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Glacier and Climate Reconstruction in Southeast Iceland During the Last Two Millennia: a Reconnaissance

Jack D. Ives

Introduction

It is generally assumed that the period of the *Settlement of Iceland* (AD 870–1000), or the broader *Viking Age*, was warmer than at any time during the following nine centuries. The exception is the last 15 years when predictions of a "greenhouse warming" imply that we are entering a period of anthropogenically induced climate change that is possibly evolving out of control. These general statements apply to many regions where detailed field research has been performed, but especially in mountain areas, such as the European Alps, Scandinavia, and the New Zealand Alps. While no general statement can be made from provisional work in part of one small island in the North Atlantic, nor is this intended, all such local studies take on additional importance because of the practical implications of the great range of current climatological speculation. Iceland, however, as well as the higher latitudes of the entire North Atlantic region is of particular interest, following the conclusions of the pioneer glaciologist, Dr. Hans W. Ahlmann, who predicted that the amplitude of climatic, or glacier, fluctuation would be progressively greater with increasing latitude (AHLMANN, 1948).

In the context of the current debate about climate warming, therefore, it is imperative that we not only attempt reconstruction in small areas for their own sake, but also because such studies may have a bearing upon evaluations of the relative amplitude of on-going changes.

The investigation undertaken in the present instance is reconnaissance in nature. It focuses on the Viking Age settlements of Skaftafell and Svinafell and former, as well as extant, farms, and outlet glaciers surrounding Iceland's highest summit, the culmination of the Öraefajökull massif, an active volcano. It also attempts to bring together field evidence, historical records, and folklore.

Location and General Description

The extant farms of Skaftafell and Svinafell are located to the northwest of the great ice-mantled dome of Öraefajökull (highest summit, Hvannadalshnukur, 2,119 m). The two settlements, partially separated by the glacier tongues of Skaftafellsjökull and Svinafellsjökull and their meltwater rivers, face out onto the large Vatnajökull outlet glacier, Skeidararjökull and its extensive outwash plain (*sandur*: Icelandic). Skaftafell has virtually lost its status as an active group of farms and today is the core of the Skaftafell National Park, with a modern visitors' center, parking lot, and camp ground. One of the original Skaftafell families, which claims near permanence of occupation back to the Settlement of Iceland (IVES, 1991), has recently moved to Freysnes, some 10 km distant, and established a small hotel on the "old" outer moraines of Svinafellsjökull. It is this family, and especially the late Ragnar Stefansson, that has related much of the local folklore and collected the two important samples of wood, washed out from beneath the glaciers, thus providing critical radiocarbon dates.

The present-day climate of this area can be described as ranging from cool temperate maritime, to arctic maritime and glacial, depending upon altitude. Precipitation is considerable: meteorological records are derived from the farms close to sea level and show high values (about 1300 mm/yr) but with little winter snow cover. Glaciological observations in the 1950s indicated much higher amounts at greater elevations (about 3000 mm/yr at 1200 m: IVES and KING, 1955). At still higher levels, especially in the upper accumulation area of Svinafellsjökull and on the upper slopes of the Öraefajökull ice cap, amounts in excess of 5000 mm/yr are likely. Under these conditions it is not surprising that outlet glaciers reach close to sea level. The maximum local relief is 2000 m over a horizontal distance of 9 km.

The glaciers Skaftafellsjökull, Svinafellsjökull, Kviarjökull, Fjallsjökull, and Breidarmerkurjökull are the ones particularly relevant in terms of this study (Fig. 1). Direct glaciological observations began under the guidance of Dr. JON EYTHORSSON (1963) in 1931, later taken over by Dr. SIGURJON RIST (1984). Under this scheme the local farmers measured the annual variations in the glacier termini in relation to fixed points in the glacier forefields. The data were accumulated and published periodically in the Icelandic journal *Jökull*. Glacier mass balance and rates of movement were calculated for Morsarjökull, and rates of movement for Skaftafellsjökull and Svinafellsjökull in 1953–54 (IVES and KING, 1954/55; KING and IVES, 1955/56). Liverpool University expeditions made detailed studies of the latter two glaciers in the 1980s (THOMPSON, 1988) and BLACK (1990) studied the moraine and outwash stratigraphy of Kviarjökull.

Many other incidental observations have been published over the last 60 years; there are also important records from the travels of the famous Icelandic physician and naturalist, Dr. SVEINN PALSSON, in the 1790s (GROVE, 1988; IVES, 1991). Finally, quite precise references to the frontal positions of Breidarmerkurjökull, Hrutarjökull, and Fjallsjökull in the late-17 and early-18 Centuries are found in the 1708–09 land register (see below).

Holocene Glacier Fluctuations

Svinafellsjökull and Kviarjökull have many similarities. Both originate from very high on the Öraefajökull ice dome, so that their accumulation areas extend almost to 2000 m; both have extensive and gently sloping lower tongues fed by spectacular icefalls and both have prominent Little Ice Age end moraines. In addition, the outermost end moraines of each glacier have pronounced soil and vegetation cover and have long been suspected to be pre-Settlement in age (THORARINSSON, 1943; THOMPSON, 1988). However, BLACK's work on the Kviarjökull moraines was the

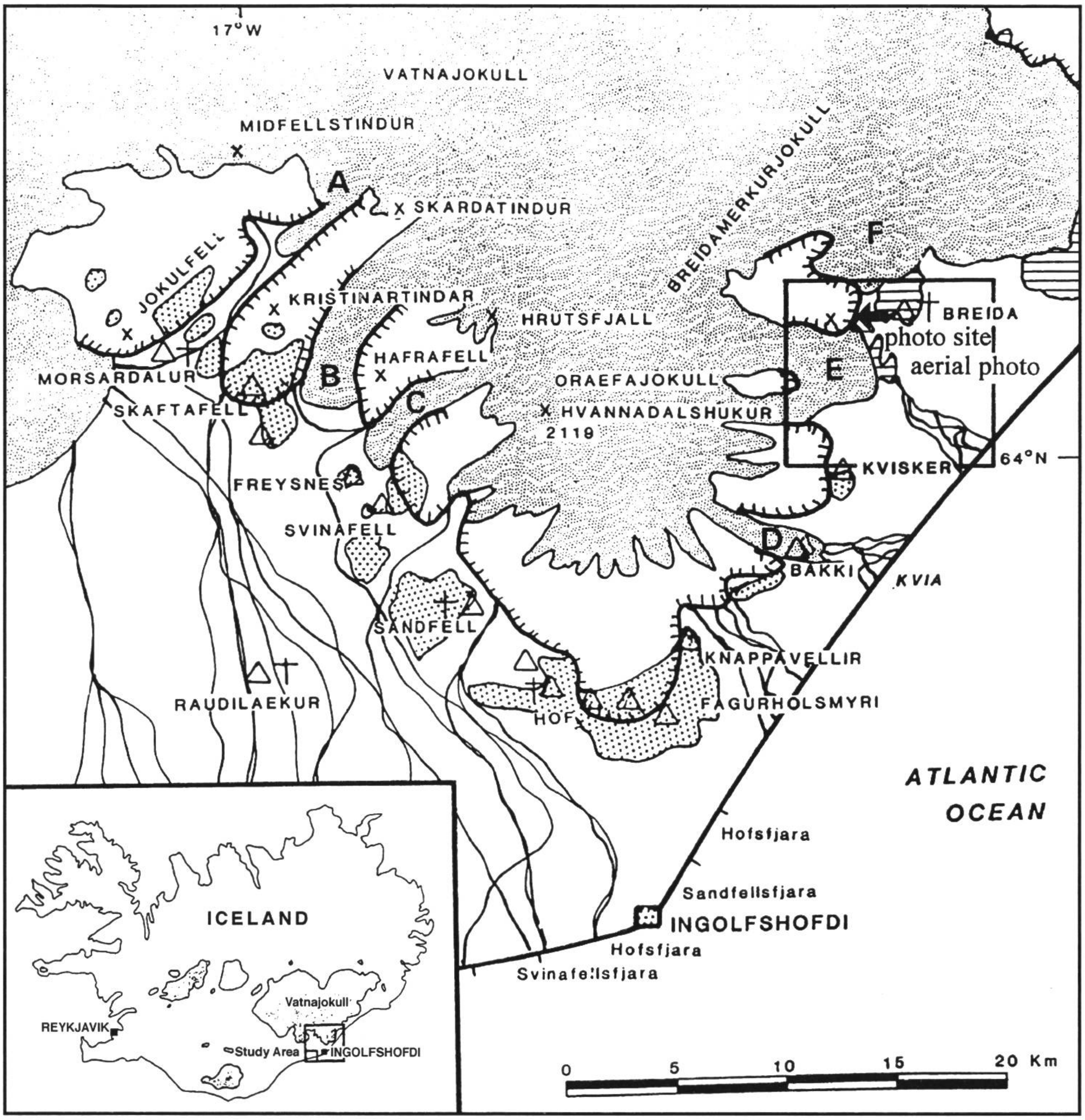

Fig. 1: Southeast Iceland showing the Öraefajökull ice cap of Vatnajökull. Both extant and former farm groups and churches are denoted △ and † respectively. Outlet glaciers: A Morsarjökull, B Skaftafellsjökull, C Svinafellsjökull, D Kviarjökull, E Fjallsjökull. X: Midaftanstindur, within location of Fig. 2 and 3.

first to provide limiting radiocarbon dates indicating a probable Subatlantic age. This conclusion is based on a combination of lichenometry, tephrochronology, and ^{14}C dates of about 2000 yrs BP on buried birchwood. From this a rough outline of glacier fluctuation can be drawn.

While Kviarjökull and Svinafellsjökull, therefore, bear many similarities, the latter contrasts sharply with its nearest neighbor, Skaftafellsjökull. The latter has a much lower accumulation area (1000–1450 m). Ice supply also descends through a much more modest icefall to its lower tongue. The termini of the two glaciers were merged into a common piedmont lobe in the 1930s and had probably been in contact since the early advances of the Little Ice Age (early 1700s). During the early 20th Century warming, both glaciers thinned substantially and eventually separated in the late-1930s. This separation was due primarily to the retreat of Skaftafellsjökull by about 1 km by 1954 (KING and IVES, 1955); Svinafellsjökull remained in contact with its high end moraines.

The thinning and retreat of the two glaciers accelerated after 1930, although there were important local readvances in the 1960s and until the most recent observations by the author in 1993. The contrast in the dynamics of these glaciers will be reintroduced below when discussing the significance of the ^{14}C dates on birchwood logs that have been washed out from beneath them.

While available data allow a very general outline of the Öraefajökull glacier terminal fluctuations, the limited absolute dating and the lack of systematic fieldwork preclude a precise statement. This stands in sharp contrast to the superb work undertaken by members of the Institute of Geography, Berne University, for example, on the Grindelwald glaciers in the Swiss Alps (MESSERLI et al., 1978; ZUMBÜHL, 1980; PFISTER, 1981, 1992). Furthermore, the available absolute dates, excepting those from the birchwood washed out from beneath Skaftafellsjökull and Svinafellsjökull, provide only minimum ages for glacier advances.

Although reconstruction of glacier advances provide general indications of local climate cooling, provided that changes in precipitation can be taken into account, our present concern is with the possible reconstruction of warm periods. Some indications can be obtained from the folk history and the church and land register records.

Farm Sites and Climate Change

Fig. 1 shows the locations of the farm clusters of Skaftafell, Svinafell, Hof, and the former settlements of Raudilaekur and Eyrarhorn, and the individual farms and former farms of Kvisker, Fjall, Bakki, and Breida. Most of these place names are amongst the oldest in Iceland and are found in the Icelandic Book of the Settlement (*Landnamabok*), especially Skaftafell, Svinafell, and Breida. Ingolfur Arnasson, the first person recorded as over-wintering in Iceland, made his landfall at Ingolfshofdi, on the coast south of Hof. Eyrarhorn and Raudilaekur were overwhelmed, presumably by the 1362 volcanic eruption of Öraefajökull, and their sites were underwater during the *jökulhlaups* which are believed to have begun with the early Little Ice Age glacier advances (THORARINSSON, 1956, 1957; IVES, 1956, 1991). Skaftafell and Svinafell, for instance, are not only listed in the *Landnamabok*, Svinafell plays a prominent role in *Njals Saga* as the home of Flosi, leader of the party that burnt Njals family. Fjall, Bakki, and Breida have disappeared; presumably they were overrun by glacier advance in the 1690s or 1700s. Breida is of special significance. While I have previously discussed in general terms the relationship of all three of these farms to glacier advance (IVES, 1991), for the present study the importance of Breida will be emphasized, the site of which I attempted to locate in 1993.

From the church records we know that Breida suffered from the AD 1362 eruption; there is a reference to the Breida church having no ornaments and being without livestock in 1387. Nevertheless, farming was certainly underway in 1525, and there is a similar reference dating from 1587. The 1708/09 land register, however, comments that "fourteen years ago the tun [home field] and ruined buildings [of Fjall] were still to be seen, but everything is now covered by ice". Breida, its neighbor, appears to have been abandoned by 1698. It is even claimed at that time that the tombstone of Kari Solmundarsson (see below) could be seen in the ruins, but was covered by ice in 1712. Breidarmerkurjökull and Fjallsjökull, along with Hrutarjökull, must have developed their common piedmont lobe over the sites of the two farms between about 1695 and 1710.

The significance of the location of Breida and its changing conditions is related to two points: (a) as the farm chosen by the author of Njals Saga for the final homestead of Kari Solmundarsson, sole survivor of the burning and Flosi's terrible antagonist, it must be assumed that Breida was prosperous in the late-13 Century, the

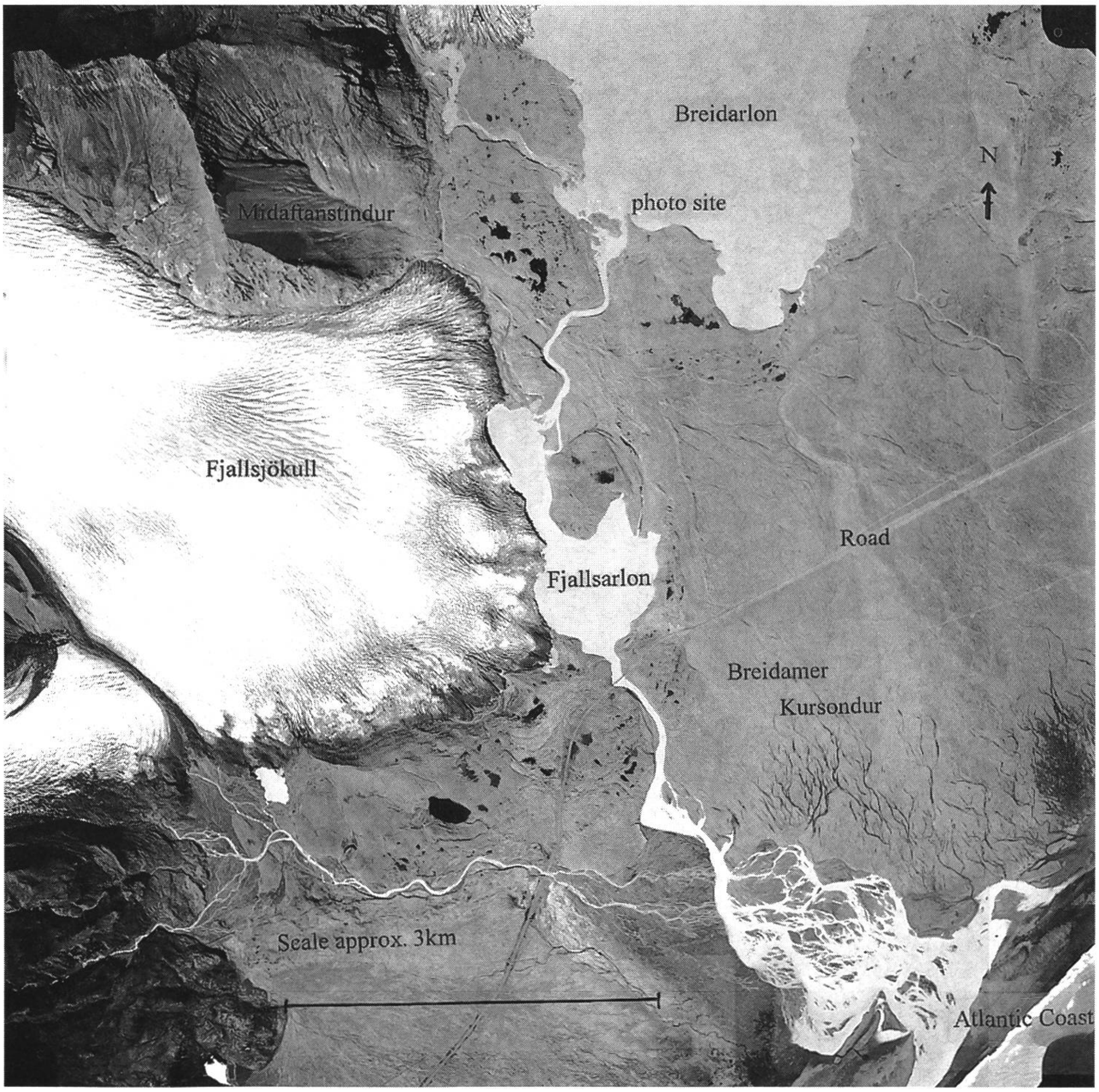

Fig. 2: 1988 airphotograph showing the modern glacier margins, ice-frontal lakes, and melt-water rivers, together with the ground photograph site for Fig. 3.

time when Njals Saga was put into written form, and thus fitting for such a preeminent hero; (b) description of its siting raises the possibility of pinpointing its actual position today. As mentioned above, this was attempted in July 1993. Unfortunately, only a single compass bearing is provided so that a precise resection along two converging bearings, the ideal, is denied.

The mountain, Midaftanstindur, a prominent summit of the Breidarmerkurfjall group, is reported to lie due west of the farm. Fjall, apparently, lay 2 km west of Breida. Thus, armed with the 1:50 000 scale topographical map and air photographs, I was able to occupy a position due east of Midaftanstindur in July 1993. The sketch map (Fig. 2) illustrates the present-day configuration of glacier margins, frontal lakes Breidalon and Fjallsarlon, and the Breida and Fjallsa rivers. Fig. 3 is a photograph of the immediate foreground and nearby glaciers and mountains. I estimate that I was probably within one kilometer of the actual site of Breida.

The primary conclusion from this exercise is that no farm within a 2–3 km radius of the proposed location could exist today. Of course, we must consider that Kvisker does exist today as a viable farm 8 km to the south-southwest, but its position is much more sheltered and it is protected from glacier piedmont development by being backed by a steep and high mountain slope. For Breida and Fjall to thrive during the period AD 870–1362, far more advantageous conditions than those of today must have prevailed. Thus it is postulated that the climate of the Viking Age

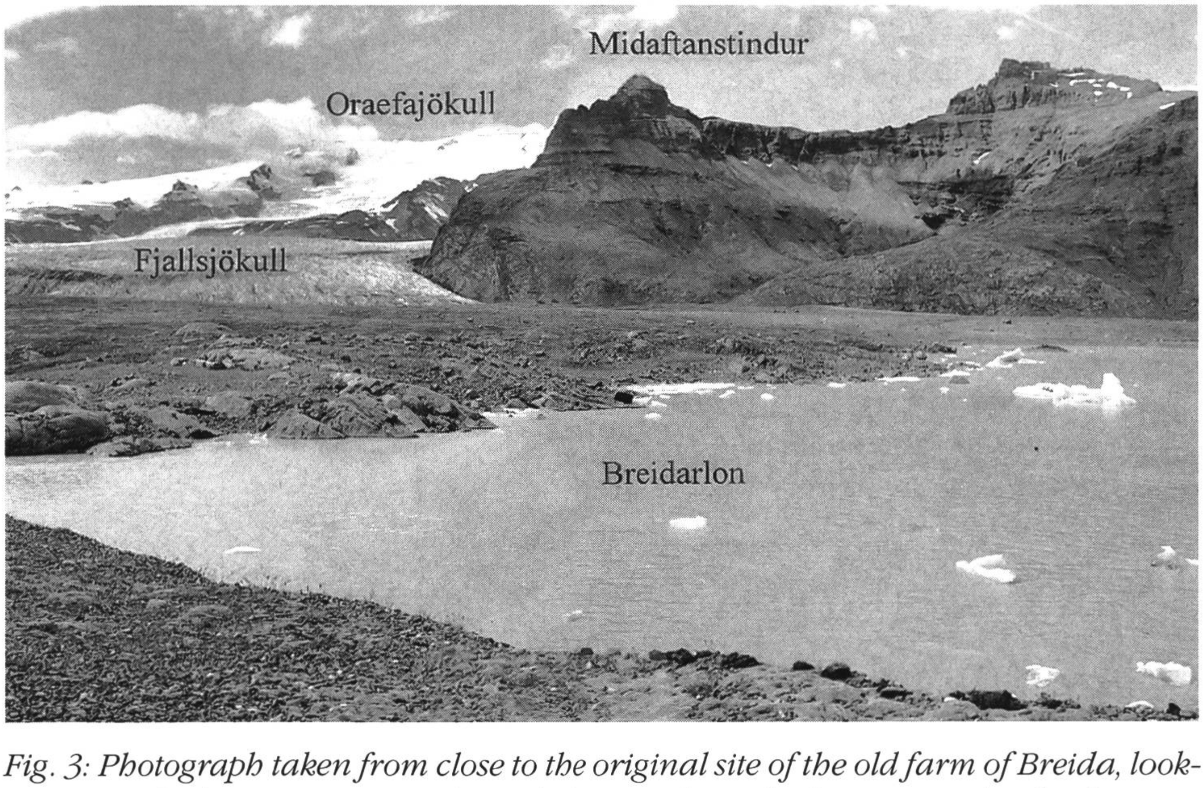

Fig. 3: Photograph taken from close to the original site of the old farm of Breida, looking towards the prominent peak, Midaftanstindur, which is reported to lie due west of the farm. Here the author of Njals Saga placed Kari Solmundarsson, the only survivor of the burning of Njall and his family. No farm could possibly operate on the terrain of today.

and the period of the Icelandic Republic, at least for these coastal, mountain-foot settlements, must have been considerably warmer than during the current decade, warmer even than is usually proposed for this period. In particular, the termini of the Breida glaciers must have been significantly back from their present positions; this point raises a similar problem to that of accounting for the substantial retreat of Svinafellsjökull.

Glacier Minima

On my first visit to Skaftafell in 1952, Ragnar Stefansson showed me pieces of birchwood that he had located in the 1930s within the outwash stratification of the forefield of Skaftafellsjökull. These had been preserved from a large deposit inside the outermost moraines, exposed by the undercutting of a meandering meltwater stream. The main deposit had been "mined" by the local farmers for several years as a valued source of fuelwood. Ragnar deduced that the wood, which was not *in situ*, had been swept out from beneath the glacier and deposited within the glacial outwash plain sequence between strata of sand and gravel. He surmised that the wood derived from a former birch forest that, according to local folklore, had existed several kilometers behind the glacier terminus during the warmer times of the Republic.

During this first encounter I was an undergraduate student and ^{14}C dating was unknown to me. When offered the wood sample, I requested that, since Ragnar had kept it safe for nearly 20 years, he should continue to do so. In 1987 I finally accepted half of the larger piece and submitted it for radiocarbon dating. Of course, I was expecting an age of about a thousand years; in fact, it dated to 2020±80 yr. BP (Lab no. GX-13965).

In 1993, on my most recent visit, Ragnar had retrieved a large tree trunk, washed out from beneath Svinafellsjökull. It was in the garden of his new Freysnes home awaiting my arrival. We sawed off several pieces; the radiocarbon date was 1690±60 yr. BP (Lab no. Beta-66445). THOMAS BLACK also recovered a piece of birchwood, in this case from the forefield of Kviarjökull in 1987; it dated to 2040±80 yr. BP. It enabled him to infer a minimum age for the outer moraines of Kviarjökull thus ascertaining a pre-Settlement Holocene advance at least as old as the Subatlantic.

Ragnar Stefansson's grandfather, Jon Einarsson (1846–1925) informed him that he had been told by an old woman of Svinafell (who died about 1900) that the valley now covered by Svinafellsjökull supported a large birchwood several kilometers inside the then glacier terminus. This was based on folklore, which contains many other references to a very warm period in the distant past.

The various references to folklore, the radiocarbon dates on birch logs, and the documentation of former farm locations necessitates an examination of the regime of Svinafellsjökull. Fig. 4 is a long profile of the glacier drawn from the topographical map. Annual movement was about 170 m/yr. in the 1950s (KING and IVES, 1955); precipitation in the upper accumulation area was probably about 5,000 mm/yr., mainly as snow. Given the high accumulation area, the spectacular icefall, and the long gently sloping lower tongue, a very big change in climate would be needed if

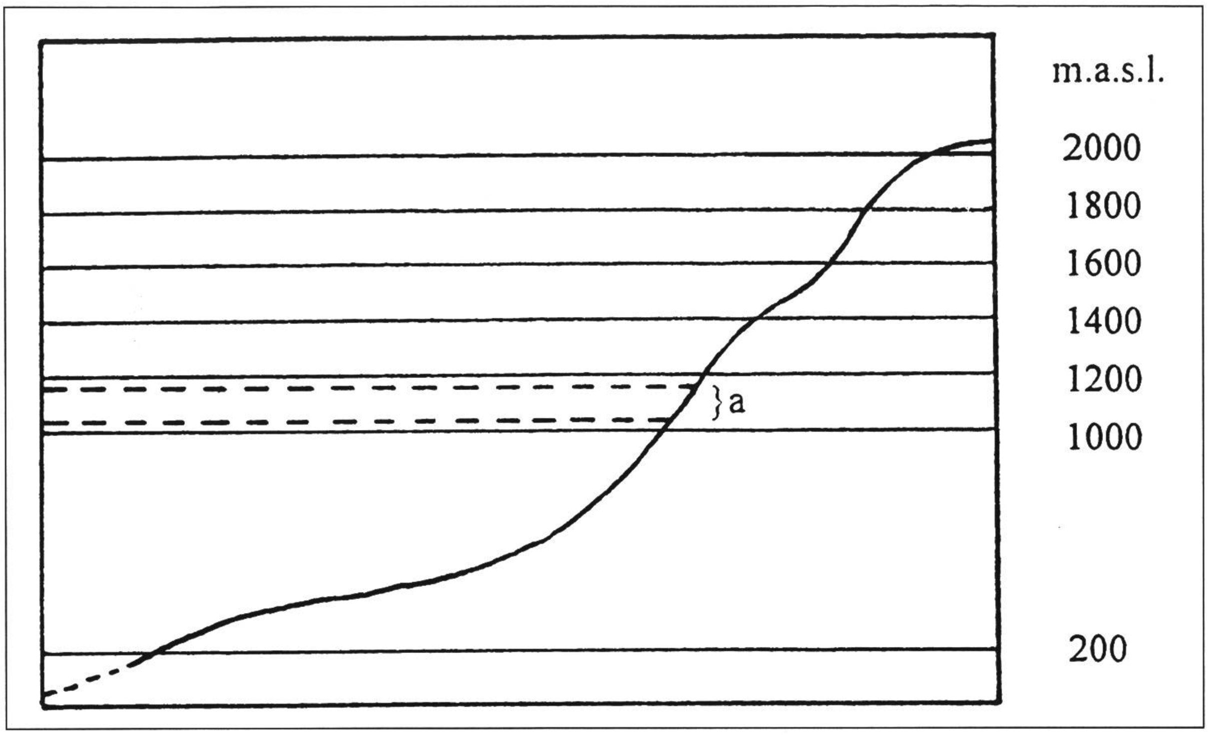

Fig. 4: Long profile of Svinafellsjökull (see C in Fig. 1). The profile is drawn from Iceland topographical map, revised 1982, scale 1:100 000, sheet 87/88 – Öraefajökull. Note that even a significant increase in the elevation of the equilibrium line would only change the proportion of the ablation area to the accumulation area by a small amount.

the glacier terminus were to retreat several km behind its present position. Thus we must draw the same conclusion: on all counts, climate at some time in the past, and presumably during the Viking Age, must have been considerably warmer than is generally assumed.

Conclusions

The evidence presented, although fragmentary, indicates a period in the past (about 1700–2000 years ago) when birch forest flourished several kilometers inside the glacier termini of the 1930s–1990s. To ensure such a situation, the climate must have been considerably warmer than at present. The folklore accounts, and the partial identification of the location of Breida would imply that this period fell within the time of the Republic (i.e. after AD 874). At first glance this appears to be in conflict with the radiocarbon dates. This issue cannot be resolved at present. However, there are two reasonable working hypotheses: (a) there were two very warm periods, one following the Subatlantic cool phase (2500 BP), the other during the Republic; (b) the wood samples are younger than recorded due to contamination in a volcanically highly active environment.

Regardless of this persisting ambiguity, we can stipulate that the amplitude of temperature fluctuations in the coastal area of southeast Iceland during the late-Holocene has been greater than that of the last decades. Furthermore, the climatic downswing from about AD 1300 to the maxima of the Little Ice Age is at least comparable in amplitude to the warming of the period 1850 to present. If the latter (warming) is assumed to be the result of post-Industrial Revolution anthropogenically induced changes in atmospheric chemistry, what is the cause of the former (cooling)? These are very large and controversial questions to base upon an incomplete study of a small area. However, if we are to devise convincing scenarios for future climatic change, they cannot be ignored. A general recommendation is that accelerated studies in the broad area of mountain geoecology are urgently needed. In this context, it is appropriate to pay tribute to Professor BRUNO MESSERLI, and his colleagues and students at the University of Berne, for making such a major contribution to this vital field of enquiry over the last three decades. This leadership needs to be maintained.

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Personal

Born, 15 October, 1931, in Grimsby, England; B A honors, Geography, 1953, University of Nottingham, England; Ph.D., Geomorphology, 1956, Mcgill University, Montreal, Canada; emigrated to Canada, September, 1954; emigrated to Boulder, Colorado, August, 1967; moved to University of California, Davis, CA, 1989.

I first met Professor Bruno Messerli in 1972 in the Canadian Rockies. This was on the occasion of the IGU Mountain Commission symposium organized by the late Professor Carl Troll. Since then we have worked together in the Alps, Himalaya, and the Andes, and have shared experiences as alternating chairmen of the IGU Commission on Mountain Geoecology and Sustainable Development, and as research coordinators for the UNU project on Mountain Ecology and Sustainable Development. Our initial collaboration began in 1973 in our efforts to help develop UNESCO's MAB Programme, Project 6. This led to my being the first Visiting Professor at the Institute of Geography, University of Bern, on a Guggenheim Fellowship in 1976–77. In all our symposia and travels, we have toured most of the world's mountains together.

I regard Bruno as my special mountain colleague and friend whose constant support and inspiration led us to the UNCED Earth Summit in 1992 (Rio de Janeiro). Our co–authorship of The Himalayan Dilemma (Routledge, London and New York, 1989) is one of the many examples of this cooperation. There remain many more mountains beyond the horizon.

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