

Rock Characterization using Drilling Parameters

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Drilling Parameters



Drilling parameter recorders are computerized systems which monitor a series of sensors installed on standard drilling equipment.

These sensors continuously and automatically collect data on all aspects of drilling, in real time, without interfering with the drilling progress. The DPR used for this project has the capability of recording data on the following parameters:

- Advance rate
- Downthrust pressure
- Pull-up pressure
- Rod torque
- Rotation rate
- Drilling mud / water pressure
- Drilling mud / water flow
- Depth
- Time

Using individual DPR measurements, variations in the drilling parameters are interpreted to reveal the presence of fractures, changes in lithology, and competency of the bedrock.

Several methods of interpretation have also been developed using compound parameters that combine individual parameters into expressions which reflect the resistance of the geological material to drilling.

Drilling Parameters Contributing to Each Compound Parameter

Drilling Parameters	Compound Parameters					
	Specific Energy	Drilling Energy	Somerton Index	Hard Parameter	Exponent Method	Alteration Index
Penetration Rate	X	X	X	X	X	X
Thrust	X	X	X	X	X	X
Torque	X	X	X	X	X	X
Rotation Rate	X	X	X	X	X	X
Weight on Bit	X	X	X	X	X	X
Bit Diameter				X	X	
Bit Cut Area	X					
Maximum Penetration Rate						X
Maximum Weight on Bit						X

Introduction

Identifying natural fractures in contaminated bedrock from conventional borehole investigations is an integral part of an in situ bioremediation project in New Hampshire, USA. A series of boreholes has been used to develop protocols for bioremediation.

The project test site, located at the former Pease Air Force Base, has been contaminated by TCE (trichloroethylene) and other degradation by-products from degreasing operations. This contamination has migrated downward into the groundwater and bedrock.

The ability to characterize the geologic rock units to identify connecting fractures between boreholes allows for the monitoring of groundwater flow and evaluation of the effectiveness of the bioremediation techniques.

During the advance of each borehole, a drilling parameter recorder (DPR) was used to characterize the site and identify fractures. The drilling parameters were compared to downhole geophysical measurements.



DPR on site.

Drilling Methods

For this project a series of boreholes, 150 mm in diameter and up to 60 m in depth, were drilled in bedrock using the DPR. Water pumped from an uncontaminated well was used as drilling fluid for each borehole and, because of the TCE contamination, all return flow had to be contained and trucked to a water treatment facility.

Two drilling methods were used:

Cored Drilling



Triple core barrel resulting in 100 mm rock cores.

Non-Cored Drilling

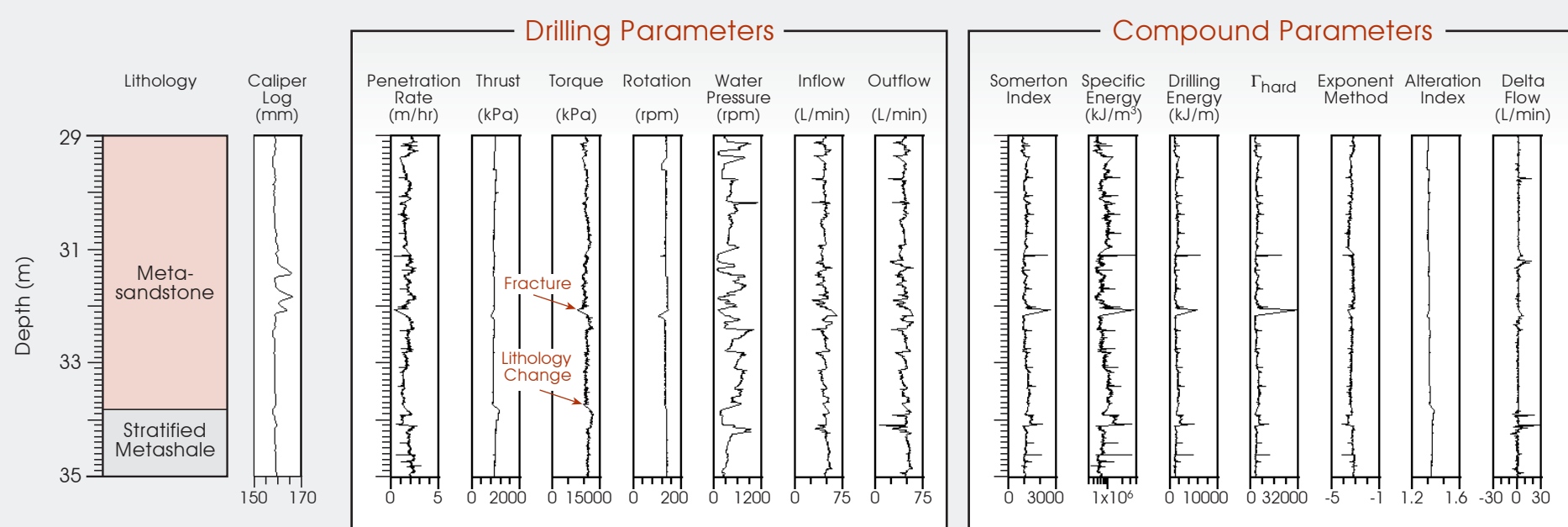


Tricone button bit.

For both techniques several drilling parameter combinations were tried to: maximize the core recovery, minimize liner blockages during drilling, and in the case of destructive drilling, provide a clearer picture of subsurface features unobstructed by the presence of the core barrel and core in the borehole.

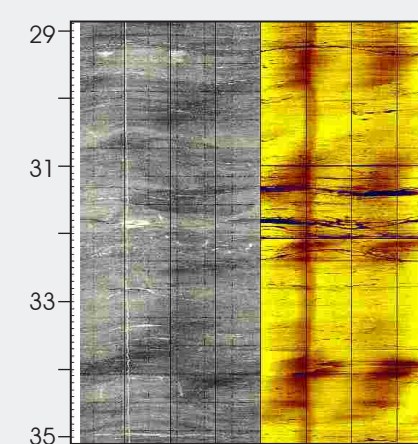
Results

Cored Drilling: BBC-4



The response in drilling parameters is more significant for horizontal fractures. For example, at 32.1 m, a decrease in water pressure and increase in water inflow are more apparent. At depths of 31.4 and 31.8 m, the fractures are dipping more than 30 degrees and thus only about 1% of the surface of those fractures are intersected by the core bit. As a result, only a slight increase in penetration rate and a decrease in drilling fluid are observed at those depths.

Optical and Acoustic Televiewer Data

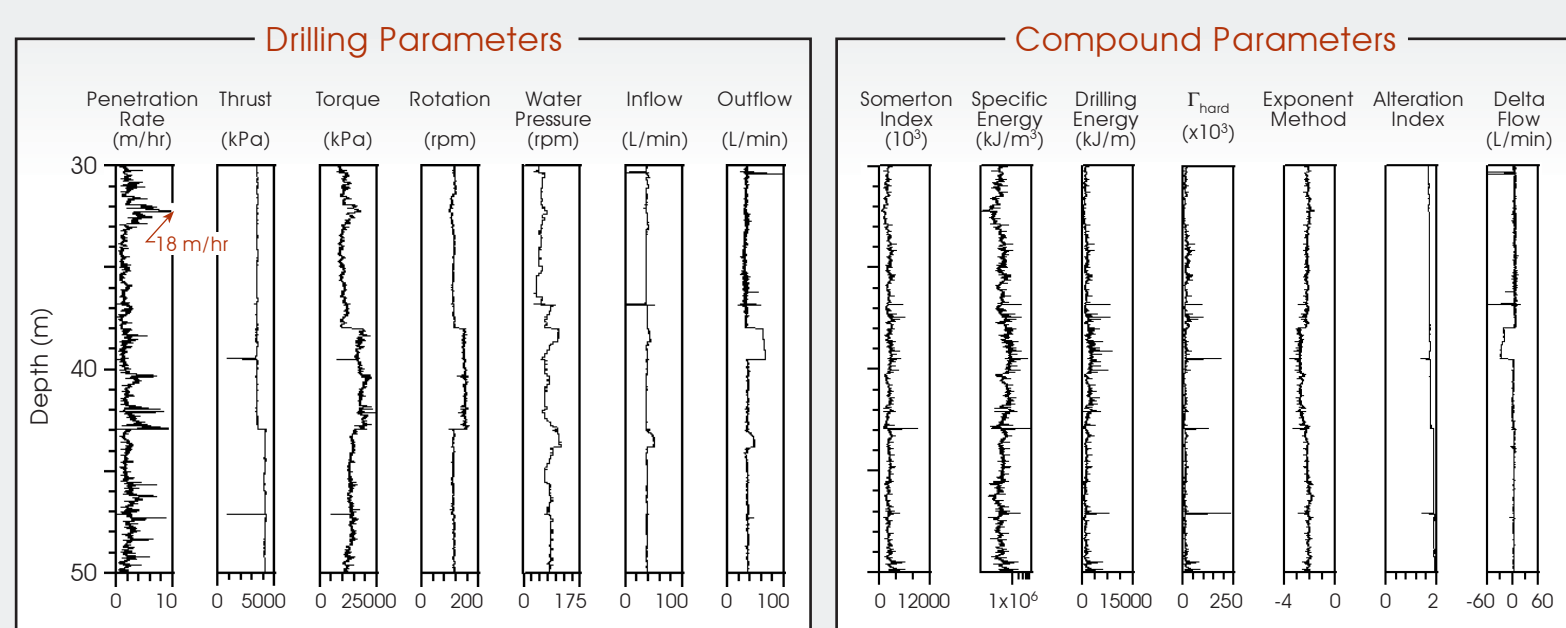


The geophysical logs for this borehole help define the condition of the bedrock.

Rock Core



Non-Cored Drilling: BBC-7



Thrust and rotation rate were kept constant during this destructive non-cored boring.

Depth (m)	Thrust (kPa)	Rotation Rate (rpm)
30 - 38	3,500	120
38.0 - 42.9	3,500	150
42.9 - 50.0	4,100	120

From the drilling parameter records, an increasing rotation coupled with a constant thrust directly translated into a doubling of the torque pressure without an apparent change in the penetration rate. Below 42.9 m, the increase in thrust also resulted in an increase in torque but not as significantly as the effect from increasing the rotation rate. This small increase in thrust did not result in a noticeable increase in penetration rate.

Since the thrust and rotation rate were kept constant, the variations in penetration rate and torque pressure provided a good indication of both fractures and lithologic changes. For example, at a depth of 32.2 m, the penetration rate increased by a factor of eight with an associated 35% increase in torque pressure, correlating to a fracture zone.

Conclusions

Using drilling parameters for this project improved the quality of cores and the efficiency of the drilling progress, and reduced the amount of fluid being introduced and lost into the aquifer.

The use of both conventional and compound parameters accompanied by core logging and geophysical testing enhanced the ability to locate fractures and changes in stratigraphy.

For both cored and non-cored drilling, bit wear significantly affected the drilling parameters; however, current interpretation methods do not properly take bit wear into account.

For non-cored drilling, fracture zones are more readily identified using penetration rate and torque as indicators when thrust and rotation rate are held constant.

The results of this investigation will be used to develop protocols for drilling and use of drilling parameter recorders (DPR) for future sites and other geological conditions. These protocols will provide in situ characterization rapidly and more cost effectively, limiting the need for expensive coring during rock investigations.

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