Accoustic and Optical Televiewer Borehole Logging

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Abstract

This review paper is focused on Borehole Televiewer. Barehole Televiewer or (BHTV) was used to obtain high-resolution acoustical images from the borehole wall. A probe with a high resolution downward looking camera is used. The camera has specific optics (a conical mirror with a ring of bulbs) with just one shot needed to capture the entire borehole circumference as a 360 panoramic view. Settings similar to traditional cameras (exposure, quality, light, frame rate and resolution) make it effective in almost any type of borehole fluid. After each shot, a series of horizontal pixel strings are acquired, giving a rasterized RGB picture in real-time which is transmitted to the console and finally to a monitor. The orientation device embedded in the tool, which is made of 3 inclinometers and 3 magnetometers, allows the inclination and azimuth of the probe to be computed in real-time, correctly orienting the borehole images. Besides, Acoustic and Optical Televiewer has been introduced as its advanced in technological research. Its logging has been successfully applied to geotechnical investigations and mineral exploration (Schepers et al., 2001) due to advances in beam focusing, increased dynamic range, digital recording techniques, and digital data processing (Schepers, 1991). Thus, this paper will go through to the basic principle of (BHTV) as one type of data collection today.

Keywords: Borehole, panoramic view, Acoustic and Optical Televiewer, data collection
1. Introduction

Borehole Televiewer enables scientists especially geophysicists to characterize any conditions of subsurface in considerable detail, detailing of lithology and groundwater flow conditions and identifying faults, layers, fractures and veins within the subsurface rock strata, facilitating the characterization of intrusions for mining and geotechnical assessments. Such surveys require multi-sensor logging instrumentation to describe the fracture and bedding plane dip and strike angles. There are two techniques that familiar being used now. This review paper will focus on these two methods for site characterization which commonly known as Acoustic and Optical Televiewer. Imaging with Acoustic and Optical Televiewers will result in continuous and oriented 360 degree views of the borehole wall from which the orientation, character, relation of lithology and structural planar features can be defined. The combined application of acoustic and optical imaging provides critical information for a site assessment.

2. Acoustic Televiewer

An ultrasonic pulse-echo configuration with a 0.5–1.5-MHz transducer is used for Acoustic Televiewer (ATV) imaging systems. To generate high-resolution caliper logs, the transit time and amplitude of the reflected acoustic signal are recorded as photographic-like images, and the transit-time data can be used (Fig. 1).

ATV tools of 1.7–3.7 m in length and 40–50 mm in diameter are commonly used. Previous of ATV systems sent an analog signal up the logging cable that was displayed and photographed on an oscilloscope. Nowadays, the analog signal is digitized downhole, and the digital signal is sent up-hole for display and analysis on a computer. ATV images from analog and downhole-digital systems is compared as presented in Fig. 2.

In a conventional ATV system, the transducer is rotated on a motor-driven shaft while the tool is pulled up-hole. In a fixed transducer system, the acoustic beam is bounced off a rotating convex reflector. Vertical resolution of downhole-digital, rotating low frequency transducer systems is on the order of 5–7.5 mm and maximum borehole diameter generally is 230 mm or less. Fixed high-frequency transducer systems have vertical resolutions of 1–2 mm and can be used.

![Fig. 1. Three-arm mechanical and acoustic caliper logs and acoustic transit-time and amplitude televiewer images in a 150-mm diameter borehole completed in metabasalt.](image-url)
Fig. 2. Amplitude images from acoustic televiewer in a 150-mm diameter borehole completed in schist with pegmatite: (A) analog (note vertical line where image was spliced to correct for an orientation error found after log collection); (B) downhole digital.

Fig. 3. Amplitude images from acoustic televiewer in a 150-mm diameter borehole completed in gneiss: (A) fixed high-frequency transducer; (B) rotating low-frequency transducer.

For a borehole, ATV images can be collected in water-filled or light mud-filled intervals. Borehole enlargements related to structures such as fractures, foliation, and bedding planes scatter energy from the acoustic beam, reduce the signal amplitude, and produce recognizable features on the images (Paillet et al., 1990). Acoustic impedance contrast between the borehole fluid and the wall indicates the relative hardness of the borehole wall. If there is sufficient acoustic contrast, changes in lithology, foliation, bedding, and sealed fractures may be detected even when there is no change in borehole diameter.
3. Optical Televiewer

A ring of lights to illuminate the borehole, a CCD (charge-coupled device) camera, and a conical or hyperbolic reflector housed in a transparent cylindrical window are being used in the Optical Televiewers (OTV) imaging systems. Typically used OTV tools are 1.4–2.8 m in length and 40–50 mm in diameter. The CCD camera measures the intensity of the color spectrum in red, green, and blue. The reflector focuses a 360 degree slice of the borehole wall in the camera’s lens. Light intensity is either preset prior to logging or, in some systems, may be adjusted while logging. The optical image scan is either sent up the logging cable as an analog signal and digitized up-hole or digitized downhole or sent up as a digital signal. A comparison of images from uphole- and

downhole-digital, conical and hyperbolic reflector OTV systems is presented in Fig. 4. Typically, the maximum borehole diameter in which OTV images can be collected are 300 mm or less. Vertical and horizontal resolutions of OTV images that are commonly used such as 0.5, 1, or 2 mm and 180, 360, or 720 pixels per line, respectively. The selected vertical and horizontal resolution, system design and cable type can determine the logging speed for OTV images. Typical logging speeds for most systems are on the order of 1 m/min.

Subsurface of lithology and features of structures such as fractures, fracture infillings, foliation, and bedding planes are viewed directly on the OTV images. OTV images can be collected in air-filled or clear-water-filled intervals of boreholes. Factors that can influence the quality of OTV images such as unflushed drilling mud, chemical precipitation, bacterial growth, and other conditions that affect the clarity of the borehole water or produce coatings on the borehole wall.

4. Comparison and analysis of acoustic and optical televiewer images

OTV images allow for direct viewing of the relation between lithology, foliation, bedding planes, and fractures, whereas the relation between lithology and structural features is not always clear on ATV images (Figs. 5 and 6). Foliation, bedding planes, and changes in lithology may not be apparent on ATV images if they are not associated with sufficient borehole relief or acoustic contrast. Fractures generally are recognizable on both ATV and OTV images. However, in darker rocks, fractures that are readily apparent on ATV images are difficult to distinguish from dark-colored zones on OTV images (Fig. 7). Iron staining and other chemical precipitation, free product, and bacterial growth that may be indicative of groundwater flow and (or) contamination are readily apparent on OTV images (Fig. 8) but not ATV images. Drilling-related gouge affects the appearance of fractures on both ATV and OTV images. The drilling process typically gouges out fractures and increases their apparent aperture (Paillet et al., 1985). The top and bottom of steeply dipping fractures typically are gouged and appear to have a greater dip (Cohen, 1995). Fractures infillings may be gouged out so that sealed fractures may appear open. Closely spaced fractures may be gouged out and appear as a single large zone, in which the orientation of only the top and (or) bottom fracture may be determined. The most efficient and powerful analysis of ATV and OTV images is done with computer programs that allow for
simultaneous and integrated interpretation. Integrated analysis of ATV and OTV images displayed side by side at the same scale and orientation provides complementary and synergistic results. Experience has shown that independent analysis of ATV and OTV images produces data sets with multiple discrepancies in fracture location and orientation. Although some discrepancies are expected because of the inherent difference in the response of the tools, many apparent inconsistencies are readily resolved by integrated image analysis. Structural and lithologic planar features are classified and fitted interactively with sinusoidal traces, and the true orientation is calculated using analysis software. The classified fractures and other planar features and their orientation commonly are displayed on tadpole and stereo plots. Tadpole plots provide a depth-dependent display of fracture orientation that can be readily compared with other conventional geophysical logs. Stereo plots provide a means for the graphical display of the distribution of fracture orientation for a borehole, selected depth intervals, or multiple boreholes. Additional information on the analysis of fracture-orientation data from boreholes and approaches for correcting for bias is presented by Martel (1999).

Fig. 5. Televiewer images of a 75-mm diameter borehole completed in gneiss: (A) acoustic; (B) optical (Stumm et al., 2001).

Fig. 6. Televiewer images of a 75-mm diameter borehole completed in sandstone: (A) acoustic; (B) optical (Williams et al., 2002).
5. Conclusions

ATV and OTV imaging results in continuous and oriented 360 degree views of the borehole wall. Fractures are more clearly defined under a wider range of conditions on ATV images than on OTV images including dark-colored rocks, cloudy borehole water, and coated borehole walls. However, OTV images allow for the direct viewing of the feature and relation between lithology, fractures, foliation, and bedding. The most powerful approach is the combination of both applications using ATV and OTV imaging with integrated interpretation. ATV and OTV images provide a good combination of qualitative and quantitative information in order to characterize lithology and fractures penetrated by boreholes. It is also useful to identify potential contamination, help in the data collection, interpretation of hydraulic and water-quality data and other geophysical logs. The images also provide insight for conceptual models of fractures, groundwater flow, and contaminant transport.
References