

# **Geotechnical data from optical and acoustic televiewer surveys**

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## **Introduction**

Diamond drill core is typically the only available source of geotechnical information during the investigation phase of mining projects. In recent years downhole surveys using optical (OTV) and acoustic (ATV) televiewer tools have been increasingly used as a complementary source of data for the identification and orientation of structures. The array of data collected from these tools however, have not been applied in a manner that enables the comprehensive assessment of the geotechnical environment.

A methodology has been developed that accurately evaluates the full suite of geotechnical properties of a rock mass from OTV and ATV surveys. The process has been specifically developed to have application in diamond and percussion drill holes or existing open holes, to optimise geotechnical drilling programs by reducing the cost and time for data acquisition.

The data collected is sufficient to enable the independent determination of all the major rock mass classification systems including:

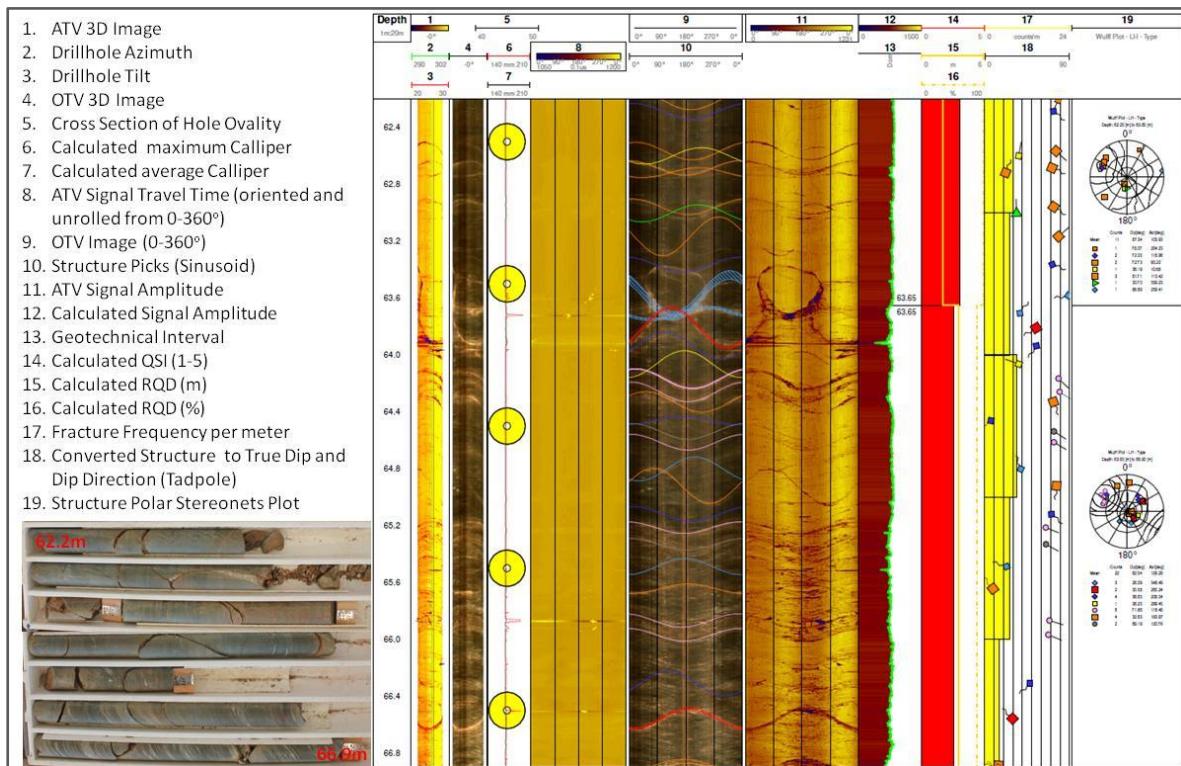
- Rock Mass Rating (RMR) after Bieniawski (1976, 1989) and Laubscher (1990)
- the Norwegian Geotechnical Institute Tunneling Quality Index (Q), Barton (1974)
- Geological Strength Index (GSI), Hoek (1995).

## **Process and methodology**

### ***Data acquisition***

Optical televiewer data consists of a continuous true-colour image, generated via a rotating prism and camera housed with an internal lighting unit in a downhole tool. The ATV tool transmits and records the amplitude and travel time of successive ultrasound pulses reflected off the borehole wall. Both tools allow the orientation of images and determination of the borehole azimuth and inclination. The tools commonly used in mining applications can accommodate borehole sizes ranging from a diameter of approximately 50-500 mm.

Figure 1 shows OTV and ATV images presented alongside the drill core over the same interval.



*Figure 1. Image from acoustic and optical tools and geotechnical interpretation compared with drill core photo.*

It is common practice to use the data produced by both instruments for the identification of geological features (bedding, joints, lithological boundaries, etc); the dip and dip direction can be calculated for each feature that is identified using typical data/image processing software. For geotechnical data however, acquisition it is important to identify and differentiate the structures that are open from the usually much greater number of closed rock fabric structures detected by televiewer (TV) surveys. The surface roughness and nature of any infill present is also required for geotechnical purposes.

#### **Data validation/calibration using drill core**

To generate a reliable geotechnical dataset it is vital that the televiewer data for a project is validated and calibrated using geotechnical logging of diamond drill core for the identified lithological units in the area of interest.

The amount of traditional core logging required for the calibration process is dependent on the size of the project area and variability of lithologies, but is typically in the order of two to four drill holes or from 200-500 m.

#### **Data interpretation**

The process of interpreting TV data is carried out in much the same way as with geotechnical logging of drill core. That is, natural defects are identified (allowing for the calculation of fracture frequency and rock quality designation), rock strength is estimated and geotechnical domains are identified based on the geotechnical characteristics.

Additionally, the TV surveys provide the orientation of each structure which can be subsequently used in rigorous structural analyses. The nature of the survey data allows for a more accurate appraisal of highly fractured or drilling induced broken zones where significant core loss intervals may occur that cannot be characterised accurately by traditional core logging.

The various categories of geological structures typically identified from TV surveys are shown on the left side of Figure 2. Significant geotechnical defect classes in this generic categories list are highlighted by the red arrows. The further ranges of open structure characteristics expanded on the right side of Figure 2 show the range data that can now be interpreted from the TV data and which are required for the rock mass rating systems RMR and Q.

The figure consists of two tables. The left table lists 24 typical geological structures, each preceded by a small colored icon. The right table lists 16 specific types of open fractures, also preceded by colored icons. Red arrows on the left point to structures #16 through #24. A bracket on the right groups structures #41 through #46.

#10 - Water table
#11 - Casing
#12 - Lithology Contact
#13 - Low Confidence
#14 - Bedding/Foliation
#15 - Open Bedding/Foliation
#16 - Minor Closed Fracture
#17 - Vein/Sealed Fracture
#18 - Random/Non Continuous
#19 - Partial Open Fracture
#20 - Minor Open Fracture
#21 - Major Open Fracture
#22 - Weak Zone
#23 - Micro Fault
#24 - Fault Zone

#41 - Minor OF - Planar - Smooth
#42 - Minor OF - Planar - Rough
#43 - Minor OF - Undulating - Smooth
#44 - Minor OF - Undulating - Rough
#45 - Minor OF - Stepped - Smooth
#46 - Minor OF - Stepped - Rough

#109 - Major OF - Undulating - Smooth - Gouge Infilling
#110 - Major OF - Undulating - Smooth - Soft Infilling
#111 - Major OF - Undulating - Smooth - Hard Infilling
#112 - Major OF - Undulating - Smooth - No Infilling
#113 - Major OF - Undulating - Rough - Gouge Infilling
#114 - Major OF - Undulating - Rough - Soft Infilling
#115 - Major OF - Undulating - Rough - Hard Infilling
#116 - Major OF - Undulating - Rough - No Infilling

Figure 2. Typical structure classifications for geological structures (left) and with categories expanded for geotechnical purposes (right).

Defect roughness is interpreted from a careful review of the individual structure shape seen in the image. It is acknowledged however, that the finer distinction of surface roughness that can be identified from tactile and visual assessment of drill core cannot be so reliably achieved from TV surveys due to image resolution limitations. Therefore, the interpreted roughness is in part derived from the typical joint conditions established by the calibration core logging.

For ATv data, the presence and nature of infill is assessed by making reference to both the travel time and amplitude images and is observed from the true-color OTV image. The aperture of an open structure or filled structure can be measured in one tenth of a millimeter by observing both travel time and amplitude data arrays or the contrast of OTV image with assistance from imaging software.

A rough and undulating joint identified from ATv images is shown in Figure 3. The aperture of open defects such as this can be directly measured from the ATv data.

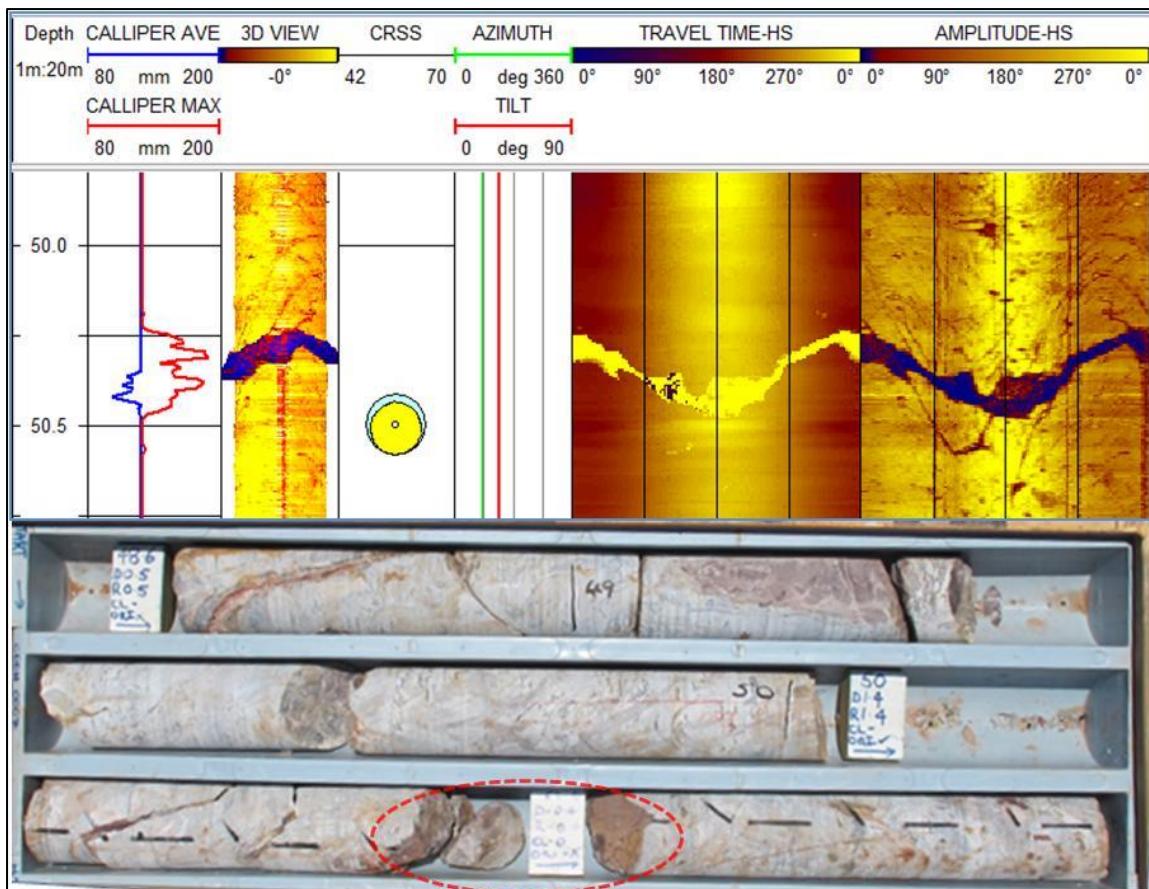


Figure 3. Example of a rough and undulating joint identified in acoustic viewer tool data and drill core.

Following the identification of structures, the fracture frequency and RQD can then be directly calculated using the given depths.

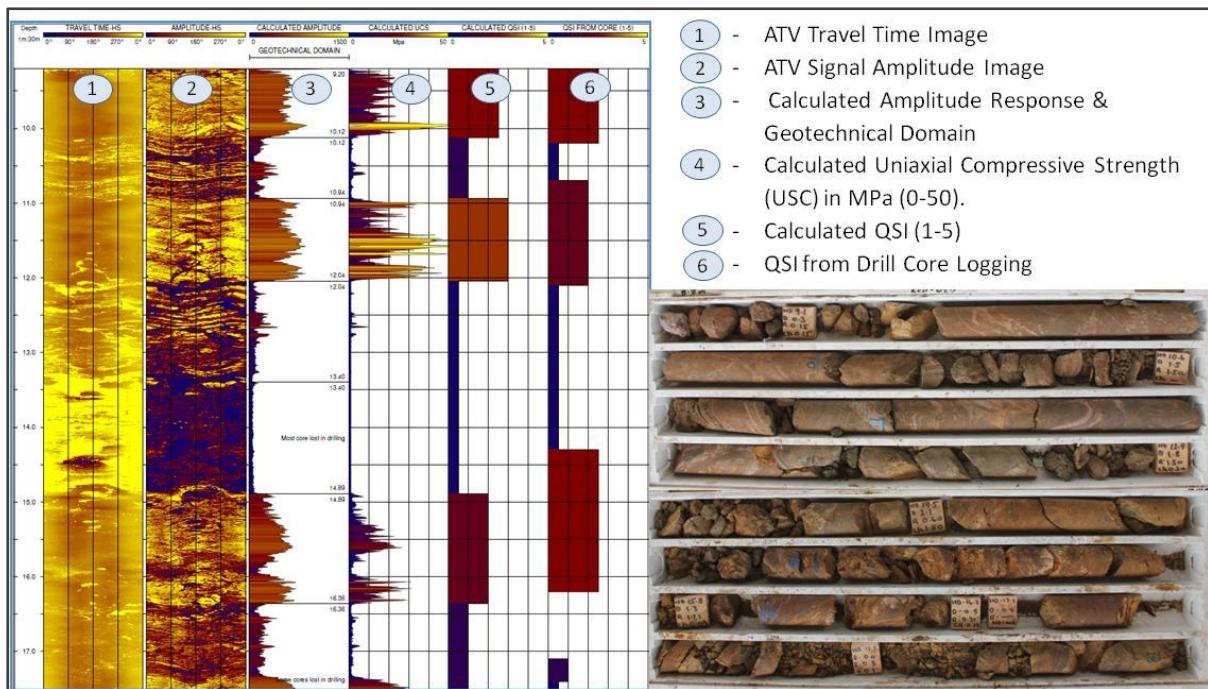
Rock strength is assessed from ATV data by interpreting the acoustic impedance, which has a non-linear relationship with the amplitude of the reflected acoustic signal (Schepers, 1996). This value set produced by the ATV tool has been found to be sufficient to indicate a range on a strength scale such as the Quality Strength Index ("QSI") after Dempers *et al* (2010), and is generally considered to provide more consistent strength data than that produced from tactile assessment by personnel during logging of drill core.

As with the identification of structures, the calculated Uniaxial Compressive Strength (UCS) from the acoustic response should be calibrated for particular rock types within a project area, preferably in conjunction with the use of laboratory testing.

Rock strength cannot be determined from OTV data without calibration of the particular geotechnical domain. The OTV image can give an indication of the integrity of the rock strength in a similar way to visualisation of drill core photographs.

Figure 4 shows in order from left to right:

- the acoustic travel time log
- amplitude
- calculated acoustic response/ geotechnical domain
- calculated rock strength in MPa
- calculated QSI on a 1-5 scale based on geotechnical domain
- QSI from core log and core from the same depth.



*Figure 4. Image from acoustic televiewer tool and geotechnical interpretation compared with drill core photo.*

Once relevant structural features have been identified (thus fracture frequency/RQD) and where possible rock strengths have been estimated, the work-flow then involves the selection of geotechnical domains in much the same way as for the geotechnical logging of diamond drill core, as detailed by Dempers *et al* (2010).

#### **Comparison of rock mass rating determined from logged core and televiewer data**

This comparison has been carried out with data from a number of mines and a variety of commodities including iron ore, nickel and gold.

Figure 5 presents a comparison of the final rock mass rating (RMR) values for an interval of a particular hole, derived from ATV data and logged drill core.

The correlation between data from diamond drill core and ATV data is considered high, demonstrating the reliability of the technique for application in geotechnical analysis and design.

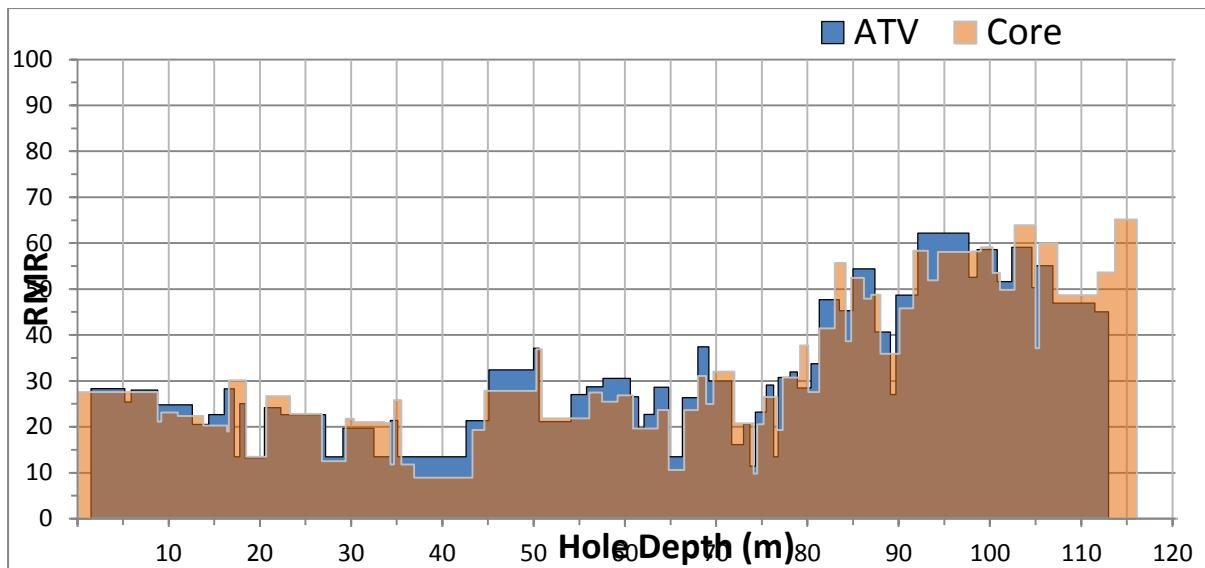


Figure 5. Rock mass rating values derived from logged drill core and acoustic televiewer tool data.

#### Mining rock mass model comparison

Two mining rock mass models (Seymour *et al* 2007) were constructed using RMR values calculated from logged core data and from geotechnical data interpreted from televiewer surveys. The models were statistically evaluated and this showed a good correlation between the two models, with a maximum variation between RMR values of two rating points, ie a two per cent variation. A comparison of the estimated RMR values between the two models is shown in Figure 6.

The models are very similar with the block model cross-sections showing similar trends, ie a zone of poor ground with RMR values of less than 20 as highlighted in Figure 6. This indicates 3D geotechnical models constructed from televiewer derived data are of comparable accuracy to those derived from logged core data.

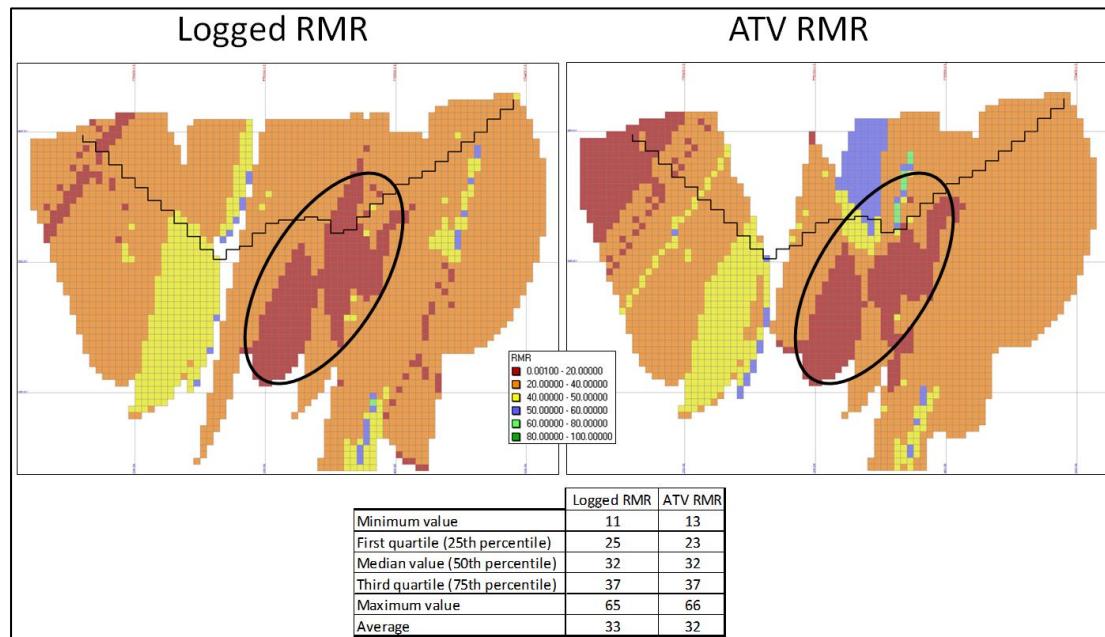


Figure 6. Rock mass model sections showing estimated rock mass rating values for logged versus acoustic televiewer tool data.

## **Conclusion**

Acoustic and optical televiewer surveys can now be used to accurately evaluate the geotechnical properties of a rock mass. The methodology outlined can be applied to diamond and percussion drill holes as well as existing open holes and, as such, may be used to optimise geotechnical drilling programs by:

- reducing the amount of diamond core drilling and geotechnical logging required
- reducing the time required for data acquisition
- improving the quality of structural data acquisition
- reducing the overall cost of the geotechnical investigations.

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