Acoustic and Optical Televiewer Logging to Assess Bedrock Fracture Characteristics in Support of the Engineering Design of a Gravity Sewer Tunnel

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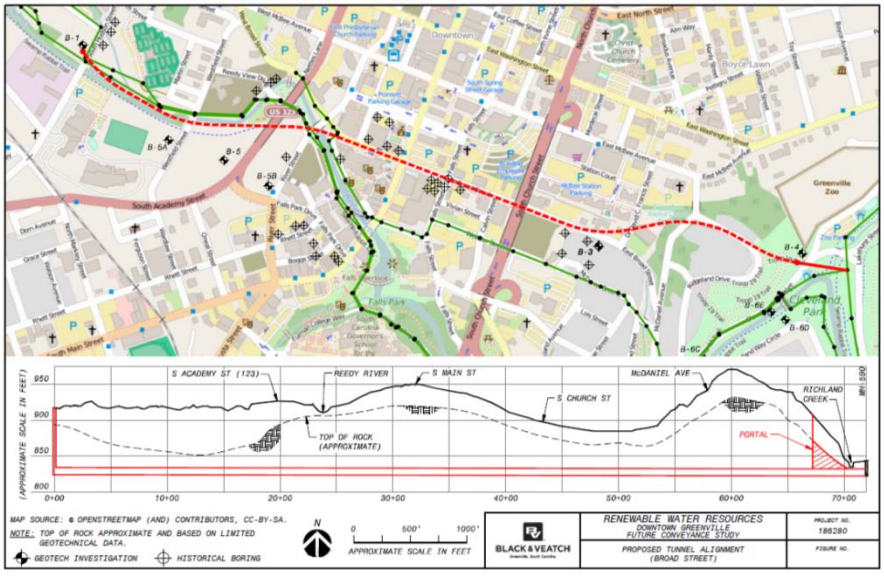

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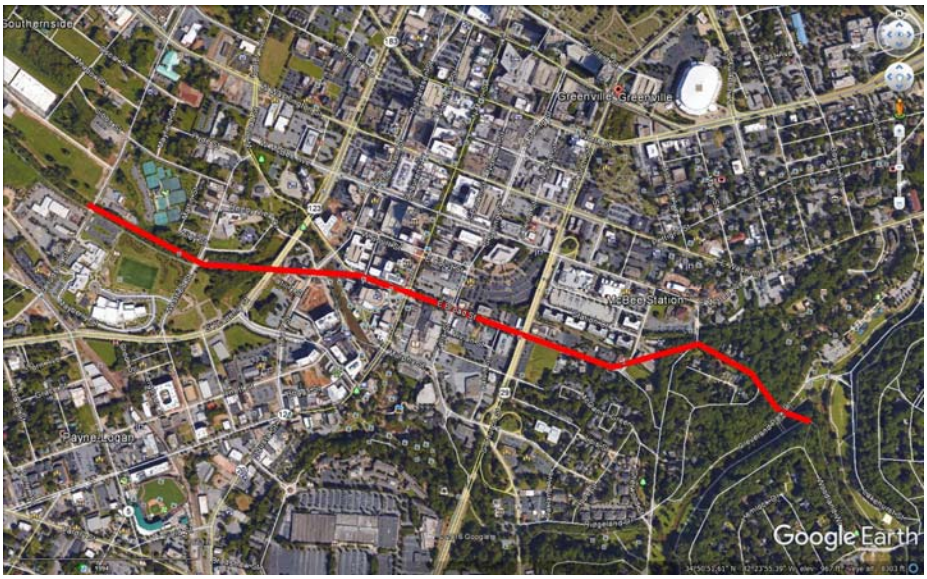

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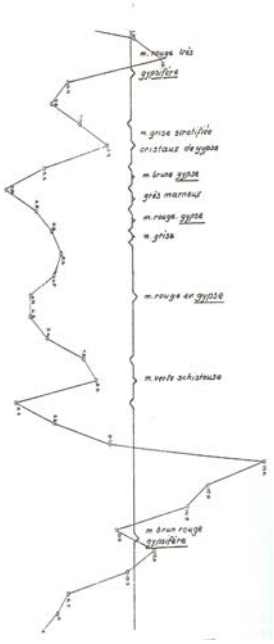


Extract from the first Resistivity log
Conrad and Marcel Schlumberger
France,1927

Borehole logging system

Logging cable carries signals to and from the downhole tool

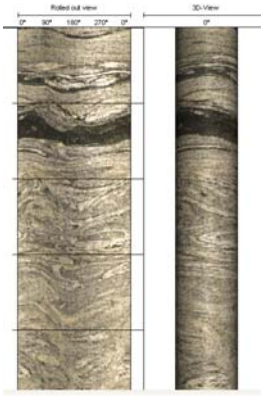
Logging Control Console

Winch and Cable

Data Storage, Processing and Visualization

Optical Televiewer

Camera that generates a **continuous, oriented, 360-degree image** of the borehole wall



- **Produces extremely high-resolution images**
- **Can be used for determining fracture dip angle, dip direction and aperture**
- **Can be used in dry wells or in optically clear fluids**
- **Equipped with deviation log to correct for borehole deviation**

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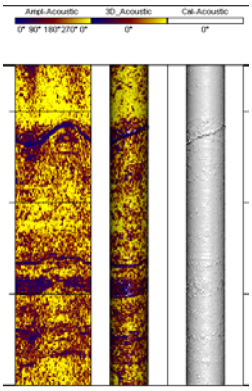
Acoustic Televiewer

Ultrasonic device that generates a **continuous, oriented, 360-degree image** of the borehole wall



- **Produces extremely high-resolution images**
- **Can be used for determining fracture dip angle, dip direction, and aperture**
- **Also measures travel time which can be used to develop 3D caliper logs**
- **Needs fluid-filled holes, water can be clear or muddy**
- **Equipped with deviation log to correct for borehole deviation**

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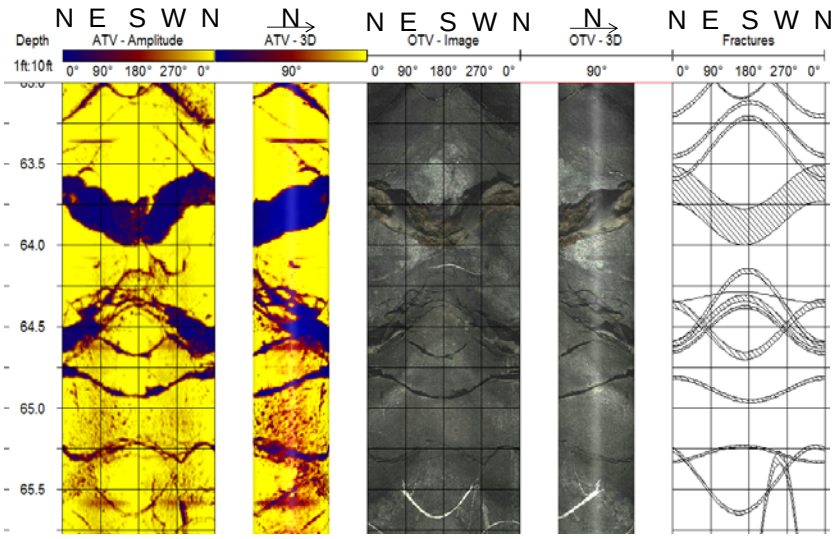

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Regional Geology

The project site is located in the Piedmont Physiographic Province, an area underlain by ancient igneous and metamorphic rocks.

The virgin soils encountered in this area are the residual product of in-place chemical weathering of the rock. The boundary between soil and rock is not sharply defined. This transitional zone is termed partially weathered rock (PWR). Weathering is facilitated by fractures, joints, and the presence of less resistant rock types. As a result, the profile of the partially weathered rock and hard rock is quite irregular and erratic, even over short horizontal distances.

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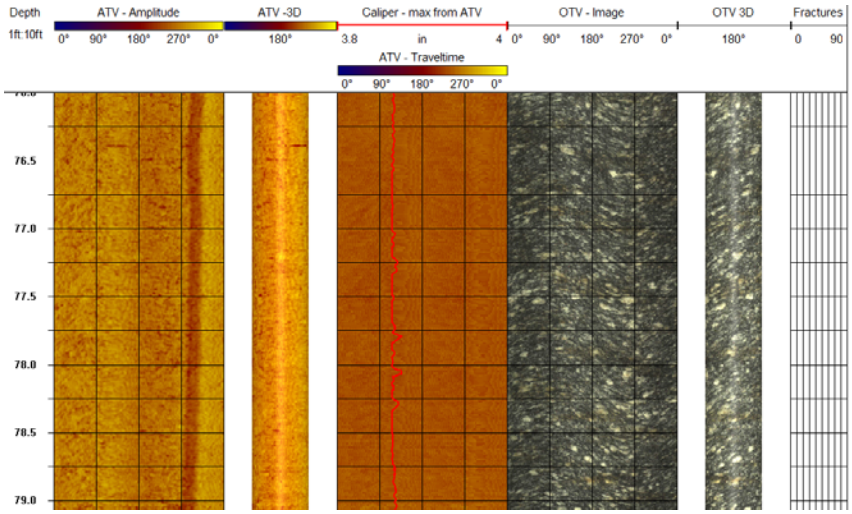

Images of fracture-free rock section

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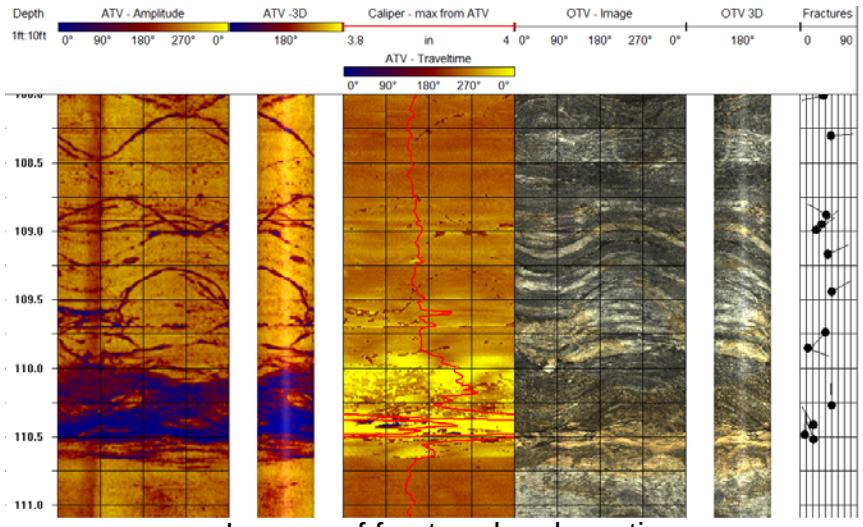

Images of fractured rock section

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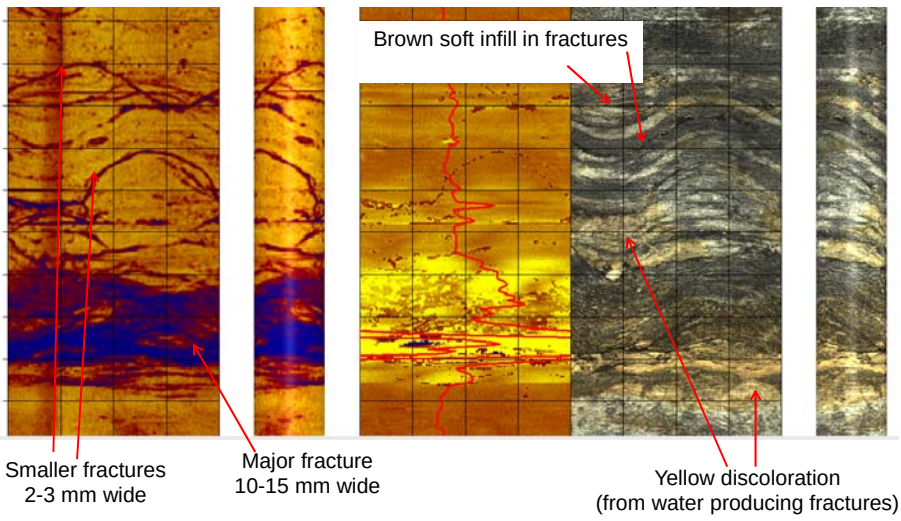
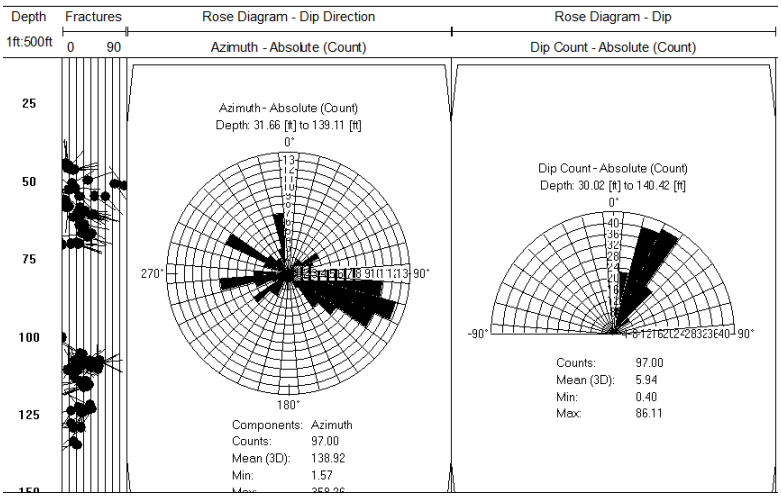
Images of fractured rock section



Facture orientations (corrected for borehole deviation)



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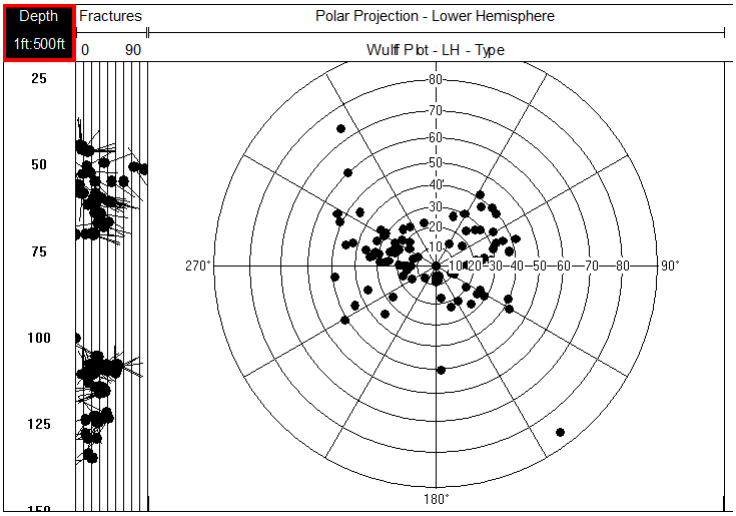


In addition to the field logging, there are a variety of laboratory tests that have been performed including:

- Brazilian Tensile Strength - provides a measure of rock toughness as well as strength.
- Cerchar Abrasivity - measures rock abrasivity for determining cutter wear and costs.
- Punch Penetration - indicates the excavatibility of the rock, i.e., the energy needed for efficient chipping.

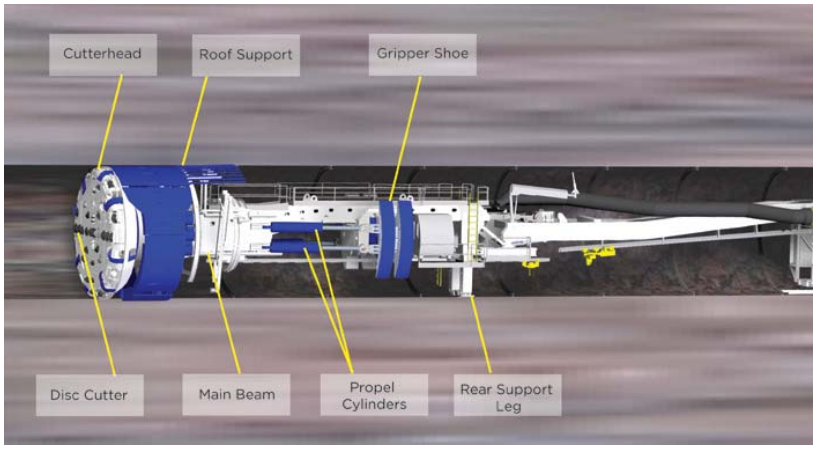
- Thin Section Petrographic Analysis - The thin section petrographic analysis provides useful information about microscopic features of rock, which might significantly impact its boreability behavior (grain suturing/interlocking, certain alignment/orientation of hard minerals, tight matrix, micro fractures, etc.).
- Unconfined Compression with static elastic constants - consists of measuring compressive strength and recording the axial/lateral deformation of the sample.
- Direct Shear – used for evaluating joint strength and potential for slow creep movements.

- Point Load Index – index test for strength classification of rock materials.
- SINTEF - A suite of drillability tests including Brittleness Value (S_{20}), Sievers' J-Value (SJ), Abrasion Value (AV) and Abrasion Value Cutter Steel (AVS) developed at NTNU. These tests and corresponding classification system are used to develop drillability indices including Drilling Rate Index™ (DRI), Bit Wear Index™ (BWI) and Cutter Life Index™ (CLI).

How is the data used?

The acoustic and optical televiewer data as well as the array of laboratory tests incorporated into the exploration program are geared toward **evaluating, selecting and predicting the performance of the TBM**.

Tunnel Boring Machine (TBM)



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Conclusions:

- Acoustic and Optical Televiewer data can be used for a full analysis of rock fractures including
  - Orientation
  - Aperture
  - Fracture statistics
  - Assessment if water producing
  - Fracture infills (e.g. clay filled, grouted, open)
- Using ATV and OTV data complete and correctly oriented virtual cores can be developed (no lost sections due to poor rock quality)

Conclusions (continued):

- ATV and OTV data combined with detailed lab testing is critical in selection of appropriate tunneling methods/equipment.
  - Face and wall stability
  - Groundwater management
- Accurate assessment is required to predict:
  - Excavatibility
  - Cutter wear and cost
  - Energy requirements
  - Production

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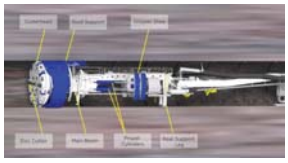
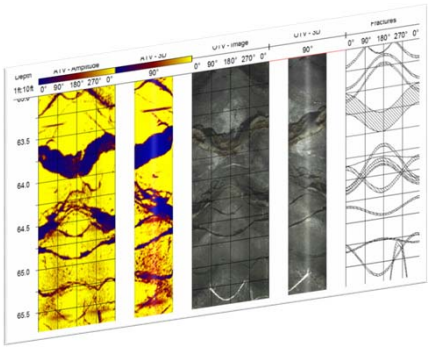
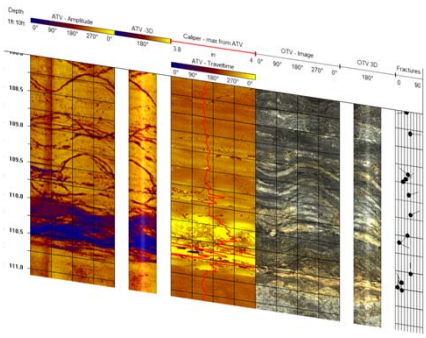
Questions?







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