



Boreholes are among the most frequently used methods of exploration in engineering geology and rock-related construction. The greatest yield of geotechnical data is obtained from these boreholes when the borehole walls are investigated in addition to the core. Investigations of this type are possible by geophysical means and especially by optical methods.

The further development of borehole exploration methods was triggered by the need to supplement core drillings particularly in those areas where it often proves impossible to obtain any results because the rock - weakened and decomposed - reaches the surface completely broken into lumps by the drill bit. It is precisely these rock areas, however, that can be of exceptional geomechanical significance so that their detailed exploration assumes special importance.

Optical borehole explorations are possible in several ways:

- The simplest method is to use an optical system consisting of a lens, several extension tubes, plus an objective tube with lamp and prism for deflecting the image.
- The second method works with a miniature TV camera that functions together with a rotating inclined mirror to present a picture of the borehole wall on the TV screen. Viewing direction is determined by means of a compass that is mounted in the TV camera and which also appears on the monitor.
- The most modern method uses a borehole scanner presenting the borehole wall via a truncated cone mirror. The truncated cone images that are taken when monitoring the borehole give, joined together, a deformed reproduction of the explored borehole section. By means of an arithmetical rectification of the images with the help of geometric relations a continuous image of the borehole wall is created on the screen.

Optical explorations are ideal not only for monitoring and petrographic assessment of borehole walls but also for measuring the spatial position of layer and fissure surfaces and for determining the width of fissure openings and the degree of planar separation.



The geophysical method of presenting the structural details of the borehole wall uses the fact that differences in rock strength and even fissures lead to different acoustic reflections.

As measuring principle the pulse echo method or Acoustic Televiewer (ABF) is used. A piezoelectric transducer, located in the probe, rotates six times per second, transmits ultrasonic pulses with a frequency of about 685 Hz and receives the echoes of the borehole wall.

With the help of a magnetic orientation system in the probe the evolution of the borehole wall can be recorded and presented line by line from the north to the north; one line corresponds to one rotation of the transducer. Thus, in connection with a depth measuring setup a profile similar to the optical image of the borehole wall develops.

Whereas the optical methods may be used in water filled as well as in empty boreholes, the acoustic method works only underwater. To compensate this drawback the acoustic methods have the advantage that the borehole must not be rinsed. With optical methods a long rinsing is absolutely necessary because just a slight turbidity detracts the visibility considerably.

With the optical methods the various borehole probes can be used up to a depth of about 800 m at present. With the purely optical system with ocular (endoscope) you can examine boreholes up to 34 m, whereas depths up to 5000 m and more with simultaneously high temperatures are possible with the acoustic borehole probes.

To use the systems for greater depths minimum borehole diameters of 101 mm are necessary, with the endoscope boreholes of 30 mm diameter can still be explored without difficulties.



Monitoring with our borehole video inspection probe BTV 51 is a simple kind of electro-optical borehole exploration. With this camera vertical to subvertical boreholes with small diameters (from 60 mm on) can be explored up to maximum lengths of 50 m. Slide rods enable the exploration even in horizontal and ascending boreholes. By extension of the housing the camera can even be used when the stability of the borehole wall is not guaranteed, f. e. in back-fillings of railway tunnels. An additional module allows monitoring with side look, which is especially used for cavities or larger outbursts of the borehole wall. But this additional module needs boreholes at least of 80 mm diameter.

The borehole video inspection probe BTV 51 is particularly suitable for reliable control of drillings, or for exploration of injection boreholes to guarantee the success of the injection. In boreholes where the direction and the angle of incidence of fissures are to be determined, we recommend an exploration with the video probe ETIBS[®].

The complete equipment of the borehole video inspection probe BTV 51 consists of the following components as shown in Fig. 1: Camera with integrated lighting ring for optimum illumination of the borehole wall, cable reel with 50 m cable and electric depth indicator, rod adapter, 50 m precision slide rods, monitor with depth indication, video recorder.



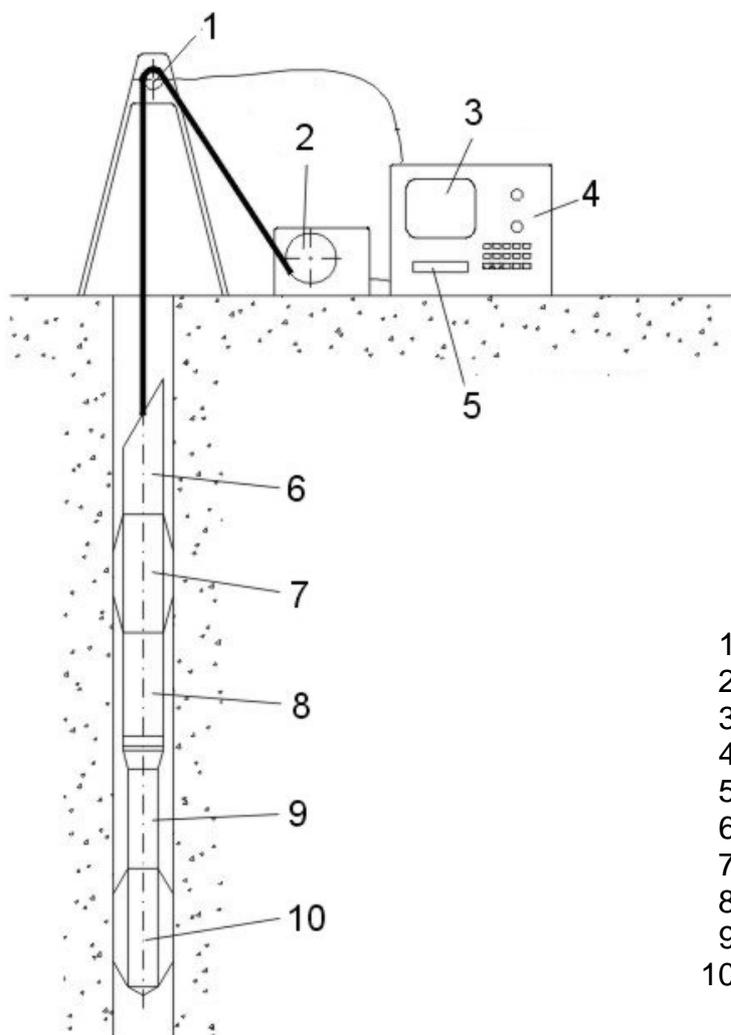
Fig. 1 Components of the borehole video inspection probe

Technical Data:

Diameter of housing:	51 mm (71 mm with side look module)
Length of housing:	1200 mm
Lens:	2.1 mm; $f = 2.0$
Horizontal resolution:	460 TV lines
Frame scan:	Pal system 625 lines at 50 Hz
Video output:	FBAS (VHS)



The optical borehole televiewer probe ETIBS® (Ettlinger Total Image Borehole System) is applied for optic control of geological exploratory drillings or cased well borings. This entails a recording of the borehole wall with a CCD camera by way of a truncated cone mirror. The truncated cone images that are taken when monitoring the borehole give a deformed reproduction, joined together in cross stripes, – that's why the probe is called optical borehole televiewer probe. Its depth position is determined by an electric depth meter over which the cable runs into the borehole. Fig. 1 shows the principle of the monitoring device.



- 1 Deflection pulley
- 2 Winch with depth meter
- 3 Monitor
- 4 Computer
- 5 Data recorder
- 6 Connection device
- 7 Center device
- 8 Compass module
- 9 Camera module
- 10 Center device

Fig. 1 Principle of the monitoring device with the optical borehole televiewer probe ETIBS®



By means of an arithmetical rectification of the images with the help of geometric relations a continuous image of the borehole wall is created on the screen. By simultaneously measuring the azimuth, probe related, and the inclination of the drilling the spatial position of the reproduction is known and the continuous image can be provided with geographical coordinates.

The structural elements as jointing, bedding, schistosity, etc. are also represented as intersection lines with the cylindrical drilling. From their graph resp. from the position of the inflection points of these curves the direction and the angle of incidence of the structural elements can be calculated with a special software and the width of fissure openings can be measured. The RQD-values, determined with the help of the drill cores, can be checked with the scanner recordings as drill-related core ruptures can be identified.

The resolution along the borehole axis amounts to 0.2 mm, the borehole circumference is resolved with 1200 points per line. Due to the digital recording of the images a manifold of user-specific presentations is possible, furthermore the user itself can compile and transform the images in PDF form using standard software. The image data are available on compact disc to duplicate them without degradation.

By comparing the recording with a colour standard you can check the retention of the rock colour. By touching up the bitmaps the colour can also be matched additionally according to a standard colour scale.

Our experience with the borehole probe ETIBS® has shown that the used probe must be adapted to the diameter of the borehole to be explored.

The annular gap between probe and borehole wall should be as small as possible to obtain an optimum image of the borehole wall. This is especially important when monitoring underneath the groundwater level. Only this guarantees that the water filled annular gap can be penetrated by the light of the probe, even if the water is troubled by floating particles.



Several borehole probes ETIBS® are available which have been designed for drilling diameters from 75 up to 300 mm. The borehole probe ETIBS® 97 is entirely used in vertical exploration drillings. Due to their light construction the borehole probes ETIBS® 76 and ETIBS® with interchangeable head are also ideal for inclined or overhead boreholes because they can be pushed into boreholes of this type by means of slide rods.

Technical Data ETIBS^Ø 96

General conditions

- Exploration of geological drillings down to a max. depth of 300 m,
- pressure-water-tight up to 30 bar,
- borehole diameter of up to 200 mm.

Dimensions

Camera module	l = 810 mm, Ø = 96 mm
Center device	l = 390 mm, Ø 100 - 147 mm
Connection device	l = 125 mm, Ø = 96 mm
Probe complete	l = 1325 mm
Truncated cone mirror	Ø 80 x Ø 30 x 25 mm

Weight

Probe complete	approx. 25 kg
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Lens

Max. resolution along borehole axis	0.2 mm (dependent on the difference between borehole and mirror diameter)
Resolution along borehole circumference	approx. 1200 points

Compass

Resolution	± 0.5 °
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Technical Data ETIBS⁰ with interchangeable head

General conditions

- Exploration of geological drillings down to a max. depth of 300 m,
- pressure-water-tight up to 30 bar (starting from camera head 96),
- borehole diameter of up to 300 mm.

Dimensions

Camera head 70	l = 195 mm, Ø = 70 mm
Camera head 96	l = 210 mm, Ø = 96 mm
Camera head 142	l = 370 mm, Ø = 142 mm
Camera module	l = 500 mm, Ø = 70 mm
Center device	l = 700 mm, Ø 75 - 300 mm
Connection device	l = 125 mm, Ø = 70 mm
Probe complete	l = 1875 up to 2006 mm depending on camera head

Weight

Probe complete approx. 24 kg

Lens

Max. resolution along borehole axis 0.2 mm (dependent on the difference between borehole and mirror diameter)

Resolution along borehole circumference approx. 1200 points

Compass

Resolution ± 0.5 °

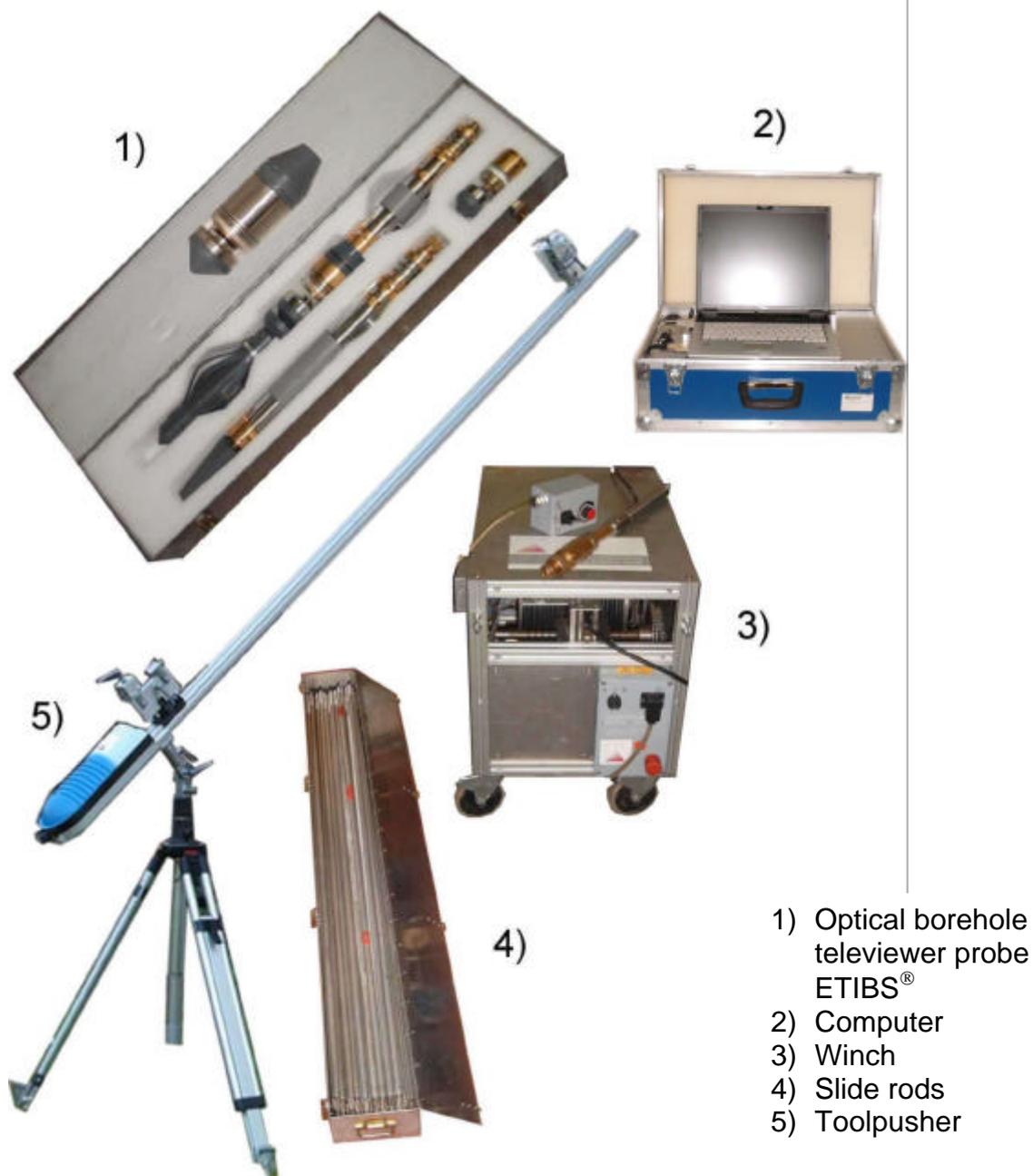


Fig. 2 Components of the Optical Borehole Televiwer Probe ETIBS®



Sales Information and Prices

12.2.1	Probe for interchangeable camera heads with integrated compass	8.925,00
12.2.2	Interchangeable camera head 70	6.825,00
12.2.3	Interchangeable camera head 96	8.085,00
12.2.4	Interchangeable camera head 142	10.185,00
12.2.5	Center device for interchangeable camera head 70 and 96 in vertical drillings	3.485,00
12.2.6	Center device for interchangeable camera head 70 and 96 in inclined drillings, please indicate desired borehole diameter	2.600,00
12.2.7	Center device for interchangeable camera head 142 in vertical drillings	2.485,00
12.2.8	Probe cable per m	18,20
12.2.9	Tripod with 2 deflection pulleys	2.080,00
12.2.10	Winch with depth meter and cable guidance	15.382,00
12.2.11	Slide rods consisting of individual lengths of 2 m	167,00
12.2.12	Slide and pull device (Tool Pusher)	11.340,00
12.2.13	Data recording and data readout unit	10.284,00
12.2.14	Evaluation program with 1 day instruction at GIF	4.900,00

All prices in EUR plus V.A.T.
 Plus costs for packing and transport
 Our General Conditions of 2004-04-29 are valid



Drillings in old mining areas with unknown galleries or not documented panels sometimes meet underground cavities, whose dimensions may be very important for the planning of a construction project. When drilling in rocks that tend to karstification, especially in sulphate- and chloride karst, underground cavities may be met, too, which result in sinkholes when breaking through to the surface. The dimensions of these cavities are just as important for a construction project.

We may offer you two methods to measure cavities out of drillings:

- In drillings above the groundwater level **laser distance measurements**
- In drillings underneath the groundwater level **acoustic log measurements**

In both methods the measuring instrument (Fig. 1) is - guided on a rod - lowered into the cased borehole and pushed through the drill bit into the uncased borehole section to be investigated. The inside diameter of the drill bit must be at least 101 mm. The maximum length that the measuring instrument can be extended from the casing until the lower center device of the rod meets the drill bit amounts to 2.74 m with the laser and 4.68 m with the acoustic log.

At the top end of the casing the installation rod is held from a center device, too. But this device allows at the same time a predetermined horizontal-sweep of the rod and thus of the probe through 360 °.

If the cavity to be investigated exceeds the above mentioned heights, in case of the acoustic log the casing must be lifted by a respective number of guide grooves, because with the acoustic log horizontal sections in different depths of the cavity are measured that, joined together, result in a spatial picture of the cavity.



The dimension of the laser in measuring direction is so big that it does not go through the bit of a wire line core barrel SK6L. Therefore the probe is swivelled when installed in the borehole axis and after having passed the drill bit it is turned to the borehole axis with the help of a servomotor in such a way as to measure a vertical section of the cavity and that by turning the rod any number of vertical sections of the cavity are measured which together result in a spatial picture of the cavity.

The diameter of the cavity to be measured must be at least of 70 cm. Smaller cavities are not suitable for our laser and acoustic log they are better to be measured with a calibre log. With the laser cavities of up to 20 m radius can be measured with an accuracy of ± 1 cm, with the acoustic log they are scanned with a measuring accuracy of ± 10 cm. The application depth of laser and acoustic log is limited to max. 100 m.

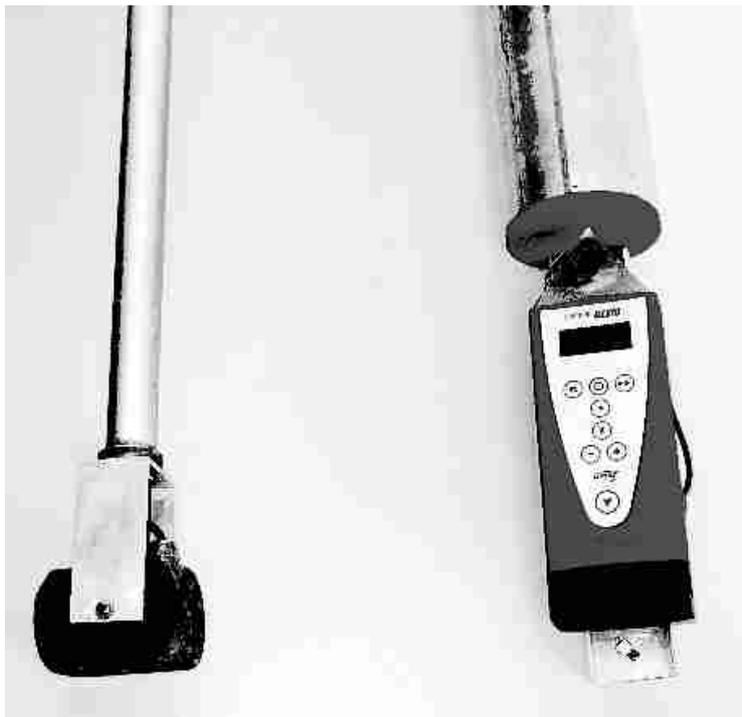


Fig. 1 Acoustic log sensor (left) and laser sensor (right)



The acoustic borehole scanner is a development of the oil industry, and since the late eighties it is more and more applied in ground exploration, too. In oil drillings, often very deep and filled with heavy mud, optical borehole exploration was not possible, which gave reason to the construction of acoustic scanners.

The acoustic borehole scanner uses the physical effect that differences in the dynamic rock properties, but also joints, lead to different acoustic reflections.

As measuring principle (Fig. 1) the impulse reflection method is used where a piezometric converter located in the probe sends ultrasonic pulses with a special repetition frequency and receives the echoes from the borehole wall. By electronic image editing a sort of "line image" of the wall can be recorded and be figured as continuous image. By moving the probe in the borehole a lot of individual "line images" are received which are put together to an overall picture of the borehole wall, which can be shown as continuous image or as virtual core in 3D.

For that purpose a depth measuring set-up and a magnetic orientation system based on gravity is installed in the probe, which helps orientating the continuous image of the borehole wall line by line from north to north and determining the borehole profile (dip and azimuth).

The method can only be used in water or mud filled boreholes. Basically cuttings or support media do not obstruct the procedure, but the ultrasonic impulses are attenuated which means that the maximum possible borehole diameter can only be scanned in case of clean water. The method cannot be used in dry boreholes.



The radial image resolution of the acoustic scanner depends on the scanning of the borehole wall and the borehole diameter. The image resolution towards the borehole axis depends on the velocity with which the probe is moved in the borehole.



Fig. 1 Rotating ultrasonic transducer of the borehole scanner in oil bath

Strength (amplitude) and runtime of the reflection are recorded or the total waveform of the reflection. The amplitude is very responsive to changes of the elastic rock properties; therefore the amplitude image contains structural information as joint surface, bedding planes and schistosity planes, joint spacings, degree of separation, joint opening and filling. These structural information can be presented orientated and statistically evaluated in a global coordinate system by arithmetical consideration of the borehole running.

The runtimes of the reflections change according to the form of the borehole, thus the runtime image is a high-resolution caliber log; therewith for example open and closed joints can be distinguished and the exact borehole geometry can be recorded.



The image resolution of the acoustic scanner from the company Century Geophysical Corp. used by us is 5 mm along the borehole axis, the borehole circumference is resolved with 254 pixels per line.

The method is suitable to determine the dip direction and the dip angle of distinctive joints, bedding and schistosity planes. It is used to detect joint spacings, wall outbursts or cavities. The quality of the produced images of the borehole wall cannot be compared with the visual image, on the one hand because the image resolution with the acoustic scanner is very rough, on the other hand because the false-coloured image does not give the possibility to the trained eye of the geologist to identify the rock (see Fig. 2).

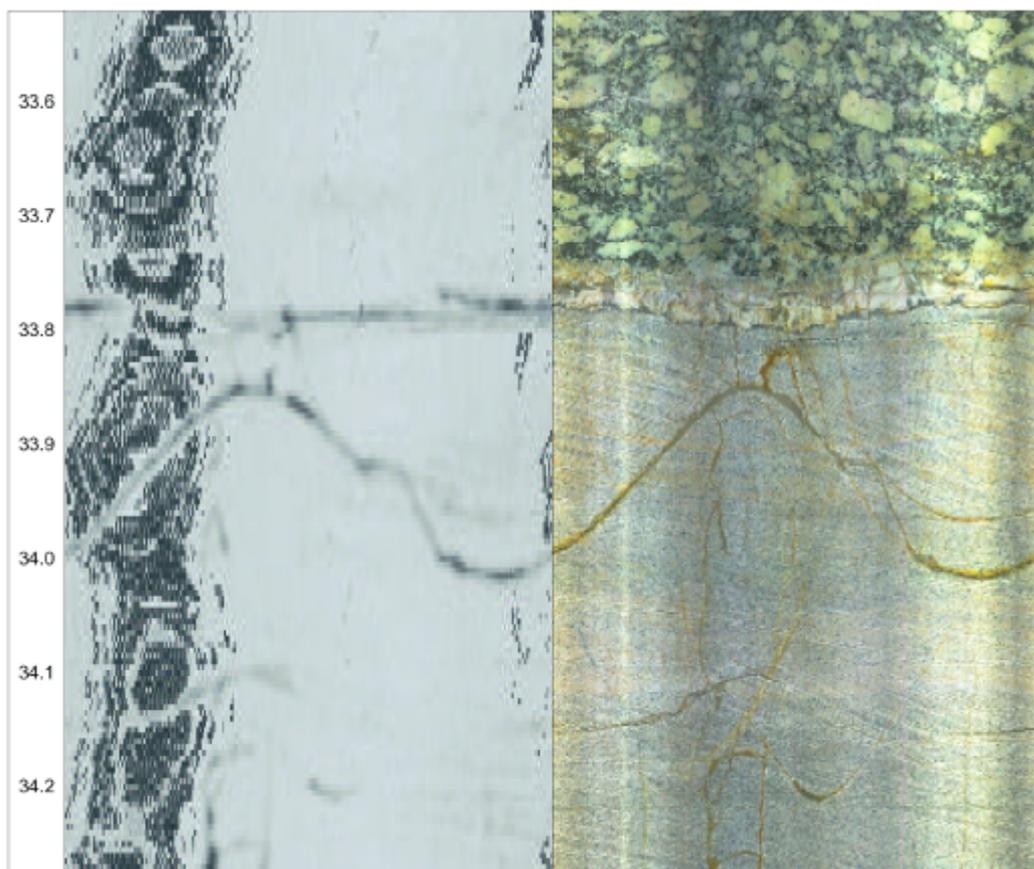


Fig. 2 Comparison of a borehole monitoring with acoustic scanner (left) and optical scanner (right)



At present the application depth of our equipment is limited to 300 m. The minimum diameter of the borehole must be 74 mm. The maximum diameter of the borehole should not exceed 230 mm.

Technical Data

General Conditions

- Exploration of geological boreholes up to max. 300 m depth
- Pressure-water-tight up to 100 bars
- Borehole diameter from 74 up to 230 mm

Dimensions

Probe length 193 cm

Outer diameter 50.8 mm

Weight

Probe complete 14 kg

Orientation System

Resolution for inclination $\pm 0.5^\circ$

Resolution for azimuth $\pm 2.0^\circ$

Image Resolution

- Max. resolution along borehole axis 5 mm
- Resolution at borehole circumference 254 pixels