ROBERTSON GEO
Unlocking Your GeoData

GeoUnlocked©

GLOBAL GEODATA NEWS ISSN 2754-7043 | ISSUE 22 | WINTER 2023/SPRING 2024

Hawaii

A leading water well drilling and services company in Hawaii purchased the Robertson Geo Gyro probe, 600m Winch and Micrologger2 to assist with their drilling programme in Hawaii.

COPPER MINING IN NAMIBIA

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SLOPE STABILITY
The Role of Borehole Geophysics for Assessing Ground Conditions

Robertson Geo provides marine geotechnical ground investigations for various applications, including offshore windfarms, bridges, tunnels, piers, land reclamation studies and sea defences. Serving government bodies, private companies and some of the world's most prestigious service providers with global logging services, rentals, equipment supply and professional training.

Using geophysical logging tools such as the PS Logger® has become increasingly popular in marine geotechnics, allowing engineers to obtain accurate measurements of soil and rock properties without coring. The tool has revolutionised the field, providing engineers with a wealth of information that can be used to design safe and reliable offshore structures. As the field of marine geotechnics continues to evolve, the use of geophysical logging tools will become even more widespread.

ROBERTSON GEO SERVICES®

MARINE GEOTECHNICS

Providing downhole geophysics in the evolving world of marine geotechnics

OFFSHORE WIND FARMS

OWF (Ships & Platforms)

Robertson Geo has extensive international experience as a specialist provider of services and equipment to the renewable energy markets with a proven results-based record of reliability in securing the highest quality calibrated data from both on-shore, and with systems suitable for heave compensated drill ships or jack-up rigs from the harshest of offshore locations.

The Robertson Geo PS Logger® probe has become essential to OWF site geotechnical investigation. From 2007 to the present day, Robertson Geo Operational Services (RGS) have undertaken projects across over 40 wind farms globally. In addition, RGS has provided rental systems for OWF, with on-site training, and equipment and technologies purchased from Robertson Geo have seen action on many global OWFs.

BRIDGES & STRUCTURES

Bridges, Piers, Sea Defences, Harbours, Platforms, Pipelines, Land Reclamation

RGS and our equipment purchase clients have used our technology on some of the world's most prominent projects, including the Bay Bridge, Hong Kong – Macau Bridge and, more recently, the Male Connectivity Project. The PS Logger® has become the tool of choice for these projects and is essential for earthquake-prone areas.

The Robertson Geo technology is extensively used for ground investigation related to piers, sea defences, offshore platforms and pipelines, and land reclamation studies.

TUNNELS

Under Sea Tunnelling, Cross Harbour Studies

Geophysical logging is used extensively in the planning of cross-harbour and sea tunnels. The technique provides valuable information about the subsurface geology and geotechnical properties of the tunnel route, which is essential for designing and constructing the tunnel. These projects include offshore and land investigations.

The Robertson Geo PS Logger®, High Resolution Acoustic Televiewer (HRAT)®, High Resolution Optical Televiewer (Hi-OPTV)®, Formation Density and Triple Sonic® are just some of the probes commonly used on such projects.

Logging Services

Professional and committed service

Robertson Geo and senior personnel are affiliated with major professional organisations, including AGS, BGA, SUT and IMQS. With a commitment to continuous Research & Development programmes, often in partnership with leading UK and overseas universities, recent pioneering developments include a slim-line oilfield quad combo logging suite, plus Hi-OPTV® and HRAT® televiewers establishing new industry standards for high-resolution fracture studies.

Service logging operations

Robertson Geo engineers are experienced, highly trained, fully certified for offshore work and can be deployed to any global location. The complete equipment catalogue is available on a service basis operated by these field crews. They are capable of prolonged service logging operations with minimum outside support and are experts in data processing and interpretation. These are very cost-effective contracting services when projects do not justify purchasing equipment and the necessary backup facilities.

Equipment supply

Robertson Geo is the market leader in the supply of slim-hole logging instrumentation, with systems sold to customers in more than 165 countries worldwide. Robertson Geo is the only manufacturer with comprehensive in-house design, manufacturing facilities, and a proven operational logging service, supported by Robertson Geo staff in key global locations and a network of regional agents.

All Robertson Geo probes are fully tested and calibrated at the Deganwy facility before dispatch, eliminating testing time on-site and ensuring the probes are fully operational before downhole use. Depending on customer needs, operational and customised training can be provided; for winch use, probe deployment, logging techniques, data capture, equipment maintenance and troubleshooting.

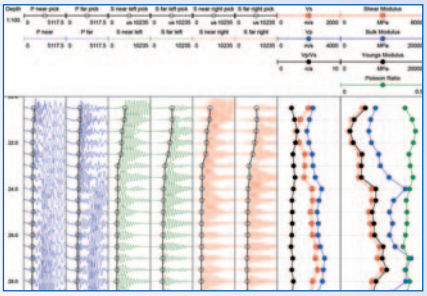
Equipment rental

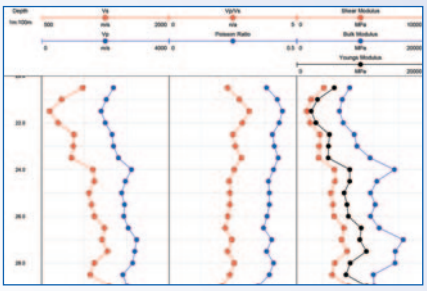
Robertson Geo equipment is available to rent with a minimum rental period of five days in the USA or 15 days elsewhere. Complete systems (including winches) or individual probes can be rented as required, with borehole and classroom-based training made available for rental customers. In-house processing service can be supplied for rented equipment, and all offshore systems come complete with spare probes and surface units, together with essential spares to eliminate problems and expensive vessel downtime.

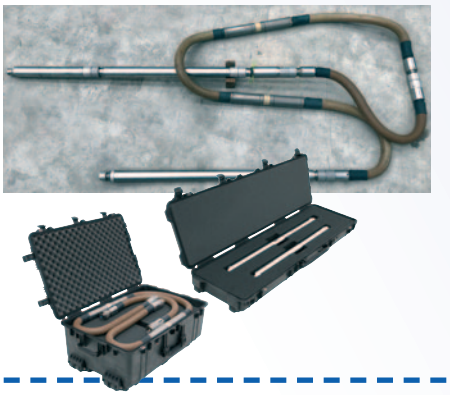
Recommended Probes

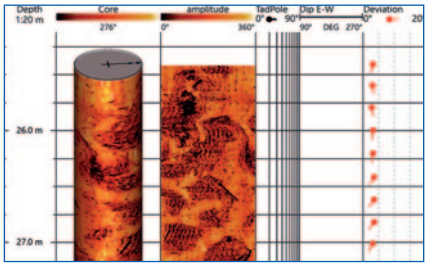
PSLogger® since 79

PS Logger®: the go-to probe for investigating seabed strength, providing measurements within a single borehole of high-resolution shear-wave and compressional velocity data in rock and soils. The probe is critical for earthquake engineering applications and the tool of choice for offshore structures and windfarms.



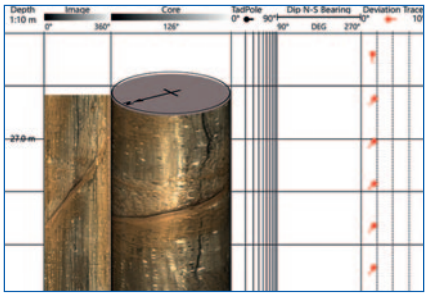






HRAT® 360° TELEVIEWER

High Resolution Acoustic Televiewer (HRAT)®: used for borehole imaging in fluid and mud-filled boreholes. The probe provides a 360° 'unwrapped' and orientated ultrasound image of the borehole walls. The probe is ideal for fracture identification and orientation (dip and direction), stratigraphic studies, local stress analysis (breakouts) and core orientation.



Hi-OPTV® 360° TELEVIEWER

High Resolution Optical Televiewer (Hi-OPTV)®: provides a continuous, very high-resolution oriented image of the borehole walls. The probe can be used in dry and water (clear fluid) filled boreholes. The probe offers a full-colour image of the borehole, which can assist in mineral identification. It is ideal for fracture identification and orientation (dip and direction), stratigraphic studies, mineral identification, and core orientation.

TripleSonic®

Full Waveform Triple Sonic®: is explicitly designed for geotechnical and mining applications. It acquires transit-time and full wave data simultaneously from a single transmitter and three receivers. Formation velocity is calculated in triplicate independently of the borehole fluid path, and the waveform data is used for the calculation of compressional (P), Shear (S) and Stoneley velocities.

Natural Gamma: measure the activities of naturally occurring or man-made isotopes.

Formation Density: uses multiple detectors to provide an accurate borehole-compensated density measurement with excellent bed-boundary resolution. This can be used to determine lithology, density and porosity, rock strength and elasticity parameters when combined with the sonic probe and detection of weathered or fractured zones.

3-Arm Caliper: provides a single continuous log of borehole diameter as recorded by three mechanically coupled arms in contact with the borehole wall - an ideal tool for checking the borehole condition before logging.

Other probes are available.

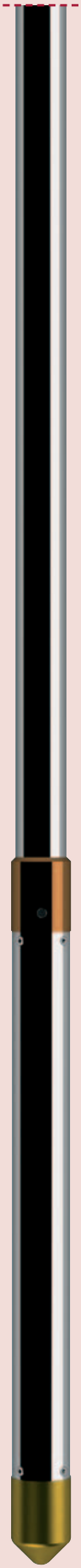
SAFETY IS KEY ©

Compliance is the key to success

Robertson Geo's tool calibration and ISO 9001-2015 procedures provide reassurance that data acquisition complies with the various industry standards. This level of confidence is critical in defining geological knowledge and technical/economic parameters for use in Public Reports, including the JORC, CIM, UNFC, CRIRSCO, PERC, SAMREC, SME and MRC International standards. Robertson Geo is licensed to factory test and calibrate its nuclear tools with corresponding radioactive sources before shipping. Unless this is achieved, logging results cannot meet the necessary compliance standards, and log data cannot be used for quantitative measurement or calculations.

THE GYRO PROBE

What applications is it used for and how does it work...



What applications is a Gyro probe used for?

The probe is used for determining borehole deviation when there are ferromagnetic materials present, which render a magnetic based orientation invalid. The probe can run inside drill string, in boreholes which are steel cased and where ferromagnetic mineral ores are present.

How does the Gyro probe work?

The probe uses a gyroscope (disk) mounted in a gimbal frame. Once the gyroscope is rotating, the spin axis direction remains constant regardless of the movement of the frame (in this case the probe body).

How is the gyroscopic principle used?

The spin axis of the disc remains constant and can be used as a reference point upon which to judge changes in the probe heading, giving a reading of azimuth unaffected by local magnetic fields.

What set up process is required?

Software and a jig are supplied with the probe. The probe needs to be securely aligned to a suitable reference direction with the gyroscope "clamped". Under software control the gyroscope is "spun up". When "unclamped", the gyroscope spin direction remains constant and the probe body orientation is easily calculated.

Do the readings need to be corrected for "drift"?

The Gyro probe readings will drift due to earth rotation and residual friction. Software and a procedure are supplied with the probe to easily make these corrections.

How are ferromagnetic ores detected?

The presence of bodies of ferromagnetic ores can be detected in an open borehole by comparing the gyroscopic azimuth with the magnetic azimuth.

GYRO PROBE TRAINING IN HAWAII

A leading water well drilling and services company in Hawaii purchased the Robertson Geo Gyro probe, 600m Winch and Micrologger2 to assist with their drilling programme in Hawaii. Training in the use of the Gyro probe was conducted on site by a Robertson Geo engineer.

On a geological timescale, the relatively new islands of Hawaii were formed directly from volcanos. The geology of Hawaii is therefore almost exclusively volcanic and is dominated by very hard basalt rocks. These rocks make drilling conditions in the region some of the most difficult to be found anywhere in the world. For water pump installation it is critical that the pump be installed vertically and any significant deviation during the drilling operation may require considerable reworking of the borehole.

The client wanted more quality control and additional information than a single shot tool could give at the target depth of the borehole. They opted for Robertson Geo's Gyro tool as this could measure azimuth and inclination as part of the drilling process without the need to remove the drill rods. This would allow them to run a quick survey check at specified intervals or anytime if it was suspected that the drilling inclination was drifting.

A three-day training programme was conducted, with the first day spent at the client's base followed by two days on an active drill site.

On the first day, the engineer installed all the necessary software to the client computer and then unpacked and familiarized everyone with the equipment. An overview of safety and safe handling was discussed with each component.

The following two days comprised hands-on training on site for the operators to familiarize themselves with how to successfully conduct a gyroscopic deviation survey. The training included how to set up the equipment, how to set up the Gyro for survey and then run a complete survey. Once shown the process, each operator had the opportunity to set up, run the acquisition software, and rig down the equipment on their own, under observation from the engineer. Training was also given on how best to present the data obtained.

Training continued until each operator felt comfortable with the system and acquisition process and all questions had been answered. Upon completion of the training, the engineer was confident that the operators could successfully run a deviation survey either during drilling or after casing had been installed.

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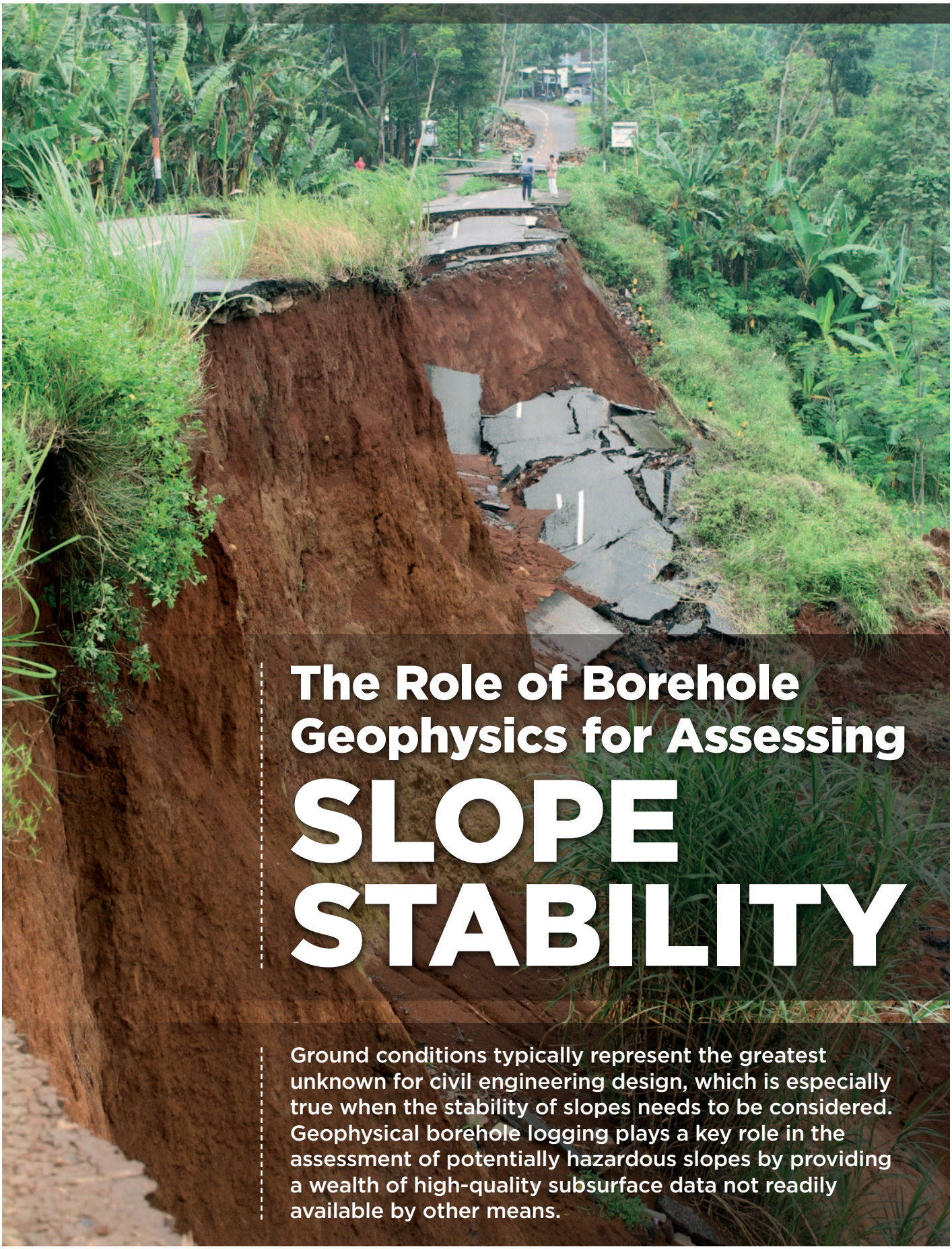


The Role of Borehole Geophysics for Assessing SLOPE STABILITY

Ground conditions typically represent the greatest unknown for civil engineering design, which is especially true when the stability of slopes needs to be considered. Geophysical borehole logging plays a key role in the assessment of potentially hazardous slopes by providing a wealth of high-quality subsurface data not readily available by other means.

Logging at distance for a hazardous slope overlooking a coastal railway.

What is Slope Stability?

A slope is considered stable when it can withstand its own weight and the external forces without displacement occurring. Slopes are analysed by calculating a Factor of Safety (FoS), defined as the ratio of forces resisting shear to those driving it, where a safety factor of less than 1.0 implies that the slope is unstable. In geotechnical design, values for an acceptable FoS may range from 1.1 to 1.4, although the value used will depend on the uncertainty of the modelling parameters and on the slope's risk profile.

The factors that affect slope stability are primarily the angle of the slope and the cohesion of the slope material, where the slope angle dictates the driving force, generally gravity, and the cohesion is the resisting force resulting from the slope material shear strength. In addition, there are many contributing factors which influence whether a slope is stable or not, including fracturing and weathering in hard rocks, and for earthen slopes, height, water table level, drainage, erosion and the presence or otherwise of stabilising vegetation.

Slope failure may occur incrementally, for example, due to erosion or freeze/thaw cycles, or be catastrophically triggered by severe events such as intense rainfall, earthquakes, volcanism or man-made factors such as earthworks and mining.

Over time there may be an accumulation of separate events that contribute to the ultimate failure of a slope. Spatial methods using laser ranging techniques from drones, aircraft and satellites allow slope profiles to be delineated cost effectively. Hazardous features can be identified and changes in profiles over time can identify the precursors of failure which may prompt more detailed investigation.

Where Slope Management is Applicable

Urban development in cities with space limited by mountainous terrain needs careful management to ensure landslide risk is mitigated, as urbanisation expands onto ever steeper slopes. Hong Kong is a good example of where such slope management is key, as buildable land is scarce, the igneous bedrock includes problematic weathered granite and the area is subject to regular typhoons and heavy rainfall. Seismically active urban areas need to take extra precautions as earthquakes notoriously trigger landslides on unstable slopes. Other cities may suffer from unregulated urbanization which can decrease the stability of hillsides by cutting into them to make space for housing development. The ensuing provision of roads, removal of vegetation and additional water from leaks and poor drainage further worsen the situation.

Linear infrastructure, in the form of roads, railways and waterways, may need to cross hilly or mountainous terrain. To achieve the goal of minimising elevation changes cuttings may be needed which need to be carefully designed and maintained to ensure slope stability both above and below the infrastructure.

Mining activities, as they constantly create and change slopes, need to manage their activities to ensure safe operations. For surface or open-cast mines, material overlying the target minerals, the overburden, is removed and deposited in a heap. Pit slope stability can be achieved with higher inter ramp angles of the mined faces by geotechnical investigation (e.g. a televiewer survey) with a significant cost benefit from reduced waste stripping. Management of heaps of overburden and mining tailings is also needed especially where an embankment dam is used to hold back liquified material from ore extraction processes.

Dams and levees in even the flattest terrain also need slope management to protect

Table 1: *Geophysical Probes Used for Slope Stability Assessment (most common first)*

Probe	Outputs	Data Usage
High Resolution Acoustic Televiewer® High Resolution Optical Televiewer®	Unwrapped, oriented borehole wall image	Fracture identification and characterisation Bed boundary delineation Depth and orientation control for core samples
3-Arm Caliper (Gamma)	Diameter, gamma	Bed delineation and weak zone identification Correlation between boreholes
PS Logger®	P-wave velocity S-wave velocity	Poisson's ratio and small strain moduli Shear strength of rock-mass
Formation Density	Bulk density	Density profiles Rock-mass determination (weight)
Nuclear Magnetic Resonance (NMR)	Porosity, permeability	Water distribution profiles Permeability estimation
Electric Log	Resistivity	Hydrogeological characterisation
Focussed Electric Log	Resistivity	Hydrogeological characterisation
High Resolution Flowmeter	Flow rates	Inflow and outflow determination
Temperature Conductivity	Temperature, conductivity	Location of aquifers

against flooding. Earth-fill embankment dams and dykes are routinely constructed to protect against the flooding of areas adjoining rivers or coasts.

The Role of Geophysical Borehole Logging in Slope Stability Assessment

Geophysical borehole logging supplies key in-situ data for slope stability analysis which complements other geotechnical investigative techniques such as spatial mapping, surface seismic and CPT. Borehole logging works equally well in all types of formation, from unconsolidated sediments through to the hardest rocks, producing digital data that can easily be combined into structural databases. The very nature of slopes means that logging crews need to be flexible to successfully log boreholes that may be difficult to access and are often angled or even horizontal. This may require logging from a distance, the use of portable systems and push systems for shallow angled boreholes. Once the logging crew have achieved a safe workable setup a range of geophysical probes can be deployed quickly and cost effectively in a single borehole. ***See Table 1*** for the probes most involved in slope investigation.

Borehole Televiewers, producing unwrapped oriented images of borehole walls, have achieved global acceptance for geotechnical investigations and are the go-to probes for slope stability investigation. Acoustic Televiewers require a fluid filled borehole whilst Optical Televiewers work in dry or clear fluid filled boreholes. When conducting a televiewer survey the logging team should always carry both types. When using Televiewers, it is not imperative that core samples are collected though this is still the normal practice. The digital data derived from processed televiewer logs now routinely enhance or replace costly traditional core logging. ***See Table 2*** for the benefits of using Televiewers versus conventional core logging techniques for slope stability investigation.

In addition to Televiewers, all the probes shown in Table 1 have also been deployed for slope stability assessment. The 3-Arm Caliper produces natural gamma profiles which are useful for bed delineation and for correlating bed boundaries between boreholes. The diameter data can be useful for identifying weak zones and providing QC for other probes affected by washouts from the drilling process.

Table 2: *Advantages of Televiewers versus Conventional Core Logging Techniques for Slope Assessment*

Factor	Benefit
Improved Quality of Data	Conventional core logging requires the logger to individually assess each fracture and may lead to erroneous identification of drill induced fractures. Televiewer data is based on the in-situ borehole wall image, improving rock mass quality estimates. Using structural information from televiewers eliminates human error from manual core measurements.
Accurate Depth Control	Televiewers measure depth with centimetre accuracy while core samples may not match driller depths due to incomplete recovery. The possibility of incorrectly reconstituting a highly fractured core sample is also eliminated. Televiewers show only the in-situ borehole wall, whereas core samples may, in the worst cases, be irrecoverably broken up. ***See Figure 1***
Automatic Orientation	All televiewers record directional information in real time so that borehole data can be automatically converted from apparent to true orientation. Whether the borehole is near vertical, steeply angled or even horizontal the derived structural features can be characterised in true orientation using automated processing software such as GeoCAD®.
Simple Fracture Zone Characterisation	It is difficult to accurately assess the orientation and true thickness of fractures from recovered core. Simple to use processing software (GeoCAD®) allows for accurate determination of the azimuth, dip and fracture thickness. Features can be displayed in a variety of ways including tadpole plots and pseudo core images then analysed statistically. ***See Figure 2***
Slope Design Optimisation	Televiewers provide more accurate structural information for fractures and bedding which improves the quality of structural databases and leads to better slope models. Slope design can then be better optimised as confidence in safety factors is improved.
Time and Cost Benefits	Digital files automatically produced from televiewer surveys reduce the time spent determining the orientation and depth of structures and speeds up input into structural databases. Traditional core logging can be time consuming, is more prone to human error and requires QC vigilance on the measurements.

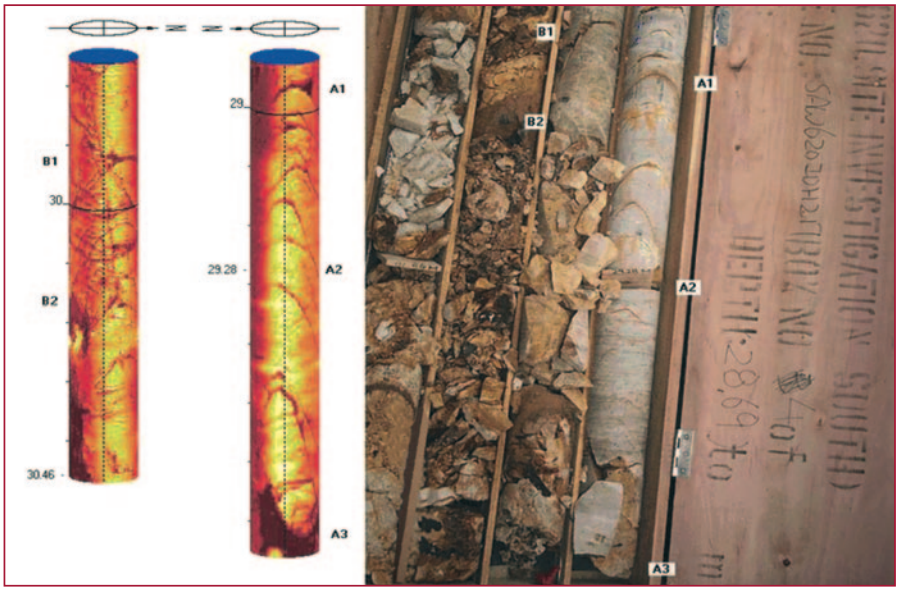


Figure 1: Televiewer generated core where recovery is poor.

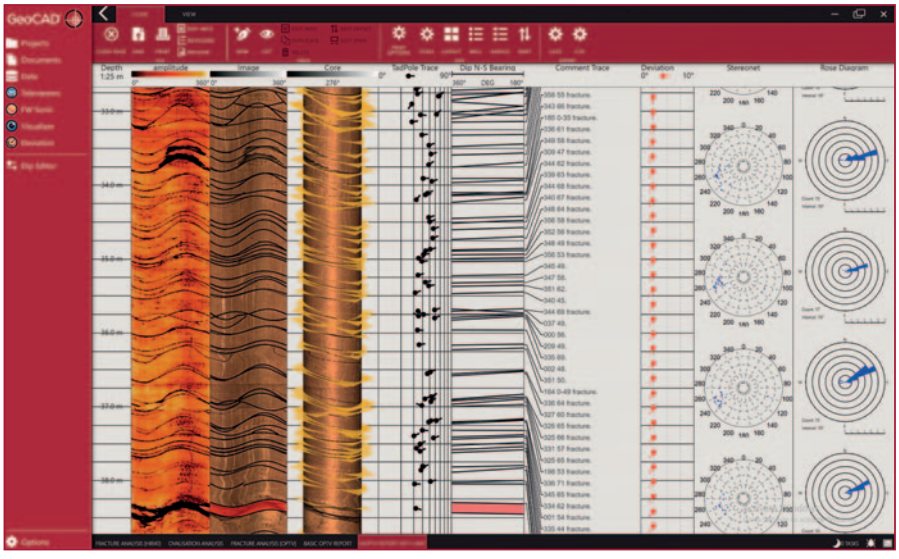


Figure 2: Processed Acoustic and Optical Televiewer data using GeoCAD® software.

The PS Logger® probe measures compressional (P) and shear (S) velocities in hard and soft formations enabling Poisson's ratio to be determined. When combined with bulk density values from the Formation Density probe, small strain moduli profiles can be calculated with the shear modulus being of critical importance when calculating cohesion for slope materials. The bulk density values also enable accurate weight calculation, usually the primary force acting on the slope. Data from the remaining probes are mainly used for determining the groundwater conditions, an important factor in slope stability. The Nuclear Magnetic Resonance (NMR) probe is now gaining popularity for its ability to discriminate between clay-bound, capillary-bound and mobile components of the overall water content when measuring porosity. From this data estimates of permeability and bulk density can be derived. The Focussed Electric and Electric Logs produce resistivity profiles which are routinely used by hydrogeologists analysing groundwater conditions. Finally, the Temperature Conductivity probe and High Resolution Flowmeter are used for identifying and quantifying borehole flows respectively.

How Geophysical Data is Used for Slope Analysis

The task of assessing natural slopes or designing man-made slopes is principally the remit of the geotechnical engineer but may require the input of professionals from engineering geology, structural engineering and hydrogeology. Within their scope will be the identification of hazardous areas, determination of failure mechanisms, sensitivity of the slope to triggers, safe, reliable economic design and the application of mitigation and remedial measures.

Portable logging setup for a hazardous slope overlooking a coastal railway.

This process requires detailed, accurate information regarding slope geometry (spatial methods), geology (trial pits and boreholes) and soil/rock mass properties and groundwater characterisation from geophysical methods including borehole logging.

Historically, limit equilibrium techniques were commonly employed for the analysis of slope stability. With the advent of modern computers and sophisticated software a range of analysis techniques are available including finite element limit analysis, discontinuity layout optimisation and finite difference methods. More recently the risk assessment concept is being used to calculate the consequences of and the probabilities of failures. Digital data from borehole logging simplifies the task of feeding these large computer models.

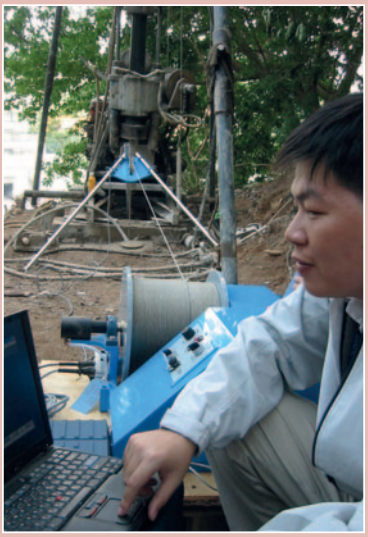
Engineers have at their disposal a wide range of methods for stabilising slopes including rock anchors and nails, slope drainage enhancement, stabilising facing systems to promote vegetation and protect from weathering and reprofiling and scaling.

The Future

The assessment, analysis and mitigation of potentially hazardous slopes is of increasing importance as society continues to expand its influence geographically. Climatologists predict that, as global temperature rises, there is an increased likelihood of major weather events, which may trigger slope failures, typically through landslides. Prevention and mitigation are always preferable to risking human lives and the costs associated with remedial action after a major slope failure. Borehole geophysics, by providing detailed and accurate subsurface data, will play an increasing role in the investigation of potentially hazardous slopes thereby improving confidence for engineers when calculating safety factors and managing slopes.

Graham Comber
Geotechnical Adviser - Robertson Geo

SLOPE STABILITY STUDY IN TAIWAN



The slope had started to fail (as some homes had slid down the hill) and a school was in danger. This is a typical slope issue in Asia. Core samples show the washed-out fracture zone.

Copper Mining in NAMIBIA

Otis Trading Enterprises of Namibia was contracted by Sinco Investments Ninety-Eight (Pty) Ltd to conduct geophysical testing for the Oamites Copper Project 50km south of the capital, Windhoek.

The mining industry in Namibia represents the country's leading economic sector and contributes over 10% of GDP, making Namibia one of the top four non-fuel mineral exporters in Africa. Namibia produces diamonds, uranium, copper, magnesium, zinc, silver, gold, lead, semi-precious stones and industrial minerals.

The Oamites Copper Project seeks to mine and beneficiate copper on site with the view of exporting high grade concentrate. The project first phase drilling program comprised 2,000 meters of rotary core drilling. The objective of the Otis Trading Enterprises survey was to measure the deviation of boreholes.

The equipment used to measure the borehole deviation consisted of a Verticality probe, a 500m Winch and a Micrologger2 surface acquisition unit. The probe includes a triaxial magnetometer to determine the bearing of a reference in the probe relative to magnetic North and three accelerometers to measure inclination. The outputs from the transducers were processed by a downhole microprocessor to give final borehole inclination and azimuth data in real time.

The logging was completed without any significant challenges.

Offshore Project: NORTH IRISH SEA ARRAY

Robertson Geo Services (RGS) was contracted to join the geotechnical survey vessel Seehorn, operated by Geoquip Marine, to conduct logging operations on the North Irish Sea Array off the coast of Dublin. Boarding the vessel in Aberdeen, the vessel sailed around the top of Scotland and down into the Irish Sea to complete the survey of three boreholes.

The North Irish Sea Array, also known as NISA, is an offshore wind energy development project located off the coast of counties Dublin, Meath, and Louth. The project will significantly contribute to the development of a clean, renewable energy future. Once operational, the anticipated 35 to 46 turbines for the site are expected to produce clean renewable energy for approximately 500,000 homes and businesses.

The drilling operations utilized a piggyback system to gather core samples of the mudstones and stiff clays for physical sampling, classification, and stress testing. Once each borehole had reached its target depth, the RGS engineer deployed three probes: the PS Logger®, 3-Arm Caliper Gamma and High Resolution Acoustic Televiewer (HRAT)®.

The caliper was run first to check borehole integrity and to provide useful QC information for the subsequent PS Logging. The acoustic televiewer produced an unwrapped oriented image of the borehole wall, delineating bed boundaries and fractures, as well as giving deviation data for the borehole. The PS Logger® probe measured P and S wave velocities at 1m intervals at depths to 65m. The resulting strength parameters derived from the velocities were to be used to feed into the foundation design calculations together with data from other sources including CPT and laboratory testing.

"GAS BLOWER" IN WITWATERSRAND FREE STATE PROVINCE

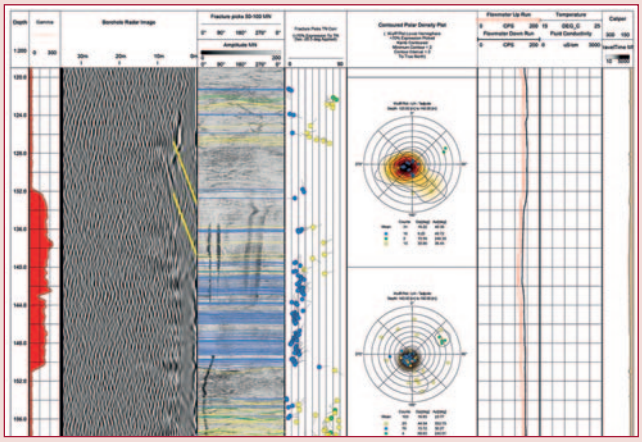
Free State Province in South Africa is famous not only for its magnificent landscapes but also for its gold mining. Its Witwatersrand gold fields are by far the largest gold producing district in the world and have produced over 40,000 tonnes of pure gold since its discovery in 1886, about a third of total world production. Modern shafts go down to almost 4,000m deep with ambient temperatures up to 60°C.

Historically, gold mining operations in the Witwatersrand region could experience safety issues due the presence of methane in underground mines. Where a borehole has intersected a gas-bearing fracture zone significant amounts of gas may be expelled at the surface, this borehole could then be termed a "gas blower". These "gas blower" boreholes have now attracted interest from gas exploration companies.

Quik Log Geophysics (Pty) Ltd was engaged to conduct geophysical borehole logging on a "gas blower" borehole of around 390m depth, in the Witwatersrand underground gold mining region. The survey objectives were to map the depths of gas ingress zones, relative to the water table, and to delineate the geometry of fractures/faults acting as gas conduits. A further exercise would be to correlate the findings with known faults mapped by underground mining.

The Robertson Geo probes used for the survey were the High Resolution Optical Televiewer (Hi-OPTV)®, High Resolution Acoustic Televiewer (HRAT)®, Impeller Flowmeter, Temperature Conductivity and the 3-Arm Caliper. The televiewers mapped the fractures and faults by recording an oriented "unwrapped" image of the borehole wall from which geologic features were picked and azimuth and dip calculated. The Temperature Conductivity probe and the Impeller Flowmeter showed water ingress and egress zones and the 3-Arm Caliper was used to check borehole integrity and to confirm bed boundaries using its natural gamma detector. In addition, a third-party borehole radar system was also run in the borehole.

The multi-tool survey showed one major gas ingress point via three closely spaced intersections and the location and geometry of these features were used to correlate with known faults from the gold mining exploration work.



RGS Debut on Sylur vessel for Next Geo Solutions

Robertson Geo Services (RGS) was contracted by Next Geo Solutions to conduct PS Logging operations on their heave compensated drill ship, the Sylur for the Nordlicht OWF on the Baltic Sea.

The project represented an important milestone for RGS, Next Geo Solutions and the industry in general, as the Sylur now provides much needed additional geotechnical drilling capacity to the expanding requirements of the offshore wind farm industry.

The Nordlicht project site is located north of the island of Borkum and should go online by the end of 2027, with a generation capacity of 980 MW (Nordlicht 1), enough electricity to meet the annual requirement of more than one million average German households. The Netherlands port of Eemshaven served as the vessel's base of operations for the project.

The initial challenge for the engineer was to assist with the installation of the 2,000m Marine Winch and sheave wheel arrangement onto the rooster box, to exacting safety standards, including weight testing. Once the equipment was installed and fully tested, the vessel proceeded to the Nordlicht site where PS Logging was conducted at seven locations. On each borehole the logging was split into three runs to maximise data recovery should unstable zones be encountered.

The PS Logger® probe, with its integral source, measures compressional (P) and shear (S) wave velocities in a single borehole in soft and hard formations. The velocity data is used to derive Poisson's Ratio and when combined with density values can be used to calculate the small strain moduli, with Shear Modulus (G) being important for offshore wind turbine foundation design.

The logging programme was successfully completed without any significant problems or deviations from the original logging plan.

Welcome to Robertson Geo, Risha!

Risha D'souza

I am delighted to introduce myself as the newest member of Robertson Geo Services (RGS). My name is Risha D'souza, and I am thrilled to be a part of this company.

Born and raised in Mumbai, India, I obtained my bachelor's and master's degrees in geology from St. Xavier's College, Autonomous, Mumbai. Seeking to expand my knowledge and understanding of the ocean, I moved to the UK in 2022 and pursued a second master's degree in physical oceanography from Bangor University.

Having spent most of my life studying, I had no prior work experience. That's when Robertson Geo came to Bangor University's career fair, and I knew right away that this was the opportunity I had been waiting for. From sending my CV to attending the interview and all follow-up meetings, the entire process was a smooth ride.

I started working for RGS in October, and I have enjoyed a diverse and exciting role, with no two days being alike with the team has been extremely supportive and welcoming. They have been a great help to me from the start, whether I am working on an onsite job or data processing in the office.

I feel grateful to be a part of such a versatile team with an amazing work culture. I am excited to see what the future holds and look forward to many more years of learning and growing with Robertson Geo.

2024 has been an *eventful* year so far!

With only the first quarter of the year gone, Robertson Geo have been busy attending events around the globe.

March saw us exhibiting at **PDAC** in Toronto, Canada; **Wind Energy Asia** in Kaohsiung, Taiwan and **POOWESS** in Manila, the Philippines; but back in February we attended **GeoTHERM** in Offenburg, Germany.

This show is the largest Geothermal show in Europe where we met new and existing clients and learnt more about the Geothermal market in Europe which is suddenly gaining a lot of investment and interest. At the show we launched our first product range focussed on geothermal applications with a range of 125c probe technologies.

UPCOMING EVENTS

At Robertson Geo we have always had good representation at the most important Geophysical based exhibitions and conferences worldwide.

This year our program continues with attendance at the following exhibitions:

IPF24
New Orleans, US
22nd - 25th April 2024 | Booth: 1904

IGIC 2024
Jeddah, Saudi Arabia
6th - 7th May 2024 | Booth: 49

Geotechnica 2024
Warwickshire, UK
3rd - 4th July 2024 | Booth: D

Australia Wind Energy 2024
Melbourne, Australia
9th - 11th July 2024 | Booth: W38

Mining & Metals Central Asia
Almaty, Kazakhstan
17th - 19th September 2024 | Booth: 9-21

Watch our events page at www.robertson-geo.com/upcoming-events/ and as always - new and established clients alike - *"we're looking forward to seeing you"*. Our direct marketing messages allow you to follow an easy enrolment procedure if you are coming.

How supporting equipment sold up to 30 years ago has propelled our success

In today's fast-paced technological landscape, where innovation and obsolescence often go hand in hand, it is rare to find a company that sells equipment and provides unwavering support for products sold decades ago. However, Robertson Geo has thrived for years by recognising the immense value of backward compatibility and support for ageing equipment.

While many companies prioritise continuous upgrades and new releases, the significance of backward compatibility cannot be overstated. By ensuring that our equipment sold up to 30 years ago remains compatible with current technologies, we have cultivated a loyal customer base and established ourselves as a trusted industry leader.

By supporting equipment sold two or three decades ago, we demonstrate our commitment to customers' long-term satisfaction. This level of support instils confidence in our clients, who know their investment in our products will remain viable and valuable for years. This trust translates into repeat business, referrals, and an unrivalled reputation in the market.

As a logging service provider, Robertson Geo appreciates first-hand that replacing equipment every few years can be a significant financial burden for businesses. By ensuring backward compatibility, we alleviate this concern for our customers. Instead of forcing them to invest in entirely new systems, we provide updates, upgrades, and compatible components to enhance the functionality of their existing equipment wherever possible.

This cost-effective approach is highly appreciated by businesses looking to optimise their resources and maximise their return on investment.

Technological advancements often come with compatibility challenges, making it difficult for businesses to integrate new equipment with their existing infrastructure. By prioritising backward compatibility, we eliminate this hurdle for our customers. Our commitment to ensuring seamless integration allows businesses to adopt new technologies without disrupting their operations or incurring additional costs. This compatibility promotes a smooth transition, enabling organisations to stay at the forefront of innovation while leveraging their existing investments.

A comprehensive support system complements Robertson Geo's commitment to backward compatibility. We provide technical assistance, troubleshooting, and maintenance services, ensuring our customers receive the help they need to keep their equipment running optimally. By offering ongoing support, we extend the lifespan of our products and provide added value to our customers.

ROBERTSON GEO

Unlocking Your GeoData

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