Yearly History of Ice Drilling from Nineteeth to the First Half of Twentieth Century

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In the early stages of human development, making holes in ice was connected with ice fishing or accessing fresh water during winter in regions with a temperate or tundra climate, and the most popular device to use for this was a chisel-shaped blade attached to a wooden pole. *Ice chisels* have been used for many hundreds of years by Eskimos and the peoples of other northern nations to cut holes through ice by hand for fishing (Fig. 2.1). The ice fragments produced by the up and down chipping action of the chisel in the hole were usually removed at intervals using a spoon-shaped device to maintain the efficient action of the chisel. Ice chisels, also called "*spuds,*" are still used occasionally for chopping holes early in the winter season when the ice is thinner.

This method of cutting a hole in the ice has the advantage that holes of practically any desired width can be made with the same simple tools. However, the hole depth is quite shallow, cores cannot be obtained, and the work is tiresome and slow if the ice is thick. To drill deeper, other drilling equipment should be used.

In 1841, L. Agassiz, one of the creators of glacial theory, made his first attempt to drill to the bed of Unteraargletscher in the Alps. He transported iron rods with a total length of 50 m to the glacier and assembled a solid lance, with which he attempted to penetrate the glacier (Clarke 1987). Percussion drilling was employed, using a bit with a diameter of 80 mm. Agassiz used all his extension rods without attaining the bed.

The following year he brought a few hundred meters of cable with him, which he used to suspend an iron lance, effectively rigging a rudimentary cable tool (Fig. 2.2). After 6 weeks of tedious effort, holes that were 16, 32.5, and 60 m deep had been completed. During the first 3 days of drilling in each hole, the typical drill rate was 13 m/day (with four men), but this decreased to 3–4 m/day (with eight men) as the hole depth increased. Discouraged, Agassiz made no further attempts to drill through glaciers.

The first patent related to ice-drilling technology was for an "*Improvement in Ice-Augers*" and was registered by W.A. Clark in the USA in 1873 (Fig. 2.3a). This patented drilling tool has the form of a screw with lips for cutting a hole of the required size. A few years later in 1883, the first patent for an ice core drilling tool, a "*Machine for cutting holes through ice,*" was obtained by R. Fitzgerald in the USA. This ice hand core drill was rather simple and consisted of a cylinder with a flanged edge to which cutting blades were applied (Fig. 2.3b).

For shallow drilling, E. von Drygalski used a *spoon-borer* while wintering in Western Greenland in 1892–1893 (Kalesnik 1963). In Antarctica, in the first German South Polar expedition with the ship Gauss, he used a hand auger and spoon-borer (Fig. 2.4) (Drygalski 1904). The spoon-borer was made of a 0.75 m long steel tube with a diameter of 50 mm. Two half-moon cutters were fixed on the lower end of the tube, and a longitudinal slot helped ice cuttings to fill the internal space of the spoon. Despite being trapped by ice for nearly 14 months, the expedition discovered an adjacent area south of the Kerguelen Islands and drilled a few 30-m-deep holes in the neighboring iceberg for temperature measurements. From April 1902 to January 1903, temperature readings were taken in the air and ice one to four times per month. In August 1902, the 30-m-deep ice temperature was −10.4 °C, and in December 1902, the temperature slightly increased to −9.6 °C.

In 1897, J. Vallot drilled a 25-m-deep hole in Montanvers, in the Alps, in 9 days (Bourgin 1950). At the turn of the twentieth century, A. Hamberg began an integrated study of glaciers in Swedish Lapland (Mercanton 1905). He used a driven pipe to study the inner structures of glaciers to depths of 5–6 m. Drilling a 4-m-deep hole took about 1 h.

A. Blümcke and H. Hess carried out one of the most comprehensive glacier surveys of Hintereisferner (Alps) and measured the ablation rate, surface altitude, and ice velocity along a series of transverse profiles. They were the first to

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Fig. 2.1 Coastal Eskimo ice fisherman, Denver Museum of Nature & Science (Caribou skin clothing n.d.)

Fig. 2.2 Cable tool used by L. Agassiz in 1842 (Clarke 1987)

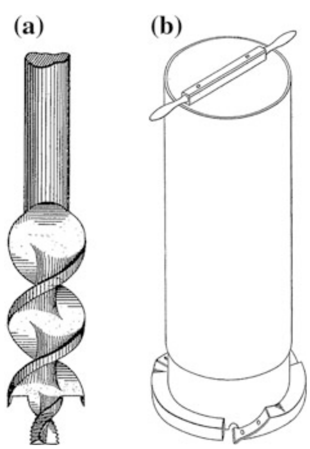

Fig. 2.3 First-ever patented ice drills: **a** ice auger drill (Clark 1873); **b** ice core drill (Fitzgerald 1883)

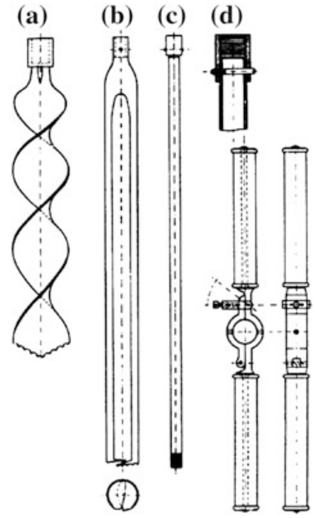

Fig. 2.4 Drilling tools used by von Drygalski (1904): **a** auger; **b** spoon-borer; **c** drill pipe with threaded connection; **d** wrench

successfully drill through a glacier, and between 1895 and 1904 they drilled 11 holes with a depth range of 40–224 m, almost all of them stopping at the bed of the glacier (Blümcke and Hess 1899; Rey 1909). The deepest hole (224 m) was not completed. Their hand-powered *rotary drill rig* was produced by Heinrich Mayer and Co. (Tiefbau-Werkzeuge-Fabrik) (Fig. 2.5). Water circulation was used to clean ice cuttings from the bottom. Typically, holes were drilled by hand-power down to 80 m with an average drilling rate of 4–5 m/h. The total weight of the equipment was close to 2.5 t, and six men were needed to operate the drill.

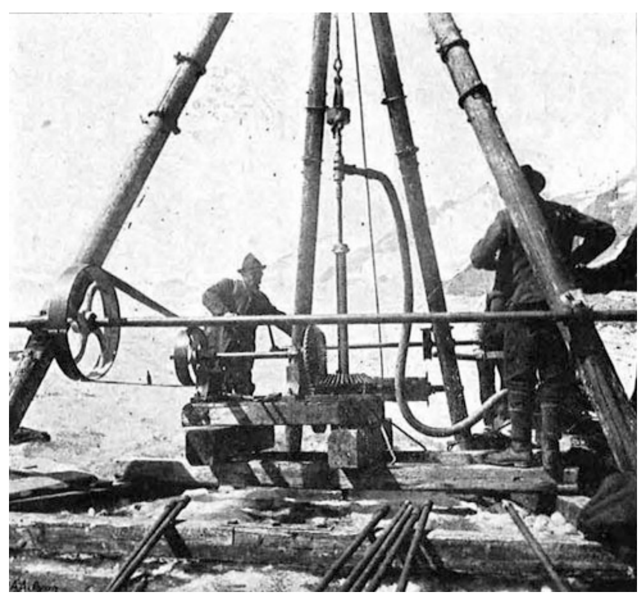

Fig. 2.5 Hand-powered rotary drill used by A. Blümcke and H. Hess to drill through Hintereisferner (Rey 1909)

Fig. 2.6 Mercanton's design for ice drill bit (Mercanton 1905)

A. Blümcke and H. Hess measured borehole temperatures down to 148 m. However, it appears probable that their results were considerably affected by the disturbing influence on the surrounding ice of the water they were obliged to use in their drilling. A casing left in a borehole in Hintereisferner in 1901 was rediscovered in 1933, and found to have developed a forward slant, implying that the velocity was greatest at the surface (Waddington 2010).

In 1900, with the help of an assistant, P.-L. Mercanton drilled in the Trient Glacier (Alps) to a depth of 12.25 m in 4 h (Mercanton 1905). Drilling the last 4.25 m took 1 h, but the rate of penetration between the 5 and 7 m depths was 6 m/h. The specifically developed drill bit had three blades that were rigidly attached to a 30-mm-diameter tube (Fig. 2.6). The outer diameter of the drill bit was 75 mm. The drill bit was connected to 2-m-long, 18-mm-diameter gas pipes rotated by the compact drill rig with a rotational speed of 30 rpm. The drill rig was suspended by a simple tripod. Ice cuttings were removed by the direct water circulation produced by a small pump with a flow rate of close to 3 L/min.

In 1912, while wintering in Northeast Greenland, P. Koch and A. Wegener built a hut on the ice (Dansgaard 2005). Inside this hut, they drilled to a depth of 25 m with an auger similar to an oversized corkscrew (Fig. 2.7). They measured the temperature at various depths and its variation throughout the winter.

In 1919, the first subglacial rock drilling project to approach an ore-body was successfully realized in British Columbia, Canada (Williamson 1920). The Sullivan "S" diamond drill and 20 t of supplies (a gasoline engine, three 7 m long poles for the tripod, gasoline, a zinc mud tank, and other tools) were hauled over the snow 16 miles from Laid law to the Lucky Four Mine property at an altitude of 1995 m on one of the glaciers in the Cheam Range (Fig. 2.8). The first location was on the bedrock base in a 9-m-deep snow pit with an area of 7.6 m × 7.6 m covered by a large tarpaulin. Snow water for circulation was melted using an oil stove. Drilling was done in three shifts. After drilling one hole with a depth of 213 m, an attempt was made to drill another hole at an angle of 15° to the west of the first hole, but glacial ice was encountered after going 18 m. Repeating the performance to the east, ice was again encountered at 10 m. In order to determine how deep the ice was and what the bedrock looked like, miners constructed a 1.2 m × 1.8 m tunnel a distance of 25 m through the ice to the bedrock. A second drill site was located about 120 m above the first one.

Fig. 2.7 Drilling by A. Wegener (Photo gallery: Alfred Wegener, n.d.)

Philipp (1920) used a hand-operated spoon-borer with a diameter of 20 mm for glacial research (Fig. 2.9). The diameter of the spoon head was expanded to 23 mm. Connections were made using 11- and 14-mm gas pipes. After penetrating 0.2–0.25 m, the spoon needed to be retrieved to the surface, disconnected using the "quick release," turned over, and emptied by a slight tap.

In 1934, a few shallow holes to a maximum depth of 15 m were drilled by H.U. Sverdrup and H.W. Ahlmann during the course of the Norwegian–Swedish Spitsbergen Expedition (Sverdrup and Ahlmann 1935). Coring and non-coring types of drills were used. The coring drill consisted of a slit piston, one edge of which was bent slightly inward (Fig. 2.10a). The end was serrated, and the bent-in edge was sharpened so as to cut the firn when the drill was turned. The drill shaft consisted of pieces of iron piping, with a length of 1 m and wall thickness of 1 mm, which were screwed together using ordinary threads. During boring, an ordinary wooden handle was screwed in. A spoon-borer

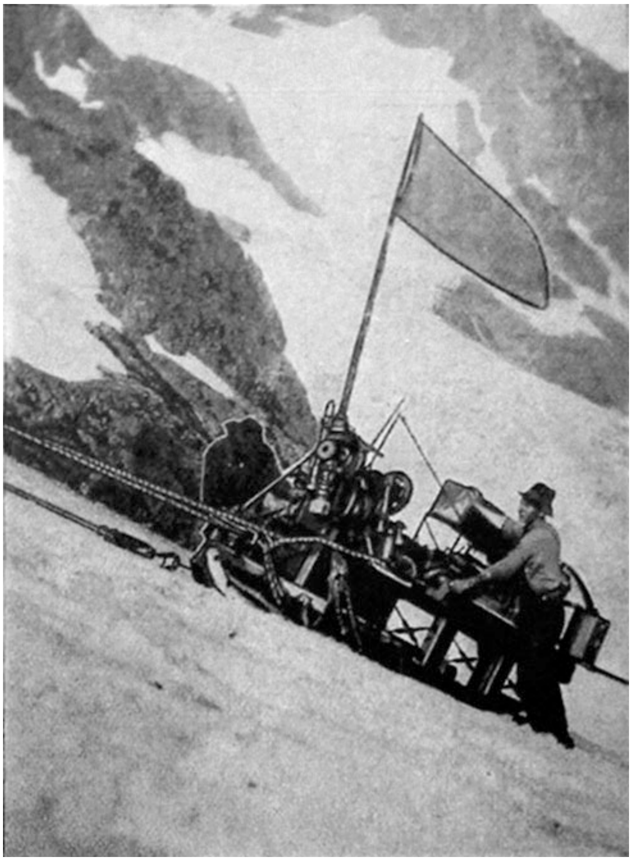

Fig. 2.8 Hauling drill rig to site in Cheam Range, Canada, 1919 (Sullivan Machinery Company 1924)

similar to H. Philipp's tool was used for drilling in solid ice in the lower part of the hole (Fig. 2.10b). This borer was not slit, and its end had two obliquely placed, scoop-shaped, sharp jaws. Both of the drills had high efficiency, and 1 m could easily be drilled, even in hard ice, in 10–12 min.

In 1938, T. Hughes and G. Seligman drilled a few shallow holes at Jungfraujoch (Alps) for continuous temperature measurements and found that at depths near 10 m, the ice had a temperature close to the melting point, even though the mean annual air temperature was −7.3 °C (Hughes and Seligman 1939; Seligman 1941). The drilling was done using two types of augers: one with a short screw flight and another with an "enormous" leading screw and powerful cutting cheeks (Fig. 2.11a). The last one was the most successful and worked admirably in blue ice. The spoon was used to remove chips (Fig. 2.11b); this was carried out using a second set of rods to save the changing time. A smaller 15 × 1½″ spoon was principally used. The rods were drawn by hand without using a derrick. A special crown-shaped head was used to bring up undamaged shallow cores from the bottom of the hole (Fig. 2.11c). The bit had 12 teeth, eight pointing inward to hold the core, and four pointing outward to do most of the cutting.

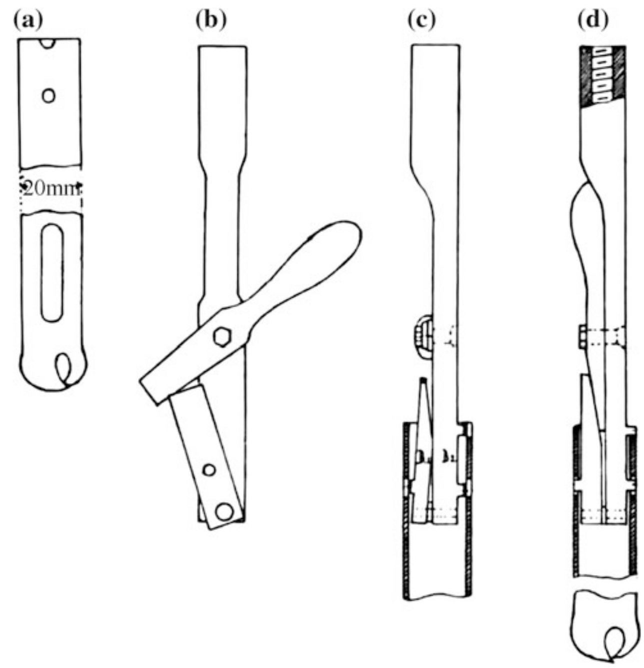

Fig. 2.9 Drilling tools used by Philipp (1920): **a** ice spoon-borer; **b** "Quick release" mechanism; **c**, **d** "Quick release" mechanism inserted and locked in spoon-borer

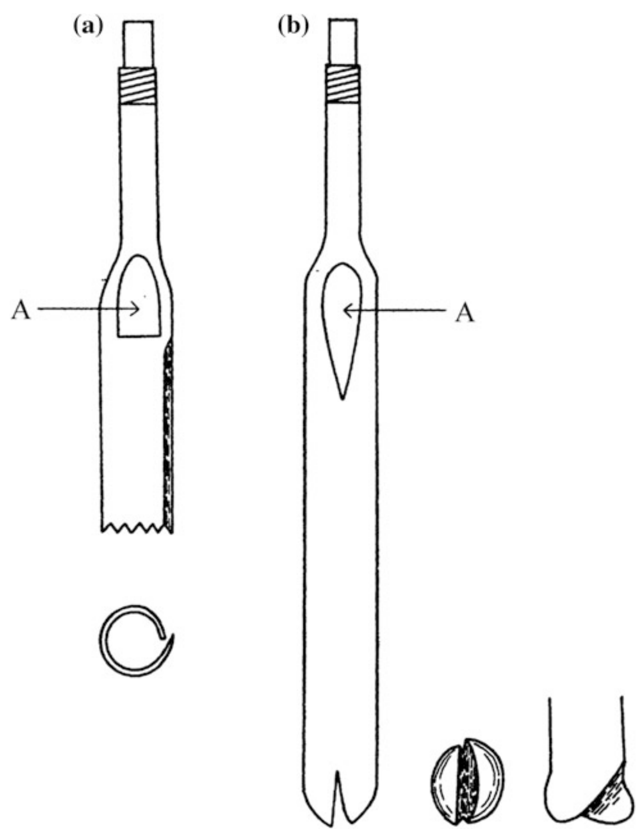

Fig. 2.10 Drilling tools used in Spitsbergen (Sverdrup and Ahlmann 1935): **a** snow/firn corer; **b** noncore spoon-borer ("A" indicates openings through which tools are emptied)

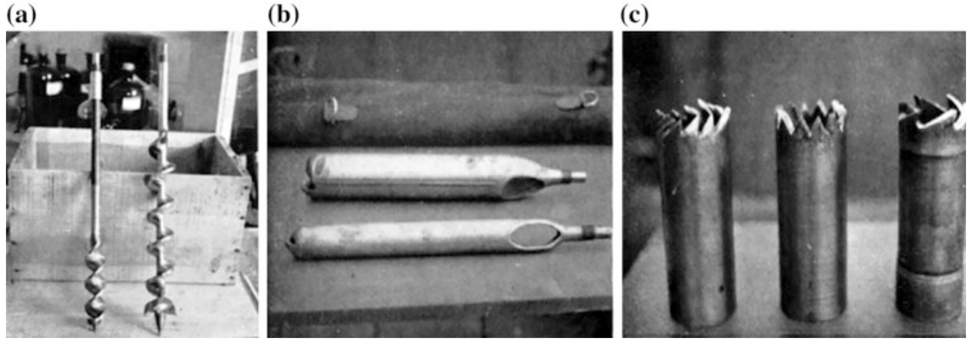

Fig. 2.11 Drilling tools used at Jungfraujoch, Alps, 1938 (Seligman 1941): **a** augers; **b** spoons; **c** coring heads

Shortly before World War II, during a reconnaissance of the glacier Mer de Glace near Chamonix, France, M. Rac–Madoux perfected another type of hand-operated ice auger that used saltwater injection to prevent the jamming of the drill hole by pieces of ice chopped off during penetration. This rig was used to drill 10 m holes in an 8 h shift, including all the operations (Nizery 1951).

Although scientific research on glaciers was interrupted by World War II at the end of the 1930s, ice-drilling technology improved significantly in the following decades. The following review will start with snow samplers. Even though sampler development began in the first half of the twentieth century, the sketch includes their entire historical evolution because the old sampling tools were very similar to the new ones. Thus, the reader will gain a greater understanding by considering their development over time.

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