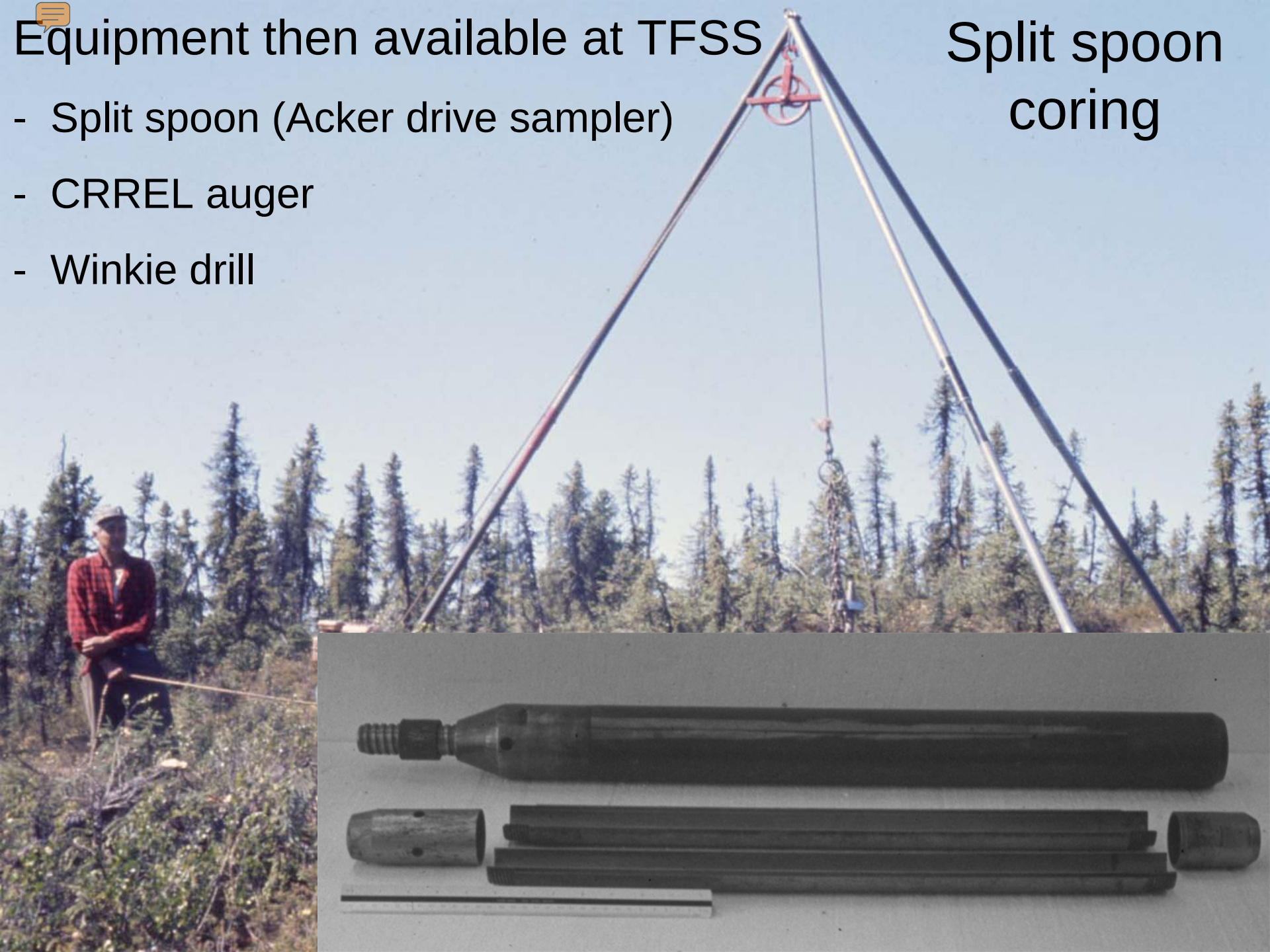
Development of light-weight permafrost coring equipment at GSC; a review

J. Veillette

Equipment then available at TFSS

- Split spoon (Acker drive sampler)
- CRREL auger
- Winkie drill

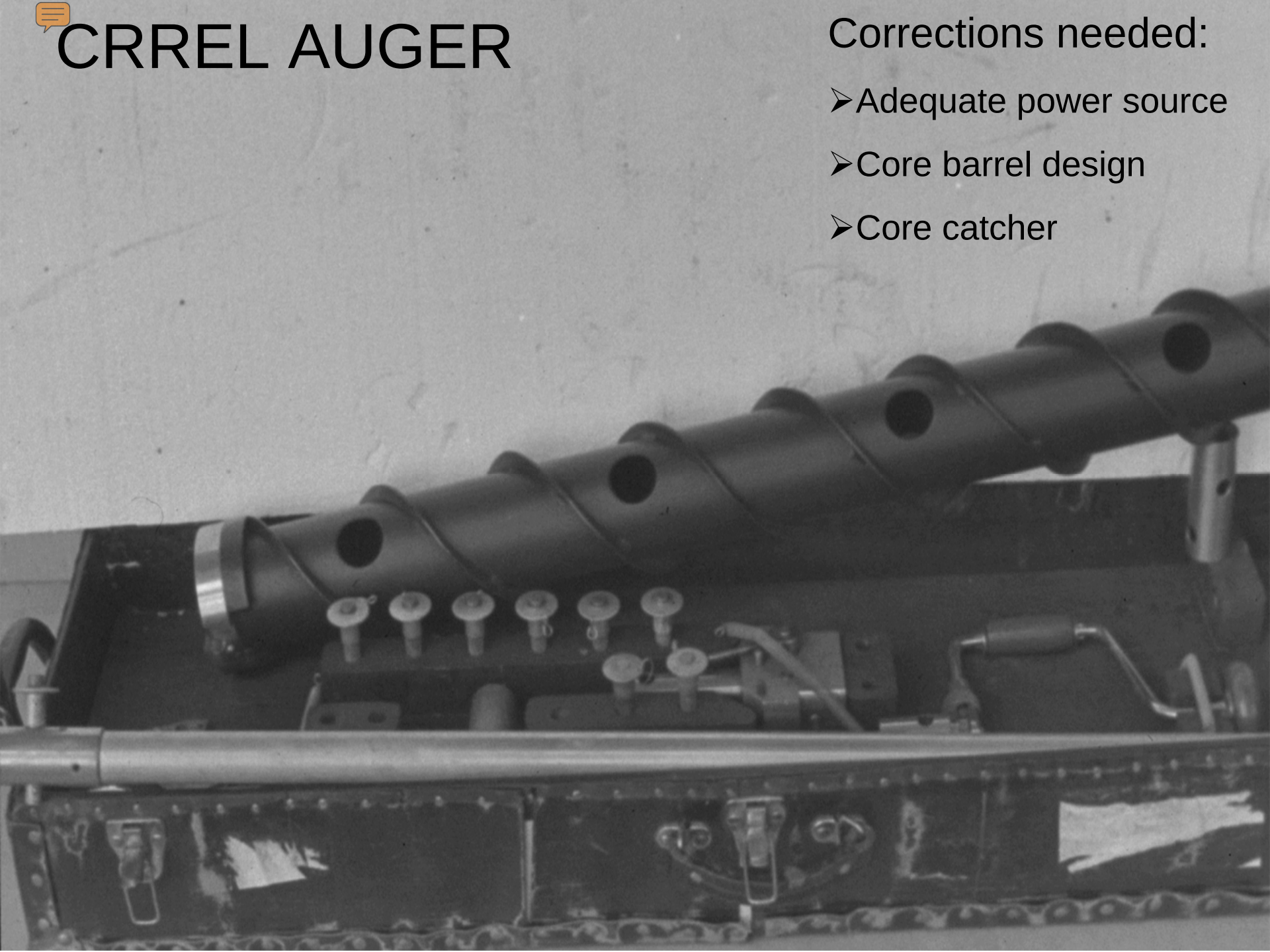
Split spoon coring



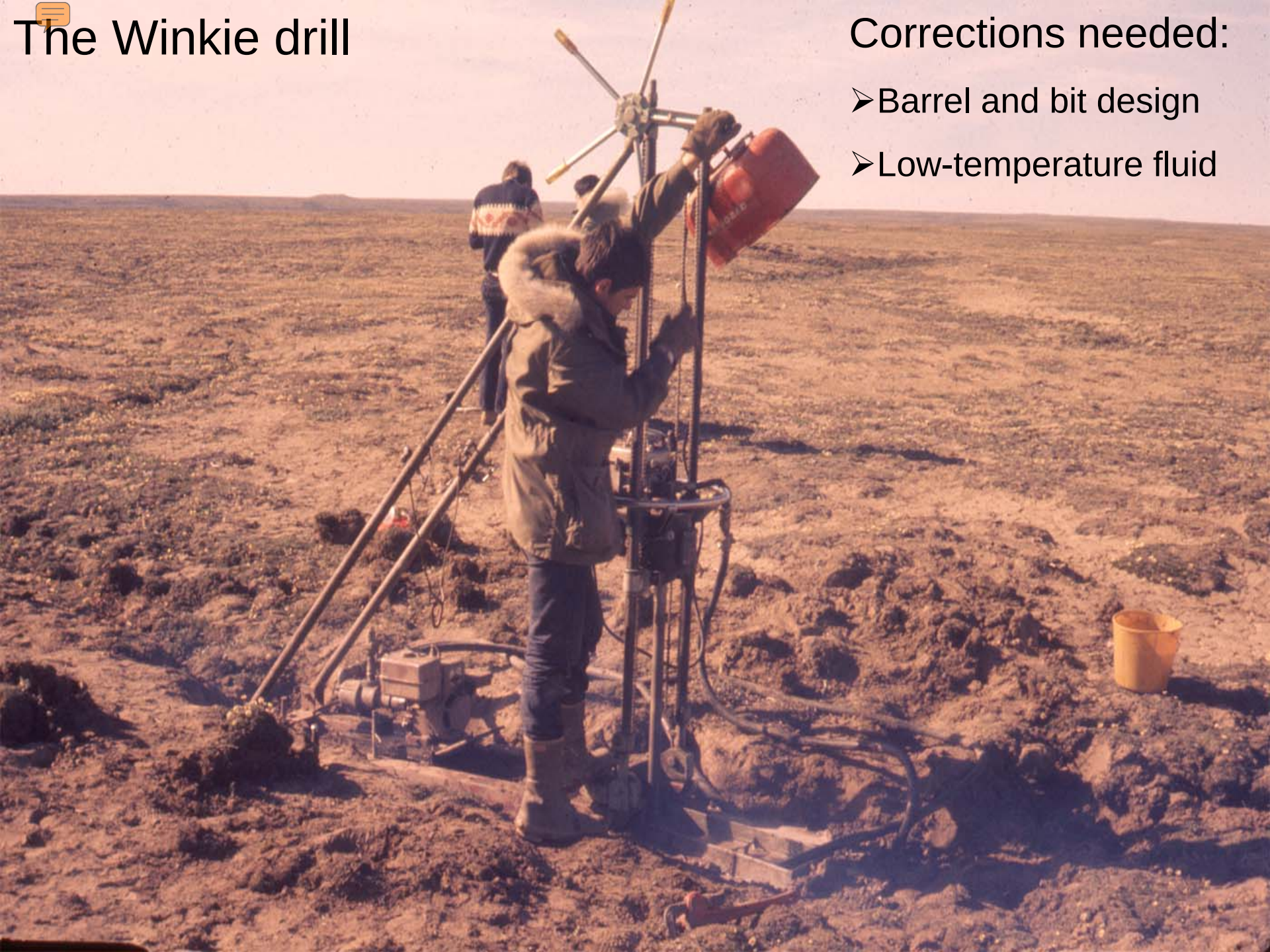
CRREL AUGER

Corrections needed:

- Adequate power source
- Core barrel design
- Core catcher



The Winkie drill



Corrections needed:

- Barrel and bit design
- Low-temperature fluid

Calgary, winter 73

Experimentation in "permafrost"

Four sections 8 ft deep

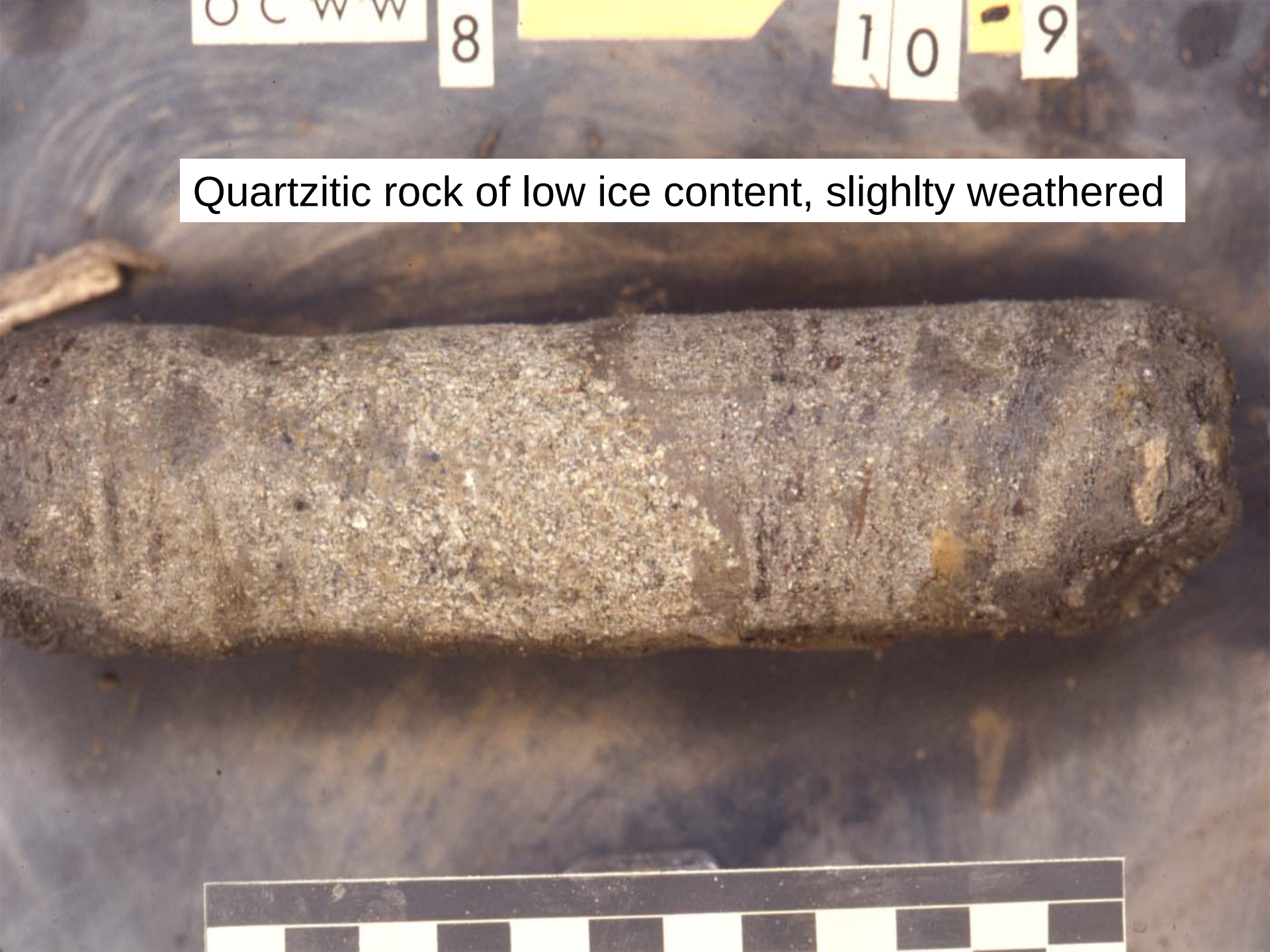
- Clean ice
- Frozen sand
- Gravelly sand
- Stony till-like material

Old Crow, Yukon, winter 73

Hughes 500 (main roter 26 ft) was used to minimize the clearing of landing sites

The whole operation was by helicoper only

Old Crow cores



Quartzitic rock of low ice content, slighlty weathered

Bathing lake cores, stony till

ARD 4
26-29
CENTIMETRES

Excellent core quality in stony permafrost obtained with a light-weight diamond drill. Why?

Drilling carried out at ambiant temperatures -10° C or lower for most of project using a drilling fluid (fuel oil) with a low freezing point chilled naturally

Drilling done from mid-March to late April, when ground temperature in the zone of seasonal fluctuations is lowest

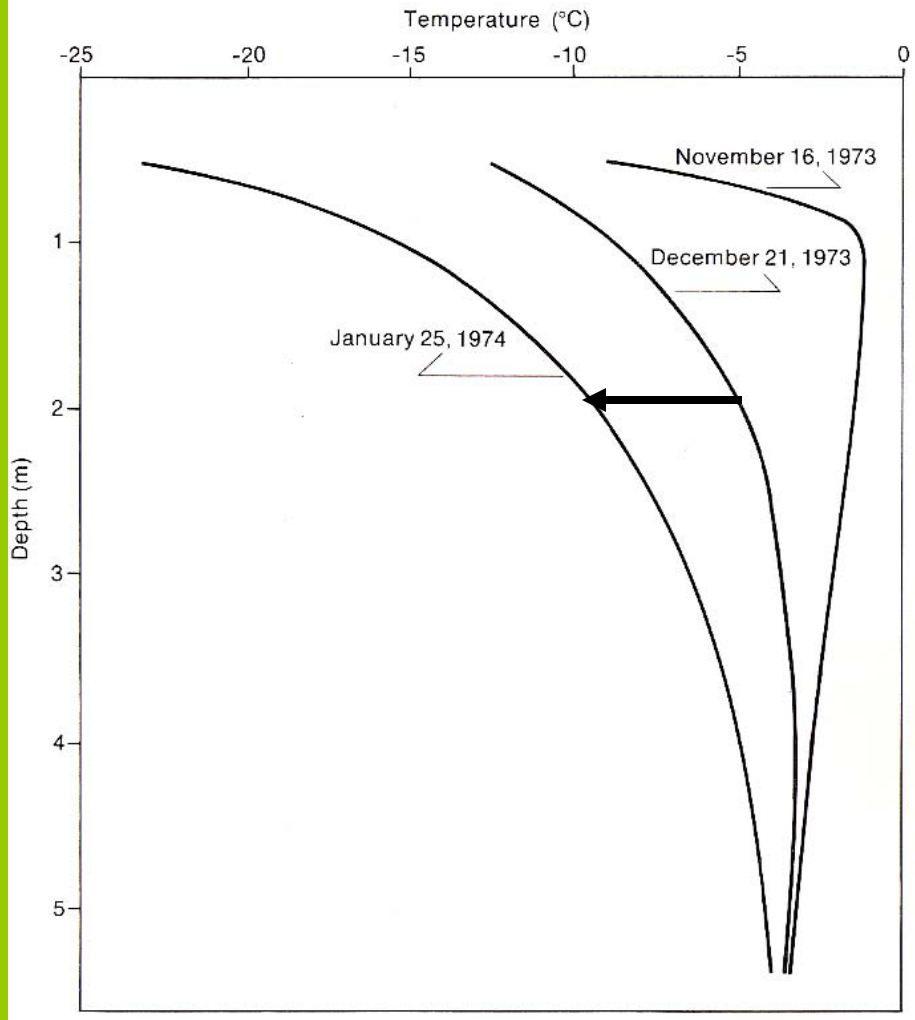


Figure 21. Ground temperature profile, Old Crow, Yukon.

Veillette and Nixon, 1980

But we kept using the Winkie in summer .....Ellesmere I. summer 73

JKS 300 1974

- summer work
- drilling to 10 m

180 kg

300 kg

Assembled

Table 5

Torque at the boring spindle obtained from coring and augering in various types of permafrost, using a 8.9 cm O.D. modified CRREL core barrel or continuous flight augers with a 7.6 cm bit. Data obtained at boring-spindle speed in the 30 to 60 rpm range, with a bit load of 200 kg

Permafrost	Torque, using CRREL core barrel (ft•lb)	Torque, using continuous flight augers (ft•lb)
Friable sand	22	–
Ice	22	–
Silty ice	22-56	–
Clay and ice	22-75	–
Soft shale and ice	22-75	–
Sand and tiny ice lenses	22-66	–
Sand and ice inclusions	94-132	94
Soft shale	38-57	–
Soft sandstone	94	283
Gravel	–	56-132

Veillette and Nixon, 1980

Table 1

Observed depth of penetration of a modified CRREL core barrel (5.1 cm core) for one run in a variety of frozen materials

Material	Penetration (% of core barrel length)	Natural water (ice) content (% by dry weight)	Ground temperature (°C)
Clean ice	60	–	<-10°
	40	–	>-10°
Sand, well bonded pore ice only	40-50	20-25	Any
Soils with 75% or more ice by volume	50	–	<-10°
	30	–	>-10°
Silt	40	25-30	<-10°
	30	25-30	>-10°
Clay	25	30-40	<-10°
	20 or less	30-40	>-10°

Note: Penetration values apply only to a core barrel held in vertical position; horizontal and inclined core barrel positions usually permit longer runs.

Veillette and Nixon, 1980

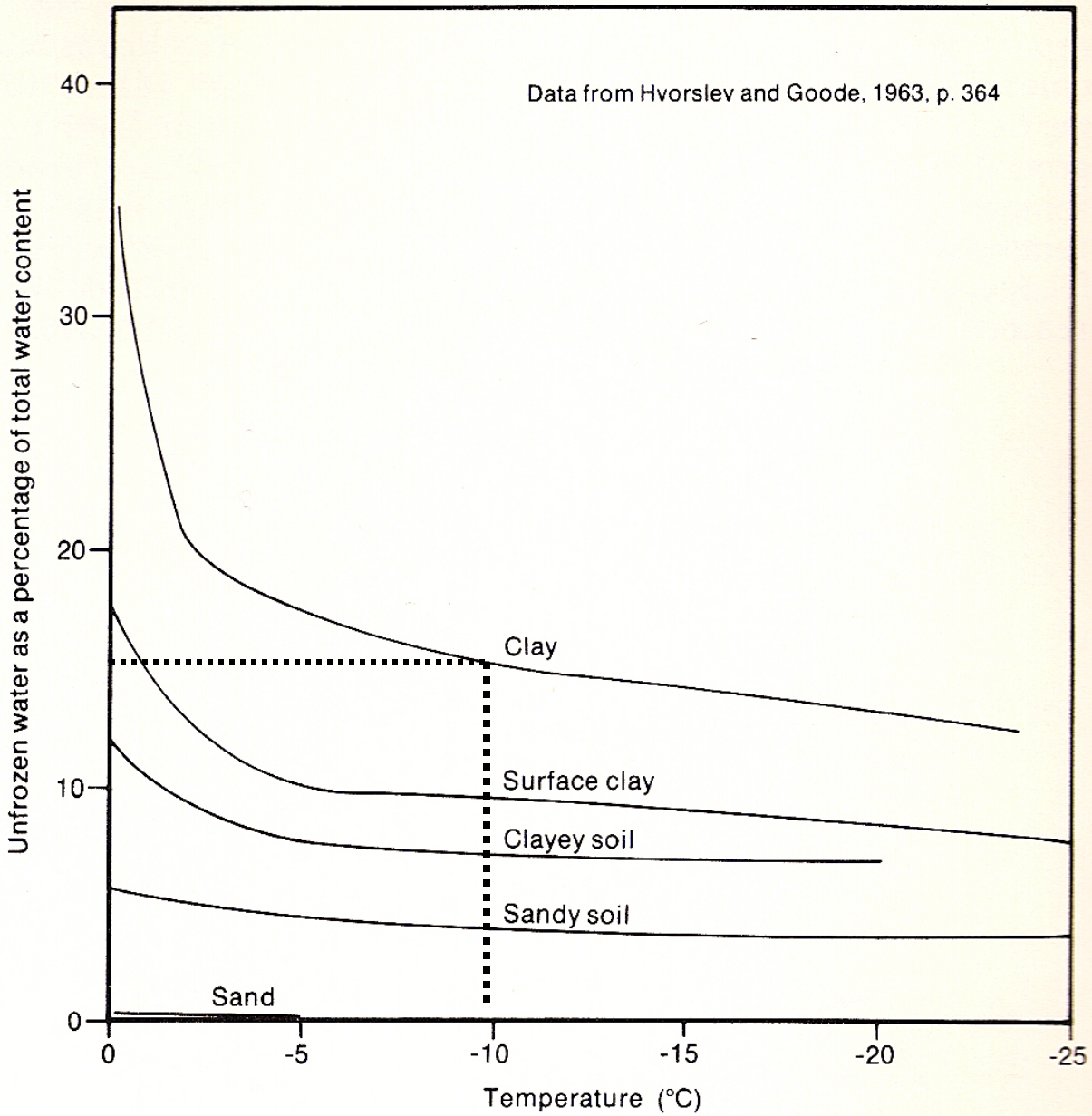


Figure 4. *Plot of unfrozen water content of frozen soils vs. temperature.*

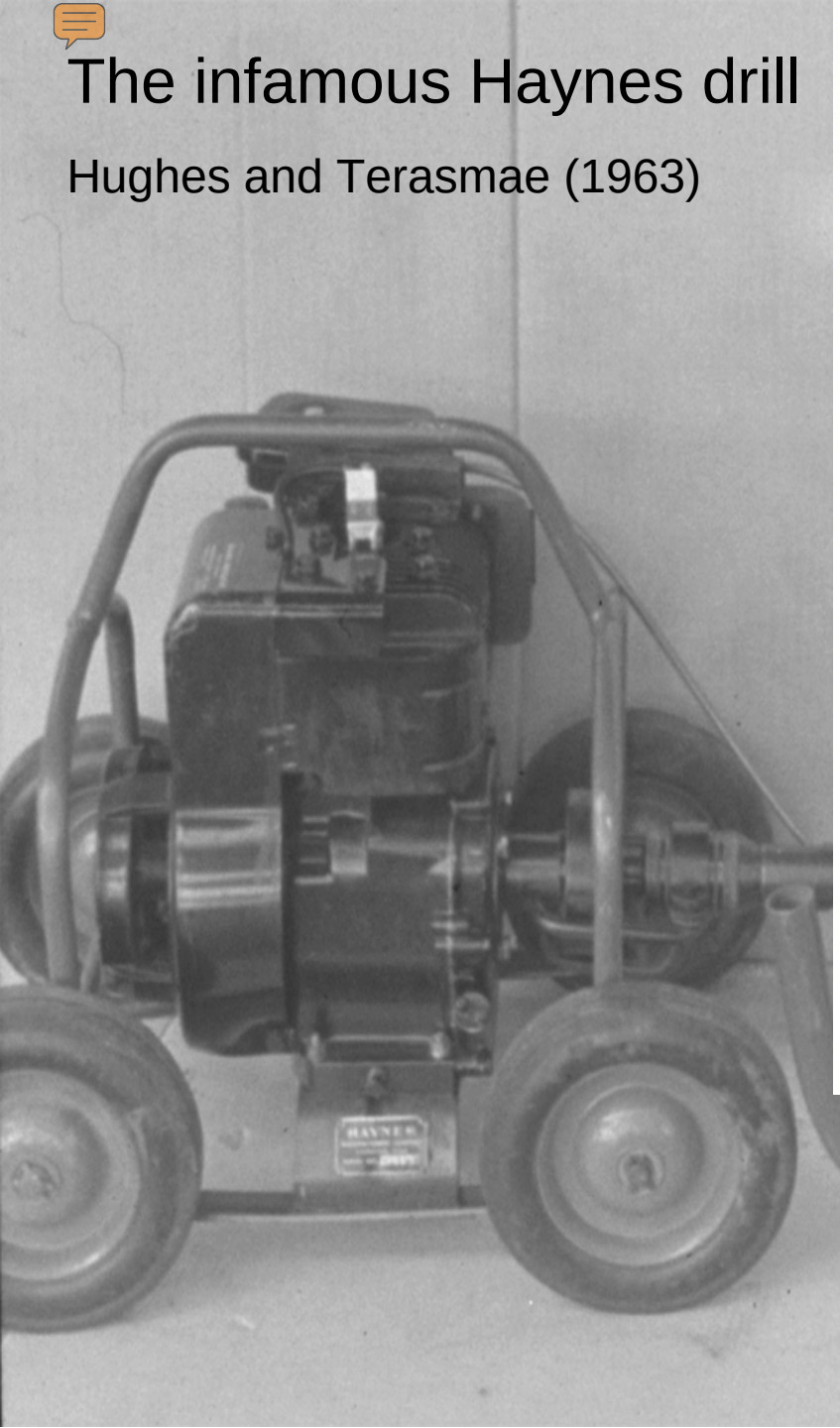
Why is frozen clay touchy to core with CRREL augers ?

Using the CRREL auger with light-weight

hand-held power augers

The infamous Haynes drill

Hughes and Terasmae (1963)



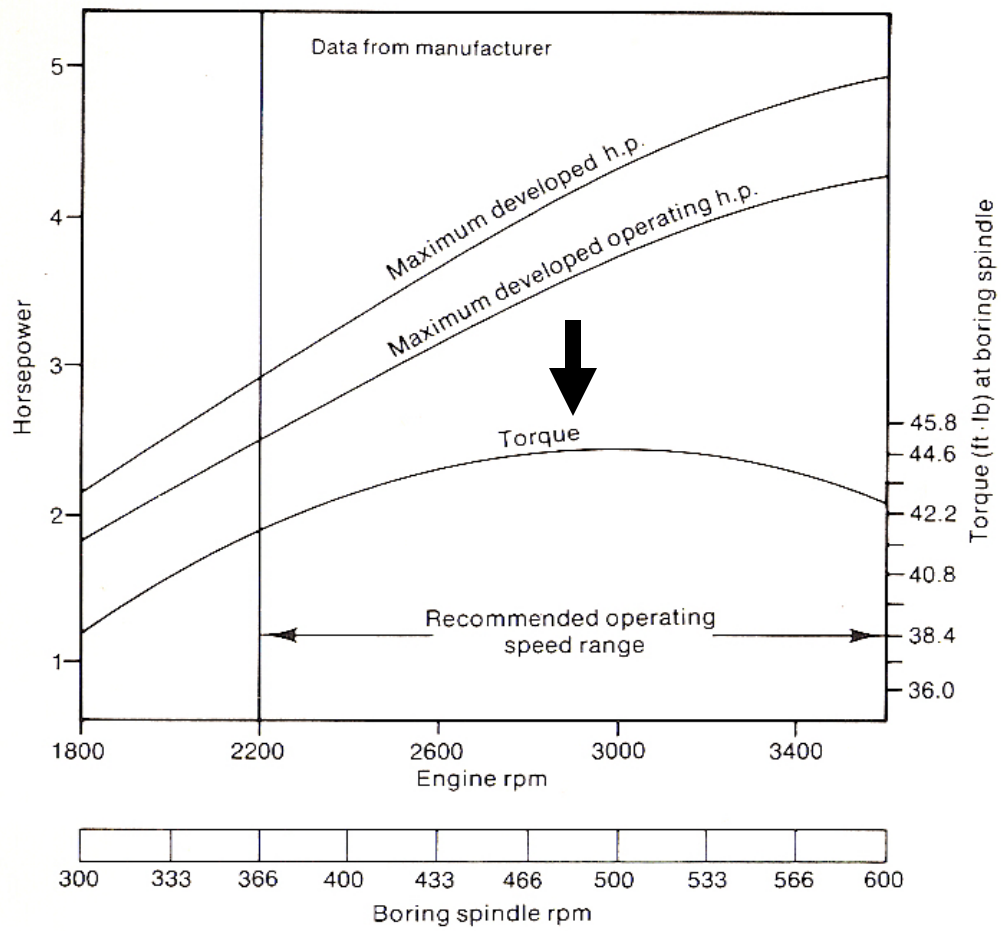
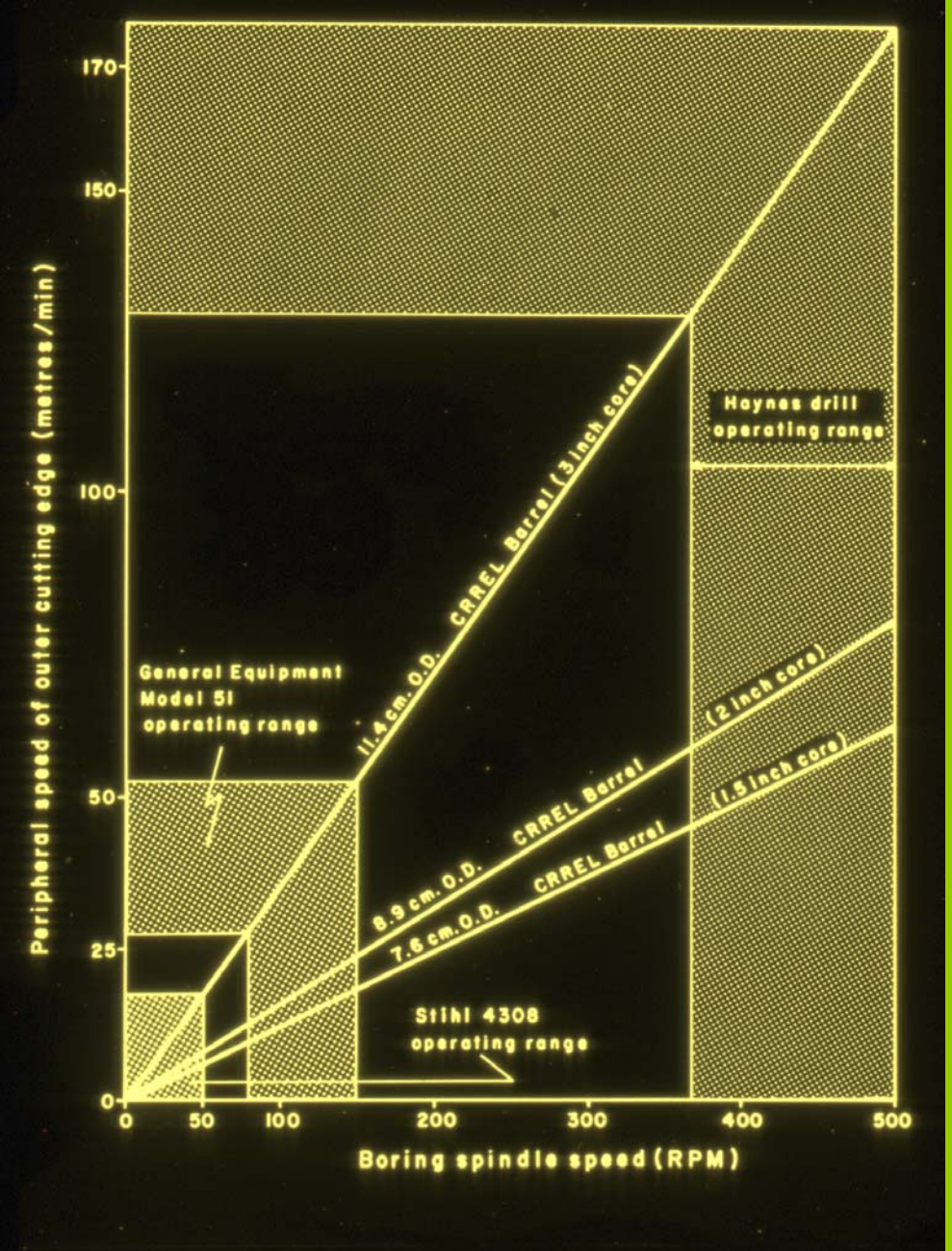


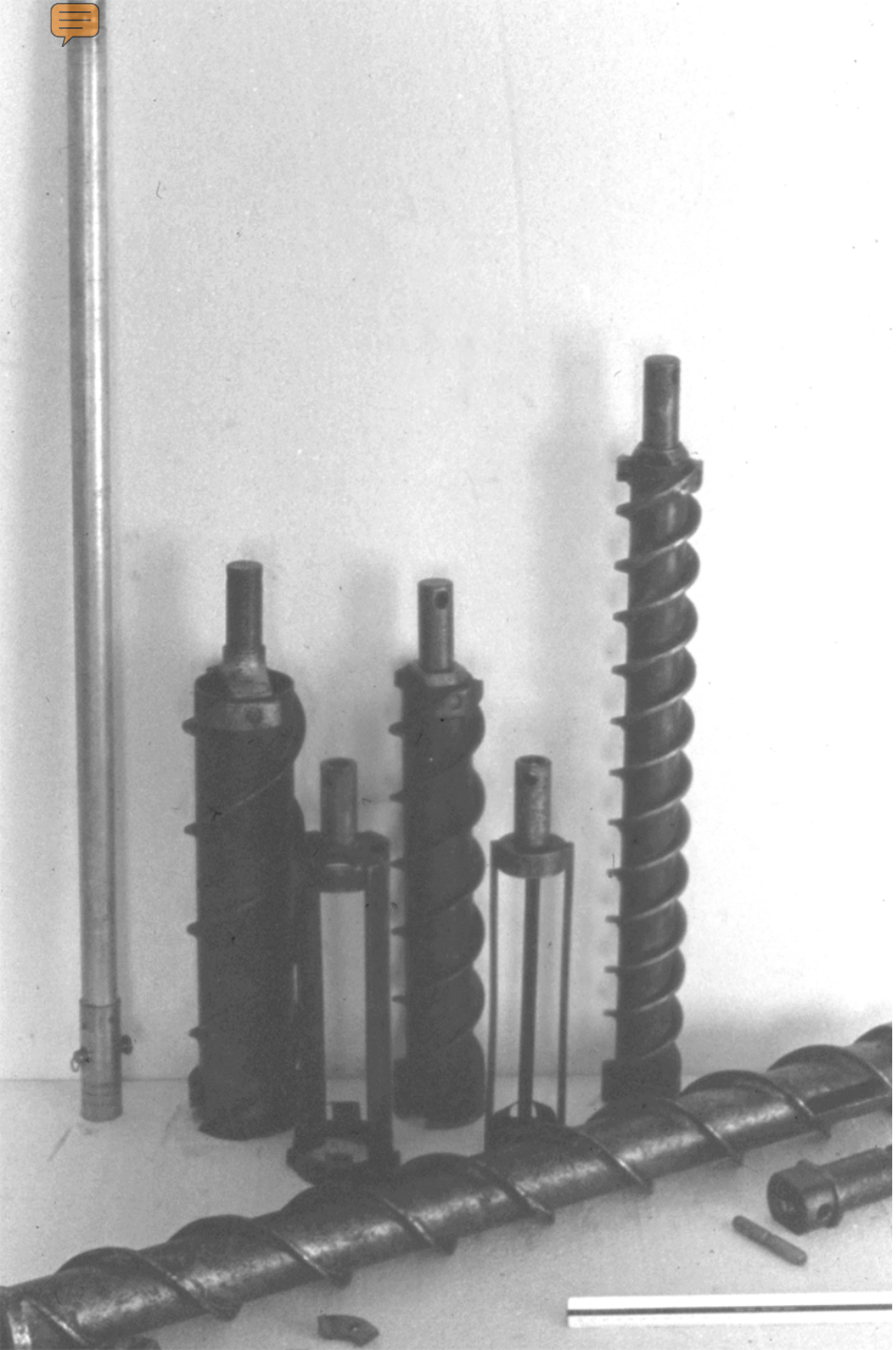
Figure 11. *Performance chart, Haynes drill, model 500.*



Boring spindle speed vs. peripheral speed of outer cutting edge for modified CRREL barrels of 11.4, 8.9 and 7.6 cm O.D. used on three different power augers.

Testing of 3 different hand-held power augers led to the choice of the Stihl 4308 for use with the CRREL auger

- reduced speed at cutting edge
- high (350 ft-lb) torque at low (50) rpm
- available across the country
- superior quality



Frozen sand core

Hand-held power augers using CRREL barrels require

- Low rotational speed
- High torque
- Perform best in low-temperature permafrost

Main limitations

- Labor intensive
- Poor feed (bit load)
- Prone to seizure in clay soils
- Gravelly deposits

ATV drill

- high mobility
- Increase borehole production
- adapted to CRREL augers
- can diamond drill and auger
- adapted to transport with fixed wing aircraft used in remote areas (Twin Otter) and helicopter moves

Somerset Island

All components including the mast fits into the loading doors of a Twin Otter

Unloaded and assembled by two persons in a day

Positioning with fixed wing aircraft

High mobility

- Mast movement electrical
- Several holes in same area
- Helicopter moves across major topographical obstacles

1977 ATV drill upgraded to all-hydraulic operation

Used mainly for geotechnical work in non permafrost areas

L.Dyke, M.Nixon

Main results

- Development work led to design parameters for light-weight power drills using CRREL barrels:
- Successful coring of frozen soils require power drills producing maximum torque at low (< 50) rpm.
- Moderate torque (< 200 ft·lb) sufficient for most soils
- Bit load is the main limitation for hand-held drills
- Stony low-temperature permafrost can be cored with high rpm light-weight drills using chilled drilling fluid

Suggestions for future work

- Permafrost coring kit; reduce weight, for gravelly soils experiment with cutters other than carbide
- Improve bit load, reduce labor (Stinkie)
- For stony permafrost: experiment with chilled drilling fluid compatible with environmental regulations, and
- experiment with sedimentation equipment to clarify drilling fluids, hydrocyclones
- Field work in late winter-early spring when possible, colder permafrost, no mosquitoes

Selected publications

Calmels, F., Gagnon, O. and Allard, M. (2005) A portable Earth-drill system for Permafrost Studies. Permafrost and Periglacial Processes, **16**, 311-315.
CEN, Université Laval. Uses thin-walled bits with no drilling fluid

Nørberg,T., Goodsite, M.E. and Shotyk, W. (2004) An improved Motorized Corer and Sample Processing System for Frozen Peat. Arctic, **57**, no 3, 242-246.
University of Southern Danemark and Heidelberg. Improvements by Blake, Targets frozen peat

Veillette, J.J. and Nixon, F.M. (1980) Portable drilling equipment for shallow permafrost sampling. Geological Survey of Canada, paper 79-21, 35 p.

Covers a variety of drilling equipment, aimed at core production