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Geophysical Borehole Logging Guide for Mining Reporting Compliance

This guide is intended for general use in borehole geophysical logging and its applicability to mining reporting standards compliance.

The scope includes logging for mineral exploration and evaluation and geotechnical logging for associated mine working structures and tailings management. The focus of this guide is on geophysical borehole practices which ensure compliance with mining standards.

Geophysical Borehole Logging Guide for Mining Reporting Compliance

Why Mining Reporting Standards are Important

Reporting standards for mining are significant in this industry which has typically long lead times and high upfront capital investment before achieving profitability. Standardisation of how mining projects are represented, especially before production commences, is needed to engender trust, consistency and accountability for stakeholders regarding financial risk and environmental impact. A list of some of the most recognised standards is shown in *Figure 1*.

Transparency for investors results from the adoption of the relevant standard for the host country whereby resource and reserve estimates are presented in a clear standardised manner, thereby reducing financial risk. Reporting frameworks such as CRIRSCO align definitions globally, so stakeholders can compare projects across countries on a like-for-like basis. Without consistent rules, one company might define a "resource" very differently from another.

Reporting standards require sign-off by qualified professionals and detailed evidence which helps prevent overstatement of potential mineral deposits. Clear reporting

allows companies, stakeholders, and investors to make informed decisions about whether a project is economically viable, technically feasible and environmentally sound. Adoption of the relevant standard may be mandatory for public listed companies as this ensures they meet legal and financial disclosure requirements.

Environment and social accountability factors are included in modern mining standards encouraging companies to disclose impacts on land, water, and communities thereby improving responsible mining practices. Companies that follow recognised standards gain credibility internationally, making it easier to attract investment and operate across borders.

Finally, reporting standards act to protect investors, improve transparency, and help ensure that projects are evaluated honestly and responsibly.

Figure 1: Widely recognised mining reporting standards.

Mining and Mineral Resource Reporting Standards

Standard	Originator	Adopted By
CRIRSCO International Reporting Template	International Council on Mining and Metals	Used by 16 member organisations to define country specific standards
JORC Code	Australia Minerals Institute	Australia, New Zealand
CIM (NI 43-101)	Canadian Institute of Mining	Canada
MRC Code	MPIGM	Mongolia
PERC Reporting Standard	Pan-European Reserves and Resources Reporting Committee	EU, EFTA, UK
SAMREC Code	SAIMM & GSSA	South Africa
SME Mining Code	Society for Mining, Metallurgy & Exploration	United States
UNCF Guidance Europe	UNECE et al	Europe
CBRR Guide	Brazilian Commission for Resources and Reserves	Brazil
CAMRA Code	China Association of Mineral Resource Appraisers	China
KCMI Code	IAGI & PERHAPI	Indonesia
Chilean Certification Code	Institute of Mining Engineers of Chile	Chile

The CRIRSCO Reporting Template

The Committee for Mineral Reserves International Reporting Standards (CRIRSCO) produces this crucial template that guides mining companies to publicly report the results of exploration, mineral resources and reserves. The template is not a standard itself but is used as a foundation for countries preparing their own local reporting rules and is adopted by the 16 CRIRSCO member organisations. See *Figure 1*.

The three core principles embodied by the template are:

- **Transparency :** *Clear detailed facts*
- **Materiality :** *Only include information investors need for decision making*
- **Competency :** *Reports signed off by a qualified expert professional*

The template provides for the description of Exploration Targets, Exploration Results and estimates of Mineral Resources and Mineral Reserves that may be used by others to prepare subsequent valuations or appraisals.

An Exploration Target is a statement or estimate of the exploration potential of a mineral deposit in a defined geological setting where there has been insufficient exploration to estimate Mineral Resources.

Exploration Results include data and information generated by mineral exploration programmes that might be of use to investors, but which do not form part of a declaration of Mineral Resources or Mineral Reserves.

A Mineral Resource is a concentration or occurrence of material of economic interest in or on the Earth's crust in such form, grade or quality and quantity that there are reasonable prospects for economic extraction. In addition there must be specific evidence to support any claim for an exploration target to be considered as a Mineral Resource.

Once these criteria have been satisfied an exploration target may be classified in terms of three ascending defined categories, see *Figure 2*.

Inferred Mineral Resource - An Inferred Mineral Resource is that part of a Mineral Resource for which quantity and grade or quality are estimated on the basis of limited geological evidence and sampling. In addition, geological evidence must be sufficient to infer but not demonstrate ore grades or quality due to low confidence. It is also reasonably expected that an Inferred Mineral Resource could be upgraded to an Indicated Mineral Resource with further exploration.

Indicated Mineral Resource - An Indicated Mineral Resource is that part of a Mineral Resource for which quantity, grade or quality, densities, shape and physical characteristics are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit.

Measured Mineral Resource - This classification is like an Indicated Mineral Resource but with a higher degree of confidence and requires an understanding of the geology, mineralogy, mineability and amenability to processing of the mineral deposit.

Once Exploration Results have determined the Mineral Resource classification, Modifying Factors must be applied before the Exploration Target can be reported as a Mineral Reserve, either probable or proved. Modifying Factors include mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social and governance (ESG) and regulatory factors. A Scoping Study, Pre-Feasibility Study or a Feasibility Study will also be required to convert Mineral Resources to Mineral Reserves, based on the classification of the Mineral Resource and Mineral Reserve.

In all cases reporting must be signed off by a suitably qualified Competent Person.

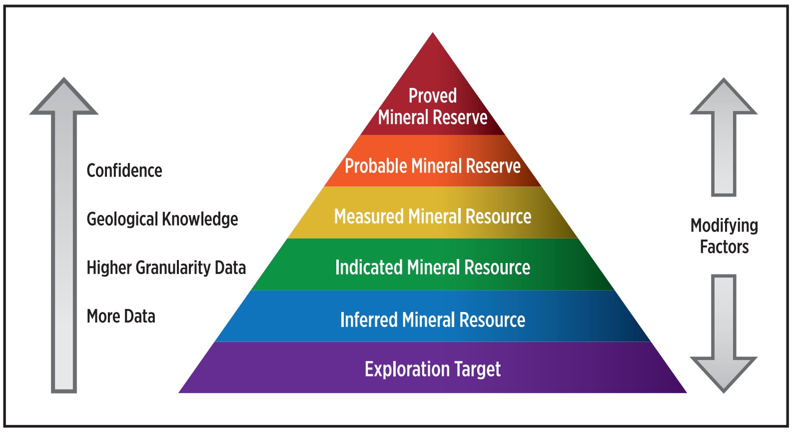


Figure 2: Escalating resource and reserve classification.

The Role of Geophysics for Mining

Geophysical methods are used extensively in mineral exploration to support the characterisation of exploration targets and their classification into resources and reserves, in line with the reporting standards applicable to the host country. Reporting standards matter in geophysical exploration because they ensure that indirect subsurface data is used responsibly, transparently, and in proper context when estimating mineral potential. Commonly used mining techniques and the applicability of geophysical borehole logging are shown in *Figure 3*.

Mining Types and Techniques

Type	Technique	Geophysical Borehole Logging Usage
Surface Mining	Strip mining Open-pit mining Mountaintop removal	Applicable at all stages of exploration. Geotechnical data for rippability and mining structures.
Underground Mining	Room and pillar Block Caving Longwall mining	Widely applicable for exploration. Boreholes may be logged underground once drifts have been constructed.
Placer Mining	Manual methods Sluicing Hydraulicking Dredging Excavator mining	Applicable for deep sea dredging, otherwise limited applicability, mostly in early stages of exploration.
In-situ Mining	Leaching	Forms an integral part of drilling and evaluation.

Figure 3: Mining types and techniques applicable to borehole logging.

Common to most standards, the geophysical methods must report, as a minimum:

- *Survey type (e.g. borehole geophysics, gravity, magnetic)*
- *Data acquisition methods*
- *Processing techniques*
- *Limitations and uncertainties*

Transparency is the key principle of interest for geophysical data supporting orebody evaluation and reports should demonstrate that data is calibrated, reproducible and that the methods used have relevance, with interpolated data being more highly valued than extrapolated data.

Methods used for Mining Exploration		
Method	**Technique**	**Detection/Measurements**
Spaceborne	Multispectral sensing	Iron oxides and clay related to ore bodies
	Hyperspectral sensing	Chemical makeup of surface rocks
Airborne	Magnetometry	Ferromagnetic rocks
	Electromagnetic	Electrical conductivity
	Radiometrics (gamma ray)	Near surface radioactive elements
	Gravity	Dense ore bodies
Surface	Geological sampling	Collection and analysis of target minerals
	Magnetometry	Ferromagnetic and ferrimagnetic rocks
	Electromagnetic	Electrical conductivity
	Gravity	Dense ore bodies
	Reflection seismology	Rock and orebody structure, faults
	Refraction seismology	Regolith and rock layer depths
Subsurface	Core drilling	Assaying and rock structure
	Borehole logging	Multiple measurements relating to rock structure, rock strength, rock properties and hydrogeological factors. Reflection TWTT conversion to depth.
	Muon tomography	Dense ore bodies in lighter host rock

Figure 4: Geophysical methods used for mining exploration.

Geophysics is often used in the early stages, where uncertainty is highest, with data density potentially increasing from spaceborne techniques through airborne methods and surface methods to geophysical borehole logging, see *Figure 4*. Areal methods are relatively inexpensive and can cover large prospect areas but in isolation can be ambiguous. The granularity of geophysical data (space between samples) typically starts off low when evaluating exploration targets and should increase as targets are upgraded through resource and reserve classification.

Once exploration targets have been identified, a drilling programme will be required to collect data to substantiate potential commercial viability. Exploratory core drilling extracts a continuous rock sample from surface to target depth whereby samples of interest can be identified and assayed. Borehole geophysics takes economic advantage of these boreholes by providing a wealth of measurements relating rock structure, rock strength, rock properties and hydrogeology, see *Figure 5*. Once caverns have been excavated, muon tomography can be used to map underground ore bodies, voids, and density anomalies with great precision.

"Reporting standards matter in geophysical exploration because they ensure that indirect subsurface data is used responsibly, transparently, and in proper context when estimating mineral potential."

Reporting codes require a Competent Person to sign off on interpretations which ensures that geophysical results are interpreted by someone with the right expertise, thereby reducing errors and misrepresentation. Geophysical data is most powerful when combined with geological mapping and results from drilling. Reporting standards enforce this integration.

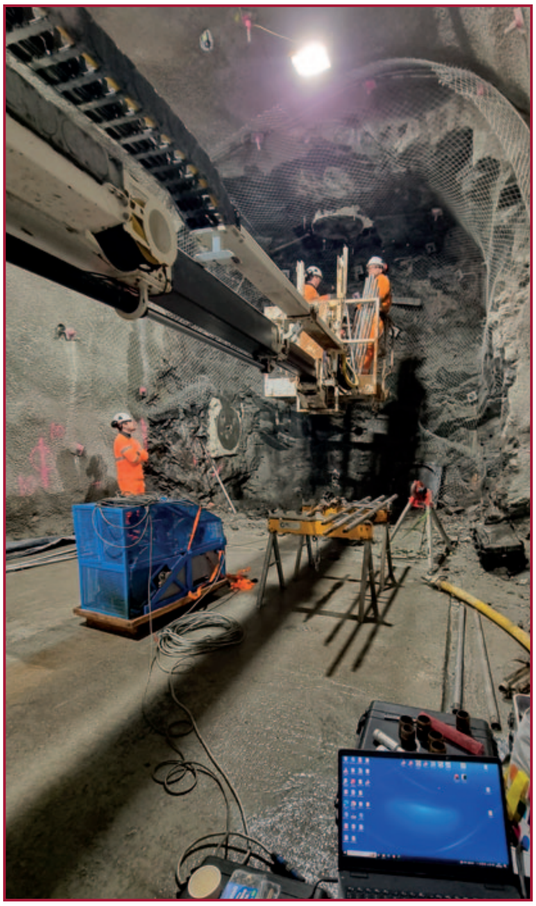
Borehole Geophysics for Mining and Minerals

Geophysical borehole logging is routinely used to collect valuable subsurface data, relatively inexpensively, from pre-existing exploration boreholes drilled for core sampling or in dedicated boreholes drilled without coring. Programmes of drilling find application for surface and underground mining and are essential for leach mining and deep sea dredging. Borehole geophysical methods don't measure minerals directly but measure physical properties, see *Figure 5*. Borehole logging is also used for geotechnical investigation around mines to provide data relating to rippability, emplacement of mining structures, slope stability, tailings management and tailings dams.

Boreholes for mineral exploration are typically of a narrow diameter (60mm to 123mm) and can reach to 2km depth or more, depending on the ore target depth. Many will be core drilled for delineation of and assaying of mineral targets. In the early stages of exploration these boreholes will invariably be drilled from the surface usually either vertical or inclined. For deep sea mining boreholes need to be drilled and logged from heave compensated drillships and may be in water depths to 2km or more.

Once potential orebodies have been identified, complex surface drilling techniques involving "mother" and "daughter" boreholes may be used. A "daughter" borehole is a secondary hole drilled off the side of an existing "mother" borehole using deflectors and directional drilling techniques achieving cost savings compared to drilling a new surface borehole.

Where caverns have been established, underground mining companies can take advantage of these by drilling shorter directional boreholes to further delineate orebodies. These boreholes can be vertical, inclined, horizontal or raised



(upward facing). Near horizontal and raise boreholes require specialised equipment, careful planning and close cooperation between drillers and logging engineers and can reach to over 800m horizontally.

Regardless of whether the exploration is at an early stage or is further along the progression to a fully working mine, borehole geophysics can measure multiple properties from a borehole in a single site visit. The data that can be collected falls into four areas: structure, rock strength, hydrogeological and rock properties, see *Figure 5*.

For structure, borehole televiewers have revolutionised the identification and delineation of faults, fractures and bedding planes. The **High Resolution Optical Televiewer (Hi-OPTV)®** operates in dry or clear fluid filled boreholes and produces the highest resolution full colour images. The **High Resolution Acoustic Televiewer (HRAT)®** requires a fluid filled borehole and images are of lower resolution but are equally satisfactory for delineating fractures. Using an oriented borehole wall image, features (appearing as sinusoids) can be easily picked and automatically delineated. This digital data lends itself well to building 3D orebody models by accurately delineating fractures and bedding planes, avoiding reliance on difficult to measure physical cores. The continuous unwrapped borehole wall image also readily replaces costly and time consuming photography on physical cores.

Rock strength can be readily determined using a **Full Waveform Triple Sonic®** probe in conjunction with a **Formation Density** probe. The P and S wave velocities allow Poisson's Ratio to be calculated and together with the bulk density can determine small strain moduli: Shear Modulus, Bulk Modulus and Young's Modulus.

Mines and water interact in three main ways: water threatens mine safety, mining threatens water quality and can also affect the local water table through constant dewatering to keep the mine dry and safe. By measuring hydrogeological properties of not only the orebody but also of the overburden, mine design, costs and risks which influence Modifying Factors can be more accurately determined. Borehole logging for hydrogeologic purposes can provide detailed data by measuring porosity, resistivity and flow characteristics, see *Figure 5*.

Rock properties can be important indicators for identifying orebodies and their extent. Borehole logging can measure ten or more rock properties from which log trends can be correlated with other data to indicate the extent of target orebodies or to identify new candidate zones.

Geotechnical borehole logging at a mine site includes studying and managing the behaviour of rock, soil and groundwater to ensure safe and efficient extraction. Supporting structures associated with a mine such as buildings, ventilation systems, dewatering systems and tailings management may also require geotechnical data. Maintaining 3D geotechnical models of a mine site enables risks to be assessed dynamically. The digital data from geotechnical borehole logging is ideal to quickly feed these models.

Borehole Geophysical Probes used for Mining Applications

Probe	Measurements (calibrated)	Application
High Resolution Optical Televiewer (Hi-OPTV)®	Borehole image, fractures & bedding	Structure
High Resolution Acoustic Televiewer (HRAT)®	Borehole image, fractures & bedding	Structure
Formation Density	Calibrated density	Rock strength
		Rock property
Density Gamma	Qualitative density	Rock property
Formation Density HD	Calibrated density to 5g/cc	Rock strength
		Rock property
Dual Neutron	Porosity	Hydrogeological
Natural Gamma	Total natural gamma	Structure
		Rock property
Spectral Gamma	Calibrated full spectrum gamma	Rock property
Full Waveform Triple Sonic®	P and S wave velocities	Rock strength
		Rock property
Electric Log	Resistivity	Hydrogeological
		Rock property
Focussed Electric (Guardlog)	Focussed resistivity	Hydrogeological
		Rock property
Dual Focussed Induction	Formation conductivity	Hydrogeological
		Rock property
Magnetic Susceptibility	Magnetic susceptibility	Rock property
Induced Polarisation	Chargeability	Rock property
3-Arm Caliper	Diameter	Structure
Verticality	Borehole inclination and azimuth	Structure
Gyro	Inclination and azimuth (in steel)	Structure
Temperature Conductivity	Fluid temperature and conductivity	Hydrogeological
Impeller Flowmeter	Flow rate – high flows	Hydrogeological
Heat-Pulse Flowmeter	Flow rate – low flows	Hydrogeological

Figure 5: Geophysical probe outputs and their application.

Recommended Practice for Geophysical Borehole Logging

Digital data from geophysical borehole logging is a key provider of supporting evidence required for resource and reserve classification. Around twenty different probes are available for geophysical borehole logging for mining applications, see *Figure 5*. All data from these probes is digital with a vertical measurement resolution typically 1cm. This data is almost invariably calibrated and uses defined calibration regimes dictated by the manufacturer. For many logs there is no interpretation required from the logging provider, just suitable data presentation. For sonic logs and televiewer logs low-level interpretation is required for velocity analysis and feature picking respectively.

The following factors should be considered to achieve the high quality data that geophysical borehole logging can provide.

Selection of logging services provider :
Borehole logging for mining is usually subcontracted in rather than conducted in-house and may be a local service or specialists operating remotely. The providers should

> "Digital data from geophysical borehole logging is a key provider of supporting evidence required for resource and reserve classification."

have a good reputation and relevant experience and be able to demonstrate a commitment to quality (e.g. ISO 9001). Good trade affiliations, documented case studies and technical publications further a company's reputation.

Quality of equipment :
The quality of probes used may be demonstrated through provision of specification sheets, pre-contract, and should always have conformance certification to demonstrate the probe was in calibration at logging time. Good quality, well maintained, equipment should minimise non-productive time (NPT), very important for remote working.

Quality of logging engineers :
Field engineers need to be fully competent and highly trained to work safely and efficiently. Proof of training and qualifications should be available on request. Engineers need to be adaptable and dynamic and good team players as close liaison with drilling crews can be necessary, especially if working underground or offshore.

Service backup :
Mines are often located in remote locations with long travel times for equipment and personnel. Good service providers will recommend that spare probes are available for the job and will provide sufficient spares for other equipment. Engineers should be capable of undertaking field repairs such as cablehead replacement.

Adherence to standards :
The ASTM D5753-18 standard is the most applicable for borehole logging for mining although additional internal standards and procedures will be required. A quality service provider should be able to demonstrate additional competencies. ISO 9001 accreditation guarantees quality for additional service aspects.

Probe calibration :
Probe calibration is vital for conformance to mining standards. See *"Calibrated Geophysical Data Supports Accurate Reporting"*.

Repeatability :
Borehole geophysical data for mining evidence needs to be shown to be repeatable. Modern logging practice often involves multiple probe runs so that data recovery is maximised where borehole collapse is considered possible or likely. The casing/drill stem may be withdrawn in stages to protect these weak areas (casing pulls) and the overlaps between the logged sections demonstrate repeatability. For single probe runs a repeat section showing discernible data features should be obtained. Real time data monitoring by the logging engineer is also an import function that immediately informs the engineer of anomalous data or potential equipment issues.

Safety :
Documented evidence of recognised safety training is vital for the often complex operations undertaken for mining. First-aid training, two-man logging crews and a good internal feedback system further enhance safety. Companies should provide Risk and Method statements before site visits and back these up with Point of Work Risk Assessments (POWRA) conducted at the logging location. A Hazard Action Card system should also be used to develop additional safety procedures identified through near misses and accidents.

Traceability :
Transparency in all aspects of geophysical borehole logging is necessary for adherence to mining standards. Field work should be documented in log sheets, which should be included in the final report along with valid conformance certificates (by serial number) for the probes. Depth matching using natural gamma traces is used to accurately align logs from different probes and should also be documented in the final report.

Log speed :
The manufacture will always recommend the correct logging speeds for each probe type. These should be documented and followed to achieve the highest quality data.

Nuclear probes :
Formation Density and **Dual Neutron** probes use radioactive sources that are attached to the probe at time of logging. The regulations covering the use of nuclear sources will vary by country and will cover many additional safety aspects including dosimetry, transport, temporary storage and field procedures.

Underground logging :
Boreholes drilled from underground caverns may be of any orientation including inclined, horizontal or raise (upwards). Logging engineers operating underground need to be experienced and capable of team working with drilling crews, as specialised equipment and techniques will be necessary to "push" probes into the boreholes safely.

Deep sea mining :
Logging boreholes for deep sea mining prospects involves working from heave compensated drill ships. This is a unique environment and specialists with experience should be engaged to perform the logging and/or train local personnel.

Processing :
Probes record raw data, apply calibration files and output fully calibrated results and processing is often procedural rather than interpreted. For televiewers (feature picking), sonic probes (semblance processing) and flowmeters there is a degree of low level interpretation, which should be documented. Processing will be performed using industry standard software, such as **GeoCAD**®, and should include an audit trail for parameters selected.

Limitations :
Boreholes for mining exploration are often drilled using a rotary coring technique which produces high quality, low rugosity boreholes with a minimum of drill induced fracturing. Highly fractured zones, bands of loose material and transitional zones may however present problems regardless of the drilling technique. Casing pulls are often employed to minimise the impact of these problematic zones. Inclined boreholes may also lead to imperfect centralisation. All limitations need to be documented and included in the final report.

Final Report :
The final report should contain sufficient evidence and detail to engender confidence for the mining company and the Competent Person to evaluate the borehole data quality. The processed data will be submitted in digital form in industry standard formats. The final report should include a logging summary for each borehole, logging methodology, probe operating principles, quality assurances, data processing procedures and any limitations encountered which affected the data.

Calibrated Geophysical Data Supports Accurate Reporting

Mining companies typically have a reliance on geophysical borehole logging as a significant part of their investigation into exploration targets and their viability. If boreholes are drilled for core recovery and assaying it makes economic sense to utilise them to collect calibrated geophysical data. Calibrated geophysical data from borehole logging grounds interpretations to reality, reduces risk, and ensures exploration decisions are based on solid evidence. International reporting frameworks such as CRIRSCO require that this supporting data be robust and validated.

By calibrating individual probes by serial number a consistency between probes is achieved. Results can also be reliably compared across different logging campaigns regardless of which individual probe was used. This consistency extends beyond the prospect under investigation so that results from different projects can also be reliably compared. The calibrated digital data from geophysical borehole logging can then be fed into 3D ground models with confidence.

Simply calibrating probes and producing calibrated data is insufficient though, with documented evidence being required to fulfil transparency requirements from reporting standards. Documented calibration regimes, retention of raw calibration data and valid conformance certificates all serve to engender confidence for mining companies, their stakeholders and Competent Persons who need to sign off public reports.

More than twenty borehole logging probes are available to collect data to support mining. Each probe will have its own calibration regime and these regimes should include factory calibrations and field calibrations and may calculate coefficients for calibration files. Details of calibration regimes for individual probes are shown in *Figure 6*.

Calibration Regimes for Mining and Mineral Probes

Probe	Factory	Field	Comment
High Resolution Optical Televiewer (Hi-OPTV)®	Axial camera rotational image alignment.	Jig supplied to check alignment.	Optional natural gamma.
High Resolution Acoustic Televiewer (HRAT)®	Acoustic head alignment.	Procedure to check head alignment.	Optional natural gamma.
Formation Density (also see Natural Gamma below)	Primary calibration LSD/HRD in full Al block and water tank. Al half-block stamped with coefficients.	Al half-block using stamped coefficients and water tank. Jig for caliper arm. Jig for natural gamma.	Probe and source must be a matched pair. Density range 1.1 – 2.95 g/cc.
Density Gamma	Density - qualitative only.	Jig for natural gamma.	Primarily for coal exploration.
Formation Density HD	Primary calibration LSD/HRD in Al half-block and steel cylinder.	Al half-block and steel cylinder supplied. Jig for caliper arm. Jig for natural gamma.	High densities up to 5g/cc.
Dual Neutron	Primary calibration at ELGI calibration facility for count ratios. Calibration jig coefficient set.	Jig supplied stamped with coefficient.	Probe and source must be a matched pair. Density range 1.1 – 2.95 g/cc.
Natural Gamma (optional on many probes)	Primary calibration in test pits. Jig stamped with API value.	Jig supplied for natural gamma.	Total natural gamma.
Spectral Gamma	Factory calibrated for normalised response (.mcf file).	Jig for total natural gamma. Mcf file supplied for spectral response.	Includes total natural gamma.
Full Waveform Triple Sonic®	Factory calibration for each sample rate.	Select correct calibration file for the sample rate used.	Natural gamma standard.
Electric Log	Factory set. Checked with test box.	Test box supplied.	Natural gamma and temperature standard.
Focussed Electric (Guardlog)	Factory set. Checked with test box.	Test box supplied.	Natural gamma standard.
Dual Focussed Induction	SCON/LCON calibrated with calibration ring.	Calibration ring. Presets & counts produce a cal file.	Natural gamma standard.
Magnetic Susceptibility	Factory set internally, checked with test block.	Test block check.	Natural gamma standard.
Induced Polarisation	Factory set.	Jig for natural gamma.	Natural gamma standard.
3-Arm Caliper	Jig to calibrate caliper arms.	Jig for caliper arms supplied.	Optional natural gamma.
Verticality	Factory set.	Procedure for orientation check.	Natural gamma standard.
Gyro	Factory set.	Procedure for orientation check.	Natural gamma standard.
Temperature Conductivity	Temperature & conductivity factory calibrated.	Cal file supplied.	Natural gamma standard.
Impeller Flowmeter	Natural gamma preset.	User function supplied.	Optional natural gamma.
Heat-Pulse Flowmeter	Natural gamma preset.	Cal file for natural gamma.	Flow readings taken statically.

Figure 6: Geophysical probe calibration regimes.

The **Formation Density** probe is designed to provide a borehole-compensated bulk density measurement using a detachable Caesium137 source and dual shielded detectors. The calibration regime documented here requires that only a matched pair of probe/source can be calibrated together. A primary calibration takes place at the factory using a full circumference aluminium block and a large diameter water tank. Customers are provided with an aluminium half block as the full block is too heavy to transport easily. Following calibration in the full block, the calibration is repeated in the half block and a coefficient is calculated to return the values to that of the full block. This coefficient is stamped on the half block and is entered into software for subsequent calibrations. This methodology effectively calibrates the half block, minimises any edge effects from using the half block, minimises the effect of variations in manufacture and materials, and the calibration remains stable as the source activity diminishes due to the half-life of Caesium (30.17 years). It is important to note is that the calibration methodology for **Formation Density** probes varies between manufacturers.

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The **Dual Neutron** probe provides a calibrated borehole-compensated neutron porosity measurement in mud-filled open holes. It is the probe of choice for quantitative formation-fluid studies. The measurement uses two 3He proportional detectors and a detachable sealed 241Am-Be neutron source. The calibration requires that only a matched pair of probe/source can be calibrated together. At the factory, a calibration jig is used which has had the count ratio between the two detectors established from a calibration procedure undertaken at ELGI, from which a coefficient was calculated. The matched pair of source and probe are first calibrated in the factory jig. This is then repeated in the jig supplied with the probe and a customer jig coefficient is calculated, which is stamped on the customer jig. When calibrating in the field the calibration software requires this coefficient to be entered when performing field calibrations. At logging time the borehole diameter must be entered into a user function to provide borehole compensation and an ex-centraliser should be used. The use of dual detectors and a ratio method provides a porosity measurement compensated for borehole diameter but not independent of it. As the 241Am-Be source has a half-life of over 432 years, source activity does not diminish significantly between calibrations. It is important to note is that the calibration methodology for **Dual Neutron** probes may vary between manufacturers.

Summary and Conclusions

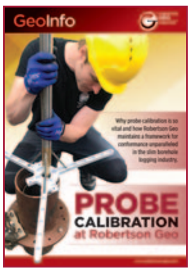
The focus of mining reporting standards is to provide standard definitions and a reporting framework for the benefit of mining companies, investors and stakeholders. While different host countries and stock exchanges adhere to different reporting standards many of the world's most significant mining organisations are CRIRSCO members and their national standards embody the CRIRSCO template.

It is the CRIRSCO principle of transparency that is most applicable for geophysical borehole logging. For transparency, it is incumbent upon geophysical service providers to provide calibrated data and the documentary evidence supporting it. The wealth of borehole geophysical data available is calibrated and has little or no interpretation applied. Interpretation of this data is undoubtedly best achieved by mining companies combining it with data from other geophysical methods, cores and assaying.

The global mining industry is forecast to grow by around 30% over the next five years, not least driven by the green economy's demand for critical and rare earth minerals. This is despite depletion of high grade ores, moves to more remote locations, more environmental constraints and long lead times from initial exploration to production. In this expanding market, the outlook for geophysical borehole logging is promising, most notably for those equipment and service providers who can meet the standards for verifiable data and service expected by mining companies building ever more accurate orebody models.

For further information on calibration see:

Probe Calibration at Robertson Geo



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For information on good practice for rigging up see:

The Basics of Rigging Up

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