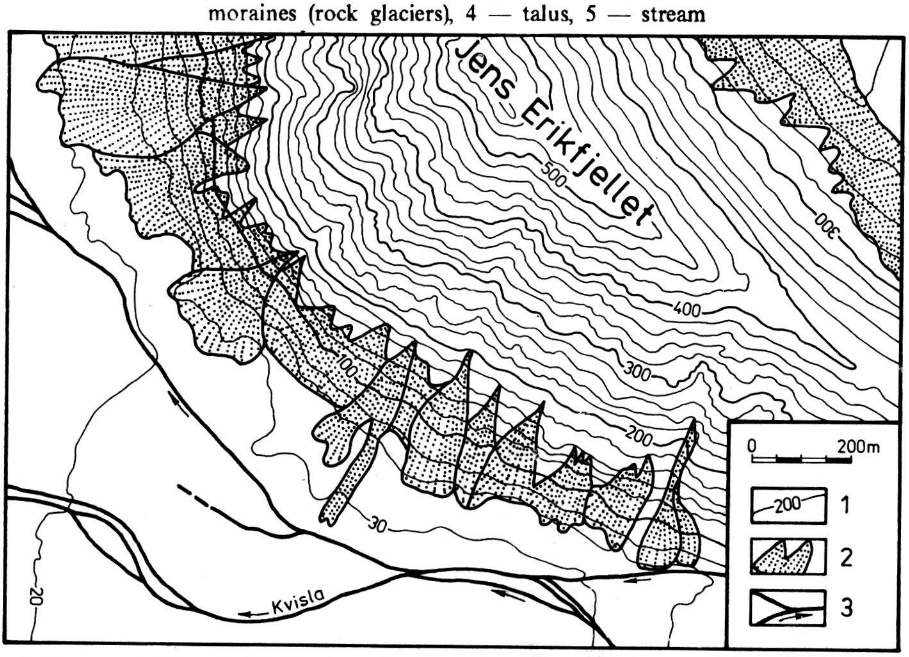

Fig. 7. Fragment of Jens Erikfjellet slope, based on the photogeologic map of forefield of the Nann and Torell glaciers (Ostaficzuk *et al.* 1980). 1 — contour lines, 2 — talus, 3 — stream

Beach

Beaches should above all be indicated on topographic maps as they are of primary importance if travelling by boat. Beaches in eastern Olsokflyene (Fig. 2) and Calypsostranda (Fig. 8) are represented by contemporary storm ridges composed of fine debris and with gentle seaword slopes. The latter permits safe landing and pulling of boats to protect them from being carried away during high tide. Moreover a beach acts as collector of driftwood, which is a most important fuel available in polar areas and is often used by research teams.

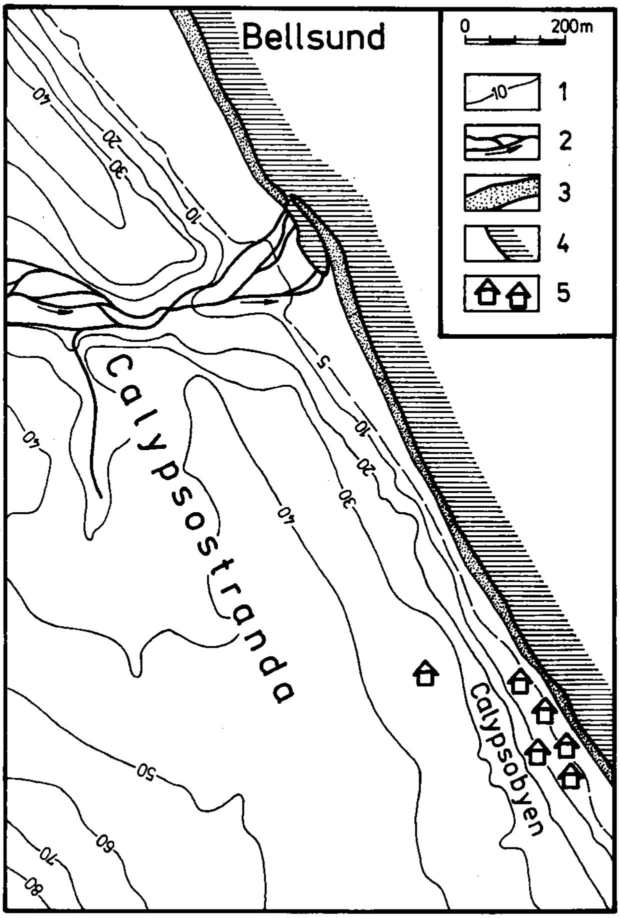

Fig. 8. Calypsostranda, based on the photogeologic map of forefield of the Renard, Scott and Blomli glaciers (Szczęsny *et al.* 1989). 1 — contour lines, 2 — streams, 3 — beach (present storm ridge), 4 — sea, 5 — trapper huts

Thick mantles of tundra vegetation

Thick mantles of tundra vegetation are particularly common on coastal plains and fill up almost every depression on marine terraces or in zones with meltwater outflow. They can easily be identified on air and terrestrial photographs. On Björnbeinflyene (Fig. 9) as well as in many other areas, central parts of depressions with mantle of tundra vegetation are occupied by periodical and permanent ponds. Most depressions developed due to melting out of stranded icebergs (Lindner and Marks 1989), or follow neotectonic phenomena (Lindner *et al.* 1986). If marked on topographic maps, the vegetation mantles being marsh- and wet-lands define the most convenient routes, especially if going on foot with heavy equipment.

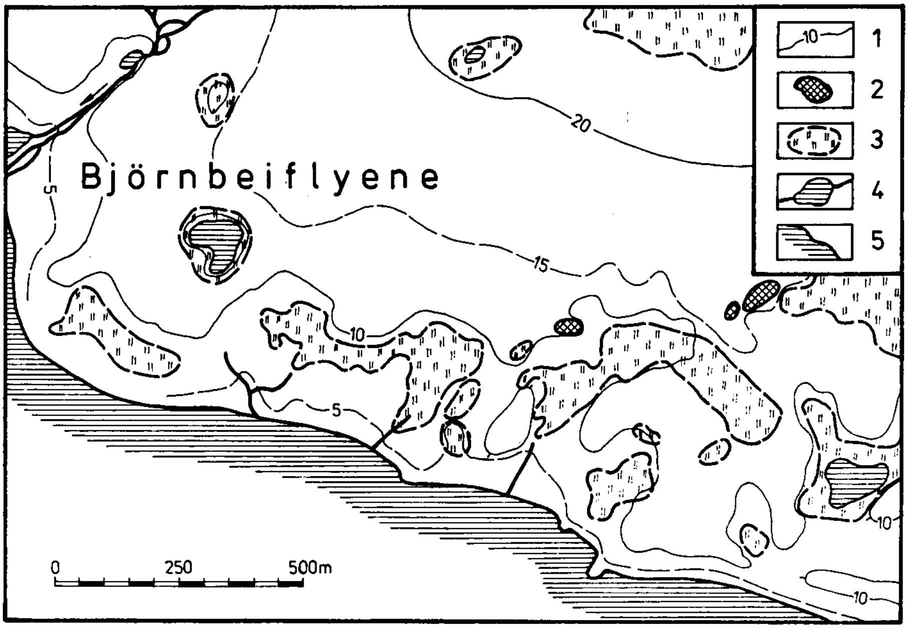

Fig. 9. Björnbeinflyene, based on the photogeologic map of Hilmarfjellet Region (Szczęsny *et al.* 1987). 1 — contour lines, 2 — rock outliers, 3 — mantles of tundra vegetation (wet-land), 4 — stream and lake, 5 — sea

Fluvial and lake patterns

Fluvial and lake patterns are commonly marked on all topographic maps of polar areas. We obviously noted them during photogeologic analysis (Figs 2, 4—9). Besides their location, also the shape enables to define their origin. Thus branching streams in Bungeleira (Fig. 5) indicate an alluvial fan whereas braided patterns of Slaklielva (Fig. 6) or in northern Calypsostranda (Fig. 8) are connected with meltwater outflow. Precise recording of hydrographic patterns on topographic maps of polar areas can also be applied in looking for drinking water and evaluation of depth of permafrost and therefore, possible development of frost structures.

Trapper huts

Trapper huts should be recorded especially on topographic maps of polar areas (Figs 8 and 10). Known location of such huts is important not only for planning of research expeditions for which they act many a time as the base stations. Such huts are also used during tourist excursions, either on foot or by boat, to say nothing of accidents and the following need to find a place to survive.

Final remarks

The proposed supplement to record on topographic maps of polar areas should not result in excessive effort by trained geodesists or photogrammetrists. Such topographic maps as insisted, have already been published for the Polish Tatra Mts (scale 1:10,000, 1984), the Alps (Silvretta-, Verstanda- u. Chammgletscher, 1:10,000, 1976), the Hindu Kush (Gletscherkarte Darrah-e, Issik-e Bala, 1:25,000, 1985), the Karakorum (The map of the Batura Glacier, 1:60,000, 1978) and Scandinavia (Hellstugubreen, 1:10,000, 1980), *i.e.* areas with glaciers or at least glacial landforms. All the proposed records are also presented together on a map of the forefield of the Bunge Glacier (Bungebreen) in Spitsbergen (Fig. 10). Such a map seems to be a proper topographic base for fieldworks in polar geology, geomorphology, hydrography, geophysics, pedology, biology, studies of permafrost and protection of the environment. Maps with such contents can also be helpful in planning of routes for research and tourist teams, travelling either on land or by sea.

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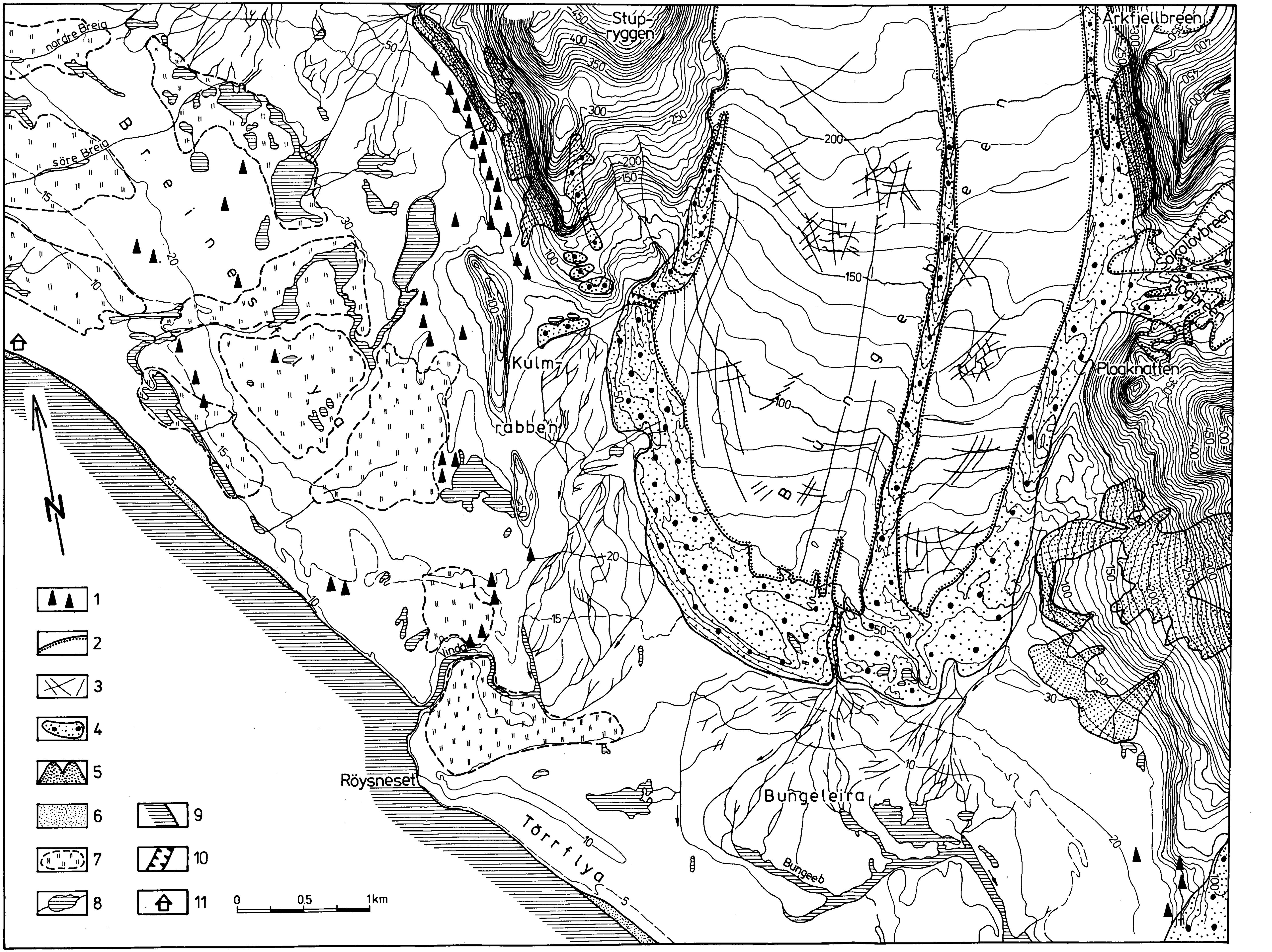

Fig. 10. Topographic map of the forefield of the Bunge Glacier on hypsometric base of the photogeologic map of this area after Ostaficzuk *et al.* (1982). 1 — rock outliers, 2 — glacial boundary, 3 — glacial crevasses, 4 — debris and ice-cored moraines, 5 — talus, 6 — beach (present storm ridge), 7 — mantles of tundra vegetation (wet land), 8 — stream and lake, 9 — sea, 10 — gorge, 11 — trapper hut

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Streszczenie

Autorzy artykułu przedstawiają propozycję wzbogacenia treści map topograficznych obszarów polarnych na podstawie doświadczenia zdobytego w zakresie sporządzania metodą analizy fotointerpretacyjnej map w skali 1:10 000 (fig. 1) oraz spostrzeżeń podczas prac terenowych na Spitsbergenie. Propozycja dotyczy takich elementów rzeźby, które są łatwe do rozpoznania na zdjęciach lotniczych lub naziemnych a ułatwiają lokalizację i poruszanie się w terenie. Mapy topograficzne obszarów polarnych oprócz dokładnego rysunku poziomicowego powinny zawierać takie wydzielenia jak: skałki — w tym szkiery (fig. 2), kontury lodowców i szczeliny lodowcowe (fig. 3—6), moreny — w tym moreny niwalne i lodowce gruzowe (fig. 3—6), stożki usypiskowe (fig. 6—7), plażę (fig 2 i 8), skupienia roślinności tundrowej (fig. 9), rzeki i jeziora (fig. 2, 4—9) oraz chaty traperskie (fig. 8 i 10). Wzbogacone podkłady topograficzne stanowią podstawę do sporządzania szczegółowych map tematycznych i różnokierunkowych prac terenowych (m.in. geologicznych, geomorfologicznych, biologicznych, pedologicznych). Takie mapy topograficzne są nieocenione przy planowaniu zarówno marszrut lądowych (ze względu na zaznaczenie na nich szczelin lodowcowych, rzek i podmokłości w strefie skupień roślinności tundrowej) jak morskich (zaznaczenie szkierów i plaży). Pozwalają również wyznaczać dogodne miejsca lokalizacji stacji badawczych i obozowisk (zaznaczenie chat traperskich i źródeł wody pitnej). Z tych względów mogą być także wykorzystywane jako mapy turystyczne.