

Exploring New Frontiers of In Situ Geochemical Analysis

Using the Thermo Scientific Niton XL5 XRF Analyzer

Author: M. Bauer, Thermo Fisher Scientific, Tewksbury, MA USA

Introduction

With substantial capital investments at stake, it is crucial for mining companies to quickly identify and recover the most economically viable resources. Handheld XRF has become an indispensable tool for geological exploration and mining operations. Using handheld XRF assists users in obtaining accurate and representative data on-site and in real time. Rather than waiting hours, days, or weeks for laboratory analysis, users are able to generate results instantly, in the palm of their hands.

Increasing productivity and profits are key drivers for mining operations. Seeking portable technologies that aid in identifying high quality deposits, while increasing discovery success rates, sets the foundation for profitable and productive mining companies. Thermo Scientific™ Niton™ XRF analyzers have helped thousands of users bring their lab to the field to obtain pertinent geological data. Products such as the Thermo Scientific™ Niton™ XL3t, and Thermo Scientific™ Niton™ XL2, have empowered mining operations to make faster decisions, while increasing operational efficiencies and financial returns.

Thermo Scientific™ Niton™ XL5 XRF Analyzer

Now, there's a new tool available to mining and exploration professionals. The Niton XL5 is the smallest and lightest handheld XRF analyzer available for elemental determination.¹ Featuring a 5W miniaturized x-ray tube, large area silicon drift detector (SDD), and optimized geometry, the Niton XL5 provides the latest



The Thermo Scientific Niton XL5 in use, analyzing a geological sample.

in cutting edge technology for the most demanding requirements of in-field geochemical analysis.

Versatile and easy to use, the Niton XL5 is purpose-built for hostile mining environments. With an IP54 rating, the Niton XL5 is splashproof and dustproof- ideally suited for the rugged surroundings of exploration fields and mines. A standard integrated GPS facilitates spatial visualization of data using GIS programs. Additionally, wireless data connectivity (WiFi and Bluetooth), provide data transfer of analysis results when immediate assessments are required at the rig, base, or remotely.

Analytical Performance

The Niton XL5 with mining mode is designed to optimize each measurement. The x-ray generator operates over a large voltage range and automatically adjusts the current to maximize count rate, providing users with superior analytical performance. Mining mode on the Niton XL5 uses up to four beam conditions with pre-defined filters and voltages engineered to enhance the signal-to-background ratios of fluorescence lines measured in the main (4-30 keV), low (3-6 keV), high (20-40 keV), and light element (1-3 keV) range of energies. At low voltage, the current can be as high as 500 μ A versus 200 μ A when compared to the Thermo Scientific™ Niton™ XL3t GOLDD+. This results in considerable improvements in the count rate and the signal-to-background ratio for light elements, such as Mg, Al, and Si (Chart 1).

Sensitivity improvements are not only limited to light elements. When compared to the Niton XL3t GOLDD+, the limits of detection (LODs) in pure silica were lower on the Niton XL5 for every element over the entire energy range (Chart 2). On average, the LOD improvement was 66%. This gain in sensitivity is not only beneficial for mining companies already using handheld XRF, but also extends the application range when lower limits of detection or faster analysis times are required.

Analytical Methods

Variability in chemical compositions represents a challenge for the direct analysis of geological samples using handheld XRF. The Niton XL5 with mining mode leverages a proprietary Fundamental Parameter (FP) based calibration. The algorithm used in the FP calibration accounts for composition variability by correcting for absorption and secondary excitation effects arising from the matrix to deliver accurate results. The “out of the box” results are relatively close, however, since mineralogy and non-measurable elements (i.e. carbon, oxygen, nitrogen) can have a large impact, biases may be observed. Users have the option to improve accuracy by applying type standardization on the Niton XL5. The optimization of the calibration is simple to perform and can be accomplished directly on the analyzer. *(It is recommended that standard reference materials, or lab characterized reference samples covering the range of composition in the deposit be used when performing type standardization.)*

The Niton XL5 provides the flexibility to configure and create custom analytical methods based on user needs. Attributes such as measurement time, beam condition timing, data field sets, element displays, pseudo element displays (i.e. oxides), and matrix specific type standardization can

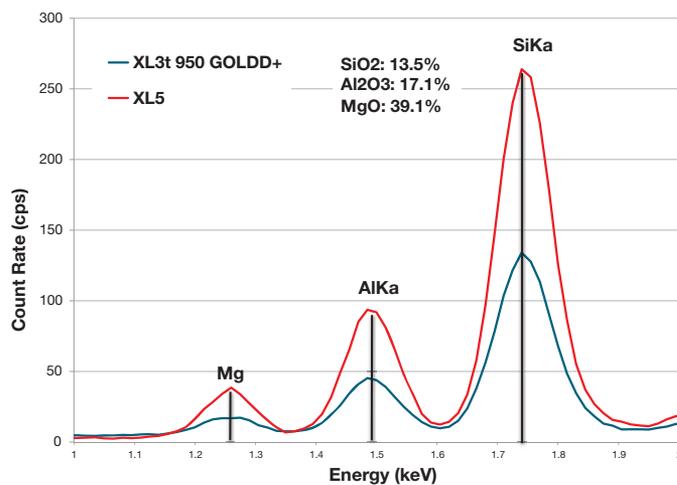


Chart 1: Comparison of spectra between 1 keV and 2 keV acquired with Niton XL5 and Niton XL3t. A reference material of dolomite Dillingier Hütte SX07-07 was used.

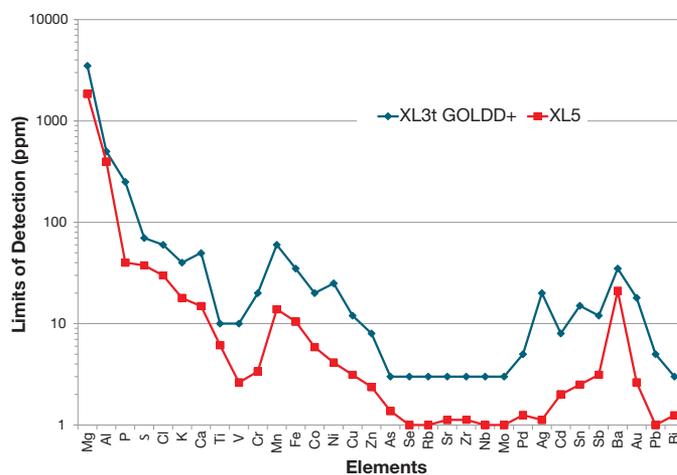


Chart 2: Limits of Detection (LODs) in of pure silica, Niton XL5 vs. Niton XL3t.

be defined by the user. Ultimately, mining mode profiles enable users to have multiple analytical methods on a single instrument to accurately analyze a wide variety of geological materials with optimal calibration (Figure 1).

Niton XL5 Accessories and Sample Preparation

Thermo Scientific™ Mini Test Stand

Geochemical analysis using handheld XRF often requires sample preparation and long measurements that necessitate test stands. The Thermo Scientific™ Mini Test Stand (Figure 2A) was created for the Niton XL5. Lightweight and compact, the Mini Test Stand effortlessly fits into a small backpack, ideal for users traveling to remote locations. The tripod base can also be configured in reverse combination, along with the easy trigger function, to improve the ergonomics of in situ measurements of soils and outcrops (Figure 2B).

Thermo Scientific™ Soil Guard

When direct contact is required for soil analysis, the Thermo Scientific™ Soil Guard (Figure 2C), specifically designed for the Niton XL5, helps keep dirt and dust at bay. This valuable accessory is used by simply clipping the component onto the front of the analyzer to keep the window bracket free from debris.

Thermo Scientific™ Direct Rock Sampler

Because most geological materials are heterogeneous, direct sample analysis may not provide an accurate representation of sample composition. Best practice requires that users grind the sample to obtain a fine, homogeneous powder. For coarse grains of soft rocks, a simple mortar and sieves may be sufficient, whereas more advanced tools, such as the battery powered Thermo Scientific™ Direct Rock Sampler (Figure 2D), provides the ability to collect fine powders from a rock face, in addition to cuttings and drill core samples.

Thermo Scientific™ Pellet Press

Powder obtained from ground materials can be pressed into a pellet using the Thermo Scientific™ Pellet Press (Figure 2E). Users are able to obtain a flat, consistent surface and density without sample film, thus improving light element performance.

Thermo Scientific™ Bulk Sample Kit

Basic tools and consumables for XRF soil and mining analysis can be found in the Thermo Scientific™ Bulk Sample Kit (Figure 2F). The kit includes necessary items such as the Thermo Scientific Soil Guard, mortar and pestle set, cleaning brushes, sample collection tools, bags, sieves, and sample cups.

Applications

Mineral Exploration

Mining companies have long used traditional lab services to send samples to off-site laboratories. This process leaves companies waiting weeks, if not months for critical quantitative data. Alternatively, companies that wish to avoid long lab lead times have installed on-site mobile laboratories. Mobile laboratories have proven to be difficult to maintain due to the inherent complexity of analytical instrumentation, fragility of equipment, and limited mobility in remote locations.

In the absence of laboratories, handheld XRF is an excellent tool to help mining companies uncover valuable resources. The Niton XL5 can be used for both qualitative analysis and lab-quality assays with basic sample preparation in different

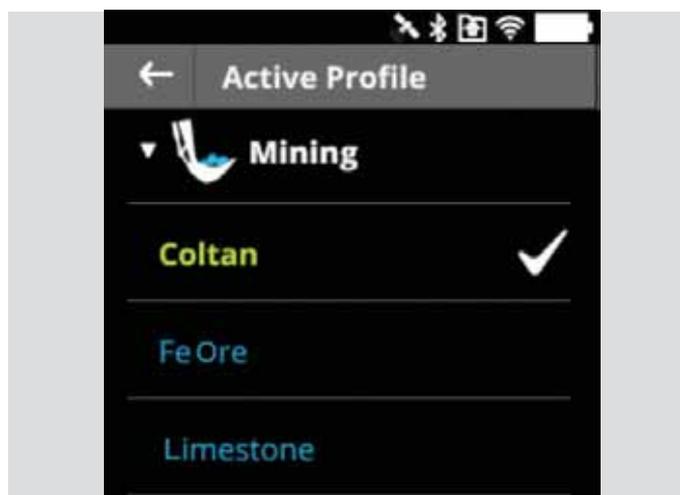


Figure 1: Niton XL5 mining mode profiles for various applications. The default "mining" profile is easily cloned and modified to adapt analysis for specific ores.



Figure 2A



Figure 2B



Figure 2C



Figure 2D



Figure 2E



Figure 2F

Figure 2: Various accessories and sample preparation tools for the Niton XL5. 2A) Thermo Scientific Mini Test Stand, 2B) Thermo Scientific Mini Test Stand (configured in reverse combination for soil analysis), 2C) Thermo Scientific Soil Guard, 2D) Thermo Scientific Direct Rock Sampler, 2E) Thermo Scientific Pellet Press, 2F) Thermo Scientific Bulk Sample Kit

phases of the exploration process to discover various base metals, industrial minerals, and certain precious metals.

Handheld XRF can be utilized to help mining companies optimize budgets by:

- Speeding up exploration timescales
- Locating anomalies in soil surveys and outcrop evaluations
- Pre-screening sample selection for laboratory analysis
- Identifying drill targets
- Initiating informed decisions about drilling depth, thus reducing rig remobilization



Oil and Gas Exploration and Production

Identifying a favorable location for oil and gas exploration and production (E&P) is comparable to finding a needle in a haystack. Potential reservoirs are huge, but chemical analysis of drill cuttings, outcrops, piston-core sediment, and oil and gas cores can be used to determine the composition of rock and infer mineralogical properties favorable to E&P.

For example, the abundance of redox sensitive elements at trace levels, as well as the mineralogy indicated by light element ratios, provides useful clues regarding the characteristics of reservoir rock. Properties such as permeability (Si/Al, Mg, Ca, K), porosity (Si, Ca), fracturability (Si), and productivity (V, Cr, Mo) help geologists infer promising characteristics of oil and gas exploration and production. The Niton XL5 can also be used in the laboratory to create centimeter scale logs during the core logging process, combined with other methods like x-ray diffraction, infrared, Raman spectrometry, and petrography to provide additional quantitative mineralogy.



Mining Operations

Both in open pits and underground mines, the use of handheld XRF has been established as a highly reliable method to analyze ore samples. Handheld XRF achieves the accuracy required to provide defensible information for process oversight, quality assurance, and various other operational decisions (such as grade control). Rapid analytics, combined with an optimized sampling strategy, can provide significant cost savings and added benefits for mining operations.

Performing instantaneous grade control using the Niton XL5 enables mining operations to:

- Ascertain the viability of lower grade resources and find localized high grade enrichments
- Delineate ore and waste boundary
- Assess rock cuts and guide blasting, excavation, and ore handling activities
- Optimize run-of-mine stockpiles and ensure consistent blending and feeding to the mill

The Niton XL5 not only quantifies elements of sought-after commodities, it also measures penalty elements in ores with enhanced sensitivity. Furthermore, the Niton XL5 is an ideal tool to monitor the enrichment process and analyze products resulting from ore processing, such as concentrates and blends.



Applications and Examples

The Niton XL5 generates faster and more extensive geochemical data. However, due to its portability, it also pioneers new uses in the field, and increases productivity for existing applications (Table 1). For example, mud logging for the characterization of oil and gas reservoirs is a new application that the Niton XL5 is able support. In addition to the quantification of major compounds, the power of the Niton XL5 is highly beneficial for precise determination of penalty elements in industrial minerals, such as limestones or phosphates.

The best way to illustrate the enhanced capabilities of the Niton XL5 is through light element determinations. Due to low information depth, and sensitivity to mineralogical and particle size effects, the determination of light elements such as Mg, Al, and Si requires special care. The solution to overcome these effects is to present geological samples as fused bead to the instrument. The problem is that while this solution is suitable for stationary laboratories, it is impractical for field analysis.

XRF Mining Applications

Base Metals Exploration and Mining

Ore Trading

Process Control

U Exploration

Au Exploration via Pathfinder Elements

Characterization of Oil and Gas Reservoirs

Penalty Elements in Coal, Bauxite, Fe-ore

Industrial Minerals: Main & Penalty Elements

Table 1: Non-exhaustive list of handheld XRF mining applications.

By using sample preparation tools, it is possible to homogenize and grind samples down to particle sizes of 100µm or less while on site. With its robust Fundamental Parameter calibration, the Niton XL5 is able to generate accurate and quantitative results. As demonstrated, positive correlations between reference and measured values of light elements, such as Mg, Al, Si, and Ca, were obtained for a large variety of geological samples (Chart 3). This includes igneous and sedimentary rocks, sediments, clays, limestones, soils, bauxite, and quartz all using the same calibration.

In contrast to light elements, and because of higher energy of analytical lines, U is almost insensitive to mineralogical and particle size effects (below 100-200µm). The Niton XL5 is able to determine U with high precision and accuracy down to levels of 10 parts per million (ppm) (Chart 4). The figure shows outstanding correlation between measured and certified concentrations of U for various samples-including Canadian and South African uranium ores, phosphates, sediments, and soils. Figure 3 illustrates the standard results expected of base metal ores. The Niton XL5 delivers accurate results for major and minor elements such as Ni, Cu, Zn, Pb, or Ag.

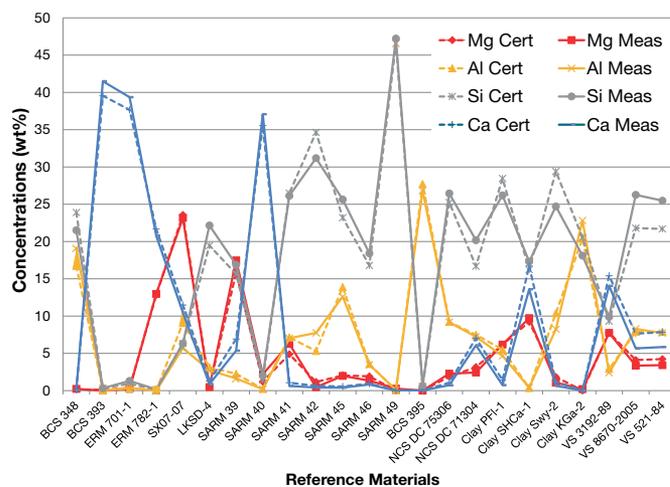


Chart 3: Light element correlation between reference (dotted lines), and measured values (solid lines), for various types of geological standard reference materials. Fine powders were introduced into sample cups fitted with 4µm PP film. A 300 second measurement time was used.

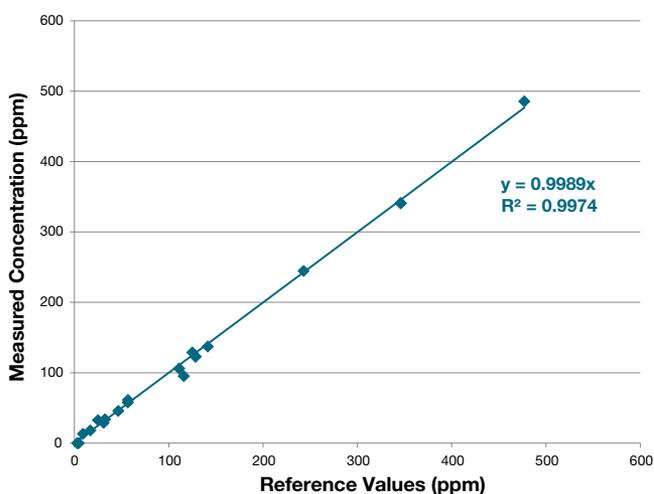


Chart 4: Certified versus reference values of U in uranium ores, phosphates, sediments, and soils. A 60 second measurement time on the "Main Range" filter was used.

Main Ele	Low %	Light ±2σ
Ni	0.535	0.009
Cu	0.252	0.005
Fe2O3	15.558	0.045
MnO	0.200	0.010
TiO2	0.235	0.036
Cr2O3	0.422	0.016
Co	0.075	0.017
Cr	0.289	0.011
Bal	87.616	0.070
As	0.001	0.000
Fe	10.888	0.032

Figure 3A

Ele	%	±2σ
Zn	30.437	0.144
Pb	3.041	0.026
Ag	0.007	0.001
S	20.888	0.109
Cr	0.011	0.003
Cu	0.649	0.010
As	0.107	0.014
Sb	0.004	0.002

Figure 3B

Figure 3: Analysis of ore reference materials. 3A) Ni-Cu ore (reference values Cu: 0.2454%, Ni:0.5723%), 3B) Zn/Pb ore (reference values Zn: 30.17%, Pb:3.25%, Ag:0.0063%, S:20.06%)

Conclusion

The Niton XL5 provides mining and exploration professionals the ability to leverage leading XRF technology. By generating high-quality analytical data, the Niton XL5 empowers users to bring the performance of laboratory-grade instruments to the field.

In conclusion, the Niton XL5 provides a fast return on investment by:

- Speeding up exploration efficiency, saving time and money
 - Identifying anomalies and drill targets quickly
 - Targeting intensive sampling in anomalous areas to delineate ore boundaries
 - Reducing rig remobilization costs
 - Pre-screening sample selection for laboratory analysis, thus maximizing analytical budgets and reducing external assay and freight costs
 - Improving confidence in daily decision making via geochemical data streams
- Enhancing mine productivity through optimized extraction and processing
- Achieving effective mine waste determinations to minimize environmental contamination



1. The Thermo Scientific™ Niton™ XL5 XRF analyzer weighs 2.8lbs (1.3 kg). The Niton XL5 is the smallest and lightest handheld XRF analyzer leveraging x-ray tube technology.

Learn more at thermofisher.com/XL5

Americas

Boston, USA
+1.978.670.7460

niton@thermofisher.com

Europe, Middle East, Africa

Munich, Germany
+49.89.3681380

niton.eur@thermofisher.com

India

Mumbai, India
+91.226.6803000

ininfo@thermofisher.com

Asia Pacific

New Territories, Hong Kong
+852.2885.4613

niton.asia@thermofisher.com

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