# Acoustic and optical televiewers- a comparism of results

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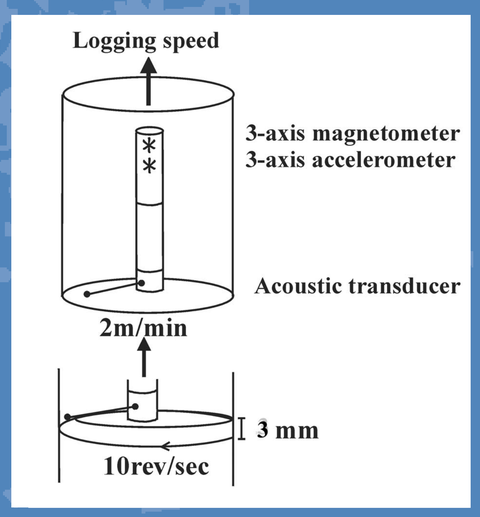
## INTRODUCTION

Each year, more then 50 km of road or railroad tunnels are constructed in Norway. Lately, the world's longest road tunnel, the 24,5 km long Laerdal Tunnel, was opened as scheduled and without serious deviations in costs. However, too many tunnels have been constructed, where budgets failed, and where there were great disturbances in the environment surrounding the tunnels. One of these was the 14 km long railway tunnel connecting Oslo city with the new airport north of Oslo. As a consequence of these tunnelling problems, the road and the railroad authorities in Norway started a project with the aim of improving the quality of investigations leading up to the construction of tunnels.

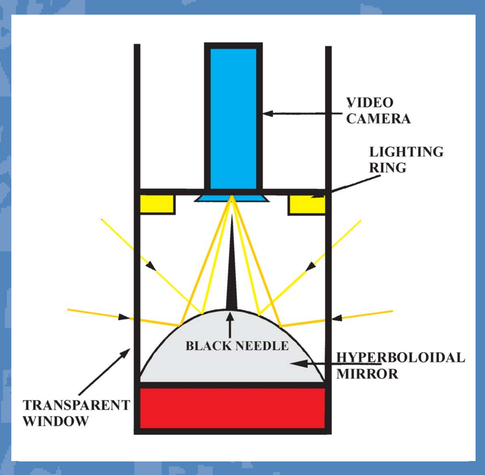
Geological Survey of Norway (NGU) has tested different kinds of televiewer-type borehole inspection tools: Acoustic televiewer (BHTV) and Optical televiewer (OPTV) from Robertson Geologging (UK) and Optical televiewer (BIPS), produced by the Japanese company Raax. A comparison of the results from these tests are presented.

## METHODS

The acoustic televiewer, BHTV, consists of an ultrasound transducer which rotates 10 times a second and for each revolution the source is fired 128 times. The sensor is elevated with a speed of 2 metres pr. minute. In a 5" borehole this gives pixels of approximately 3 x 3 mm. Both the travelling time and the amplitude of the reflected signal from the borehole wall are registered. The instrument is oriented using a three-axis magnetometer and/or accelerometers and the cylindrical picture generated by the instrument is folded out to produce a flat image. Fractures appearing as cavities in the borehole wall, can be detected from the travelling time of the acoustic waves and/or as attenuation of the reflected signal. Fractures will be imaged as a sine shaped line, and through a fitting procedure, it is possible to calculate the strike and the dip of the fractures as well as the fracture opening. Based on these results, it is possible to do statistical analyses, and study which populations of fractures are present in different parts of the borehole.

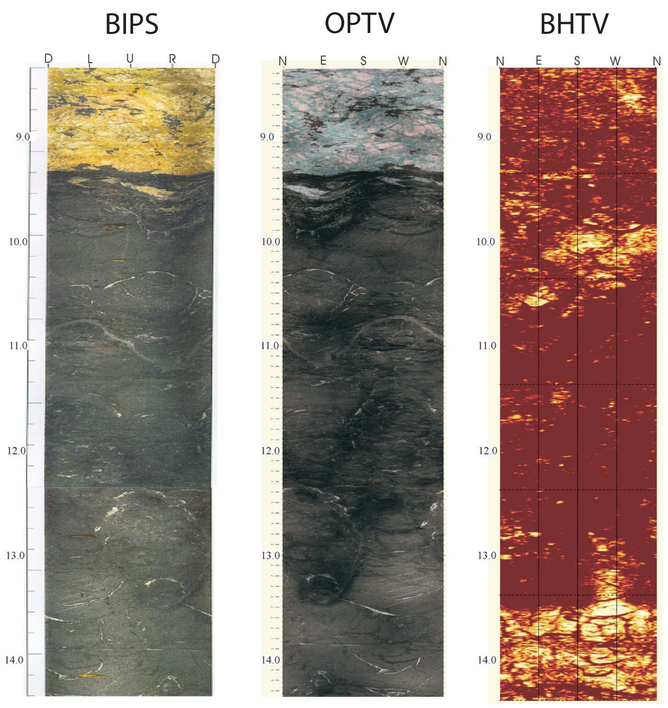


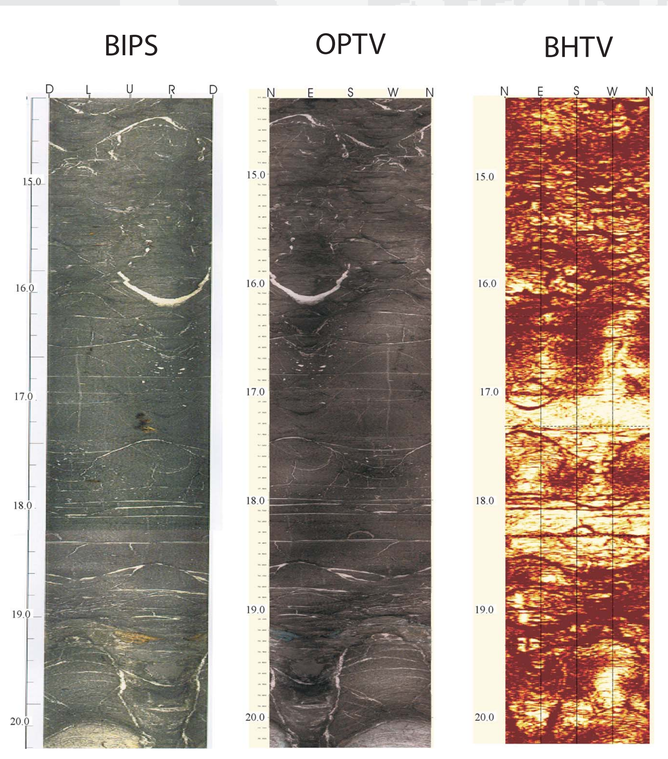

The optical televiewer consists of a digital camera directed towards a hyperbolic (OPTV) or cone (BIPS) mirror. A light source illuminates the borehole wall. For each mm down the borehole, a 360° picture is sampled at a speed of 1 meter pr. minute. In a 5" borehole this gives pixels of approximately 1 x 1 mm. The picture is oriented in the same way as the acoustic televiewer, and the same statistical analyses can be performed. The optical televiewer can be used in dry boreholes, and gives a very detailed picture of the borehole wall. Based on the probe orientation system, it is possible to produce a borehole deviation log.

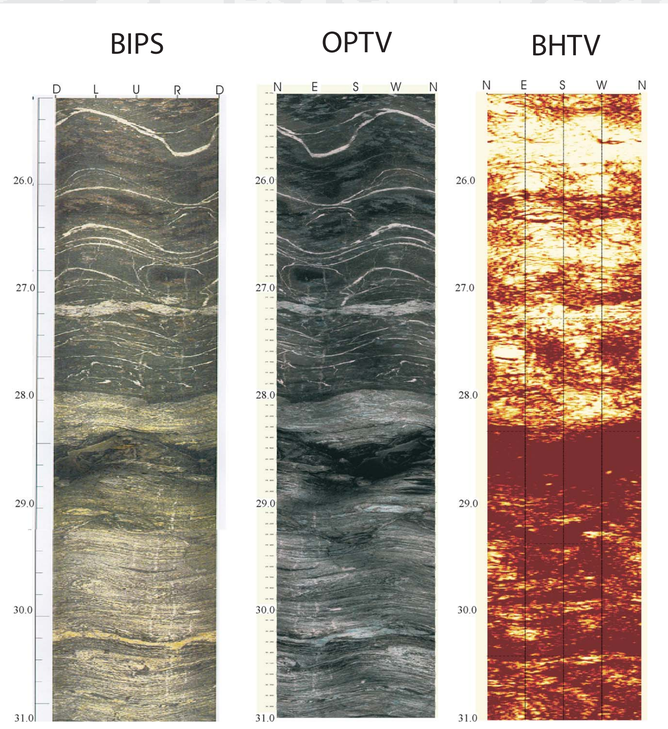



## RESULTS

The poster shows some examples pictures produced with the three different logging instruments from a single borehole located east of Oslo, just above the railroad tunnel, which led to serious water leakage and major disturbance to the environment. All three instruments give information on fracture frequency, strike and dip. In some cases it is possible to see the openings of fractures with the optical televiewers. In addition, from the optical picture, it is possible to analyse bedrock type and secondary mineralizations and alterations can be observed on fractures. In short, the optical televiewer gave much more detailed information than the acoustic televiewer. In addition, the optical technique works in dry boreholes while the acoustic does not.




Indicated fractures are digitised and statistical analyses are made. Fracture groups are identified and mean strike/dip, number of fractures and fracture frequency are calculated for each group. The results are summarized in table 1. All three methods indicate four groups of fractures, but the direction of strikes differ from one method to the other. These deviations can be explained with few fractures in each group and hence, no statistical significance. However, the acoustic and optical televiewers respond to different physical properties, and in this way complement each other. With the optical televiewer from Robertson (OPTV), it was possible to identify 120 fractures in this 60 meter long borehole. The corresponding number for BIPS was 61 and BHTV 56. It is obvious that the OPTV is able to see more events than the BHTV. From the obtained pictures, we can see that this can be explained with infill of secondary mineralizations, and hence no influence on the acoustic response. The differences between results from the OPTV and BIPS instruments can be attributed to subjective different persons analysing the data. As a final product, a fracture analyses log can be made.

### OPTV FRACTURE ANALYSES STEREOGRAM

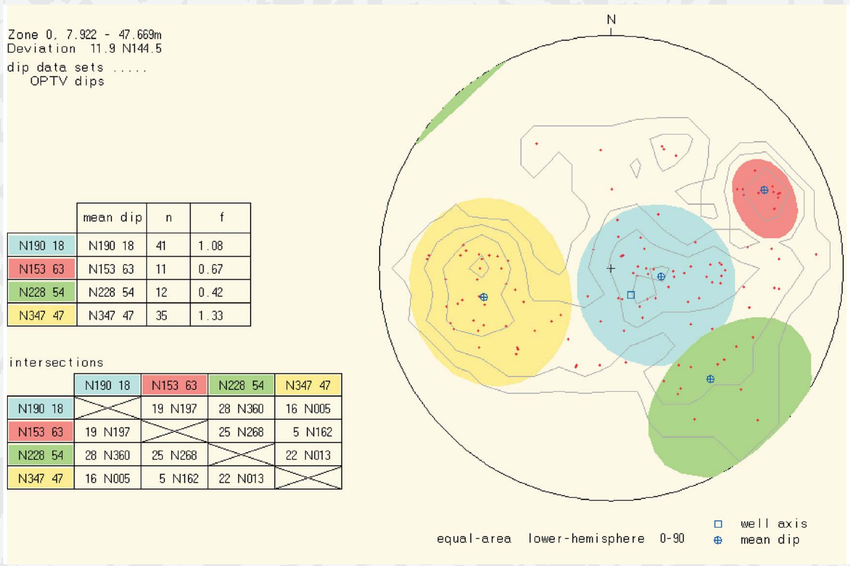
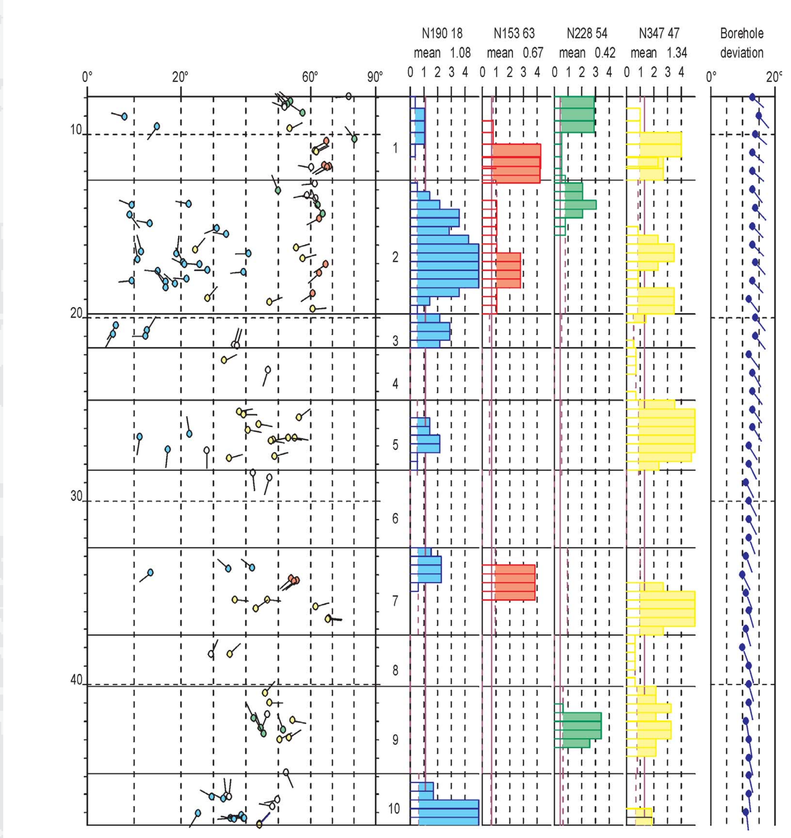



*Table1*

| Unit | Direction 1 Number | Direction 2 Number | Direction 3 Number | Direction 4 Number | Other Number | Total Number |
|---|---|---|---|---|---|---|
| BHTV | 190<br>6 | 329<br>4 | 152<br>8 | 309<br>26 | 12 | 56 |
| BIPS | 160-180<br>9 | 50 – 70<br>15 | 140 – 160<br>13 | 10 – 20<br>5 | 19 | 61 |
| OPTV | 190<br>41 | 347<br>35 | 153<br>11 | 228<br>12 | 21 | 120 |

### OPTV FRACTURE ANALYSES LOG




## CONCLUSION

Televiewers give important information on rock quality. Fracture frequency, strike and dip can be quantified. Optical televiewers can also give additional information on fracture opening, secondary mineralizations and alterations, information which is important in evaluating water leakage. Based on the first experience with these methods, we find the optical televiewer most interesting. However, the breakout log, which can only be produced with the acoustic televiewer, can be an interesting alternative in rock quality evaluation.