INVESTIGATING Chalk with GEOPHYSICAL PROBES

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Chalk Dissolution Hazards

The key physical characteristics of chalk are high porosity and permeability with soft friable and soluble nature – herein lies the challenge for ground stability and foundation design. This character allows dissolution in chalk beds that can create irregular, unpredictable subsurface voids and cavities leading to reduced rock strength and vulnerability to ongoing dissolution. These voids are extremely difficult to detect from the surface.

Downhole geophysics can provide valuable data to hydrogeologists, geotechnical engineers and civil engineers to assist in the recognition of potential dissolution hazards.

Origin and Nature

Chalk is comprised primarily of calcium carbonate derived from foraminifera and coccoliths, deposited mainly in deep water marine environments, although continental shelf deposits do exist. The familiar white and grey chalk deposits that we recognise around the UK were deposited during the Upper Cretaceous in the vast warm seas that were developing in NW Europe.

Borehole Geophysical Investigation

Given the difficulty in detecting chalk dissolution hazards from the surface, it will usually be necessary to embark on a programme of drilling and geophysical borehole logging to provide detailed information.

Firstly, from the drilling process itself, recovery rates and feedback from drillers and their logs can yield useful information as the drilling proceeds. Hardness of the formations, cavities or open fractures and the presence of flint bands can often be detected first hand. If the borehole is being cored, analysis of the samples themselves can provide a wealth of data including measures of rock stiffness and integrity.

Following drilling a selection of calibrated geophysical probes can be deployed to characterise the formation. All Robertson Geo probes are fully calibrated and then double checked in a known test borehole before conformance is confirmed.

The following geophysical probes are routinely deployed by Robertson Geo Services when investigating chalk formations.

Televiewers

A televiewer image of the borehole wall provides unambiguous data regarding the overall chalk structure and condition, especially useful when core recovery is less than ideal. Smaller diameter boreholes yield higher resolution data, but centralisation of the probe is also a factor in very small or very large diameters. Borehole diameters from 75mm to 150mm are considered optimum, but images can be obtained with diameters from 60mm to 300mm and beyond.

The image obtained is "unwrapped", continuous, oriented and of high-resolution, offering many advantages. The televiewer image data provides information about geology, structure, fractures, stress orientation and acts as a template for orientating cores and providing depth control where core recovery is incomplete.

Within chalk, the superior resolution of the optical televiewer is preferred as this will show the subtlety of the features within. However, clear or no borehole fluid is a prerequisite and it is normal to allow the borehole to stand, prior to logging, to allow the particulates to settle. This time can vary from hours to days, but overnight is often sufficient.

Where the fluid remains cloudy or time constraints apply, the acoustic televiewer can be deployed. This will pick up the presence of flint nodules, cavities and open faults easily but may miss the finer details of the chalk due to its lower resolution.

Caliper with Natural Gamma

A caliper probe will show the presence of washouts and open fractures while the measured diameter will be a good indication of the relative strength at different depths. Natural gamma values in chalk are nominally very low (< 20 API) due to the sparsity of potassium and heavier elements. Where phosphatic chalk is present though, the natural gamma level can rise significantly, up to 140 API or more. Phosphatic chalk is of particular interest, due to its weak sandy nature, the possible presence of radon gas, contamination of groundwater and the environmental impact of spoil disposal.

Temperature Conductivity Probe

This probe is a highly sensitive unit which outputs borehole fluid conductivity and temperature together with differential channels for each. It is simple and inexpensive to run. Groundwater ingress or egress to the borehole, common in chalk, will usually show as 'kicks' on the logs and thus it can readily identify zones for further flow investigation.

Flowmeters

To obtain flowrates from a borehole there are several methods that can be used. An impeller flowmeter can produce a continuous flow profile over the length of the borehole and by completing up and down logs at multiple logging speeds flow rates can be calculated at required depths. For significant flows this may be adequate, but where the flow is very small a heat pulse flowmeter can be used. This operates statically at predetermined depths and outputs flow rate directly. For detailed information on flows through aquifers a variety of packer tests can also be conducted.

Oriented unwrapped optical televiewer image showing flint bands in chalk.

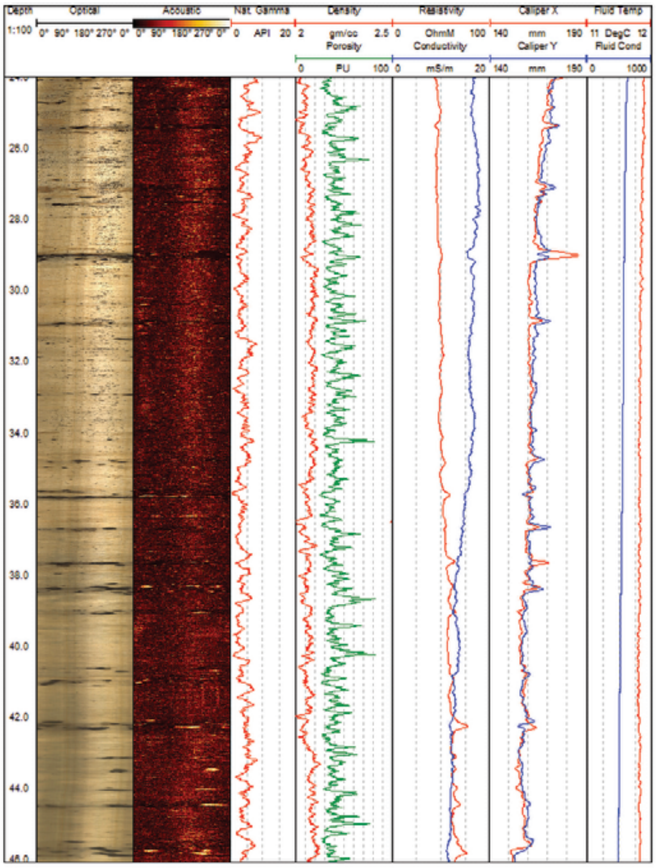
Electric Logs

In sedimentary rocks, resistivity is dominated by connected porosity, allowing for a simple, non-radioactive measurement of formation porosity using resistivity probes.

Multiple electrode electrical resistivity or conductivity measurements remain one of the dominant methods of hydrogeological investigation. The multiple electrode log (ELOG) measures the following channels simultaneously:

SP (Self or Spontaneous Potential): This is the DC bias of an electrode with respect to the surface voltage.

SPR (Single Point Resistance): The current flowing to the cable armour and the voltage at the SPR electrode are measured and resistance calculated.



Composite Log in Chalk.

Normal Resistivity: An alternating current is driven from the SPR electrode and the current return through the cable armour (insulated up to 10m) is measured together with the voltage at a fixed distance from the SPR electrode.

Long Normal Resistivity: As with the normal resistivity the voltage is measured at a fixed distance but this time greater than the normal log, giving better formation penetration.

The difference between normal and long normal resistivity logs is that the electrode spacing (16” and 64”) is a trade-off between penetration and the likelihood of reversal effects of thin high resistivity beds.

An electric log variant is the focussed electric log which uses guard electrodes to focus the current deeper into the formation. In practice this gives a more reliable measure of resistivity in hydrogeological applications.

Another variant is the induction log which records the electrical conductivity or resistivity of the rocks and water surrounding the borehole. The electromagnetic induction probe is designed to maximize vertical resolution and depth of investigation and to minimize the effects of the borehole fluid and can operate in dry or plastic lined boreholes.

Porosity Logs

The Dual Neutron probe provides a direct calibrated measurement of porosity in PU (porosity units), corrected for borehole diameter. However, the probe requires a neutron source with the attendant regulatory controls and safeguards which may be prohibitive on some sites. An alternative means of obtaining porosity is to invert a sonic log using, for example, the Wyllie equation. In addition, borehole magnetic resonance probes can yield information on total porosity, bound and free porosity and allow for calculation of permeability/hydraulic conductivity. These probes require high voltages and the cost of deployment remains high for the moment.

PS Logger

Determination of chalk stiffness in boreholes can be achieved from core samples. However, in-situ stiffness data from velocity logging provides an additional accurate alternative. The PS Logger probe measures P (compression) and S (shear) wave velocities in a single borehole without the need for external energy sources, making it simple and quick to deploy and therefore cost effective. From this data, Poisson’s ratio can be directly calculated. When combined with density data from core samples or density logs, small strain moduli can be determined, i.e. Bulk Modulus, Young’s Modulus and Shear Modulus.

Density Log

The Formation Density log uses multiple detectors to provide an accurate borehole-compensated density measurement with excellent bed boundary resolution. A caliper arm ensures close contact of the source and receivers to the borehole wall and allows for borehole diameter compensation. The data can be used to determine density and when combined with sonic data can provide stiffness and elasticity parameters. A radioactive Caesium source is required however, which again may be problematic on some sites.

In Conclusion

To investigate chalk formations or where chalk dissolution hazards are suspected geophysical borehole logging can provide detailed in-situ data which is difficult to obtain by any other means. Robertson Geo has been gathering data in chalk formations for over 40 years using fully calibrated and certified probes with traceability through our ISO 9001:2015 system.