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Combined use of traditional core logging and televiewer imaging for practical geotechnical data collection

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Abstract

Acoustic and optical televiewers are becoming routinely used to capture structural geotechnical data for use in pit slope and underground design. They provide rapid and accurate high resolution oriented images of the borehole walls and can be used as a replacement for manual core orientation techniques, with the picking of structures being left to the televiewer operator who then provide the data to the geotechnical engineers. SRK UK Ltd. has developed an approach where the raw acoustic televiewer logs are used in conjunction with manual rock mass logging of the core. This hybrid logging method allows for the detailed description of each open feature whilst making use of the accurate structural orientation measurements obtained from the televiewer data. The depth correlated structural logging data is subsequently used to populate a rock mass log, automatically producing rock mass classification values. This rapidly reduces the time required for geotechnical logging; thus reduces field time requirements of the consultant and potentially reduces cost to the client. The paper covers the current field methodology, required post processing of the logged data and discusses advantages and disadvantages of using this hybrid method. A case study from Scandinavia is also presented.

1 Introduction

Televiewers (both acoustic and optical) are becoming routinely used to capture structural geotechnical data for use in open pit slope and underground excavation design. They provide rapid and accurate high resolution oriented images of the borehole walls and are generally used as a replacement for manual core orientation techniques, with the picking of structures being left to the televiewer operator who then provide the data to the geotechnical engineers. SRK UK Ltd. (SRK) has developed an approach where the raw acoustic televiewer logs are used in conjunction with onsite rock mass logging of the core.

This paper covers the field work methodology for combining televiewer (TV) data with rock mass core logging techniques. This hybrid logging method allows for the detailed description of a structural feature including open or healed discontinuities but also lithological contacts or foliations whilst making use of the accurate depth and structural orientation measurements obtained from the televiewer data. The depth correlated structural logging data is subsequently used to populate a rock mass log, automatically producing rock mass classification values. This rapidly reduces the time required for geotechnical logging. The paper covers the current field methodology, required post processing of the logged data and discusses advantages and disadvantages of using this hybrid method. A case study from Scandinavia is also presented where TV data is compared to traditionally logged data.

2 The televiewer log

2.1 Acoustic televiewer

There are two main parameters which are important to the interpretation of structures when carrying out acoustic televiewer logging. These are images of travel time and amplitude generated as the acoustic probe is raised or lowered in the borehole. The travel time image represents variations of the borehole radius (assuming that the tool is well-centralised), whilst the amplitude image represents the strength of the echo returning from the borehole wall. The colours of the images are calculated from the travel times or amplitude values. For the interpretation, colours of the images have to be adjusted to obtain optimised contrasts. It is the contrasts that indicate the presence of structures.

The three principal factors affecting the amplitude of the received echo are: attenuation by the borehole fluid, reflection efficiency at the borehole wall (related to the formation hardness and the smoothness of the borehole wall) and the degree of centralisation of the tool (related to the geometry of the path of the acoustic signal).

The amplitude image represents the strength of the reflection, that is the denser the rock the larger the reflected amplitude. The travel time represents the two way travel time from release of the signal from the emitter until the reflected amplitude has been recorded. The amplitude image indicates where the different structures are and whether they are good or poor reflectors. The travel time provides information about the shape of the borehole. In this regard the travel time can be used as a calliper log.

Using both the amplitude and travel time image an assessment of the type of infill can be made:

- An open fracture shows a low amplitude return through loss of signal and longer travel time when compared to the country rock.
- A fracture with a soft infill, such as clay would also show low amplitude but no change in travel time when compared to the country rock.
- A vein filled with hard mineral compared to the rock matrix might have higher amplitudes but does not exhibit any change in travel time.
- Sharp contacts between lithologies of different intact rock strength exhibit a change in amplitude but no change in travel time.

The aperture of open structures or the thickness of filled structures can also be measured from the acoustic televiewer log. Figure 1 details a typical TV image of an open structure, showing the amplitude image on the left hand image and travel time on the right hand image.

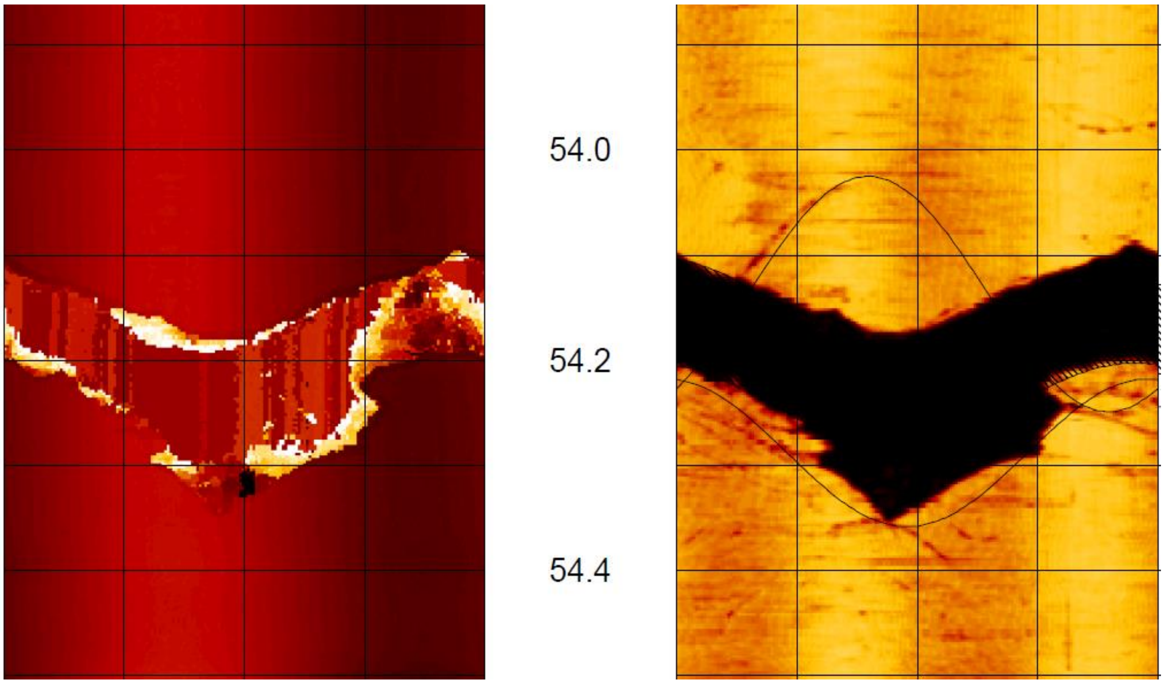

Figure 1 Example of amplitude (left) travel time; (right) acoustic televiewer log

The left hand edge of each image corresponds to the direction of magnetic north or high side depending whether the borehole was drilled vertically or inclined, respectively; the image is then unrolled towards the right in the sense east, south and west, finishing at the right hand edge with north once more. After structures are picked they have to be adjusted for orientation of the borehole trace and also for borehole diameter and magnetic declination so that the picked orientations are referenced to geographic north.

2.2 The optical televiewer

The optical televiewer (OTV) is based on using a downhole digital camera and a prism to obtain a continuous and oriented 360° image of the borehole wall.

The tool includes an orientation device consisting of a precision three axis magnetometer and three accelerometers thus allowing accurate borehole deviation data to be obtained during the same logging run. Resolution is up to 0.5 mm in vertical direction and 720 pixels in azimuthal direction. Structure picking follows the same approach as applied in acoustic televiewer images; however, OTV images do not allow differentiation between open and filled structures.

2.3 Televiewer surveys – key considerations

ATV surveying can only be carried out in fluid filled boreholes. Partially filled or dry boreholes can be filled up with water although care must be taken to avoid any air or gas bubbles in the water. This will only work where water loss through open fractures is limited or where a sufficient supply of water is constantly available. Where boreholes cannot be kept water filled, OTV can be used instead, although OTV works best when the hole is dry, and borehole wall is free from any drill mud. OTV can also be carried out in water filled boreholes, but requires the borehole fluid to be very clear and free of mud. In this sense OTV and ATV probes are complimentary tools.

As with any wireline logging tool there is a requirement that the borehole remains stable during the survey. Where unfavourable borehole conditions exists, such like presence of intensively fractured zones or swelling ground it may not always be possible to survey the entire borehole length. It is often the case that intense weathering reduces the integrity of the rock mass towards the collar of the boreholes and in such instances the borehole needs to be cased to ensure stability. As such, and if the casing is metal, no TV data will be collected from the cased section of borehole. However, ATV surveys are possible within PVC cased boreholes, although usually difficult to achieve. For a ATV survey to provide an image of reasonable quality the PVC casing is required to have a similar diameter to the borehole diameter and must be centralised otherwise this will create artefacts in the image. If installation is successful, it is possible to use ATV to capture borehole data.

When determining whether to use a manual core orientation system or televiewer system and regardless of rock mass quality or geological constraints, consideration also needs to be given to associated costs. Cost comparison between manual core orientation and TV can be highly variable depending on the location of the project site. Importation costs (and potential hold-up in customs), supervision costs and post processing costs all need to be taken into account.

In summary, OTV and ATV surveys provide a continuous log of orientated structures, their aperture or thickness and some qualitative assessment on the type of infill materials. They also provide information on borehole breakouts which can be used for stress analysis. ATV can also be used to determine depth to groundwater level. Televiewer surveys are highly dependable of borehole wall stability.

3 Standard approach to structural core logging using televiewer

It is the authors' experience from many projects that the standard approach to logging structures from boreholes is different from the method proposed within the paper. Whilst core logging (rock mass or structural) is done by a geotechnical specialist or geologist trained in geotechnical core logging, the structure picking is done in many cases by the TV surveying contractor who has little understanding of how the data collected will affect slope design and subsequent slope performance. Errors due to an 'untrained eye' can be of enormous consequence to subsequent analysis and design. As such structure picking is generally carried out without checking against the recovered core, an issue can arise with the operator to arbitrarily picking any type of structure, often including many structures which are of little interest to the geotechnical application and as such could mask important slope controlling features. There is also potential for missing critically important structures during the picking.

Figure 2 shows the results from the same borehole; the left stereoplot shows the features picked from the TV data whilst having access to the core to assess the geotechnical structures (hybrid system) whilst the right stereoplot shows the features picked using technicians that only have the TV data. It can be seen that broadly similar data has been captured, however, the pole concentration contours using the hybrid system are better defined and more individual structure sets can be identified. The pure TV logging data has a far greater scatter or data, thus masking potentially significant geotechnical sets. It also highlights that unimportant features were disregarded when access to the core was possible; a total of 185 erroneous points were removed from the dataset.

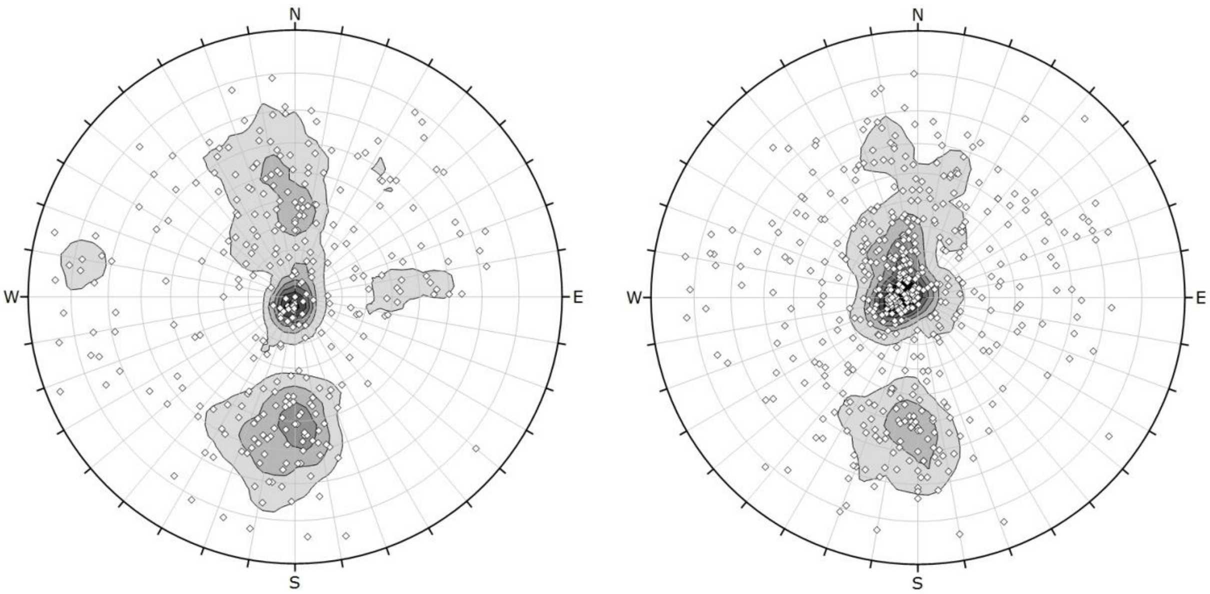

Figure 2 Comparison between TV logged by geotechnical engineers with access to the core during logging (left; 320 structures) – the hybrid system and TV logged by technicians (right; 505 structures)

For open pit geotechnics it is vital that all natural, open structures are picked and clearly distinguished from any well cemented structures. It is the authors' experience that this is often not fully achieved by those logging TV data whilst having no access to the core.

Often, an operator uses the calliper log to help with distinguishing between open (wider borehole diameter) and cemented structures (no change in borehole diameter). There is the case that where structures contain vuggy but well cemented infill, these would exhibit a change in borehole diameter in the calliper log and thus may be logged as open structures. The travel time would also be variable (slower) and also suggest that a soft or uncemented infill exists.

4 Field methodology

In the following section the authors' approach to rapid structural logging and rock mass classification is given.

In order to keep drilling costs down and not to interrupt the drilling process televiewer surveys are carried out at the end of drilling a borehole. For this reason the combined structural/TV logging is usually performed after a borehole has been completed.

The structural logging requires pre-processed TV surveys to be available prior to commencing the logging and as such the survey contractor will need to process the raw survey file and provide it to the geotechnical engineer ahead of commencing logging. Core logging should be done in a suitable logging facility where cores can be laid out on a logging table. There is a strong benefit of using a two person team instead of a single logger as it has been found that a two person team will be more than twice as fast, achieve a higher accuracy and thus are significantly more cost efficient than a single person. Where site conditions allow, core logging parameters will be entered directly into the electronic TV image file via laptop computer using WellCAD software developed by Advance Logic Technology (Advance Logic Technology, 2013). Where site conditions are problematic the geotechnical features are recorded onto print-outs of the TV logs (Figure 3).

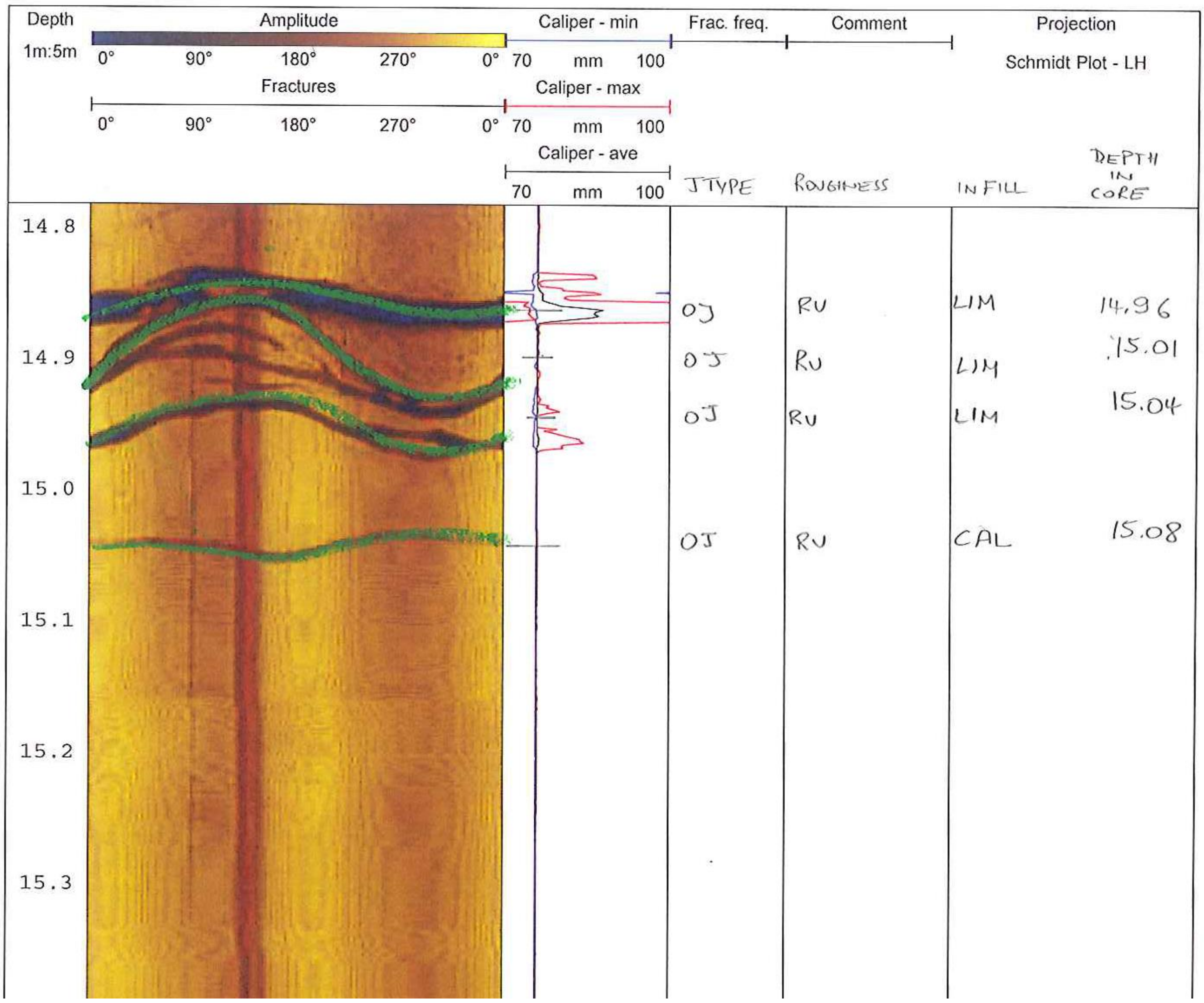

Figure 3 **Acoustic televiewer image field log for logging structural drill core data. Green lines refer to identified natural, open joints. Joint type, roughness class, infill mineralogy and core depth were logged from core. Calliper log (red) to the right of the image log**

Televiewer images can provide accurate Information on the depth, orientation, aperture and semi qualitative information on infill material and cementation of a structure. However, the type, shape and surface roughness, mineralogy and strength of the joint infill as well as joint wall strength can only be obtained from actual drill core logging. To obtain the optimum data set requires combining the TV data with data obtained from core logging. In this regard it is important that the information from the two data sets relate to the same structure. Comparing televiewer images with drill core allows distinguishing between natural structures and fractures induced by drilling or core handling. Although it must be noted that drill induced fractures can also under certain conditions develop in the borehole wall due to the change in horizontal stress field after the drill core was removed.

In this way for an individual structure, all structure-specific parameters are recorded. As each natural joint is identified in the TV log, by using stereographic projection software it is possible to classify the picked joints into joint sets to determine which joints within the core are likely to be influential on the pit slope design. It is now also possible to determine joint shear strength properties for individual structural orientation sets (where there is no joint infill) using the results of a statistical analysis of the joint roughness obtained for each structure set in conjunction with Barton's joint shear strength equation (Barton, 1976):

$$\tau = \sigma_n \tan\left(JRC \times \log_{10}\left(\frac{JCS}{\sigma_n}\right) + \varphi_r\right) \quad (1)$$

Where:

σ_n = normal stress across the fracture.

φ_r = residual friction angle, which is equal to base friction angle φ_b for unweathered fracture surfaces.

JRC = joint roughness coefficient.

JCS = joint compressive strength.

5 Using televiewer data for rock mass classification

For those borehole intervals for which a complete televiewer survey exist, rock mass parameters such as RQD, joint spacing, and fracture frequency can be automatically computed. There is no need to re-log the core to get a summary geotechnical rock mass classification value, saving time and providing data integrity between detailed structure logs and rock mass classification log. The logging of the geotechnical interval is now simplified and includes only:

- Lithology.
- Intact rock strength.
- Intensity of weathering / alteration.

For mining applications Laubscher's rock mass rating (RMR) system is often used. This system simplifies the orientations of structure sets by dividing structure orientations into three structure sets of 30 degrees range according to the angle with the core axis. This simple classification does not distinguish whether structures of the same set dip in opposite direction. Clearly in this case the two structures would be members of different structural orientation sets. Using the televiewer data structures can be distinguished into sets according to their true azimuth and dip.

The hybrid system also allows carrying out statistical descriptions of the various joint condition parameters per defined structural set and geotechnical interval. In this way statistics of structure infill, roughness shape or joint wall strength can determine the average value, the most frequent value, or the value that is considered the most influential/controlling to excavation stability.

Where poor ground conditions are intersected by a borehole, e.g. fault zones or highly weathered or altered sections, the televiewer probe may not be able to pass and thus it may not be possible to obtain any structural orientation data below the blocked borehole. In this case the rock mass classification interval log and any structural data collection have to be based only on the logging of drill core whether it is orientated or not.

5.1 Issues with combining the two data sets

A recurrent problem with identifying the same structure in the two data sources is that the depth in the televiewer image often differs from core depth.

Discrepancies between the TV image depths and the core depths are often a result of cable stretch on long boreholes or irregular tool movement when using the televiewer, whilst depth shifts and core losses can occur or core pieces may be in the wrong order (Rider and Kennedy, 2011).

Modern logging software programmes are capable of enabling bulk and manual point shifts between image logs, core logs and digital core photo logs (Rider and Kennedy, 2011). In this regard a depth referenced core photo strip log can help considerably to decide which log to shift when it is plotted side by side with the image and core log. Usually the image log depth is considered to be more trustworthy, although in practical terms it is often preferred to shift the image log to avoid time consuming re-labelling of the core blocks in the core boxes. For open pit applications slight changes in depths are considered generally negligible.

5.2 Post-processing of the logged data

Where intensively fractured zones must be dealt with it is the authors' experience that it is more practical to delineate a fracture zone as one feature in the structural log, rather than trying to pick every single structure within the fracture zone. However, to determine fracture frequency calculations for the rock mass log, the number of fractures in a highly fractured zone must be estimated/ measured. This is done by examining the core (if still on site), by using the core photos or, if they are not available, an estimation from the TV log has to be made.

Once fracture density data have been computed from the combined structure log an additional check upon the depth correlation between the televiewer image log and the core log should be made. RQD values, especially in short geotechnical intervals can be highly inaccurate if the depth correlation is out by even a few centimetres. If there is a discrepancy, a decision must be made as to which log is correct. The televiewer image logs have been found to be more accurate, however if the core has been used to aid deciding upon the geotechnical zones then the core box depths are used.

6 Confidence in orientation data

Holcombe (2013) showed that the degree of uncertainty/error caused by orientation line marking and measurement of orientation features for traditional core logging can be as high as 16° for the beta/azimuth angle (NQ core size). They estimate an error of 12 and 9° for HQ and PQ core sizes respectively. They do not comment on potential errors caused by core spin. Theoretically, TV data will be more accurate than traditional core logging as problems of core spin and orientation line marking are negated. However, when measuring orientations from TV data, the features must still be picked by hand, albeit on a computer with automatic aides to help fit the traced sinus curve. There is an inherent error associated when picking structures that do not form a perfect sin curve in the TV image data or those features that have a large aperture so that the top and the base of the sin curve may not be obvious. The authors estimate that maximum error will be no more than 5° in the azimuth angle measurement, caused by inaccurate picking of features from TV logs. This value was calculated by comparing the dip direction values measured from the same features by two different operators (84 measurements along a single borehole). Errors in orientation data from TV logging can also come from inaccurate measurements of the borehole azimuth when the image of the borehole wall is taken. The instruments used to orientate the TV hardware have published azimuth errors ranging between 0.3 and 5°, with an average of 1°. If we take the average 'picking' error and azimuth error then we can say that the beta measurements for TV data can have an error of 6° on average. This is lower than the traditional logging error of 9 to 16° (which also does not take into account possible core spin). Therefore the authors consider that confidence in TV data is higher than in traditionally borehole logging data.

However, assessing the global confidence of any geotechnical orientation logging data is problematic as, unless there are confirmed orientations from outcrop mapping, there is little information available to compare against. Corroboration can be made of the data between boreholes drilled within the same geotechnical domains. When strong pervasive foliation is known to be present within the rock mass it can be used to check the results of core orientation logging. A qualitative assessment of the confidence in the orientation logging data can be made (Table 1).

Table 1 Qualitative data confidence ratings (after Boness et al., 2011)

Confidence Rating	Description
None	There is a known fact that suggests the data is unsound.
Low	The data's credibility or plausibility is questionable, or the information is too fragmented or poorly corroborated to make solid analytic inferences, or there are significant concerns or problems with the sources.
Medium	The data is credibly sourced and plausible but not of sufficient quality or corroborated sufficiently to warrant a higher level of confidence.
High	The data is high quality information and it is possible to render a solid judgment from it. A high confidence judgment is not necessarily a certainty.

7 Case study: open pit iron ore deposit North Sweden

As part of a feasibility study for a magnetite skarn deposit located in Northern Sweden near the border to Finland a slope stability analysis was carried out to aid in determining appropriate slope design parameters.

The geology consists of a highly anisotropic, moderately to steeply dipping meta-sediment package of foliated graphite schist, serpentinite, mica schist, phyllite and massive skarns of mainly good to fair quality rock. Some weak zones located close to the ore contact zones intersect the rock mass. These weak areas are composed predominantly of highly fractured or crushed zones and some thin clayey gouge-bearing shear faults.

The existence of highly fractured zones increased the risk of borehole collapse and thus the potential of the acoustic televiewer getting stuck in the borehole which would reduce survey length. In order to increase the likelihood of obtaining structural orientation data both core orientation and acoustic televiewer imaging were carried out on all of the geotechnical boreholes. The chosen core orientation tool was the ACT2 tool developed by Reflex. To obtain undisturbed core samples triple tube wireline technique was used and the core was orientated directly at the drill site (Figure 4).

Eight geotechnical boreholes of in total 2,700 m length were drilled at various dip and azimuth angles to reduce drilling bias with the longest borehole being 450 m long. On each of these boreholes both ATV and core orientation were used. Although none of the two orientation systems were able to collect orientation data over the entire borehole length of any of the boreholes both systems are considered complimentary to each other as orientated core was obtained from borehole intervals where ATV could not achieve any surveys due to borehole blockage, whilst ATV provided orientation data where core quality, poor drilling or poor core recoveries did not allow to orientate the core. Figure 5 presents for both systems the depths for which orientated structures were logged.

Figure 4 Core orientation performed directly at the drill site using a rack of angle irons to allow connecting consecutive core runs for obtaining and assessing the quality of the orientation reference line

Over 6,728 structures were picked from the ATV images, whilst a total of 7,458 orientated structures were logged using the ACT2 core orientation system. However, of these structures only 1,937 (26%) were obtained from high confidence orientation lines. A high confidence orientation line was defined when it matches the orientation line of one or more core runs. A difference of less than 5° between orientation lines was the acceptance criteria to classify a line as a high confidence orientation line.

Figure 5 indicates that where a large number of borehole intervals were not orientated the ATV survey proved successful. Borehole SAH09008 was intentionally not ATV logged.

The stereoplot on the left side in Figure 6 which is based on core orientation data using the ACT2 tool shows less clearly defined sets of structure concentrations compared to the ATV logged data set (right side). The two plots would show quite different average orientations for some of the joint sets. For this particular project the picking of the structures was carried out by the sub contracted ATV operator whilst SRK carried out the core orientation on the drill site. A number of reasons were considered to explain the differences:

1. Different size of the two datasets. The core orientation data set is based on 1,937 measurements, whilst the ATV data set comprises 6,728 picked structures.
2. Picked structures are not the same as the structures obtained from core orientation. Whilst the core orientation focussed on logging predominantly open structures, structures picked from the ATV image included many cemented structures such as foliation, well cemented veins, and lithological contacts as the picking was done without the access to the core.
3. Structures obtained from core orientation may have included drill induced fractures as it is often difficult to distinguish natural structures from drill induced fractures.

For the reasons set out above, and using the definitions outlined in Table 1, the data captured by the ATV logging can be described as having medium confidence. Had the ATV logging been undertaken with access to the core by a geotechnical engineer the confidence would have been higher.

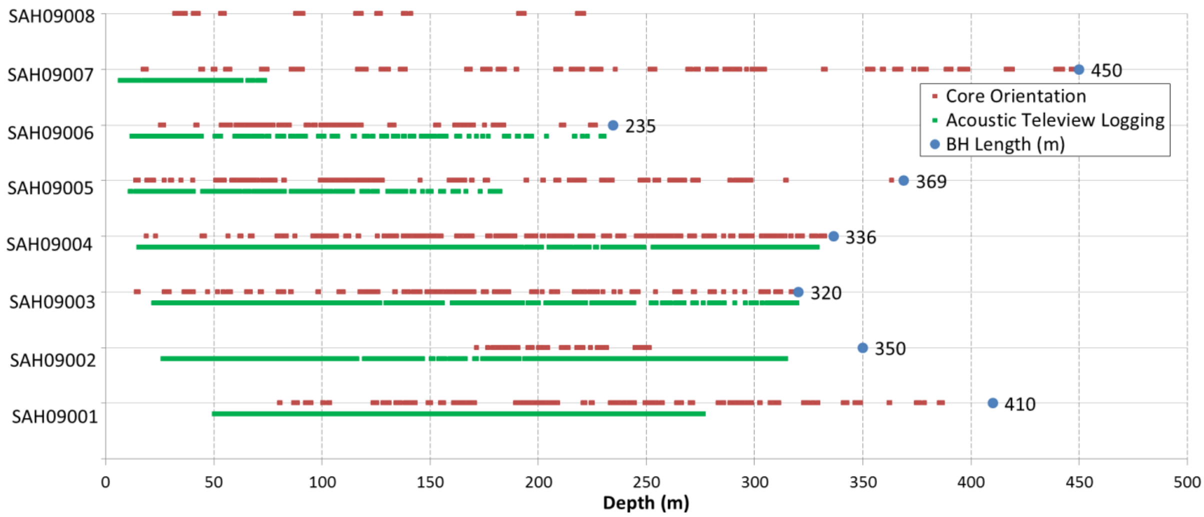

Figure 5 **Positions of the depths of orientated structures obtained from core orientation and ATV for each structurally surveyed borehole**

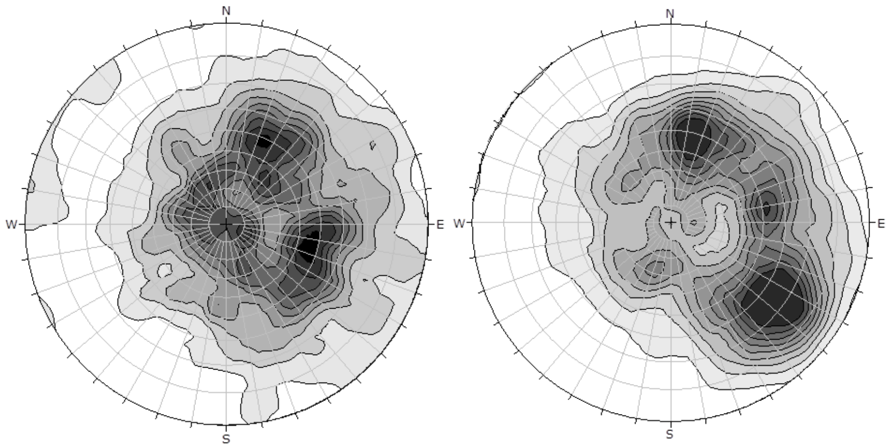

Figure 6 **Comparison of structural orientation data from ACT2 core orientation tool (left) and ATV tool (right); both stereoplots use 0.3% contour lines, the maximum being 3% (ACT2 tool – left) and 3.5% (ATV tool – right)**

8 Advantages and disadvantages of hybrid logging system

This hybrid structural/TV and rock mass logging system provides a host of obvious benefits, however having used and refined this system, the authors have found that there are also a number of disadvantages that must be taken into account when deciding on using the hybrid logging system.

8.1 Advantages

The obvious advantages of using the hybrid method are twofold:

1. The decreased time required for geotechnical logging, reducing project costs and timelines.
2. Greater accuracy from using acoustic or optical televiewer which reduces the human error when measuring structure orientations.

Logging straight into computers using a spread-sheet program (such as MS Excel) can be beneficial; the rock mass log can be automatically populated from the structural/TV log. Whilst providing a time saving, this gives greater quality control. The rock mass classification value for the defined geotechnical interval can be calculated whilst logging and the value can be reconciled against the recovered core in front of the geotechnical engineer. The geotechnical logger can be on site for a single visit to log the core at the end of the drilling programme.

Structural core logging of manually derived orientation data usually develops problems when the core orientation line is inaccurate or non-existent (Davis, 2012; Kuppusamy et al., 2011). This usually occurs when the core is particularly broken. Using the televiewer, structural data can be recorded from zones that are highly fractured/ broken. Where core is lost or open-hole drilling is carried out manual core orientation methods cannot be applied whilst logging based on televiewer surveys still provide images of the borehole wall and an idea can be garnered as to the state of the in situ rock within these zones.

There is a greater confidence in the accuracy of the orientation measurements when using the TV data when compared against manual core orientation techniques. Mechanical breaks seen in the core can be discounted if they are not identified in the televiewer image.

Geotechnical engineers are able to pick the salient features themselves, whilst logging in front of the core. This makes logging more efficient, rather than having to go through the TV log that has been processed by technicians that have not had access to the rock nor have a geotechnical background. ATV logs provide general infill material characteristics (e.g. clay/sand) for features that have a notable infill thickness. These descriptions are supplemented when combined with hand logging as each joint will have specific geotechnical descriptions of infill materials as opposed to when just ATV data is used.

The hybrid system can also provide data rapidly to other disciplines. The data can be relayed to hydrogeologists so that they can locate structures for specific hydrogeological testing (Hsu et al., 2007). The hybrid system, when combined with flow meter logging from spinner or heat pulse probes, can relate groundwater inflows to discrete structures (Bellin et al., 2011).

8.2 Disadvantages

For many rock masses TV logging needs to be undertaken as soon as the borehole has been completed to reduce the risk of borehole collapse. There is a cost and logistical issue: survey teams need to be mobilised either a few times or need to be at site on stand-by. For many projects there are no in-country wireline logging specialists who offer downhole televiewing surveys. In those cases all televiewer equipment needs to be temporarily imported. The time equipment is in transit and in customs can be considerable and is often charged by the televiewer surveying specialist.

Undergoing training to confidently use the TV logging software is required. Whilst not being an overly time consuming task, it is essential that the geotechnical engineer who is tasked with picking structures has a good understanding of the survey process and associated software.

Core spin can cause a horizontal artefact on the borehole wall which is picked up by the TV; these can be mistaken for or can mask perfectly smooth/planar horizontal joint and bedding features, however, these can easily be identified on inspection of the core.

The hybrid technique removes the need for logging at the drill site during drilling; this has time and moreover significant costs advantages, but also removes the geotechnical presence during drilling, providing less opportunity to control core quality/recovery. This can be mitigated with client supervision rather than using a consultant, thus saving costs.

It was stressed in earlier sections that the depth correlation between the televiewer image log and the rock mass log is critical for accurate incorporation of the two systems. The authors have found that correlating between the logs can be time consuming. Problems arise when there is core loss or if core depths are marked incorrectly by the drilling crew. These can be spotted as there is a marked change in the positions of discontinuity features in relation to one another. It was found that core depths and the image depths can incrementally become out of sync. It is speculated that the depth at which the TV tool is lowered and raised through the hole is not recorded correctly, or that the cable suspending the tool stretches (particularly over very long boreholes). If correlation is lost frequently then this can add significant time to the logging process, or if not picked up upon, can cause errors in the data when the structure and rock mass logs are combined.

9 Conclusions and recommendations

The hybrid geotechnical logging system allows for rapid rock mass and structural logging whilst incorporating the accuracy afforded by the use of TV data. The authors have found that the conditions that best suit the hybrid logging system (and any other core orientation system) range from predominantly fair to very good rock masses. However, as long as the borehole is stable, TV surveys of poor and even very poor rock masses can be successfully undertaken and the authors have generated good quality structural data in rock with well over 10–15 joints per metre. The hybrid geotechnical logging system has obvious advantages in terms of time and accuracy; however the potential pitfalls of using this approach must be well understood to be able to maximise these benefits (Table 2).

Table 2 Advantages and disadvantages of hybrid logging system

Advantages	Disadvantages
Geotechnical engineers are delineating structures from the TV survey whilst in front of the core. This is preferable to using a TV surveying contractor who may have little understanding of how the data collected will affect slope design.	Costs can be high if each hole has to be surveyed immediately. Significant costs for call out charge, mobilisation/demobilisation, operator stand by time.
No drill site supervision required as logging can be done at the core shed, reducing costs.	Logistics can be difficult to get TV operator to drill site when needed.
Increased speed of logging.	Logging must wait until ATV survey is completed (usually at the end of drilling campaigns).
Increased confidence in structural data – mechanical breaks can be quickly discounted.	Core spin can mask/over-estimate features that are naturally horizontal to the borehole axis.
Automatically populating rock mass log for RMR.	Depth correlation can be problematic and time consuming.
Better quality control.	If depth correlation errors are not identified the resulting data can be inaccurate.
Data can be rapidly conveyed to other disciplines.	Training in ATV logging required.
Core recovery and core quality not critical as data is collected from borehole wall.	

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