

Byrd Station drilling 1966–69

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ABSTRACT. After completion of the drilling by the US Army Cold Regions Research and Engineering Laboratory (USA-CRREL) at Camp Century, Greenland, in July 1966, the operation was moved to Byrd Station, Antarctica, during the 1966/67 austral summer. The drill employed was an electromechanical cable-suspended drill that used ethylene glycol to dissolve the chips formed, producing a core with an average diameter of 114 mm. A mixture of diesel oil and trichlorethylene was used as a borehole fluid. Ice-core drilling at Byrd Station occurred from 2 to 18 February 1967 and from 12 October 1967 to 2 February 1968 when the ice sheet was penetrated at a depth of 2164 m. During the ensuing 1968/69 season the drill was lost, and ultimately the cable was severed in early 1969/70 at a depth of 1545 m. This brief report reviews the drilling operation and some of the problems encountered primarily during the 1967/68 season, with a focus on the last few days of drilling.

INTRODUCTION

Drilling at Byrd Station, West Antarctica, was the second part of the post-International Geophysical Year (IGY) deep-drilling program which had been delayed for several years by the Greenland drilling at Camp Century (Ueda and Garfield, 1968). This was the second drilling program conducted at the station since the 1957–58 drilling at ‘Old Byrd Station’ (Patenaude and others, 1959).

ELECTRODRILL

The electrodrill (Fig. 1) was a cable-suspended rotary drill consisting of: a cutting head 156 mm outside diameter (o.d.) by 114 mm inside diameter; a core barrel; a gear reducer; a 2300 V 13 kW electric motor; a centrifugal pump rated at 303 L min⁻¹ at a 37 m head; a bailer; anti-torque skates (two leaf springs were added to augment the skates); and a swivel section with slip rings at the top. Drill rotation was 225 rpm. The drill was 25 m long and weighed 11.8 kN. Two types of cutting bits were used, one with plain steel teeth and one with diamond-encrusted teeth. The diamond bit was used in both the ice or silt and rock material. The drill was suspended from a double-armored electromechanical cable 25.4 mm in diameter, with 12 electrical conductors and weighing 2.1 kg m⁻¹.

The conventional method of removing the cuttings by letting them settle to the bottom of the bailer would have been difficult since the density of the borehole fluid and the cuttings would be nearly equal. B.L. Hansen devised a scheme whereby an aqueous solution of ethylene glycol would be sent down on each run in the bailer to dissolve the cuttings and the spent solution would be removed on each run via the bailer. An aspirating system was designed within the bailer to ensure that the more concentrated solution (sent down on each run) reached the cutting head. Any solution remaining would stay at the bottom of the borehole since its density would be higher than the borehole fluid which was a mixture of diesel fuel (DFA) and trichlorethylene (TCE).

1966/67

The Antarctic program began at Byrd Station (80°91′S, 119°31′W, 1530 m a.s.l. mean annual temperature -28°C)

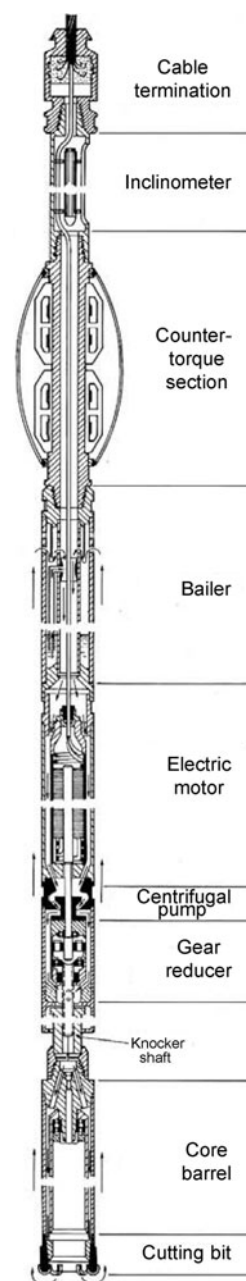


Fig. 1. Electrodrill.

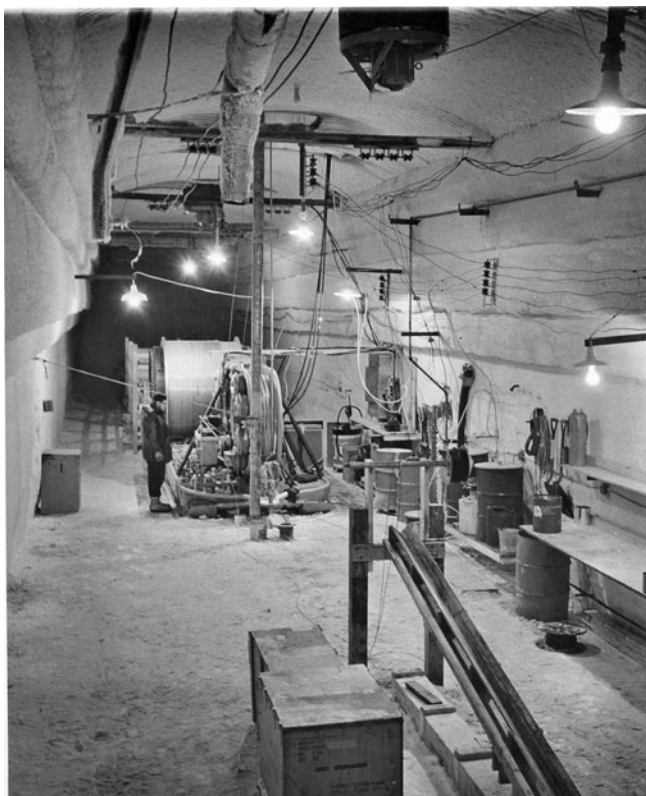


Fig. 2. Winch set-up in main tunnel, 1966.

in November 1966 (Ueda and Garfield, 1969). The drilling site was located at the south end of the main station tunnel. The first task was to open a borehole through about 6 m of snow cover and through the steel arch roof. A thermal drill with an oversized core barrel was then set up in the tunnel to drill a 76 m deep borehole for the 178 mm o.d. casing. It took until 2 February 1967 to complete setting up the operation, which included preparing the work site, constructing a workshop, opening the tunnel so that the winch (Fig. 2) and cargo could be brought in, erecting the tower and installing the casing. Figure 3 is an overall view of the operation.

Drilling with the electrodrill began on 3 February 1967 with five runs reaching 105 m. Drilling was conducted initially with the diamond bit and only enough glycol solution in the borehole to cover the drill. Trouble occurred on run 93 at 106 m when the drill became bound up and could not be raised. After pouring glycol down the borehole and waiting and trying for 4 days, the drill was retrieved. A depth of 217 m (229 m from the snow surface) was reached by 18 February 1967 to end the season.

1967/68

The 1967/68 season started in late October. All of the stored barrels of concentrated glycol were frozen solid as the freezing point was -12°C , so a thawing technique utilizing an enclosure and a space heater was devised. The process was slow but effective. An inclinometer enclosed in a stainless-steel housing was mounted on top of the drill. The initial borehole inclination was measured to be 0.5° .

Drilling began on 1 November 1967 with run 100, and a two-shift 24 hours per day, 6 days per week operation was

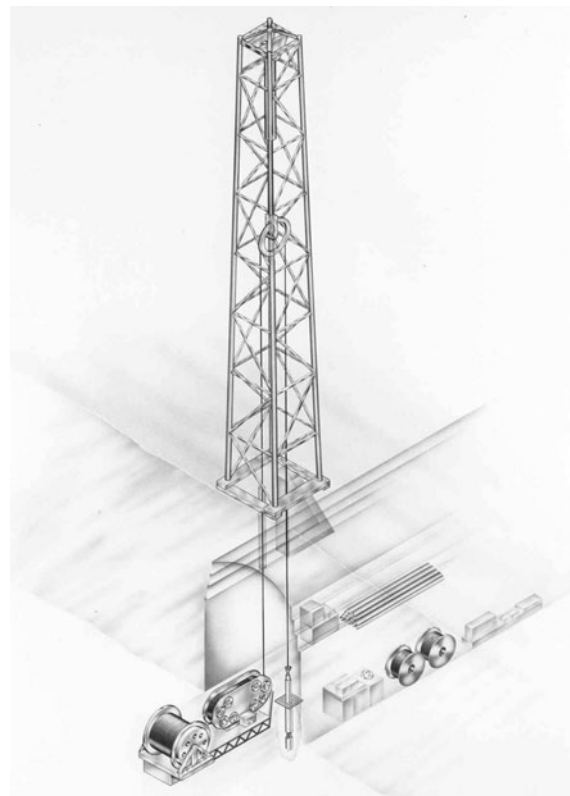


Fig. 3. Overall drilling set-up, Byrd Station, 1966.

started 2 days later. Power was 8.0–8.5 kW, with only about 1 kW used for drilling, the remainder being consumed in the circulation of fluid. Penetration rates were up to 20 cm min^{-1} with good quality cores (Fig. 4). However, the borehole inclination increased slowly until it reached 15° at the end of drilling, despite attempts to correct or retard it. Penetration per run was reduced from 5.5 to 3.0 m from the 600–1150 m depth, and the drilling rate greatly decreased, in an effort to slow the inclination rate.

Numerous problems plagued the operation almost from the beginning, the most serious of which involved the gear reducer and motor of the drill and various hydraulic



Fig. 4. Core from 1982 m depth, Byrd Station, 1968.

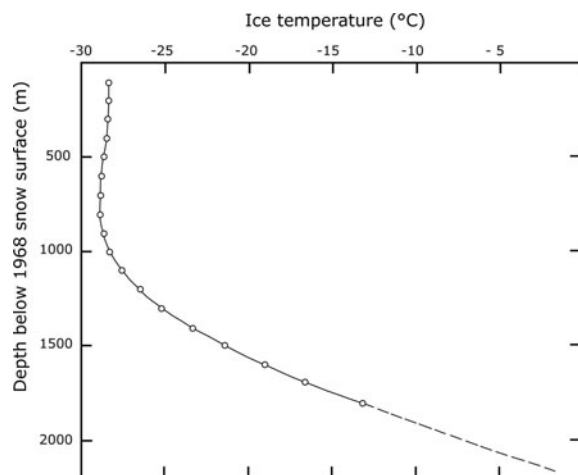


Fig. 5. Byrd Station temperature profile, 1968.

components of the winch. The winch problem was due to an inability to keep the hydraulic oil within the design temperature. Of the 16 hydraulic pumps and motors in the winch, seven became excessively worn or completely inoperative, resulting in a 40% reduction in the hauling rate. On run 399 a hydraulic pump failure occurred with the drill down-hole at 1250 m. It took 3 days before the drill could be hauled out of the borehole. The core was in surprisingly good condition.

On run 375 the diamond cutter was replaced with the steel cutter. It required less overall power (7.5 kW) and less drill weight to penetrate at 9.5 cm min^{-1} . Late in the season the TCE supply had been exhausted, so the glycol solution was left in the borehole in lieu of the borehole fluid. The solution sent down on each run was normally slightly rich as a precautionary measure, and as a result there were indications that the borehole size increased as the solution approached equilibrium. The anti-torque springs became less effective and most of the counter-torque was apparently being provided by the armored cable. Also, as the ice temperature increased with depth (Fig. 5), the dilute solution in the bailer began to freeze on the trip up the borehole.

On run 544 the power became erratic while drilling 3.1 m to 2147 m vertical depth from the top of the casing. The steel bit was badly worn and there was black sandy possibly volcanic material on the bottom of the core.

On run 545 a diamond bit without a core catcher was tried. It drilled 3.5 m to 2151 m and retrieved a 2.1 m core frozen in the core barrel containing several fine-grained granitic-type stones up to 5 cm in diameter. The fluid level was 181 m and the glycol level was 1768 m from the top of the casing.

On run 546 with no core catcher, after 46 min of drilling the power meter showed a decrease of 2 kW and an increase in the weight indicator. After 2 min the power returned to normal and drilling continued for another 15 min to a depth of 2154 m. Again, a core was frozen in the core barrel. A 2.28 m core was discovered in the upper section of the core barrel containing ice and rock debris with the top 1.24 m separated from the bottom portion by glycol ice. The core contained grey to black rock fragments, pebbles of red granite and layers of coarse sand with relatively clear ice in between. The lower section of core consisted of refrozen water which was not brackish to the taste.

On run 547 the bottom was 1.5 m above the previous run and it was noticed that the glycol level rose 43 m from run 545 and that the glycol was becoming thick and slushy. Only about 0.3 m was drilled due to problems with the drill gear reducer. Damage from the water freezing within the drill on the trip up the borehole became evident. It took 8 hours to thaw out the drill and prepare it for another run.

On run 548 the fluid level in the borehole was noted to be about 100 m above that of run 545 and the glycol level was 58 m. The bottom of the borehole was still 1.2 m less than on run 546. Penetration was only about 18 cm when the power level became erratic and there were indications of binding. A 44 cm core of ice containing rock debris was found at the top of the core barrel. More damage from refrozen water was noted.

Runs 549 and 550 consisted of several unsuccessful core-retrieval attempts. Bottom was at 2153 m.

On run 551 a cutter coated with tungsten carbide and a short core barrel were tried and drilled about 0.6 m but could not retrieve a core. Clay-like particles and the formation of rust were noticed on the drill. The carbide was completely worn off the teeth, and abrading of the cutter body and the lower 100 cm of the core barrel was visible.

On run 552 the diamond bit and the long core barrel were reinstalled. The bottom was at 2153 m and after drilling about 1.2 m at erratic power levels the drill began to bind up and appeared stuck. A pull in excess of 4.5 kN failed to move the drill. It was finally freed by restarting the drill motor. Upon reaching the surface, parts of the drill were again severely damaged from the freezing water. One more core-retrieval run was attempted. The drill stopped at about (the run notes were incomplete) 2153 m, and two attempts to grab a sub-ice core failed. Further attempts to obtain a sample were terminated. It was concluded that a thin layer of water was penetrated at a depth of 2165 m (7101 ft) from the snow surface.

Cores averaged 11.4 cm in diameter and 3–6 m in length, increasing in quality with depth. Power input was 7.5–9.0 kW. Drilling rates averaged 21 m d^{-1} despite the periods of down time when no drilling could be accomplished, and $30\text{--}36 \text{ m d}^{-1}$ was achieved even at the lower depths.

1968/69

In 1968/69 the decision was made to clean out the deep borehole and try to recover a sub-ice core. Soil samplers and an 'NX' size core barrel designed to produce a 76 mm diameter borehole and a 48 mm diameter core were ready to be attached to the electrodrill for sub-ice sampling. It was found that the slushy glycol solution was too thick to bail and it was necessary to drill through it. Near the bottom of the inclined borehole the drill started a new borehole and on 1 February 1969 the drill became stuck at 2100 m. In 1969 a recovery tool was employed without success and on 11 December 1969 the cable was severed at 1545 m from the top of the casing with an explosive wire line-cutter. Subsequent borehole surveys were possible to a depth of 1554 m (Hansen and Garfield, 1969).

SUMMARY

The first penetration of the Antarctic ice sheet was accomplished at Byrd Station in February 1968 in 104 days

of drilling, despite a myriad of problems throughout the season. A layer of water was encountered at a depth of 2165 m. After failing to reopen the borehole in 1969, the cable was severed at a depth of 1554 m.

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