

equilibrium-line altitude of the Hintereisferner is 2990 m a.s.l. and that of the Kesselwandferner is 3095 m a.s.l. (personal communication from G. Markl). Comprehensive glaciological investigations have been carried out for many decades on both glaciers which are immediately adjacent. The Mitterkarferner is close to Wildspitze which is the highest peak in the Tyrol.

Case 2. Following a fall down a crevasse (>40 m) in the ablation area of the Gurglerferner (Oetztal Alps, Tyrol) at approximately 2800 m a.s.l., the casualty was discovered on the glacier surface in 1973, about 150 m below the scene of the accident. The fatal accident occurred in 1965 and the corpse had been immersed in glacier ice for 8 years. Flow path and time of flow movement yield a velocity of approximately 20 m year⁻¹. Considering the size of the Gurglerferner (length 6.5 km, maximum width 3.0 km, depth at the accident site ~140 m), this value seems consistent with glaciological measurements (Schneider, 1970).

Case 3. After a fatal accident in the upper part of the Madatschferner (Oetztal Alps, Tyrol) in 1923, the casualty was discovered in 1952 at the very end of the glacier on the ice-free terrain, but not at the terminus of the glacier. The casualty had therefore been immersed in glacier ice for 29 years. The circumstances of the accident are unknown. There is a trail leading across the uppermost part of the Madatschferner. Assuming that the accident happened on this trail, path and time of the movement would have resulted in an average velocity between 25 and 35 m year⁻¹. Glaciological experience shows that this value is too high, because the Madatschferner is a relatively small glacier (length 1.1 km, maximum width 0.6 km). It is therefore to be concluded that the accident occurred some distance from the trail and at a lower altitude.

A glaciologically obscure case is the discovery of bones of a human skeleton in the ablation area of the Rotmoosferner (2700 m a.s.l., Oetztal Alps, Tyrol) in 1982 and in 1990. Both discoveries were made at the same location. Both sets of bones were identified as belonging to the same person reported missing in March 1943. This person had therefore been immersed in glacier ice for between 39 and 47 years, respectively. The time difference between the two discoveries at the same location is unclear from a glaciological viewpoint.

A discovery of particular historical interest was made on Theodulgletscher (Wallis Alps, Switzerland) and was reported earlier by Krämer and others (1988).

For forensic medicine, glaciological data are interesting in relation to the post-mortem findings.

Sincere thanks are due to officials of the rural police station in Soelden (Oetztal, Tyrol) for supplying necessary information. Also, G. Markl is thanked for making data available.

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The accuracy of references in the text and in this list is the responsibility of the authors, to whom queries should be addressed.

SIR,

Reply to: "Comments on: '6000-year climate records in an ice core from the Høghetta ice dome in northern Spitsbergen'"

First, we appreciate the comments and suggestions by Dowdeswell and others (1990) on our chronology and palaeoclimatic interpretation of the ice cores obtained in northern Spitsbergen (Fujii and others, 1990). Since reliable chronology of the ice core obtained from the superimposed ice zone, as at our research site (Høghetta) is difficult because of the disappearance of seasonal and even annual stratification by melting, percolation and/or wash-out, there might be a case for some chronological interpretation on the basis of the analysed data.

We should like to describe our chronological interpretation of the ice core giving some recent data and other evidence additional to that already described. In table II of the paper there is a misprint: 1770 in column "Period" should be read as 1700 as appears in the text. Therefore, we should read 1770 in the comments by Dowdeswell and others as 1700.

Core chronology for recent decades

The ice-coring site at Høghetta, Spitsbergen, is located in a typical superimposed ice zone as no firn was observed in the core. Percolation of melt water to the lower layers is not so important in superimposed ice because the water channels developed at grain boundaries only in the upper 20 cm, as was observed in the cob-webbed air-bubble layer. So the annual characteristics of the ice are considered to be preserved when the annual balance is positive, even though percolation occurs.

The tritium profile shown in figure 3 of the paper (Fujii and others, 1990) is, therefore, thought to reflect the annual characteristics when mass balance was positive. The variation pattern is compared with the recent results of tritium analyses (Izumi, in press) for firn cores obtained at site J (67.5° N, 43.5° W), southern Greenland (the

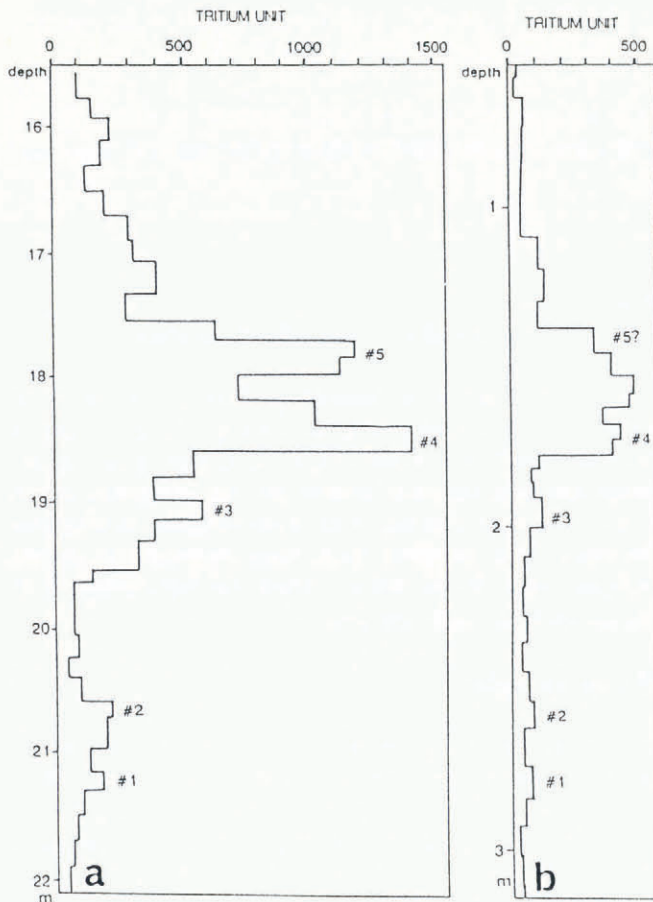


Fig. 1. Comparison of tritium-concentration profiles of site J, Greenland (a), and Høghetta, Spitsbergen (b) (Izumi, *in press*).

project has been outlined by Watanabe and Fujii (1990)), in 1989 where the mass balance was positive and the seasonal stratigraphic features were preserved. The variation pattern of the Høghetta cores is very similar to that of the site J core. The tritium-concentration peaks of the site J core between depths of 22 and 16 m which are layers of the 1950s and 1960s correspond well to those of the Høghetta core which, however, appear near the surface between depths of 3 and 0.5 m (Fig. 1). This suggests frequent occurrences of negative balance or a small positive balance after the later 1960s.

A decreased mass balance after 1963, at the latest, at Høghetta can be supported by the continuous negative mass balance of Austre Broggerbreen, western Spitsbergen (Hagen and Liestøl, 1990) during the whole observation period of 1986–88 even though there was a cold climate in the 1960s. Furthermore, as the water equivalent of the winter balance of 1986–87 was only 15.2 g (54 cm depth), as shown in figure 3 of the paper (Fujii and others, 1990), the annual balance from the end of the 1986 summer should have been at most several centimeters of water, taking account of the ablation of snow during the summer of 1987.

Chronology of the upper part of the ice core

Recently, we have obtained new results of 210-Pb measurements, as shown in Figure 2 (personal communication from T. Suzuki), which suggest 16 cm of water (or

about 18 cm of ice) as an average annual accumulation rate for the upper 10 m of the ice core. The accumulation is rounded to “about 20 cm of ice”, which was used in the paper.

The pH profile shown in figure 4 in the paper (Fujii and others, 1990) was compared with those obtained from Austfonna, Svalbard, by Zagorodnov and Arkhipov (1990) and at site J, Greenland. These three pH profiles, together with the chronological time-scale determined independently by each other, show common variation patterns. As for the chronology for the site J 205 m ice core, several different methods using the seasonal cycle of ECM records (by F. Nishio), interpretation of the pH signals (by K. Kamiyama and Y. Fujii), the tritium profile (by K. Izumi) and the density–depth profile (by T. Kameda and H. Shoji) show an average annual accumulation rate of 38–40 cm of water, which agrees with the accumulation rate of 37 cm of ice at site 2 (Clausen and others, 1988), where it is about 50 km from site J. Coincidence of the pH-variation pattern between Høghetta, Spitsbergen, and site J, Greenland, cores suggests the rationality of the chronology of the upper part of the Høghetta ice core.

The highest pH value of 8.3 at a depth of 32.5 m shown in figure 2 of the paper (Fujii and others, 1990) may be comparable to the highest Cl⁻-concentration peak of 7.73 mg l⁻¹ at 76.1 m depth which corresponded to some year in the early AD 1800s (personal communication from V. Zagorodnov). On the other hand, the age of the highest pH peak in the Høghetta ice core is estimated to be around 1810. This could support the chronology completed for the upper part of the Høghetta ice core.

Possibility of an hiatus prior to AD 1700

Recent studies by Zagorodnov and Arkhipov (1990) on an ice core from the summit of Austfonna, Nordaustlandet, in Svalbard indicate evidence of a very warm climate from

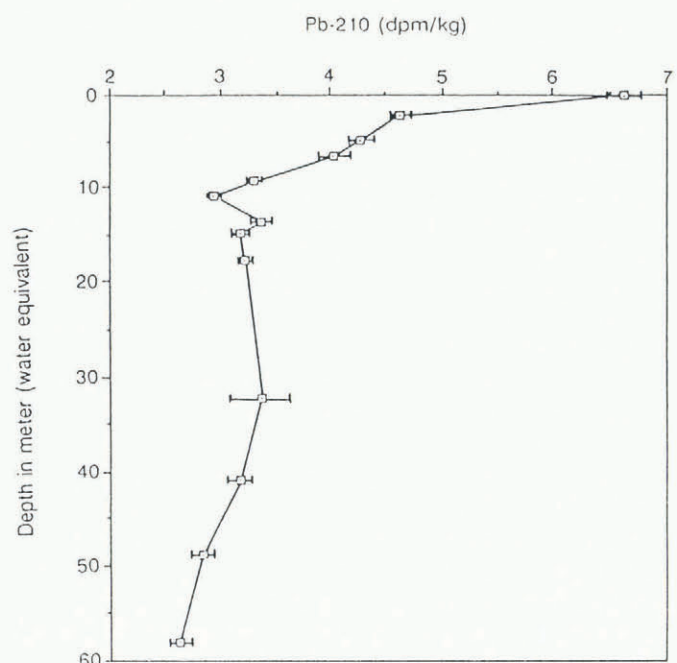


Fig. 2. The vertical profile of Pb-210 activity in the ice core from Høghetta, Spitsbergen (measured by T. Suzuki).

depths of 110 to 90 m during the Little Ice Age. They have deduced the warm climate from the concentration and thickness of infiltration ice layers. As they have proposed two time-scales for the ice core, the warm period can be interpreted approximately from c. 400 to c. 300 years BP, after the colder period began 1200–1300 years BP.

According to the oxygen-isotope profile obtained for an ice core from Vestfonna, Nordaustlandet (Vaykmae and others, 1985), the warm period continued from c. AD 1200 to c. AD 1600 prior to the cold period from c. AD 1600 to c. AD 1900.

Prior to AD 1700, there may have been a negative mass balance during these and earlier warm periods.

In conclusion, we suppose the following glaciological history at Høghetta in northern Spitsbergen: that the formation of glacier ice re-commenced at around AD 1700 during the Little Ice Age on stagnant ice after an hiatus of about 4000 years and the annual mass balance has been reduced since the middle 1960s.

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SIR,

Subglacial water and sediment samplers

The current focus of glaciological research on basal processes and hydrology makes the acquisition of samples from the subglacial environment a vital enterprise. In this letter, we describe two devices for obtaining samples of basal water and sediment within the confines of a narrow borehole. The samplers have been operated at depths ranging from 70 to 300 m. They are lightweight and require only a single operator.

Niskin sampler

Collecting water at depth has been a concern of oceanographers for centuries (see McConnell, 1982); designs for sampling bottles abound and are slowly modified by generations of researchers. The modern Niskin sample bottle consists of an open-ended tube which can be closed on command by a pair of stoppers. A Niskin bottle, attached to a wire rope, is lowered into the water and when the bottle reaches the desired depth, a messenger block is dropped along the rope. The block strikes the Niskin bottle and trips the sampling mechanism.

We have designed a modified Niskin sampler having a trigger mechanism that operates axially. This action allows the device to operate in a narrow borehole. Figure 1 shows the sampler in its open, cocked position. The sampler consists of four major units that move relative to one another: (1) The lower stopper is fixed to a hollow central rod. The central wire rope upon which the sampler is suspended passes through the rod and is held by a crimp at the bottom. (2) Two perforated brass disks are fixed within a Plexiglas sampling tube. The disks slide on the central rod and the perforations allow water to move through the tube when the stoppers are open. (3) The head block, with the upper stopper attached, is free to slide on the central rod, but two spring-loaded catches hold the block in a cocked position at the top of the rod. Two lengths of fine wire rope suspend the Plexiglas tube below the head block. The wire ropes are attached to small eye-hooks on the block and upper disk (for clarity, these fixtures are not shown in Figure 1). (4) A brass messenger block slides along the central wire rope.

The sampler, in a cocked position, is lowered into position at the borehole bottom and the messenger block is dropped along the wire rope. When the messenger strikes the catches, they spread apart and release their grip on the central rod; the head block falls against the sampling tube, the tube falls against the lower stopper, and a 220 ml water sample is trapped inside the device. The weight of the upper block ensures a watertight seal between the two stoppers and the tube. The sampler is opened, and the