Rock glaciers and relict debris bodies in Central North Iceland

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ROCK GLACIERS AND RELICT DEBRIS BODIES IN CENTRAL NORTH ICELAND

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Abstract

Active rock glaciers exist in the mountains of north and east Iceland and are also found very scattered in the south and west Iceland. They are normally found below N and NE facing cirques at altitudes higher than 800m but are occasionally detected at elevation down to 600m. In the mountainous costal areas of west, north west, north and east Iceland exist numerous debris bodies fulfilling all criteria requested for relict rock glaciers. In some cases we have continuous sequence from active rock glaciers at the top, changing over to relict debris bodies at lower altitudes. Spatial distribution of these debris formations in central north Iceland has been analysed and are discussed.

Introduction

Rock glaciers (RG) are tongue shaped bodies or lobate features generally composed of angular boulders. Their form resembles usually the form of a small outlet glaciers, in active state often with steep 20-40m high fronts and normally showing well defined surface relief. Rock glaciers are normally devised into three stages of activity; active, inactive and relict. Active RG are considered to show the most expressive indication of permafrost in alpine topography and relict RG are considered to show expression of former cooler climate (permafrost). Rock glaciers are found at various cool climate conditions, both in dry continental mountains as well as in maritime regions. At the present, they are frequently found in mountains or costal areas adjacent to present glaciers (Humlum 1996). Definition and mapping of rock glaciers has not been extensive in Iceland as well as (until recently) in other Nordic countries (Svenson 1989).

Topography and bedrock

Tröllaskagi is a mountainous peninsula between the glacially eroded fjords, Skagafjörður and Eyjafjörður in central north Iceland, see figures 3 and 10. The bedrock of Tröllaskagi is what remains of an old plateau where mountain-tops rise frequently above 1200-1300m peaking up to 1536m in the highest mountain Kerling. The bedrock consists of late tertiary (8-13 M.y.) basalt lavas, frequently 5-15m thick, intercalated with scattered relatively thin sediments. Several relict central volcanoes exist buried in the basalt plateau, consisting of various volcanic and sedimentary rock types and tectonic structures, resulting in higher susceptibility to rock weathering than the "average" plateau basalt.

Present climatic conditions in the Tröllaskagi peninsula show annual mean temperature of 3-4 °C at sea level and precipitation of 1500-1700 mm in the upper part of the mountains. The Tröllaskagi has been more or less ice-free during at least the last 10 ka (or even longer), as supported by dated shell remains, (11,2 ka C^{14} BP uncorrected) in costal sediments at the Sauðárkrókur town in Skagafjörður and 12,7 ka (C^{14} BP uncorrected) in Héðinsfjörður and 42 ka at Almenningar west from Siglufjörður).

Figure 1. Composite talus derived and glacial derived rock glaciers near Holar in Tröllaskagi.

Mapping, definition and distribution

Rock glaciers in the mountains of Tröllaskagi, have been mapped discontinuously by the present author during the last 25 years, both in the field and by interpretation of aerial photos. The definition criteria used for active, inactive and relict rock glaciers has been described in various papers (e.g.: Warhaftig and Cox 1959; Corte 1987; Barsch, 1996, Humlum; 1998.

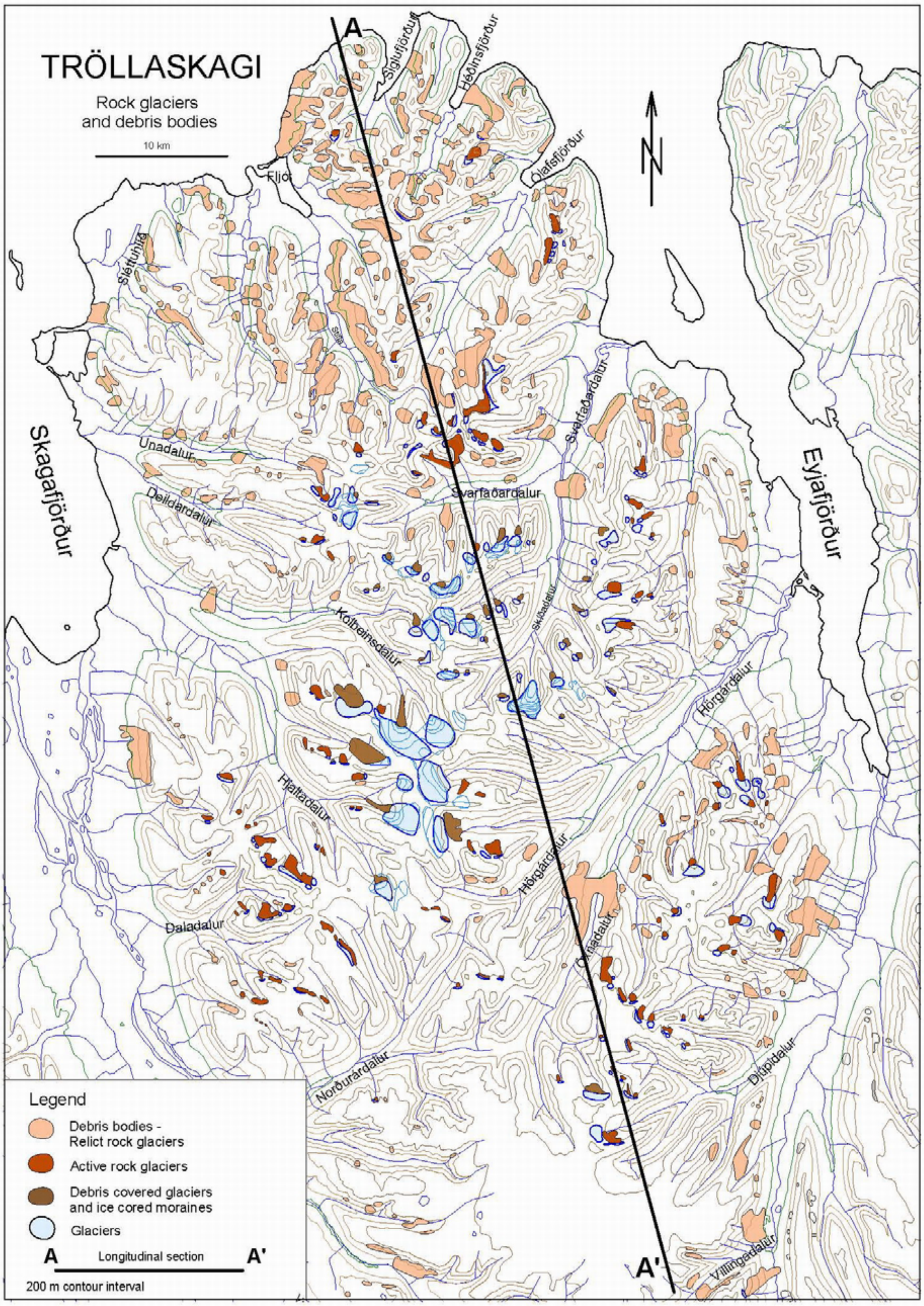

Figure 2. Map of the Tröllaskagi peninsula showing distribution of rock glaciers / debris covered glaciers

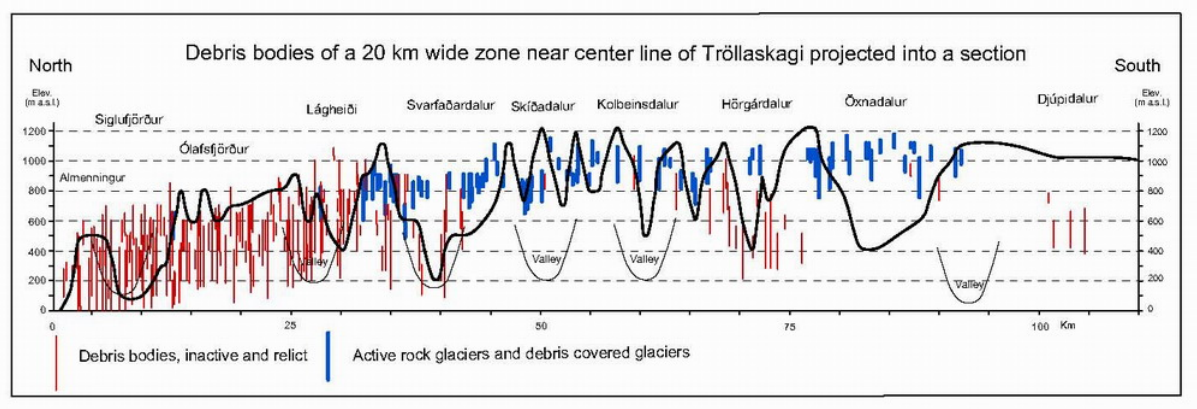

Figure 3. Section along Tröllaskagi showing active and relict rock glaciers of a 40 km wide zone, projected into section A-A'. In the central area of Tröllaskagi, only active RG exist at high altitude, probably indicating existence of glaciers there, during the formation period of relict RG in peripheral area of Tröllaskagi.

Activity and spatial distribution

All activity stages of rock glaciers are found in the Tröllaskagi mountains, active, inactive and relict. The active RG are considered to have formed during the Holocene, and the inactive RG are possibly also mainly from the Holocene time (some of them could possibly be older). Approx 570 rock glaciers have been defined, but the number might increase considerably, depending on how to define composed small lobate RG and various composite bodies of relict RG. Of the rock glaciers 165 (approx 30%) are defined active and 402 (approx. 70%) inactive and relict (most of them relict). A similar ratio of activity has been described in the Disco area W-Greenland (Humlum 1998, and in Alaska and middle west USA (Wahrhaftig and Cox 1959).

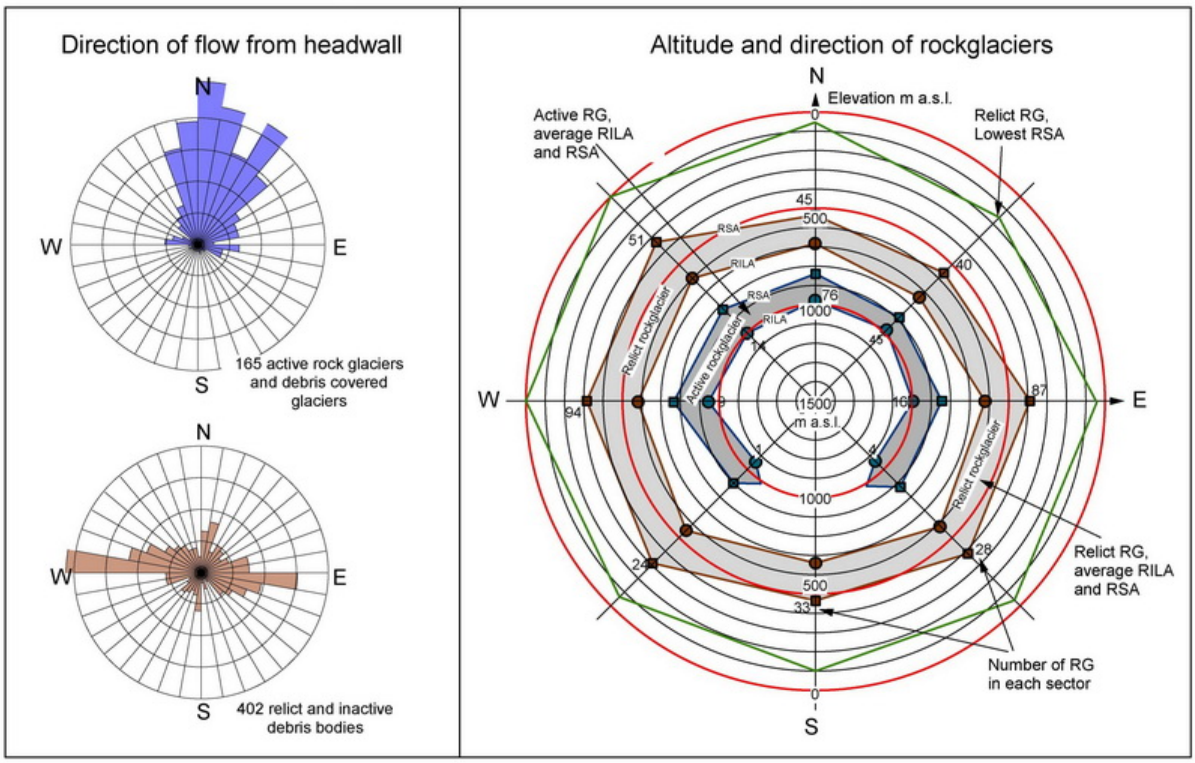

Figure 4a. Rose diagram showing directional trend of active rock glaciers and relict debris bodies defined as relict rock glaciers. Figure 4b. Diagram showing average elevation and direction of RILA and RSA for active rock glaciers and relict debris bodies defined as relict rock glaciers.

Active rock glaciers

Most of the active rock glaciers are glacially derived, showing ice on the surface in the upper part (Corte 1987). The lobate rock glaciers are normally talus derived, much smaller or especially shorter

and relatively thicker (thickness/length) than the others. these are often located side by side under steep walls or in north heading cirques (see figure 1). Both the glacial- and talus derived genetic types of rock glaciers occur in composite various stages where one tongue is overridden by a younger one sometimes forming layered pile of ice cored debris bodies consisting of up to 4-5 layers (see figure 1). The average size of active rock glaciers in Tröllaskagi peninsula is approx. 0.5 km^2 forming a total area of almost 82 km^2.

Highest frequency of the active debris bodies is heading towards N and NNE with the average inclination of 17°. The average altitude of RILA (rock glacier initiation altitude (see definitions by Humlum 1988 for explanations of RILA, RAL, RSA) is 986 m a.s.l. and average RSA (rock glacier snout altitude) is at 853 m a.s.l., thus covering an average altitude difference of 133 m. The glacially derived rock glaciers extend over considerably greater altitude difference compared to the talus derived. The creep rate of several active RG has been measured as 0,2-1m / year.

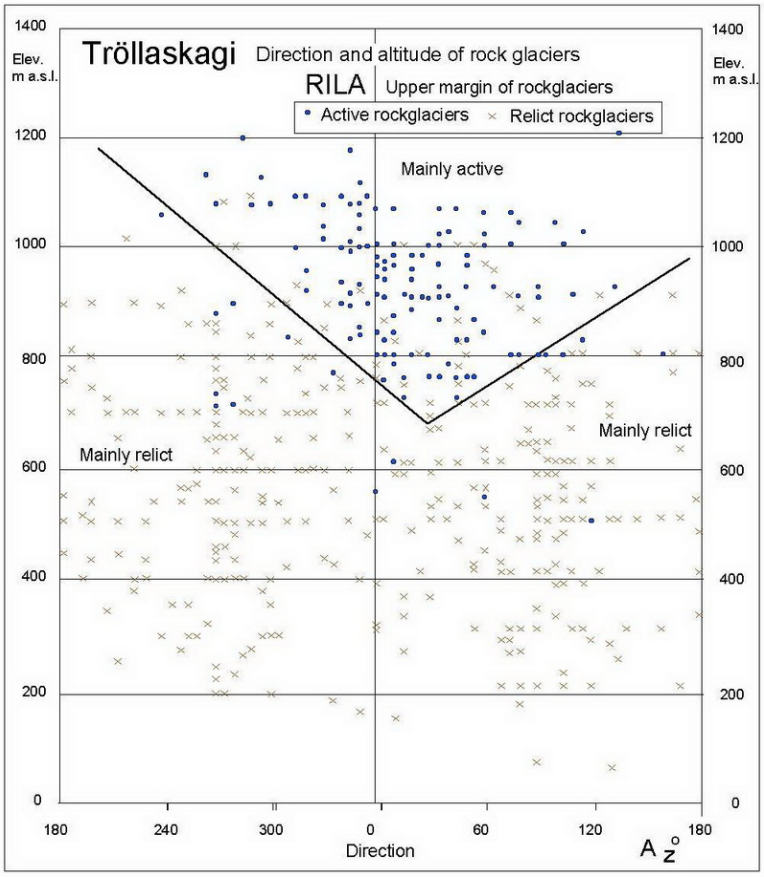

Figure 5. Direction and elevation of individual active rock glaciers and relict debris bodies.

Relict and inactive rock glaciers

Over 400 debris bodies in the Tröllaskagi area. have been defined as relict or inactive rock glaciers. The definition criteria for relict RG and the recognition of individual bodies is mainly based on surface appearance and relief (frequently defined by using aerial photos as well as in the field). The definition is also based on internal structure, layering and on grain size distribution, compared to grain sizes of other kind of sedimentations. The material and grain size distribution resembles the internal character of active rock glaciers, described in such literature (e.g. Evin 1987) and often also have grain distribution like Icelandic glacial moraines.

The average size of the debris bodies in the area, defined relict rock glaciers is approx. 0.8 km^2 forming a total area of 320 km^2. Highest frequency of the inactive and relict debris bodies are facing towards N-NNW and less frequency is facing E-SES. The average inclination of these bodies is 13°. Less frequently the relict rock glaciers is facing north and south. The average altitude of RILA is 629 m a.s.l. and average RSA 403 m a.s.l., thus covering a height difference of 226 m.

The RILA of both the active and relict rock glaciers is generally about 200 m lower altitude in the northern part of the peninsula compared to the southern part. Also there is a great increase in number and average size of debris bodies towards north, with high frequency of relict RG and lower ratio of the active ones. On the other hand, the relict debris bodies almost disappear in the innermost part of the deep walleyes in the middle part of the Tröllaskagi but increase in number and size towards the costal mountains of Skagafjörður and Eyjafjörður (fig. 1).

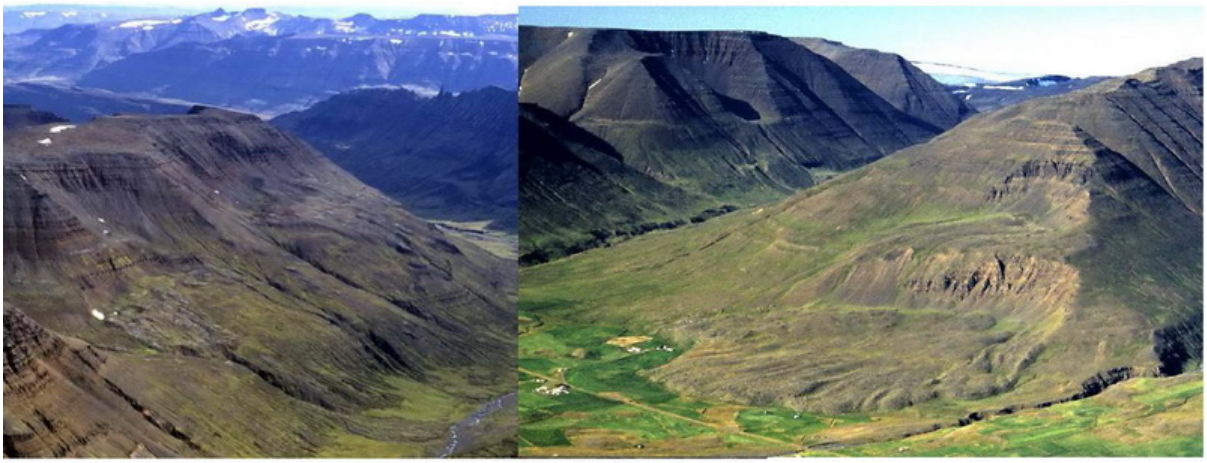

Figure 6. Debris bodies most probably of relict rockglaciers in Eyjafjörður.

Figure 7. Debris bodies of relict/inactive stratified rockglaciers at the sea shore west of Siglufjörður. The debris bodies are resting on stratified gravel containing shell remains C^{14} 42 ky. old.

Figure 8. Stratified debris bodies at the sea shore west of Siglufjörður. Layers of very coarse grained subangular and angular rock fragments inbetween more fine grained and silty sediments

On the other hand the greatest number of the active rock glaciers is found in the central part of the Tröllaskagi peninsula. The creep rate of several debris bodies or relict RG has been measured as 0,1-0,6m / year. Traditionally these debris bodies in the Tröllaskagi area as well as elsewhere in Iceland have previously been described as sedimentations formed by bergsturz (Jónsson 1976, Sigurðsson 1990, Hjartarson 1982 and 1998), and this seems to be consistent to what is widely cited or referred to as misinterpretation in papers on rock glaciers (Barsch 1996, Giardino, Shroder and Vitek 1987).

Rock glaciers in other areas of Iceland

Although active RG and ice cored moraines are most frequent and best developed in the Tröllaskagi area, central north Iceland, such RG features also exist, almost up to the same degree in the peninsula east of Eyjafjörður as well in the mountains south of Vopnafjörður and in the mountains of east Iceland south from Héraðsflói. Scattered active RG and ice cored moraines exist in the highest mountains of east Iceland. Additionally scattered active RG are found in the surrounding mountains of Vatnajökull and a few near Langjökull, see figure 9 for brief locations..

Debris bodies classified as relict rock glaciers (and formerly ice cored moraines and debris covered glaciers) are very frequent in the peripheral range of the Vestfirðir (north west peninsula). They exist in the Snæfellsnes peninsula and in the alpine mountains of Faxaflói (Esja - Skarðsheiði). In northern Iceland the debris bodies are frequent in the high- and costal mountains of Húnaflói and Skagafjörður area, culminating around Eyjafjörður (both sides). In east Iceland the relict debris bodies are frequent in the mountains south of Héraðsflói, gradually decreasing south to the Djúpivogur area. From there (Djúpivogur) such relict debris bodies are very rare in south Iceland, along the inland and the south coast to Faxaflói.

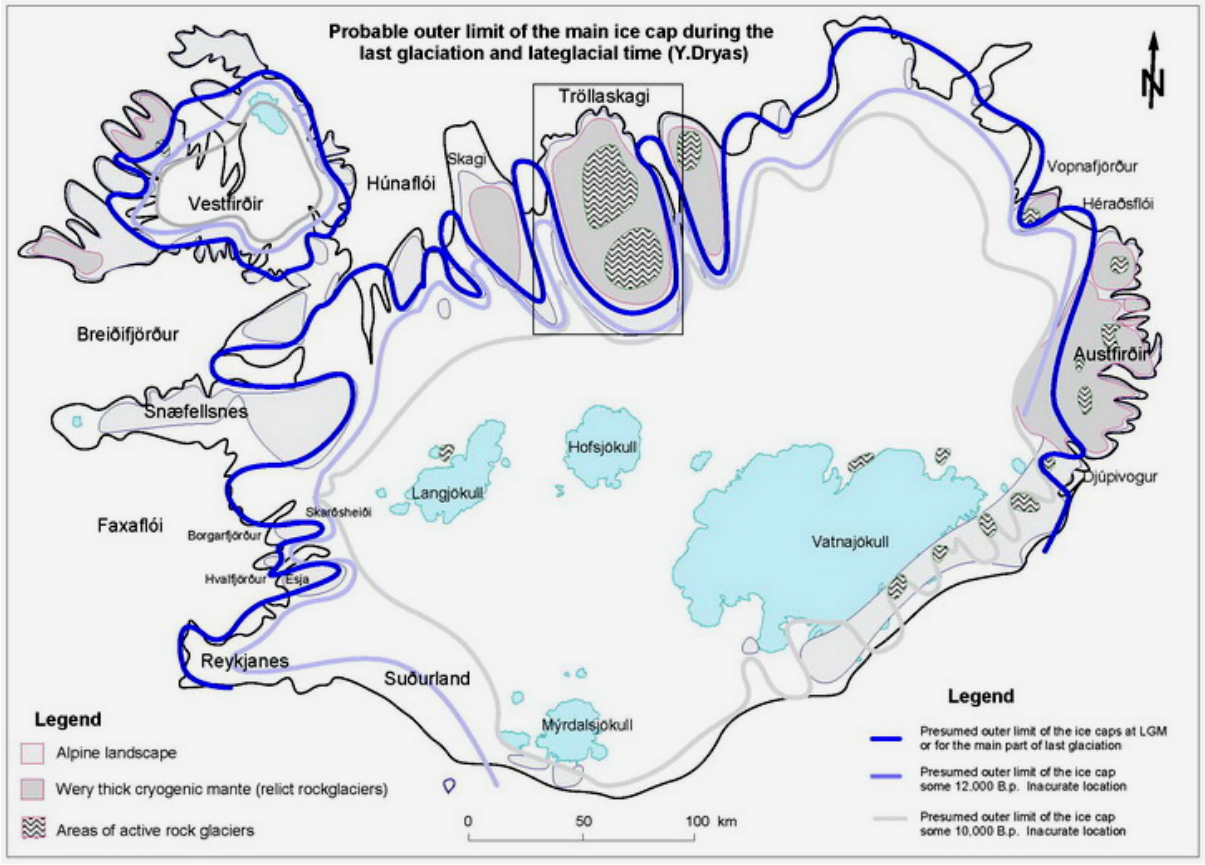

Figure 9. Iceland, distribution of rock glaciers areas and possible outer limits of the ice cap during considerable part of last glaciation.

Conclusion

Rock glaciers of all stages of activity (active, inactive and relict) exist in the mountains of Tröllaskagi middle north Iceland. The active RG are formed during the Holocene time with some periods of varying production activity resulting in layered or stratified rock glaciers.

The formation of relict rock glaciers probably took place during the Weichselian glaciation and late glacial time. At the northernmost coast of Tröllaskagi, sea shore sediments are encountered, containing shell remains expressing with dated carbon figures of over 42 ka (conventional ^{14}C BP). Directly on the top of these sea shore sediment exist relict debris bodies of relict RG presently creeping slowly towards the cost (Figs. 7 and 8). Numerous debris bodies, defined as relict rock glaciers, designate no major glaciers in the northern part of Tröllaskagi area during last glaciation.

Glacial moraines in the Skagafjörður district in addition to dated shell remains from the town Sauðárkrókur and Héðinsfjörður, indicate limited glaciers and no major glaciers in the Tröllaskagi area in lateglacial time. Distribution of debris bodies defined as relict rock glaciers in the peripheral range of the peninsula, and the low frequencies of these in the middle part of Tröllaskagi indicate valley glaciers of limited extent in the area at least during and since late glacial time.

Dated shell remains from the Reykjanes peninsula (SW Iceland) show measured dating figures in the range of 20-35 thousand years and dated volcanic rock formed over 40 thousand years ago from the same area, indicate limited glaciers in SW Iceland during the later part of last glaciation. (No dated shells have been found in Iceland from the period 13-20 thousand years ago, probably as a result of relatively low sea level during that period. The dated shell remains and rock from the Reykjanes-Faxaflói area support limited extent of the inland ice cap during Weichselian glaciation, making possibilities for growth of rockglaciers in the peripheral mountains of Iceland.

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