CHAPTER 2 INVESTIGATIONS, 1959-81

2.1 Technical Notes

2.1.1 The drilling

An open system hot water drill was used to bore glacier ice. The system consisted of a pump, a heater and the pressure hose with the drilling nozzle (Fig. 2-1). The water was normally taken from a melt water river on the glacier. For drilling in the cold season or in the firn area, snow had to be melted and stored in plastic pools.

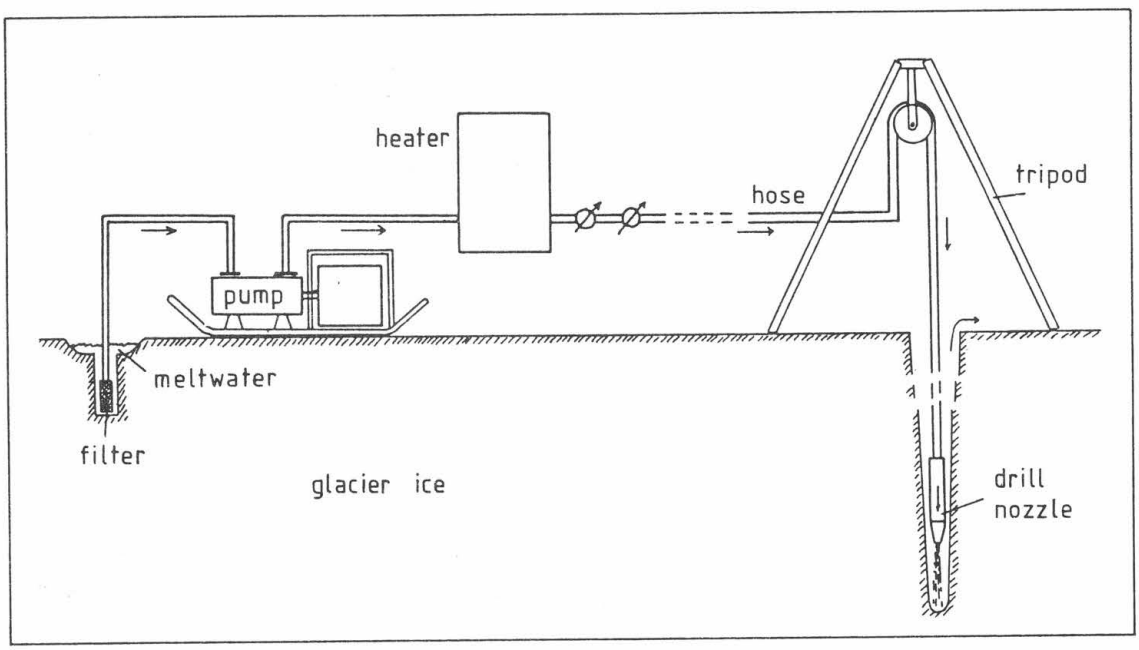

Fig. 2-1 The open system hot water drill

The pump delivered between 20 to 40 litres of water per minute with a pressure of around 20 to 30 bars. The water was heated to 60 to 80 ^{o}C with propane in the first model and with diesel fuel in an improved and stronger model.

The drilling reached a speed of 50 to 100 m per hour and a depth of 380 m. The hole was filled mostly with water during the drilling, however, the water level could not always be seen in the top part of the hole.
During drilling, the hose was sunk at a rate of about 2 m/min, but after about 4 m it was pulled back about 2 m and again sunk 4 m. This pulling back allowed the hole to be widened at the bottom and the tube with the nozzle could hang vertically again. It is believed that this method results in almost vertical holes. Measurements with inclinometers on Swiss glaciers by Röthlisberger, Iken and Haeberli, VAW, ETH Zürich, confirmed this assumption (Röthlisberger, private communication). The diameter of the hole at the top end grew to around 10 to 20 cm, depending on the duration of drilling. At the bottom it was at least 5 cm wide according to the diameter of a plexiglass ring mounted on the drilling nozzle.
After pullout of the hose, 12 or 15 core cables with thermistors were inserted and frozen in. After 2 to 3 weeks, the temperatures in the core cooled close enough to the equilibrium state to allow a measurement to be taken. This was verified by control measurements a year later.

2.1.2 The temperature measurement

The temperature measurements were carried out with Fenwal GB 31 P2 thermistors. The electrical resistance was around 7000 Ω at a temperature of -20°C and around 3000 Ω at 0°C.
The Fenwal thermistors had to be calibrated. This was done with a thermally stabilized aethanol bath at the Institute for Forestry, ETH, at Birmensdorf (near Zürich), with a reading accuracy of 0.1°C. The cables had also a resistance of 7 Ω /100 m and had to be taken into account according to their length.

Although the thermistors were calibrated to ± 0.2°C accuracy, measurements with overlapping cables in the drill holes showed deviations of up to 0.4°C. The accuracy of the temperature measurements in the glacier ice is therefore estimated to be ± 0.2°C, with few unexplicable deviations from smooth temperature profiles.

The readings of the temperatures were made with a Tettex resistance bridge. This proved to be quite reliable at all air temperature conditions on the glacier since this is a voltage compensation measurement where all parts show a similar temperature dependence.

The thermistors were mounted into plexiglass tubes which then were filled with an Epoxy resin to prevent breakage. This proved to be very resistant to damage, and even when subjected to beating the calibration of the thermistors barely changed.

The accuracy of the depth to which the thermistors were inserted in the holes is estimated to be better than $\pm$ 2 m, although it is not clear how straight the holes are drilled. It was also difficult or impossible to judge whether the drill reached bedrock or not. Big rocks in the ice can also stop the drilling. At some sites in the lower ablation zone, the water level in the usually filled holes dropped suddenly at the end of the drilling. Since these holes end in a layer of temperate or near-temperate ice, it is not clear how close to bedrock the drill came. Therefore, the given glacier depths in the profiles (Figs. 2-5, 2-6, 2-7, 2-8, 2-9, 2-11 and 2-17) have to be considered with care.

The positions of the sites were surveyed with a Wild T-2 theodolite. Repeated measurements indicated an accuracy of few meters which is more accureate than can be marked on the 1:10,000 scale maps.