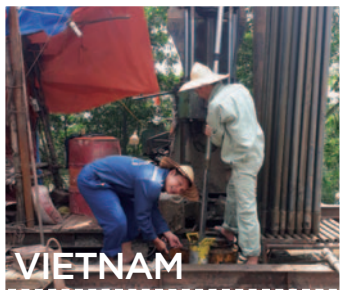

VIETNAM

The Sidewall Density Guard Probe - tool of choice for the Vietnamese coal mines

INDONESIA

On-site field training and support at West Nusa Tengarra

NEPAL

Discovering the anatomy of the world's highest glacier

ROBERTSON GEO

Unlocking Your GeoData

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GLOBAL GEODATA NEWS

ISSUE 06 | AUTUMN 2019

Another GeoKey® system shipped to

WEST AFRICA

Qatar

ROBERTSON GEO LOGGING equipment in use for data acquisition for side wall density, resistivity and fluid conductivity in deep and shallow boreholes and wells in Doha, State of Qatar.

Hydrogeological surveys in

GREENLAND

and logging in

CHINA

CHILE

Offshore logging with Robertson Geo

INSIDE:
FOUR PAGE EDITORIAL INSERT

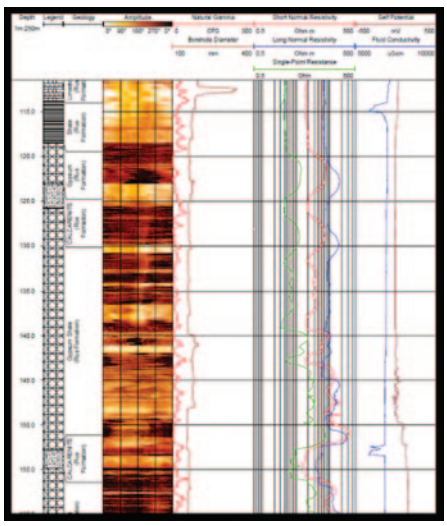
Investigating **Chalk** with Geophysical Probes

Success with **Deep Recharge and Monitoring Wells** at Doha

THE SITE IS located in the middle of Doha, State of Qatar. Robertson Geo customer Gulf Laboratories Co was commissioned for the drilling and geophysical logging and pumping test. A total of four boreholes were drilled to the following depths - geotechnical borehole 160m; deep injection well 400m; deep monitoring well 400m and a shallow monitoring well to 50m.

Caliper, Resistivity, Fluid Conductivity, High Resolution Acoustic Televiewer and Side Wall Density logs were performed in the geotechnical borehole together with Caliper, Resistivity and Fluid Conductivity logs in the deep injection well. Caliper and Resistivity logging was also performed in the deep and shallow monitoring wells.

The Robertson Geo HRAT provided the precise information about the lithology which was supported by the Natural Gamma Ray log. The Fluid Conductivity log was successfully correlated to the location of a more porous zone where mixing of comparatively more conductive water was taking place.



Example of logging data.

Nam Mau Coal Mine, North Eastern Coal Basin, Vietnam

Tool of choice for the Vietnamese coal mines

The Sidewall Density Guard Probe

YEN TU MOUNTAIN is in Uong Bi city of Quang Ninh province, in Northeast Vietnam. The area is located between Hanoi (110km) and a short drive of 50km from Halong Bay. The province is a major coal mining region of Vietnam.

Logging equipment was deployed to log an 850m deep borehole located at Nam Mau Coal Mine on the Yen Tu Mountain at around 608m above sea level. Robertson Geo customer Vietbac Geological Survey Company ran the Sidewall Density Guard Probe to help determine the depth, thickness and quality of the coal seams, in addition to acquiring data on the overburden and general lithology.

The Density Guard Probe has been the tool of choice for the Vietnamese coal mines over the last 25 years, as they value the proven reliability of the calibrated data and its traceability to international standards. Robertson Geo is the only geophysical company that factory tests and calibrates nuclear tools before shipment with the actual radioactive source to be used. This is not only critical for quality control but enables Vietbac to comply with both local and international regulations on the traceability of log data - a key factor in any audit undertaken on the methodology and credibility assessed reserves.

Robertson Geo supplied the entire vehicle mounted logging unit, complete with 2000m winch, boom, probe racks and accessories.

Field training at West Nusa Tengarra, Indonesia

THE PURPOSE OF the visit was to provide on-site training to support Roberston Geo customer AMNT in the use of a 2000m winch deploying a High Resolution Acoustic Televiewer (HRAT). The field training was carried out during an active drilling/logging campaign with additional training for the surface data acquisition system. There was a requirement for a repair/field calibration of the HRAT.

The camp was a prospecting site for an upcoming open cast copper and gold mining quarry. The main difficulty was access - sea plane, helicopter and a hairy 4x4 ride was needed to get there, the HRAT got repaired successfully, the on-site training went well and the project is ongoing.

Robertson Geo logging **offshore in Chile**

THE OUTER PORT project, known as the Puerto de Gran Escala is envisaged to be a major expansion of the existing port infrastructure of Puerto San Antonio, Chile. The proposal involves staged development over a 19-year time span, with an estimated overall cost of $3.4 billion.

When fully completed, San Antonio's outer port will have a breakwater of over 3.9 km long. The design includes an access channel and dredging of the turning basin and the interior harbour to ensure accessibility for E-class container ships, including under unfavourable weather conditions.

Work on the breakwater could begin by 2020, and the geophysical analysis of the immediate subsurface is under way.

Roberston Geo customer Geo Marine commissioned the use of the PS Logger to collect data from six 40m offshore boreholes; the probe was deployed by a 2000m marine winch. The location was 100m from the shoreline and the MV Investigator was a ship that did not have a dp2 system unlike most drill ships. In the continuous heavy weather four anchors were used to aid the stability of the ship during the logging process.

The data successfully collected was good given the sea state.

GeoInfo

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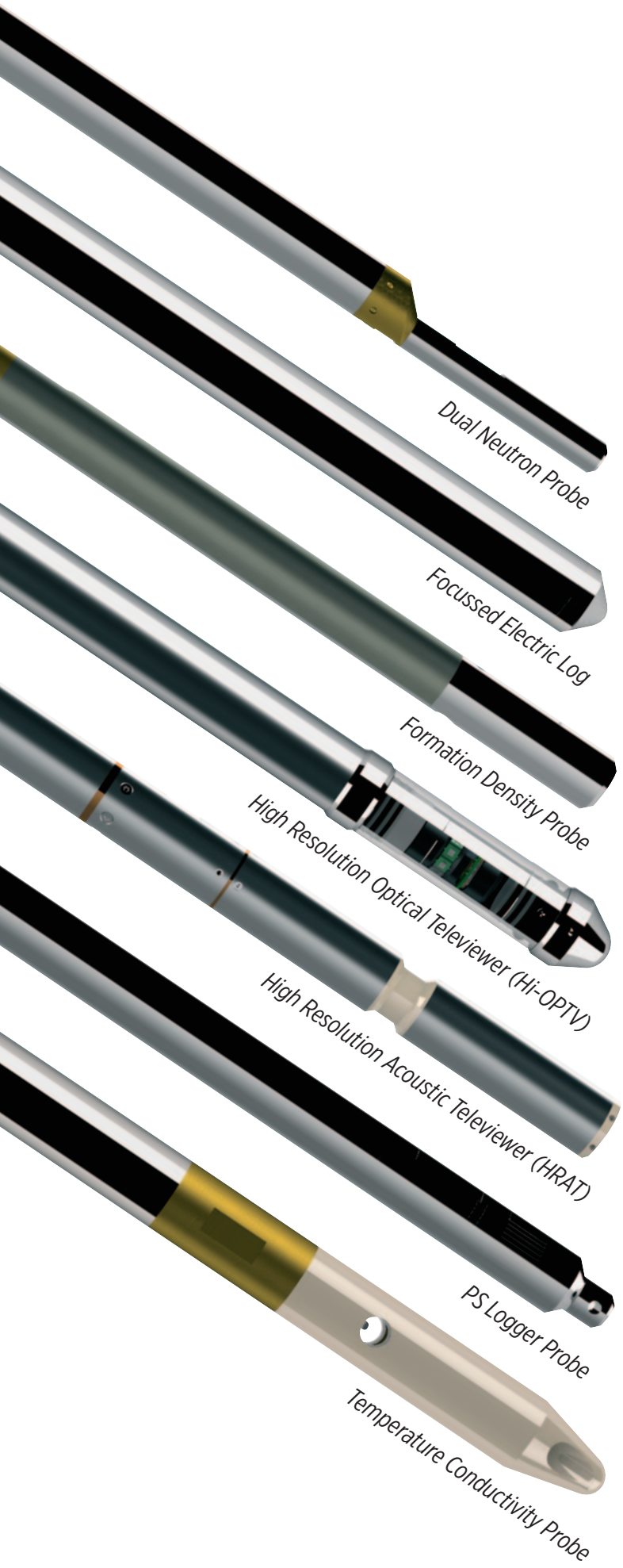
INVESTIGATING Chalk with GEOPHYSICAL PROBES

Graham Comber
Logging Services Manager,
Robertson Geo

Investigating Chalk with Geophysical Probes



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.

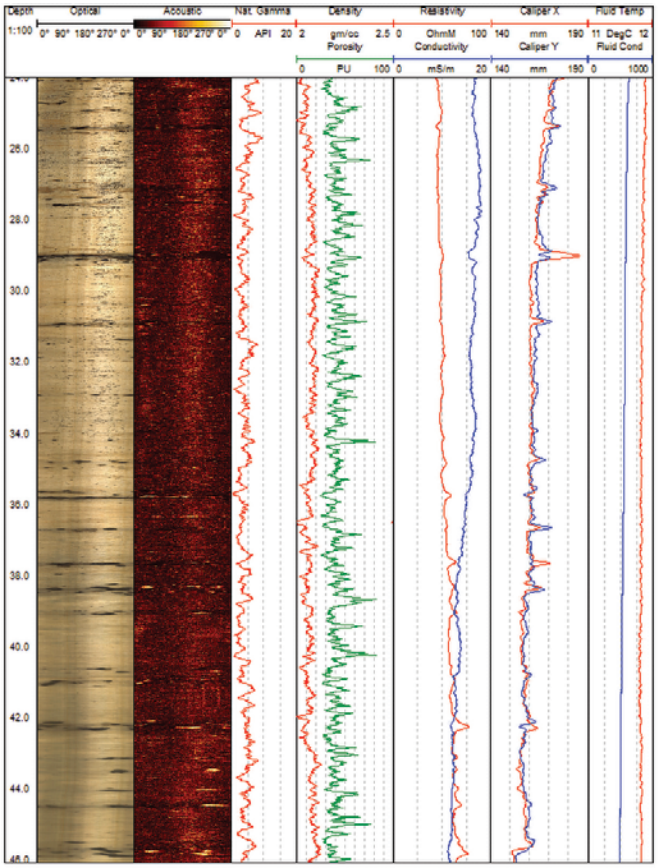
Electric Logs

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.

The EverDrill project, a NERC-funded collaboration between the UK universities of Aberystwyth, Leeds and Sheffield, aimed to investigate what lies beneath the surface of a high-elevation, debris-covered glacier - **Khumbu Glacier, Nepal**

Left: Logging a 155 m deep borehole on Khumbu Glacier. Centre: Logging a borehole immediately next to a surface pond on the glacier. Right: The surface debris made securing the equipment difficult; ice screws and rope were used to secure the mini winch. The debris around the borehole had to be cleared and the tripod was often melted into the surface for additional stability.

Discovering the anatomy of **the world's highest glacier**

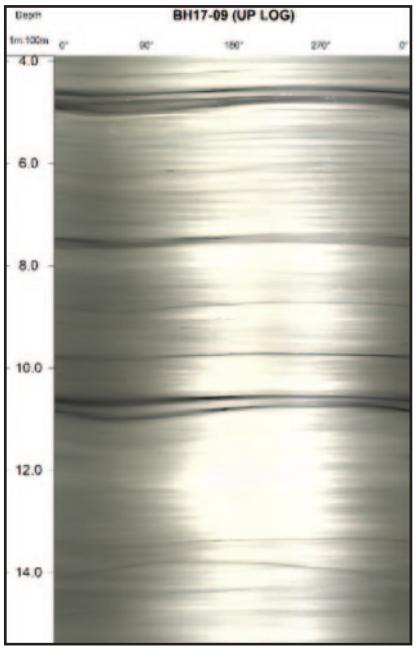
KHUMBU GLACIER FORMS in the Western Cwm of Mount Everest, flowing down the Khumbu Icefall into the lower glacier which is still ~5,000 m above sea level. The surface debris cover over the lower glacier (a layer of rocks and dirt ranging in thickness from mm to over 5 m) influences how the glacier melts, but also makes it very difficult to study the glaciers in the field or from space. As a result, measurements within debris-covered glaciers are severely lacking.

The EverDrill project used hot-water drilling technology to access the glacier's interior. Over two field seasons across five sites we drilled 27 boreholes, each up to 192 m deep – with a cumulative depth of 760 m. Sensors were installed for over two years to measure the ice temperature, motion and hydrology, the data from which will inform modelling predictions of how the glacier will respond to future climatic warming.

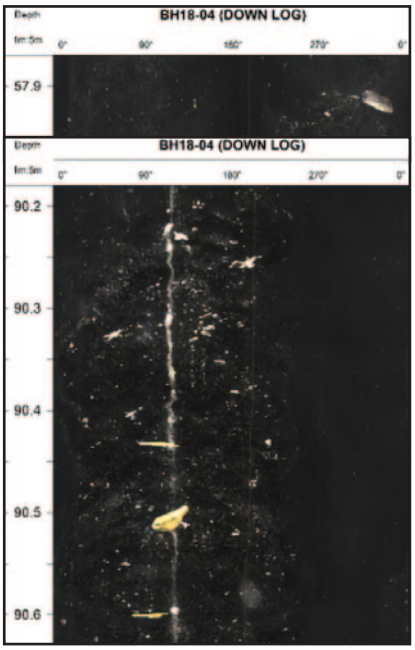
The final piece of the EverDrill puzzle was to reveal the physical anatomy of the glacier: for example, debris-covered glaciers can contain debris within the ice as well as in the surface layer, yet concentrations are almost completely unknown. A Robertson Geo high-resolution optical televiewer (Hi-OPTV) was used to image four of the boreholes at different locations on the glacier. In the interest of portability, as helicopter loads at high elevations are significantly reduced, a mini winch was used which limited the logging depth to the cable length of 150 m. However, this proved plenty, allowing the first-ever view inside a high-elevation debris-covered glacier.

Whilst the full logs are still being analyzed, initial results show that there is debris inside the glacier, varying in concentration according to location and ranging in size from tiny scattered particles to large clasts. The concentrations of debris within the Hi-OPTV borehole logs are to be calculated to estimate the debris content for the glacier as a whole. The millimeter-scale resolution of the Hi-OPTV means that details such as colour and roundness/angularity can be seen on the larger debris clasts, which may even determine the various debris sources on the surrounding mountainsides. Finally, the Hi-OPTV images show layers within the ice that will enable the reconstruction of glacier flow and deformation. All this information will ultimately be included in, and hopefully help to improve, model forecasts of the future of debris-covered glaciers and the water they provide to millions of people downstream.

Katie Miles and the EverDrill Team, Aberystwyth University.



Layers of varying ice density showing as dark/light layers in a borehole Hi-OPTV log from Khumbu Glacier.



Larger debris clasts visible within borehole Hi-OPTV logs from Khumbu Glacier.

Hydrogeological surveys in Greenland

GEO IS AN established customer of Robertson Geo, a Danish geo consultancy providing site services using Robertson Geo logging equipment within the international markets for construction, infrastructure, industry, energy and water supply.

In connection with the expansion of the Qorlortorsuaq hydroelectric power station, a dam is planned to be established at Qooroq Kangilleq to enable the melting of melt water from the Sermeq Kangilleq glacier. Geo has been contracted to complete geophysical and hydrogeological surveys for the project. The study has consisted of seven individual wells, from 2m to 15m below ground, in addition to flow logging and temperature and conductivity fluid measurements with and without pumping.

HYDROGEOLOGICAL LOGGING IN Guangxi China

THE LITHOLOGY OF the strata in Guangxi, China, is dominated by carbonate rocks, with a large number of dissolved pores, caves and cracks.

Logging data has been used to analyze the development and distribution of fractures and caves in strata limestone.

The borehole depths were up to 650m, with a diameter of 130mm for the 350m boreholes and 110mm for the 350m-650m range.

During a 48hr testing period Robertson Geo probes were successfully deployed by a 500m surface winch with High Resolution Acoustic Televiewer (HRAT) and Full Waveform Triple Sonic probes providing the data acquisition.

Steffan Roberts,
Welcome to Robertson Geo

Introducing Steffan Roberts

I'm Steffan Roberts, recently appointed Senior Mechanical Design Engineer here at Robertson Geo.

I'll be heading up the Mechanical Design and Engineering team during this extremely exciting and busy period. My background is in the Marine Engineering Industry serving as an Engineering Officer for BP on a variety of Oil and Gas Super Tankers. I have a sound operational knowledge of machinery and hope to carry this operational experience over to the Mechanical design and development of Robertson Geo products.

Prior to serving in the Merchant Navy I completed a Mechanical Engineering Degree at Loughborough University gaining valuable skills in Mechanical Design and Manufacture, Computer Aided Design and Finite Element Analysis which I'll be able to apply to the ongoing development projects that Robertson Geo is currently undertaking.

Throughout my service I have travelled globally and been places that I never knew existed, but it feels great to be back on dry land and in North Wales using my mother tongue in an industrial design environment.

Find the logo...

Gavin Rowlands and our new Agent for Kazakhstan Serik Tleubayev at the recent Mining & Minerals 2019 Kazakhstan Exhibition - there were some 140 exhibitors and the welcome board showed all the Company logos - follow the fingers to see ours ...*Gavin is on the left!*

Serge's workshop tips

DC4 silicon grease

A good everyday grease that will be useful for insulating any electrical applications, but for us here at Robertson Geo it is used more importantly on the only thing between the O-ring and the metal when probes and probe heads are mated. Its main job is to lubricate the O-ring sliding in to its mating part rather than helping the seal.

When maintaining probes, probeheads, and replacing O-rings, I would recommend carefully using the O-ring repair kit that we can supply as it has tools that are specifically made to reduce the risk of damaging O-rings (if reusing them) and also not damaging the O-ring surface.

O-ring repair kit

This item, personally I think is indispensable. Not only can the kit be used for O-rings, it has two spikes that help greatly when remaking the cable heads. One of these is straight and one is bent 90 degrees, both of which are very useful for removing O-rings.

Other tools in the kit include two small extendable hooks also good for O-rings and useful for pushing and pulling wires in and out of small cavities such as when maintaining slip rings on winches or inspecting connectors on probes.

GeoKey® on the move...

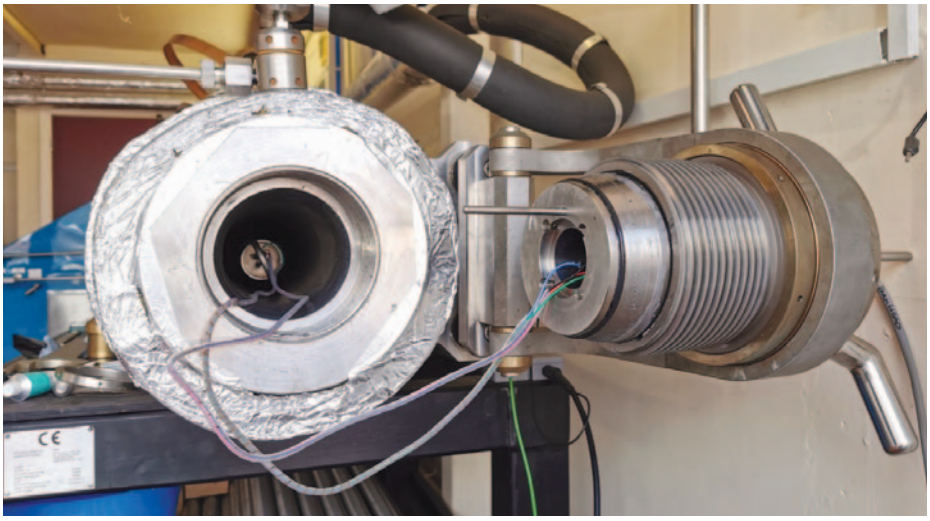
Another GeoKey® system shipped to West Africa

A NEW GEOKEY® system has been shipped for land based oil and gas production drilling in West Africa. The E&P client purchased the GeoKey® logging system as part of a self-sufficiency strategy to bring open hole logging capabilities in-house.

Manufacture of the GeoKey® Triple Combo System under the ISO9001 certified manufacturing processes was completed in August of this year. The system was tested to 125°c/12,500psi in Robertson Geo's Hydratron test facility followed by final Quality Control verification of system log response in the Deganwy test borehole.

The Hydratron stresses the logging system under real-world environmental test conditions to maximum system specification, first ramping to maximum pressure then increasing the temperature from ambient to 125°c, holding this temperature for a two hour soak test.

The system was tested to 125°c/12,500psi in Robertson Geo's Hydratron test facility.



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