DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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The Roles of the Geologist and the Driller in Engineering Geology

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(prepared for incorporation in the
National Water Well Association's
Drillers Training Manual, 1975)

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INTRODUCTION

When drilling with any sort of rig for an engineering geologist, the driller is part of a team consisting of the driller, engineering geologist, and design engineer. The engineer calls on the geologist to provide him with information on the rock, soil, and groundwater conditions at the site; the geologist gathers information from aerial photographs, previous reports on the area, and field mapping, and often has to collect subsurface information from test pits and drill holes. These notes are concerned primarily with diamond drilling for engineering geological investigations.

PLANNING AN ENGINEERING GEOLOGY DRILLING PROJECT

What is the geologist looking for?

Usually the geologist knows the rock types, present, but he may not know precisely where the boundaries between the various rock types lie. He is particularly interested in what he calls the rock mass; although rock material may be strong (e.g., any sample of granite) the rock mass with all its defects - joints, shears, faults, and zones of weathering - may be weak; or it may be the weathered rock mass near the surface that is of interest. It is necessary to know as much as possible about the rock defects and rock weathering in order to know how the rock mass will behave.

The geologist selects the site and the orientation of holes so as to intercept a target; the target may be the boundary between limestone and shale, the joint pattern in a fault zone, or merely to check that there are no rock defects. One thing that is certain at each hole is that the geologist is more interested in bad rock than good rock, and since he will have sited his holes to intercept bad rock, the aim of the driller is to try to get 100-percent core recovery of material that may be shattered, weathered to clay in part, have the appearance and consistency of a soil, contain thin layers of clay on the joints, or contain voids in which drilling fluid is lost. It is a difficult task, but if core is lost there may be no way of knowing what the core loss represents.

Equipment

Depending on the type of equipment, a driller confronted with such a drilling project will have varied success in obtaining 100-percent core recovery. If he is using a double-tube core barrel with NX bits, he will find that there will be a loss of core in clay zones and zones of crushed, weathered, and softened rock. For the geologist, core loss has the greatest engineering significance: he cannot assume that the rock is weak because good rock can be ground away and lost by careless drilling, or by the use of unsuitable drilling equipment; therefore, the interpretation of core loss is always difficult and may be misleading.

The most successful equipment available for 100-percent core recovery was developed during work on the Snowy Mountains Hydroelectric Scheme. It comprises hydraulic feed drills, NMLC coring equipment with a stationary inner tube, and bottom discharge barrel, and is the type of equipment specified by geologists on major engineering investigations.

Drilling specification

The geologist will offset a peg from the site as a reference and will then prepare a drilling specification that will indicate the exact location and orientation of the hole, the reduced level of the collar of the hole, the depth of the hole, the drilling target for the hole, an account of the rock types and rock conditions that are expected, the expected water-table, and allowable tolerances and other information likely to be of assistance to the driller. A good geologist will discuss every part of the specification with the driller, and both will then consider the best means of gaining the required core recovery, including the best equipment for the task. A driller should not change to a drilling practice that is outside the specification without prior discussion with and the consent of the geologist. The geologist will normally, unless otherwise specified, check the accuracy of the position of the hole and its orientation before drilling is commenced.

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GEOLOGICAL LOG OF DRILL HOLE

PROJECT GINNINDERRA SEWER TUNNEL
LOCATION At centre of proposed shaft 3 .4·20m west of centre line of tunnel at station 33+15·24m.
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
COORDINATES 199130E 609750N R.L. OF COLLAR 565m.

HOLE No. GST [illegible]
SHEET 2 OF 3

Drilling Information — Method; Casing; Water; Pressure test * (lugeons); Lift & % core recovery; Depth (metres)
Rock Substance — Graphic log & core loss; Substance description: rock type; grain characteristics, colour, structure, minor components; RQD; Weathering
Rock Mass Defects — Strength Is (50) (MPa); Defect spacing (cm); Defect description: thickness, type, inclination, planarity, roughness, coating, strength (Particular / General); Rock mass condition No.

Depth (m)	Method	Pressure test (lugeons)	Lift & % core recovery	RQD
20–21.5	NMLC	0	100%	30
21.5–22.3	NMLC	0	100%	10
22.3–23.5	NMLC	0	100%	20
23.5–25	NMLC	0	100%	50
25–26.5	NMLC	0	100%	65
26.5–28	NMLC	0	100%	93
28–29.5	NMLC	0	100%	75
29.5–30	NX	0	100%	25
30–33	NX	0	100%	75
33–35	NX	0	100%	75
35–36	NMLC	0	100%	75
36–37	NMLC	0	100%	30
37–38.5	NMLC	0	100%	90
38.5–39.5	NMLC	0	100%	75
39.5–40	NMLC	0	100%	100

Substance description

20–33 m: GRANITE PORPHYRY
Pale pinkish, green grey, very Hard, & very strong. — Weathering: FR

33–37 m: GRANITE PORPHYRY
Green. Hard and strong. Softer than above. Easier to drill. Sheared and healed with chlorite veins throughout. — Weathering: FR but altered and slightly chloritized.

37–40 m: GRANITE PORPHYRY
Mainly very hard and very strong. Some slightly chloritised zones and some zones with many calcite veins. — Weathering: FR

Defect description — Particular

- ~21 m: Vertical joints with thin veneer of clay.
- ~22–23 m: 1m. of rock fractured with joints at 80° & 30° some clay on joint surfaces.
- ~32 m: Core ground and broken by drill.
- ~35 m: Core ground and broken by drill.
- ~36.5 m: Vertical fractures with calcite (weak).
- ~39.5 m: Some clay, calcite & pyrite on joints.

Defect description — General

- 20–33 m: Rock mass moderately tight to v.ry tight. Most joint, 0-30°, some at 60°, some at 80°-90°. Joints cemented with calcite and chlorite. Cement moderately strong. Joints planar to wavy and rough and tight. Some narrow fractured zones with clay. — Rock mass condition: 3; 3–4; 2–3
- 33–37 m: Rock mass tight. Joints cemented with calcite & chlorite. Most joints tight & strong but some vertical joints weakly cemented. — Rock mass condition: [illegible]
- 37–40 m: Rock mass very tight & strong. Joint surface rough. Most cemented with calcite. — Rock mass condition: 2–[illegible]

Drill type Mole
Feed Hydraulic
Core barrel type NMLC with triple tube-split inner
Driller Derreck (DHC)
Commenced 10-4-75
Completed 21-4-75
Logged by P. Lang
Vertical scale 1cm = 1m

Weathering
FR — Fresh
SW — Slightly weathered
MW — Moderately weathered
HW — Highly weathered
EW — Extremely weathered

Water
10 Oct. '73 water level date shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Notes:
Bedding & Joint Planes — Angles are measured relative to a plane normal to the core axis.
* Water Pressure Tests — Values in lugeons should be read in conjunction with computation sheets. Test sections are indicated by blacked in strips.

Core Photograph Negative No

Depth (m)	Black & White	Colour

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Geological drill log

As drilling proceeds, the geologist prepares a log of the hole (Fig. 1), which records a description of the rock, and the defects of the rock mass such as joints, shears, faults, and weathering zones.

GEOLOGISTS' REQUIREMENTS DURING DRILLING OPERATIONS

What drilling information does the geologist want to know?

The drillers' 'Shift Report' (Fig. 2) usually provides all the information required from the driller by the geologist. Any special observations can be placed in the 'Remarks' column; those of most significance are:

(a) The hydraulic pressures used and the changes in hydraulic pressure should be recorded as this information is generally useful in deciding on the best drilling practice for optimum core recovery for a particular type of rock.

(b) The return of drilling fluid should be recorded regularly as a percentage, and the colour of the drilling return water should be noted as it may often be correlated with rock defects or with loss of core.

(c) Any change in drilling rate, or fast advance of the drill, should be recorded as it may correlate with a change in the condition of the core that is recovered.

(d) Changes in drill bits, or damage to bits, should be recorded.

(e) The measurement of the water levels at the end of drilling on each day, and before drilling commences each day, are required to provide information on the water-table, and to give some indication of the permeability of the rock.

Boxing and storage of core

Core is placed in boxes lift-by-lift as it is drilled, and is disturbed as little as possible during transfer from the core barrel. Pieces

SNOWY MOUNTAINS AUTHORITY

№ 47250

RETURN TO DRILLING OFFICE

DIAMOND DRILLING — SHIFT REPORT

for 27th May 1971 (date) from 7.00am to 4.30pm (time) Shift 1

LOCATION CHAINAGE 27,000' **HOLE No.** TS 12 **DRILL CREW** (names) Driller M. DZIWULSKI Assistant K. CARSON Others 1

TIME FROM	TIME TO	OPERATION IN PROGRESS	HOURS	DRILLING LIFTS: DEPTH FROM (FT. IN.)	DEPTH TO (FT. IN.)	DST. DRLD (FT. IN.)	CORE REC. (FT. IN.)	DRILLER'S DESCRIPTION OF: CORE	SLUDGE	WHEN CORE IS NOT RECOVERED DRILLER'S ESTIMATE OF: KIND OF CORE LOST	REASON FOR LOSS	REMARKS
7.00am	8.30am	DRILLING NMLC	1½	66' 3"	76' 3"	10' 0"	10' 0"	Slightly Weathered dacite	—	—	—	Rock very hard
8.30	10.30	As above	2	76' 3"	80' 3"	4' 0"	0	—	clayey	Very soft, completely weathered rock	Washed away	60% drilling water loss
11.00am	1.00pm	As above	2	80' 3"	86' 3"	6' 0"	6' 0"	Fresh dacite	—	—	—	Rock very hard
2.00	4.30	Water pressure testing from 66'3" to 86'3"	2½									
		TOTAL FOR SHIFT				20' 0"	16' 0"					

REAMING—For insertion of NX size casing. Reamed from 0' to 60' Distance 60' feet Cementing from 0' to 25' Distance

CASING IN—Size NX Length 60' from surface to 60' PULLED OUT—Size - Length - from - to -

WATER TESTS—Depth to water in hole at beginning of shift 46' 8" Drilling water lost/~~gained~~ at 76'3" ft. Leakage measured — galls. in — secs

PLANT	PLANT NO.	TYPE	RUNNING TIME	FUEL IN (TYPE)	OIL IN	OIL CHANGE TIME OF	REMARKS
DRILL	6-A-18	BOYLES	7 HRS.	9 GAL.	PT.	AT	OPERATION O.K.
CIRCULATING PUMP	16-E-71	1200	7 "	2 "	"	"	"
SUPPLY PUMP	16-E-90	1200	— "	— "	"	"	"
LIGHTING SET			"	"	"	"	

BITS	SERIAL NO.	SIZE	DRILLED FROM	TO	D'TANCE	CONDITION
CORING	88699	NMLC	66'3"	76'3"	10'0"	POLISHED
CORING	84891	NMLC	76'3"	86'3"	10'0"	STILL USING THIS BIT
CORING						
REAMER SHELL	79331	NMLC	66'3"	86'3"	20'0"	GOOD
CASING BIT						
SHOE						
CASING CORING						

REMARKS:

Bearing 345° (GRID)
Angle of Hole -45° (from horizontal)
Ht. of Collar 3260'

Driller (Signature) John Scott
Foreman Paul Grech
Works Foreman M. Peach
Geologist [illegible]

FORM NO. 12/1

Fig. 2

of core commonly become separated during the process, and these must be fitted back accurately and compactly to avoid distributing the core over a greater length in the box than in the ground. The bottom piece in each lift is immediately marked neatly, preferably with paint or non-fading ink, indicating its depth, and a corresponding depth mark is placed on the core box. A small allowance may have to be made for the fact that sometimes the core may break off an inch or two above the bottom of the hole with the result that the core is shorter by this amount than the depth indicated by the drilling rods plus core barrel. However, the shortage is overcome in succeeding runs and there is no cumulative error.

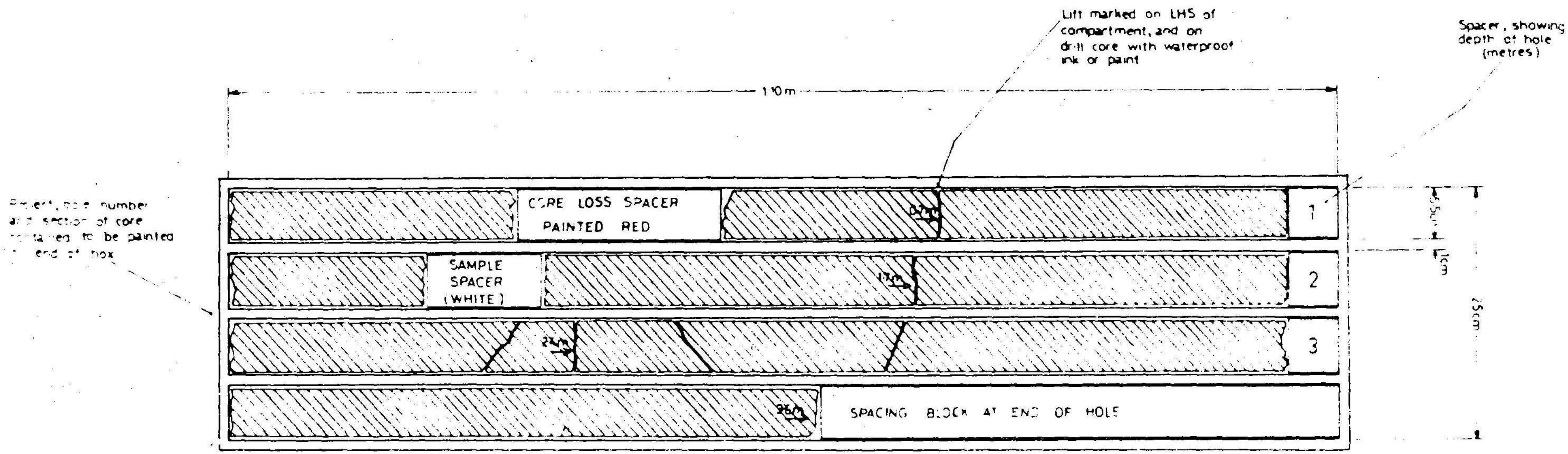
The total length of core storage in a box is always equal to the corresponding length of hole drilled, and, when the core is packed, all core losses are indicated as gaps of the correct length filled with square-section foam plastic or wood painted red (Fig. 3).

All depths in the core are measured by the length of the drill string, and they are the measurements marked on the core box. The amount of core recovered cannot be measured from the length of the core because joints and other defects in the core open up, and because core loss cannot be measured.

If the position of the core loss within the lift is not known, then, by convention, it is shown at the top of the lift. The length of a box may vary for particular projects. If the length of the core box is one metre for example, the depths which are marked at the end of each compartment read 1, 2, 3....etc. In practice this method of boxing requires core to be broken at intervals of one metre, but as this cannot be done precisely the boxes are made about 1.1m long to allow for irregularities.

The advantage of this system is that it ensures that the extent and location of all core losses are obvious. Any core removed from the box for laboratory testing is replaced by square-section foam plastic or wood painted white.

Figure 3



* Core loss spacer blocks to be painted red
* Core removed for testing to be replaced by spacer blocks painted white

BOXING & MARKING OF NMLC DIAMOND DRILL CORE

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The cores should not be removed from the site until logged by the geologist, after which they are taken into storage. They are then kept at least until the project is completed. During this time they may be examined repeatedly by geologists and various engineers as the project develops, and by contractors, particularly during the tendering stage.

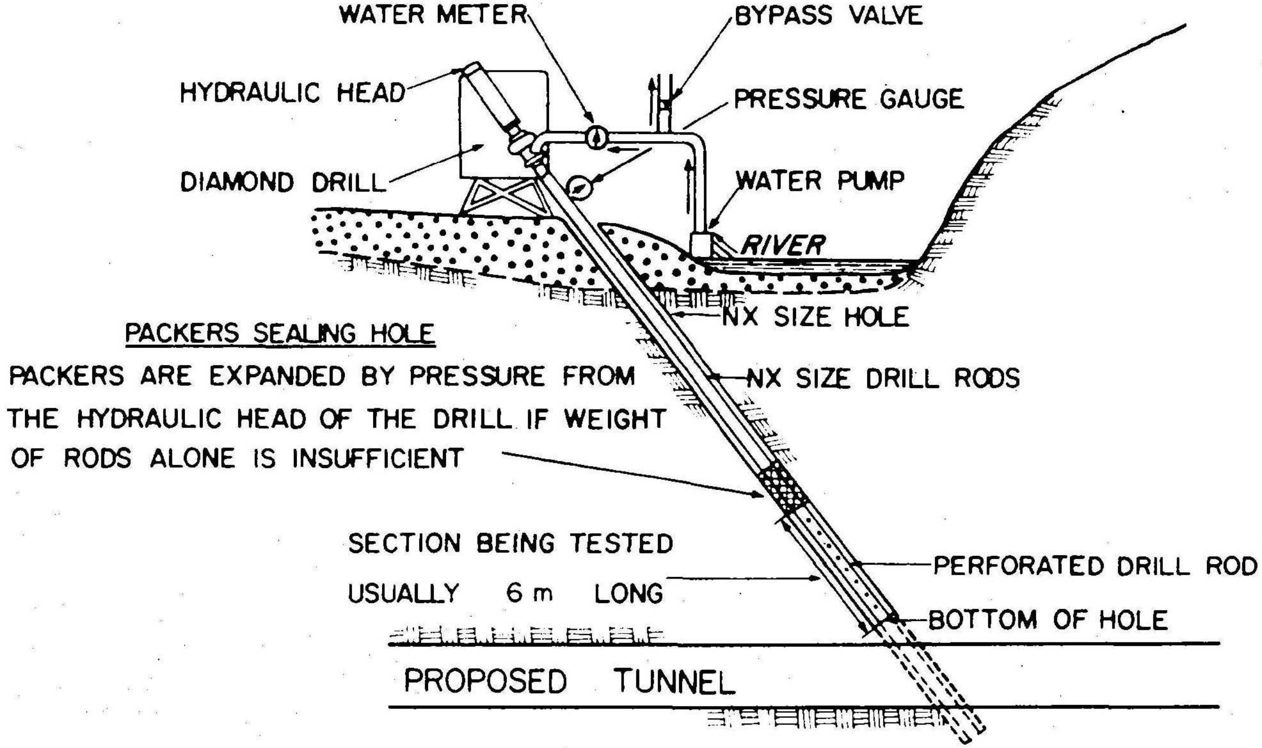
The geologist may require the cores to be photographed in the core barrel before they are transfered to the core box; however, cores are usually photographed in the core boxes immediately after they are removed from the site. Usually this is done from a specially built tripod or platform. Care is taken to have the axis of the camera at right-angles to the plane of the core boxes to minimize distortion. The photographs are enlarged to a uniform scale for documentation and are an extremely useful record, especially where used in conjunction with the geological log.

Water-pressure tests

Water-pressure testing can be used to indicate how much water is likely to flow into a tunnel under construction, or, for a dam, how much leakage may take place through bedrock under the dam and what form of grouting is required to reduce the leakage to an acceptable minimum.

The holes are systematically water-tested during the drilling of the hole. After the hole has advanced a certain distance, usually about 6 m, drilling is suspended and the test carried out by placing a packer 6 m above the bottom of the hole and pumping water into this section at a constant pressure measured on a gauge at the ground surface. The rate of flow from the hole into the surrounding rock is measured on a water meter, and usually stabilizes in a short time; it is then measured over a period of 5 minutes at each of 3 different pressures as pressure is increased, and repeated as pressure is decreased; the maximum pressure must not exceed the vertical rock pressure at the test section, roughly calculated as 23 kPa/m cover, to avoid uplift. Drilling is then resumed and after another 6 m the hole is again tested (Fig. 4).

Figure 4



WATER PRESSURE TESTING OF DIAMOND-DRILL HOLES (Moye, 1955)

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The results of the tests are analysed by graphical methods and indicate the permeability of the rock. Permeability is given in Lugeons; one Lugeon is defined as a loss of water at a rate of 1 litre/min/metre of standard hole tested. If rock is jointed and not homogeneous,permeability will vary with the frequency and condition of joints.

Testing in stages during drilling has been adopted to minimize, as far as practicable, reduction in permeability caused by drill cuttings sealing off the openings in the rock mass, and also so that only one packer need be used. The alternative water-Pressure testing the hole after it has been drilled to final depth is not favoured, and two sets of packers would be required to test separate sections of the hole.

Drilling-mud is rarely if ever to be used in spite of the acknowledged advantages which it gives when drilling through unstable ground. The use of mud would prevent water-pressure testing and meaningful observations on the water-table. A similar ban applies to the use of grease on drill rods for the same reasons.

<u>Oriented drill core</u>

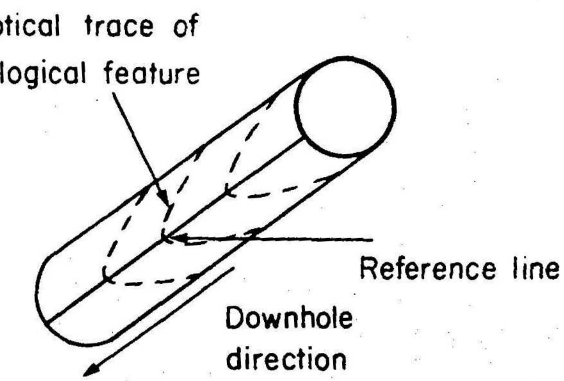
Core orientation may be required to enable the geologist to work out the attitude of the rock defects. If the geologist knows the orientations of the defects, he can recommend an alignment for a tunnel that will reduce excess breakage or falls of rock during tunnel construction; or he may use the data to determine the most favourable orientation of a machine hall in the underground structure, or to determine the location and type of footings for a building.

To orientate the drill core it is necessary to mark on the core a line whose position in space can be fixed. Three methods of core orientation are in common use:

(a) The Craelius Core Orientator is one of a number of mechanical devices that when used in the core barrel allows the top side of the core to be identified and marked. As azimuth and

Figure 5

CORE ORIENTATION FROM KNOWN GEOLOGICAL FEATURE



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inclination have been specified, and can be verified by a downhole survey, no further information is required. These devices cannot be used in a vertical or near-vertical hole.

(b) A magnetic core orientator is usually used in combination with an inclinometer. A small compass indicates the azimuth of the hole, and the inclinometer provides the inclination and allows the top side of the core to be identified and marked. This device cannot be used in horizontal, or near-horizontal holes.

(c) A geological feature of known orientation, such as bedding or cleavage, may be visible as elliptical traces on a core; these traces provide a means of orientation. A line joining the extremities of the elliptical traces that are convex in the down-hole direction is a suitable reference line (Fig. 5).

TESTS AFTER COMPLETION OF THE DRILL HOLE

Several other tests can be made on drill holes after they are completed. For this reason drill holes are permanently preserved by leaving drill casing (or a cheaper substitute), fitted with a substantial cap, in at least the top part of the hole.

Electric logging

After drilling has been completed, drill holes are logged by lowering an electrode down the hole. A recording instrument at the surface plots depth against changes in the electrical properties of the rock forming the walls of the hole.

Seismic tests

Drill holes are useful for up-hole seismic shooting to determine seismic velocities for calibration of test data and interpretation of results from regular seismic refraction surveys.

Temperature logs

Rock temperature logs are made on many drill holes so that temperatures in tunnels under deep cover and in underground power stations may be predicted.

Other tests, and recording aids

Many helpful recording aids and other useful tests can now be applied to the wall rock of drill holes; they include borehole photography, borehole inspection by closed circuit television, acoustic logging in petroleum exploration wells, measurement of rock modules by in situ loading tests, and pump-in or pump-out permeability tests.

A range of tests may be conducted on a core, and, for some tests, special methods of preserving the core in its 'as drilled' condition are used; e.g., a sample may be sealed to retain the moisture content of the clays on a joint in the core.

CONCLUSIONS

The purpose for which a hole is being drilled should always be kept in mind, and the success of the drilling will depend greatly on the co-operation between the geologist and the driller. The driller is the master of his rig, but to get the best recovery he should use information concerning the rock substance and rock mass provided by the geologist; sometimes the information contributed by the geologist is a deduction based on the drilling information that has been observed and recorded by the driller. This is what is meant by co-operation between the driller and geologist; without it the value of the drilling as an aid to geological investigation is greatly reduced.

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