Application Note

Applications for Portable XRF Technology in Analysis of Industrial Minerals

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Key Words
Industrial minerals, Niton, portable XRF, elemental analysis, non-destructive testing, fertilizer, limestone, gypsum

Goal

The goal of this note is to illustrate how portable XRF analyzers, by accurately measuring elemental composition, can rapidly identify and quantify certain industrial minerals.

Introduction

Industrial minerals are mined geologic materials that hold commercial value. The class excludes metallic materials such as copper, iron and gold ore, as well as fuel minerals like oil, gas and coal.

Industrial minerals include clays, sand, talc, limestone, gypsum, pumice, potash, barite, asbestos and zeolite, to name a few. Some gemstones such as diamond and zircon are also classified as industrial minerals. These materials are used in many industrial and consumer products, from fertilizers to building materials, from pigments (coloring agents) to fillers, as well as in abrasives, brick and ceramic, cement, refractories, fluxes and petroleum.

Portable x-ray fluorescence (pXRF) is an analytical technology that has the ability to deliver fast, accurate and repeatable analysis of industrial minerals, with little or no sample preparation. While pXRF is commonly used in the hard rock and oil and gas segments of the mining industry, it has also found significant application in the exploration and production of industrial minerals. Advantages of portable XRF analyzers include:

- Lightweight, rugged and field-ready;
- Exceptionally easy to use;
- Lab-quality analysis of light and heavy elements.

Thermo Scientific™ Niton™ XL3t GOLDD™+ analyzes 37 elements and optimizes analysis speed.

Fertilizer – promoting plant growth and food production

Despite some earlier estimates that the world food supply could not sustain a population above five billion people, the world continues to produce enough food to support the present population of seven billion, and growing.

One of the main reasons that food production has kept pace with rising population is the increased use of fertilizers that promote plant growth and food production. Three principal fertilizer components (nitrogen, phosphorous and potassium) are necessary for plant growth, and their application substantially increases crop yield. Two of these elements can be easily identified and quantified by pXRF. (Nitrogen cannot be detected because it is a very light element.)

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Phosphate

Phosphate fertilizers, originally made from bones, are now processed from phosphate rock. Phosphate is recovered as apatite [$Ca_5(PO_4)_3(F,OH,Cl)$] from 3 types of geologic settings: 80% sedimentary, 15% igneous and 5% guano (excrement) from sea birds.

Portable XRF can readily detect and quantify Ca (calcium) and P (phosphorous) in apatite. The amount of F (fluorine), OH (hydroxide) and Cl (chlorine) is commonly low. Phosphorous is a light element, so use of the analyzer's light filter on a pulverized sample is recommended. (See application note "Use of Sample Preparation Tools in Mining and Mineral Exploration Projects" for more detail.) Apatite is the most common mineral of P in nature. Therefore, the presence of P in the pXRF data indicates the presence of apatite.

Potassium

Potassium fertilizers, long derived from the potash of hardwoods, are extracted from evaporite deposits today. (Potash, originally named for ash used in pots for plants, results from burning hardwoods.) Although potassium (K) occurs in most rocks, it is not economically viable to extract K from these rocks. The only viable economic deposit of K is evaporites, which crystallize and precipitate from seawater. Near complete evaporation results in the deposition of large amounts of halite (NaCl) and smaller amounts of K and K-Mg salts, such as sylvite (KCl) and carnallite (KCl. $MgCl_2.6H_2O$).

In addition to the common elements in these salts, pXRF can quantify K, Mg (magnesium) and Cl. A light filter on a pulverized sample is recommended because Mg and Cl are light elements. The presence of Cl confirms that the mineral is a salt. The presence of both K and Cl indicates presence of sylvite.

Potash

Relatedly, potassium salts are called potash. The most common of these salts is sylvite, mainly used as a fertilizer. Some other applications include aluminium recycling, metal electroplating, oil-well drilling fluid, snow and ice melting and steel heat-treating. Potash is also used in medicine to treat hypokalemia, as well as in soap manufacturing and water softening. Portable XRF can be used to quantify potash in the same way it is used in potassium, explained earlier.

Gypsum – heat it to form plaster of Paris

Gypsum ($CaSO_4.2H_2O$) occurs in marine evaporites as a result of evaporation of marine water. It is the main ingredient of plaster, which is made by heating or calcining gypsum.

When gypsum is heated to 177 degrees Celsius, it forms a new compound, called plaster of Paris ($CaSO_4.1/2H_2O$). When this compound is mixed with water, it solidifies by rehydrating and reverting to a finely interlocked mass of tiny gypsum crystals.

Portable XRF can quantify Ca and S (sulfur) in gypsum. (Sulfur is a light element and needs a light filter.) Calcium is a very common element in many minerals. Co-existence of Ca and S in the sample can indicate the presence – or not – of gypsum, as illustrated in the charts below.

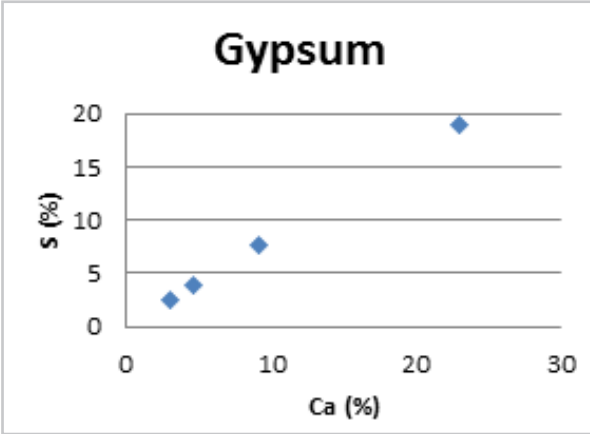


Figure 1. Positive correlation between Ca and S.

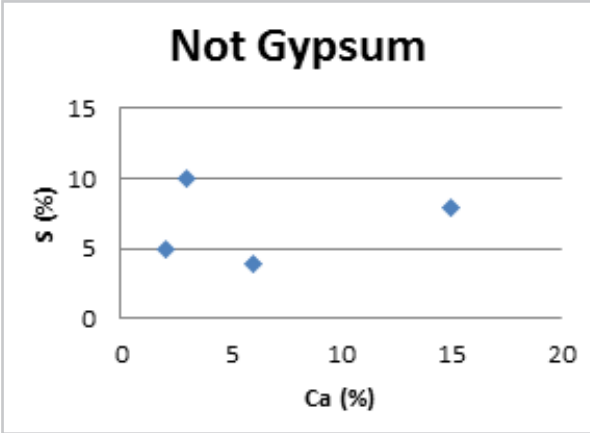


Figure 2. Ca and S present but no positive correlation.

Barite – lubricating the drill stem

Approximately 90% of world barite production is used in oil and gas production. Barite is finely ground for use in drilling mud to lubricate the drill stem, cool the drill bit, and seal off the walls of the hole.

A specific property of barium is its high density. ("Barys" means heavy in Greek.) As a result, barium (Ba) minerals are dense. Its common natural minerals are barite (barium sulfate, $BaSO_4$) and witherite (barium carbonate, $BaCO_3$).

Ba is a heavy element that pXRF can detect and quantify with high precision and accuracy, without sample preparation or light filter. The test data can be used for Ba mineral identification. Presence of Ba and S in the pXRF data indicates the presence of barite, whereas presence of only Ba (without S) indicates the presence of witherite.

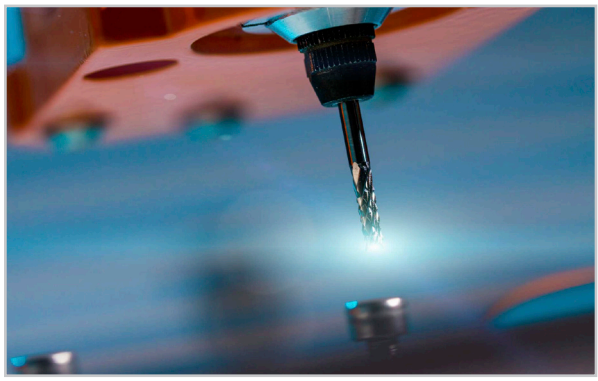
Gemstones – diamonds in the rough

The use of minerals as gems goes back to ancient times. Some people believe that the wearing of gems preceded the wearing of cloth.

From about 3000 known species of minerals, only 100 meet the requirements (color, luster, transparency, durability, and rarity) to be classified as gems. Other minerals from the gemstone group do not have all the requirements of a gem and are used in industries such as abrasives to cut, shape, grind and polish material. Examples include low-quality diamond, corundum and zircon. Synthetic diamond and corundum are commonly used as abrasives.

Portable XRF can easily quantify zirconium (Zr). This element mainly occurs as zircon ($ZrSiO_4$) in nature and, therefore, a small amount of Zr in pXRF data indicates the presence of zircon in the sample. Also, hafnium (Hf) is a common element, replacing Zr in the zircon structure, and might be detected by the analyzer.

Natural and synthetic diamond is made of carbon, which is not detectable by XRF. As a result, pXRF will not show any data for pure diamond. However, trace elements, depending on their concentrations, may be detected by pXRF.



Limestone – a top petroleum reservoir

Limestone is one of the most common sedimentary rocks on Earth. This rock is mainly composed of calcite ($CaCO_3$), though other carbonates such as aragonite (with the same formula as calcite but different crystal structure), and dolomite [$(Ca,Mg)CO_3$] are found in limestone too.

Limestone is one of the best petroleum reservoirs. Its application in industry varies widely: from building materials to architecture; in cement, asphalt, steel, glass, furnace, and even medicines and cosmetics. Identification of limestone is relatively simple, as it is soft and fizzes with weak hydrochloric acid.

Each industrial user requires a certain quality of limestone. A combination of common tests (such as fizzing) with pXRF data is the best method to evaluate limestone quality. Portable XRF can report Ca as well as several other elements (e.g. Mg, Sr, Fe, Ba) that commonly occur as minor impurities within limestone. A high amount of Mg converts limestone to dolomite.

Summary

Portable XRF technology provides lab-quality test results to determine mineral composition. Thermo Scientific™ Niton™ analyzers deliver rapid, accurate analysis in the field, improving work flows while speeding up decision making.

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