Altitudinal trends of talus-derived lobate rock glaciers on Disko, central West Greenland

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Talus-derived lobate (TDL) rock glaciers follow the altitudinal trend of the equilibrium line (ELA) on contemporary glaciers, and based on an analysis of a cross-section, North Disko, it is suggested that the vertical distance between the zone of TDL-rock glaciers and the lowermost occurrence of tongue-shaped rock glaciers relate to the amount of precipitation.

Key words: *Talus-derived lobate rock glacier, Climate, Palaeoclimate, Central West Greenland, Disko, Little Ice Age.*

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Talus-derived lobate rock glaciers are small rock glaciers which take the form of lobes, covered by angular rock waste, that generally head in steep mountain walls (Fig. 2). Beneath the surface layer of coarse debris, more fine-grained sediment is usually found. Active lobate rock glaciers have a steep, unstable front at, or near, the angle of repose, while inactive and fossil forms usually appear more subdued. Talus-derived lobate rock glaciers (abbreviated as TDL-rock glaciers) are abundant on Disko island, central West Greenland (54°W, 70°N, Fig. 1, see also Humlum 1983). Based on altitudinal trends of TDL-rock glaciers in a transect across the northern part of the island, some considerations on climatological requirements for initiation and growth of this rock glacier type will be discussed.

ROCK GLACIERS IN PALAEOCLIMATIC STUDIES

An assessment of the climatological requirements for TDL-rock glacier activity is valuable especially from climatic and palaeoclimatic points of view. That rock glaciers and rock glacier sequences can be used parallel to glacial moraines for reconstructing outlines of past climatic history has been established since the work of Wahrhaftig and Cox (1959) on rock glaciers in Alaska. The initiation and growth of rock glaciers have since been used as indicators of periods of climatic deterioration. Several investigators have assumed periods of rock glacier activity to be characterized by low temperatures and low precipitation because, otherwise, normal glaciers would probably have developed instead. Also pointing toward a dry climate is the supposition about importance of the Balch ventilation for rock glacier vitality (Thompson 1962), a mechanism which is impeded by a very heavy snow cover. Heuberger (1966), however, stressed the importance of the seasonal distribution of solid precipitation, and suggested that the growth of a sequence of rock glaciers in the eastern Alps was initiated during a period characterized by heavy summer snowfalls.

Fig. 1. Disko, central West Greenland. The investigated transect is shown by grey screen.
Fig. 1. Disko, Vestgrønland. Den undersøgte zone er vist med grå raster.

In the last few years, papers suggesting a more explicit formulation of climatic requirements for rock glacier activity have appeared (Kerschner 1978, 1980 and Haeberli 1982). In these studies the distribution of fossil (i.e. without ice, cf. Barsch and King 1975) rock glaciers and the equilibrium line on contemporary glaciers are used to estimate palaeo-temperatures and former amount of precipitation. Fundamental for this approach is the conception of rock glaciers as permafrost features, and that their lo-

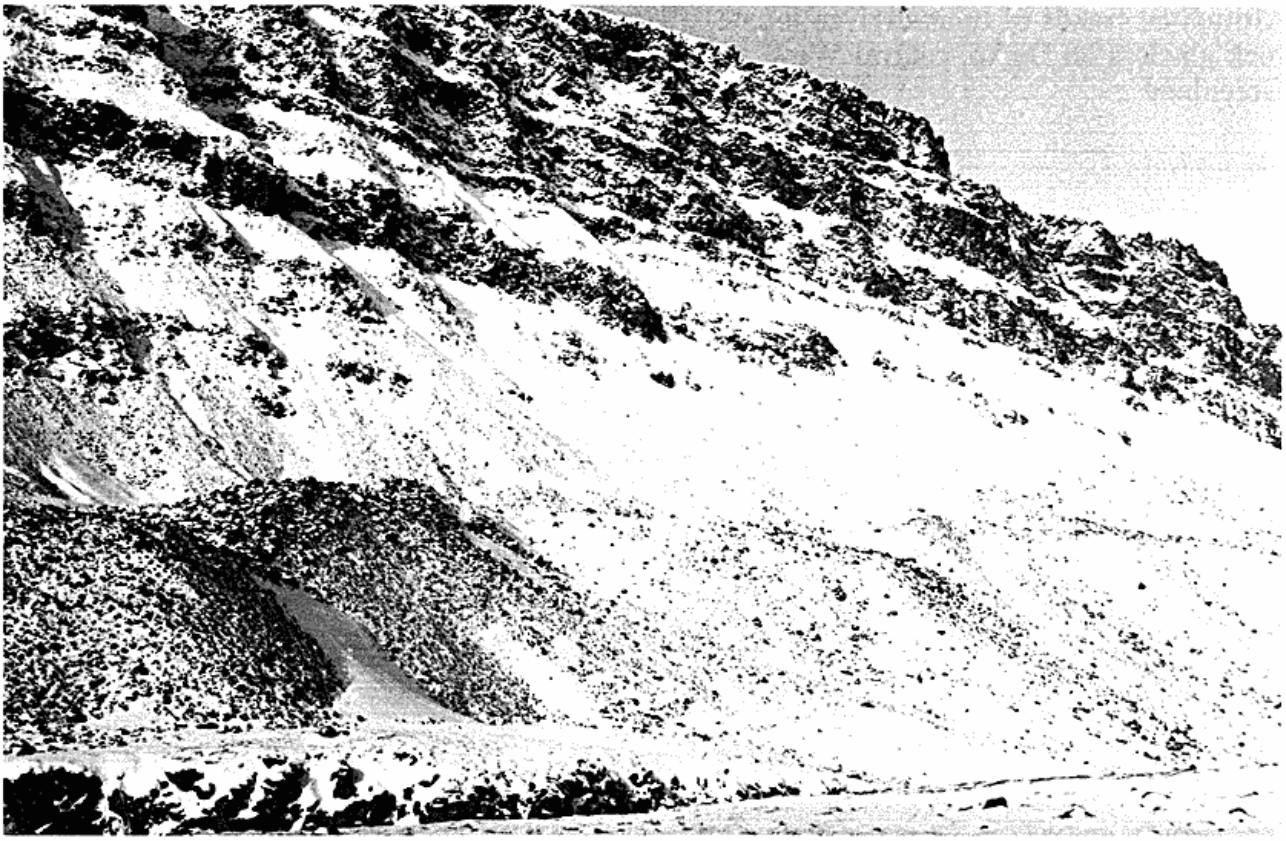

Fig. 2. Inactive, talus-derived lobate rock glaciers lining NE-facing mountain wall near Godhavn, southern Disko. The 20-30 m high rock glacier terminus is about 500 m a.s.l. Top of mountain wall above is about 800 m a.s.l. 29.09.1983.

Fig. 2. Inaktive TDL-blokgletschere ved foden af NØ-exponeret fjeldvæg nær Godhavn, sydlige Disko. Blokgletscherfronten er 20-30 m høj. Fjeldvæggen bag blokgletscherne er ca. 300 m høj, toppens absolutte højde er omkr. 800 m. 29.09.1983.

wermost occurrence indicates the lower limit of discontinuous permafrost at the time of rock glacier activity. As a result of studies of recent rock glaciers, a mean annual air temperature has been attached to rock glaciers, according to aspect and type of surrounding terrain. (e.g. Haeberli, 1982).

Most investigators of rock glaciers have concentrated on the analysis of large, tongue-shaped rock glaciers, while the smaller lobate rock glaciers (Fig. 3) appear to have attracted less interest. In view of the above-mentioned works treating the distribution of fossil rock glaciers in detailed palaeoclimatic studies, it seems appropriate howver, to consider the climatic characteristics of initiation and growth of the smaller rock glacier types, also. An attempt to gain preliminary insigtht into this problem will be presented below.

The study of rock glaciers also has some direct implications for our understanding of recent climatic conditions in areas with active rock glaciers. Because the establishment and survival of ice bodies – whatever the precise origin – in rock glaciers among other things must be a complex function of responses to temperature, insolation, and winter- and summer precipitation over a period of time (say, 10 to 100 years), the altitudinal distribution and-trends as well as origin of these ice bodies also contain unique climatic information on a macroscale, much the same as glaciers do. The importance of this type of information is emphasized, because most areas with rock glaciers occur at high altitudes or high latitudes, where weather stations are sparse and often confined to coastal- or valley sites at low elevations.

OBSERVATIONS

In figure 4 are shown the altitudes for the lower end of rock glaciers found in a 15 km wide transect across northern Disko (Fig. 1). For the TDL-rock glaciers, due to their small length, no great difference in altitude exists between head and terminus.

Judging from weathering of boulders and the degree of lichen cover, most TDL-rock glaciers on Disko seem to have been inactive, or even fossil, since the close of the Little Ice Age (ending about AD 1900 in West Greenland; see e.g. Weidick 1968). Some tongue-shaped rock glaciers

may still be active (Humlum 1983), but probably the majority has been inactive since around AD 1900, again judging from weathering and lichen cover.

The rock glaciers shown in figure 4 were identified in the field or from aerial photographs (1:55000 and 1:35000). Elevations were found from topographic maps (1:250000) with contour interval 50 m. Elevations between contours were interpolated and based on the topographic form between contours. Altitudes are estimated to be accurate within a range of ±25 m.

Also shown in figure 4 is the distribution of Little Ice Age equilibrium lines corresponding to 35 glaciers. The equlibrium line altitude (ELA) was reconstructed from fhe former outline of the glaciers, using a steady-state accumulation area ratio of 0.65. This value was used as several studies (e.g. Meier and Post 1962, Glen 1963, Grossval'd and Kotlyakov 1969, Gross etal. 1977) indicate that for steady-state glaciers the accumulation area/total area ratio varies between 0.6 and 0.7. The Little Ice Age glacier outline and ELA were determined as described for rock glaciers above.

Tongue-shaped rock glaciers, which on Disko with few exceptions can be classified as glacier-derived (Humlum 1983), clearly reach considerably lower altitudes than both TDL-rock glaciers and Little Ice Age ELAs. Of greater interest is, however, the coincidence in the investigated transect between ELAs and TDL-rock glaciers. As shown in figure 4, they follow each other with no greater difference in altitude than 50-100 m, which apparantly suggest that climatic prerequisites for initiation and growth for this rock glacier type and normal glaciers in the transect are more or less identical.

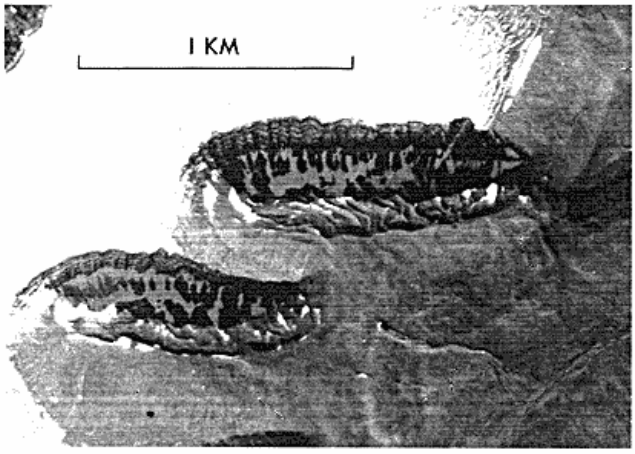

Fig. 3. TDL-rock glaciers as seen in vertical aerial photographs. North toward bottom of picture, West Disko, 27.08.1964. Reproduced with permission A 251/84 of the Geodetic Institute, 268F/224.

Fig. 3. Lodret flyfoto af TDL-blokgletschere, vestlige Disko, 27.08.1964. Nord er nedad.

The coincidence does not appear to be incidental, e.g. by comparing TDL-rock glaciers and glaciers with different aspect. This is demonstrated by figure 5, where the

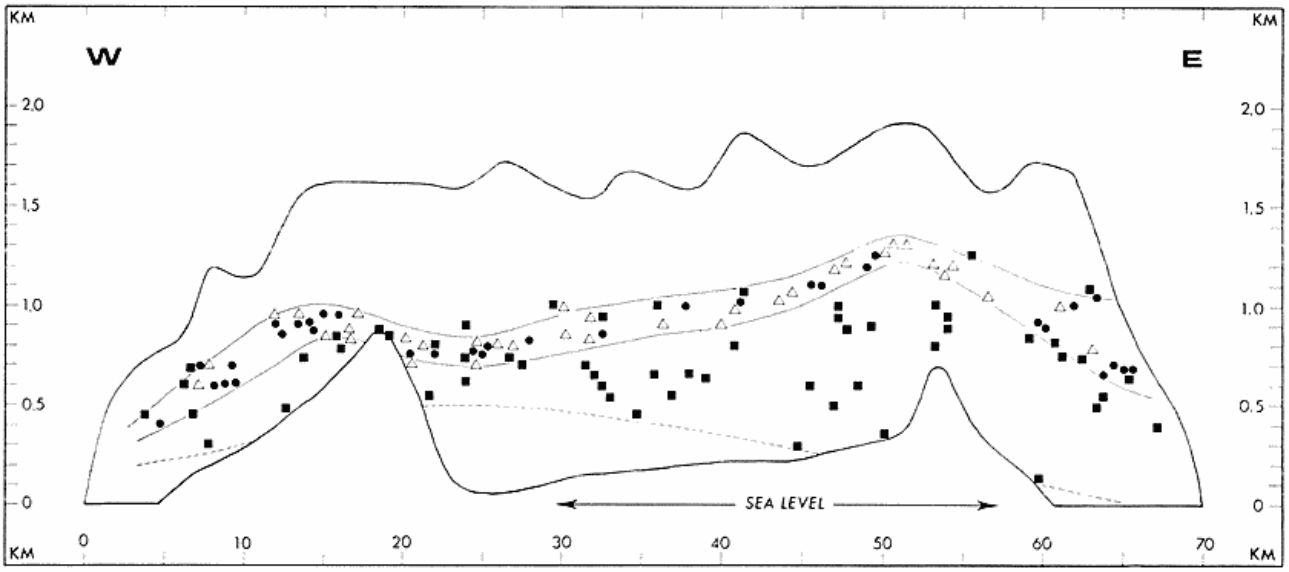

Fig. 4. East-west transect of North Disko (Fig. 1). The distribution of TDL-rock glaciers is shown by black circles, glacier-derived tongue-shaped rock glaciers (terminus) with black squares, and Little Ice Age equilibrium lines are shown by open triangles. Thin lines designate the zone of TDL-rock glaciers and Little Ice Age ELAs, while the dotted line below indicates the lower limit of tongue-shaped rock glaciers in the transect. Heavy lines above and below show the upper and lower limit of terrain in the transect.

Fig. 4. Øst-vest snit gennem det nordlige Disko (fig. 1). Terminus af tungeformede blokgletschere er vist med sorte firkanter, TDL-blokgletschere med sorte cirkler, og ligevægtslinier under Den Lille Istid med åbne trekanter. Øvre og nedre grænse for terræn i undersøgelsesområdet er angivet med kraftig linie.

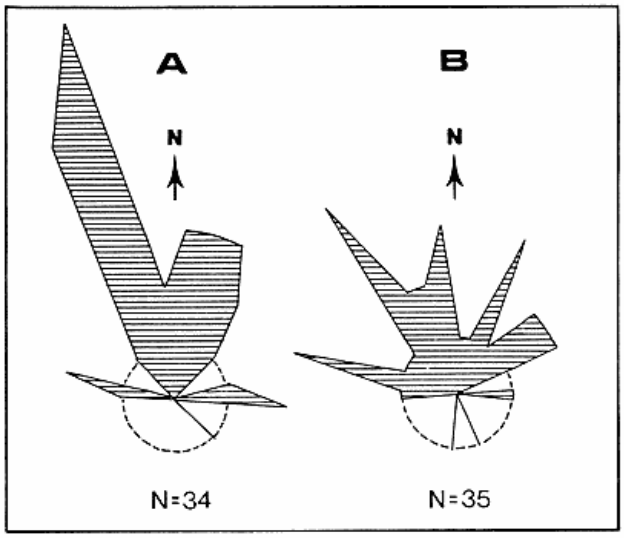

Fig. 5. Rose diagrams showing orientation of A: TDL-rock glaciers and B: true glaciers within a 15 km wide, east-west transect across northern Disko.
Fig. 5. Rosediagrammer visende orienteringen af A: TDL-blokgletschere og B: gletschere i undersøgelsesområdet vist i figur 2.

orientation of the 34 TDL-rock glaciers and 35 glaciers from figure 4 is shown as rose diagrams. Because of the restricted, and local, number of possible observations, a statistical treatment is far too early. It is conspicuous, however, that almost all graciers, rock glaciers as well as regular glaciers, face north or northwest, which makes the comparison made in figure 4 justified. The preferred orientation toward north and northwest is probably due to insolation, combined with the effect of frequent easterly and southeasterly air flow over the island from the semipermanent anti-cyclon over central Greenland; the resulting snowdrift favours accumulation of snow on slopes with northwesterly aspect.

DISCUSSION

The ELA on glaciers, at which accumulation and ablation balance, is a function of precipitation and summer temperature, primarily. The altitude varies with the amount of precipitation, with its seasonal distribution, and with the proportion of solid precipitation. Moreover superimposed ice, condensation, evaporation, solar radiation and degree of cloudiness are of importance, and each parameter's influence may become quite substantial. But in most cases the position of the equilibrium line is mainly determined by the amount of precipitation and by the temperature of the melting season. The smaller the solid precipitation, which is the dominant type of precipitation at the equilibrium line, the less heat is needed to melt or evaporate it; therefore, the tempeature at the ELA will be lower. The recognition of this basic context goes back to Ahlman (1924), and a similar idea has later been used by Krenke (1975) to estimate precipitation in mountain areas of the Soviet Union.

Following Kerschner (1980) and Haeberli (1982), the lowermost occurrence of rock glaciers can be used for reconstruction of annual air temperature trends. In the Alps, the lowermost active rock glaciers relate to mean annual air temperatures about -2°C, depending somewhat on aspect (Barsch 1977). This value seems to be about the right order of magnitude for Disko also, maybe a little too high, as the mean annual air temperature at the former town Qutdligssat (3 m a.s. l.) at the eastern end of the profile (Fig. 4) according to official weather statistics 1961-1971 was about -4°C. From weather statistics (starting 1873) from the town Jakobshavn 100 km farther to the southeast it appears that during the Little Ice Age deterioration annual air temperatures may have been as much as 2°C lower than during the period 1961-1971. Using this value for northern Disko, and by adopting a mean lapse rate of 0.65°C/100 m, the Little Ice Age annual air temperature at the level of TDL-rock glaciers and ELAs is estimated to range from -7°C to about -12°C. The reconstructed annual air temperature is in general highest to the west, and decreasing toward the east.

As terrain suitable for development of TDL-rock glaciers (high mountain walls with northerly aspect) is found also at lower levels than the Little Ice Age ELA, TDL-rock glaciers should obviously not be used as an indication for annual air temperature trends on Disko. Rather I would suggest the difference in altitude between tongue-shaped rock glaciers and TDL-rock glaciers mainly to be a function of precipitation. The coincidence with the Little Ice Age ELA points toward this interpretation. From this, one can also draw the conclusion that TDL-rock glaciers on Disko appear to be nourished primarily by snow, and by other types of ice (e.g. segregation ice, see Wayne 1981) only secondarily.

The zone with TDL-rock glaciers is seen to approach the lower limit of tongue-shaped rock glaciers at both ends of the investigated transect (Fig. 4). Following the line of thought outlined above, this convergency is interpreted as being the result of increased orographic precipitation on marine-oriented slopes; toward the Baffin Bay to the west and the sound Vaigat to the east. Especially toward the Baffin Bay, where open water is found most of the year near Disko, this effect is pronounced. The overall increase in continentality toward the Greenland Ice Cap to the east (distance about 90 km from eastern end of transect) may explain the overall trend in this direction toward greater vertical distance between the lowermost tongue-shaped rock glaciers and TDL-rock glaciers.

Summing up; while the lower limit of tongue-shaped rock glaciers appears to relate to mean annual air temperatures about -2°C (Barsch 1977, Kerschner 1980, Haeberli 1982), the altitudinal trend of TDL-rock glaciers ap-

pears to relate also to precipitation. At least this is the case for northern Disko. In humid areas the zone of TDL-rock glaciers may merge with the lower limit of rock glaciers; in dry areas TDL-rock glaciers lie above the lower limit of rock glaciers.

PALAEOCLIMATOLOGY

More detailed investigations are needed to verify the hypothesis presented above. It seems expedient however to call attention to the potential palaeoclimatic significance of TDL-rock glaciers. Fossil tongue-shaped rock glaciers are now being used as indicators of paleo-air-temperatures (see Kerschner 1980 and Haeberli 1982), while information on precipitation usually is obtained from altitudes of contemporary equilibrium lines on glaciers. In continental mountain areas, where glaciers are rare or absent, fossil TDL-rock glaciers might represent a source of knowledge on palaeo-precipitation. However, before the geomorphic significance of these features is known from other parts of the world, this technique should only be applied with the utmost care.

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Lobeformede blokgletschere, dannet ved deformation af talusskråninger (TDL-blokgletschere), er et alpint terrænelement, om hvilket der endnu kun foreligger få undersøgelser. På øen Disko, Vestgrønland, findes et betydeligt antal af denne blokgletschertype (Humlum 1983), og i nærværende artikel redegøres for en preliminær analyse vedrørende TDL-blokgletscheres klimatiske signifikans. I en undersøgt sektor tværs over øens nordlige del optræder TDL-blokgletschere konsekvent i samme højde som den samtidige ligevægtslinie på gletschere i samme sektor. Større tungeformede blokgletschere findes væsentligt lavere i terrænet, med undergrænse nær -2°C-isothermen for årsmiddeltemperaturen. TDL-blokgletscheres forekomst synes derimod i høj grad at være nedbørsbestemt, således at den vertikale højdeforskel mellem TDL-blokgletschere og undergrænsen for tungeformede blokgletscherforekomst vokser med stigende grad af kontinentalitet.

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