

Fig. 3. (a) Concentration of diatoms and diatom fragments in the Crête ice core as a function of time of deposition. Only diatoms whose largest linear dimension is greater than or equal to  $10\ \mu\text{m}$  were counted. Since each sample represents a fraction of a year, the number of diatoms in each is not large and in some cases it is zero. Note that since snowfall is not constant throughout the year, one cannot treat the time-scale as linear.

(b) Concentration of insoluble microparticles in the Crête ice core as a function of time of deposition. In our work (Gayley and Ram, 1985), we measured the size distribution of insoluble microparticles in the radius range  $0.05\text{--}1.31\ \mu\text{m}$ . Only those particles in our largest radius range,  $0.38\text{--}1.31\ \mu\text{m}$ , were included in this study, since they are closer in size to the diatoms. The qualitative features of the curve remain unchanged when all particles are used rather than the larger ones. The dashed line indicates a region where particle measurements were not made (the particle distribution on the filter was not uniform), although the diatom content was determined.

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SIR,

In-situ measurements of electrical conductivity and pH in core samples from a glacier in Spitsbergen, Svalbard

The Japanese Arctic Research Project in the Svalbard region, in the Arctic, began in the early summer of 1987. The object was to clarify fluctuations in past and present sedimentary environments which would help us to forecast future features of the Earth's environmental system. An ice core gives us various information on the past. The precise details of this project together with information on the coring site have already been reported by Watanabe and Fujii (1988).

At the top of a glacier in Spitsbergen, we were able to obtain complete ice-core samples down to the bedrock at 85.6 m depth. In the lower part of the core, at 75.33 m depth, there is a band of organic matter, which possibly corresponds to a layer formed during warmer decades. Because of logistic limitations, we were unable to bring back all the core samples in a frozen condition and parts of the core had to be left behind. It is desirable to carry out certain of the analyses *in situ* throughout the whole core. One of the successful field measurements reported here is d.c. conductivity on the solid core samples (Nefel and others, 1985); this represents the acidity of the cores. We have used the measurements of electrical conductivity (EC) and the pH values of the liquid phase of the whole ice core to give us basic information on the coring field and to help us to consider, *in situ*, the chemical composition of the cores and the values of EC and pH that would represent the local sedimentary environment (Delmas and others, 1982; Kamiyama and others, 1987).

## METHODS AND MATERIALS

By coring at the top of a glacier, the whole core from the surface to the bottom was obtained with individual core lengths of *c.* 60 cm. Each sample was examined visually to determine the stratigraphy, and contained bubble and dust features. Some of the core samples were prepared so that they could be carried back to the home laboratory in a frozen condition. Some of the others were used for the determination of density and crystal structure. The remainder were converted into the liquid phase as follows.

The surface of each sample was scraped carefully with a knife after being cut with a band saw into suitable shapes. The decontaminated samples were put into pre-cleaned 1 litre bottles, which were immersed in warm water so the contents could become liquid. The melted samples were then put into other pre-cleaned 100 ml bottles; these were then used for the determination of both EC and pH.

The measurement of EC was done at 0°C with an electrical conductivity meter (CM-1K, TOA Electronics Ltd), to which was attached a sensor for low conductivity (CV-1001SC, TOA Electronics Ltd), and pH by a pH meter (HM-30S, TOA Electronics Ltd). In the laboratory at home, major ion and micro-particle concentrations were determined on some samples.

Here, we show the continuous vertical distributions of the EC and pH values in the core, measured *in situ*, which will be useful for the later re-arrangement and reconstruction the various continuous information from the core data.

RESULTS AND DISCUSSION

The sampling interval was about 10–20 cm and there were as many as 500 samples. The vertical profiles for EC and pH are shown in Figure 1. Two high values of EC were observed adjacent to each other just below a 30 m depth; this corresponds to the respective lowest and highest values throughout the core. For these samples, we repeated both the sampling and the measuring procedures twice independently, which proved that the remarkable variation had not been due to contamination during the sampling and measuring procedures. The pH value gradually increases with depth, a tendency which is a little more marked above a 20 m depth. These data reflect the recent increase in acidity of the precipitation in the region.

The core records represented by the EC and pH values were divided into three fractions: upper, middle, and lower. The upper fraction is from the surface to *c.* 20 m depth, the middle from *c.* 20 m to *c.* 50 m depth, and the lower from *c.* 50 m depth to the base of the glacier.

The characteristics of each fraction are as follows: in the upper fraction, the pH value increases with depth and

the increase in the EC value causes the decrease in pH; in the middle fraction, both EC and pH values fluctuate anomalously and here the lowest and the highest values occur in both EC and pH; in the lowest fraction, variations in both EC and pH with depth are small and the EC and pH values remain comparatively low and high, respectively.

Such fractions possibly correspond to those decades of similar past sedimentary environments. The chemical compositions of the ice-core samples will give us more refined information about past environments. Here, we have shown only the vertical distributions of the EC and pH values obtained *in situ* and these will be further discussed later, together with other information such as chemical composition, etc.

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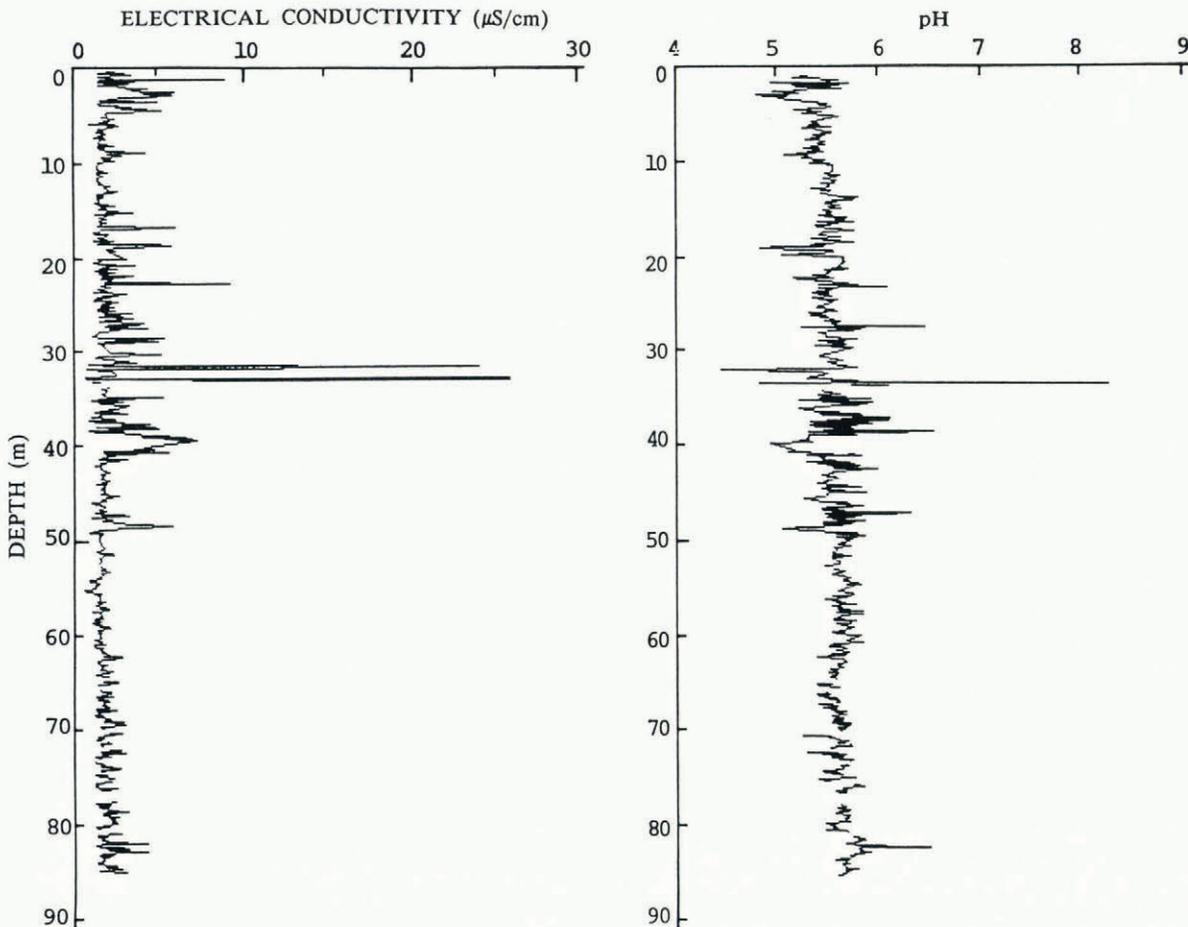


Fig. 1. Vertical profiles of electrical conductivity and pH in the liquid phase of core samples.

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SIR,

*Vertical dispersion of Chernobyl fall-out  
on Kesselwandferner, Oetztal Alps, Austria*

In the accumulation area of Kesselwandferner (Oetztal Alps, Austria; 3250 m a.s.l.), snow samples were taken within an area of 10 000 m<sup>2</sup> in the years 1986-88. We have measured gross  $\beta$ -activity and gamma-activity of samples in vertical profiles contaminated by radioactive fall-out from the Chernobyl accident. Profiles in 1986 cover a depth range from the surface down to 1 m, in 1987 down to 6 m, and in 1988 down to 11 m (Ambach and others, 1987, 1988). This allows us to study the displacement of radioactive contamination in firn.

The depth range contaminated expands from the surface to 1 m (1986) to the range from 3 to 6 m (1987), and to the range from 5 to 11 m (1988). The upper boundary of the contaminated depth range migrates to greater depths due to net accumulation. Peak values of gross  $\beta$ -activity in vertical profiles are reduced by radioactive decay and by leaching out from 149 Bq/kg (1986) to 47 Bq/kg (1988). The upper boundary of the contaminated range serves as a significant marker, as the activity changes from the low natural background to high values. The lower boundary of the contaminated depth range is less clearly defined due to percolating melt water.

Whereas in 1986 samples <sup>95</sup>Zr, <sup>95</sup>Nb, <sup>103</sup>Ru, <sup>103/106</sup>Ru/Rh, <sup>110m</sup>Ag, <sup>125</sup>Sb, <sup>134</sup>Cs, <sup>137</sup>Cs, and <sup>144</sup>Ce could be detected by gamma spectroscopy, in 1988 only traces of <sup>110m</sup>Ag, <sup>106</sup>Rh, and <sup>125</sup>Sb were detectable without significance. The main gamma-activity results from <sup>134</sup>Cs and <sup>137</sup>Cs contributing 13 and 87% to total gamma-activity.

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SIR,

*Glacier ice-cored rock glaciers in the Yukon Territory,  
Canada?*

An increasing number of measurements, soundings, and drillings has led to the widely recognized concept that rock glaciers are morphological expressions of creeping mountain permafrost (for example, Gorbunov, 1983; Haeberli, 1985; Barsch, 1988; Belloni and others, 1988; Blumstengel and Harris, 1988; Carton and others, 1988; Giardino and Vitek, 1988; Haeberli and Schmid, 1988; Haeberli and others, 1988; Zhijiu Cui and Zhu Cheng, 1988; Evin, unpublished). The idea of rock glaciers developing from glaciers has never been based on any firm evidence from appropriate field measurements or reliable model calculations. After reviewing the presently available information from geothermal, electrical resistivity, radio-echo, and seismic refraction soundings, it has been concluded that relations between glaciers and rock glaciers are indirect, accidental, or non-existent (Haeberli, 1985, p. 122), and that the idea of an exclusively glacial origin of rock glaciers remains purely speculative (King and others, 1987, p. 94).

In their description of rock glaciers within the Dalton Range, Yukon Territory, Johnson and Lacasse (1988) claimed that rock glaciers form from glaciers which have become totally covered in debris. They made a strong point with this idea, implying that Barsch (1988), Gorbunov (1983), and myself (Haeberli, 1985) have overlooked an obvious and easily recognizable aspect of rock-glacier formation. They wrote that "continuity of glacier ice is visible ... from current glaciers through lateral moraines into rock glaciers". Such reasoning is not new (cf. Whalley, 1974, 1979; and earlier papers by P.G. Johnson as quoted by Johnson and Lacasse, 1988), but has repeatedly been criticized (for instance, Haeberli, 1985; Barsch, 1987) and does not gain credibility with time. The well-known fact that remains of buried snowbank and glacier ice, as well as other forms of massive underground ice (segregation ice, injection ice; cf. Shumskiy, 1955; Washburn 1979), can be embedded within rock glaciers is not in contradiction to the commonly accepted permafrost model of rock-glacier formation; at the same time, however, the potential inclusion of dead glacier ice by no means implies that rock glaciers as a whole can have a glacial (in contrast to periglacial) origin. The observations reported from Dalton Range even fit the concept of periglacial rock glaciers perfectly; the described rock glaciers are in a permafrost condition (Johnson and Lacasse, 1988, p. 331); the reported resistivity of the sub-surface material (10 000-15 000  $\Omega$  m; p. 329) is lower than the resistivity values measured in mountain glaciers, snowbanks, or dead glacier ice by several orders of magnitude and is typical for perennially frozen ground rich in ice (cf. Haeberli, 1985; King and others, 1987; Evin, unpublished; and the references given in these publications). Finally, the photographs illustrating the article (Johnson and Lacasse, 1988, p. 328, 329) do not show glaciers but a number of snow patches (a common feature of mountain permafrost), the dimensions of which are by orders of magnitude smaller than the dimensions of the discussed rock glaciers.

Johnson and Lacasse must have been aware of these points, because they quoted the corresponding literature. What is then the reason for yet again making a strong statement on the "glacial origin" of rock glaciers, a concept which can obviously not be "understood" but must be "believed"? In view of the numerous definitive studies that have seriously challenged this long-standing belief, and in the absence of solid supportive evidence, Johnson and Lacasse's claim for a clear glacial origin for the rock glaciers they described has no merit. Moreover, the introduction of their cumbersome term "glacier ice-cored debris-system rock glacier" is unnecessary and most probably misleading.

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