Field portable geochemical techniques and site technologies for mineral exploration

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Obtaining geochemical results on the field has been a persistent dream for exploration geologists until around 1990, when portable instruments allowed on-site measurement of the first key metals in solids. By 2010, most geochemists could have access to them.
Field analytical techniques are not aimed at providing the level of accuracy laboratory analyses do. They are designed for where there is no other option, where they offer flexibility, where they offer reactivity. They also offer extended possibilities when they cooperate with the laboratory.

TECHNIQUES

pXRF

The portable (or handheld) X-ray fluorescence spectrometer is the most widely known and used field instrument in exploration, apart from the pH- and EC-meters (Kalnicky & Singhvi, 2001; Houlahan et al., 2003; Higueras et al., 2012, Hall et al., 2012, Sarala, 2016, Lemiere, 2018). Current validated applications for pXRF in exploration comprise:

- fast decision-making measurements and analyses: mining rock face evaluation, ore processing monitoring, soil remediation and waste management operations, etc.),
- site recognition soil grids and stream sediment surveys,
- fast drill-hole logging and drilling decisions, based either on cores or on RC cuttings,
- screening of samples to select which ones will be analysed in the lab,
- identification of potential resources from waste piles or core libraries.

Some of the most important issues with pXRF lie in sampling and sample preparation techniques. If samples are prepared on site as required by the laboratory, there are better chances to obtain reliable analyses with field methods. Measurements obtained on raw or roughly prepared samples may provide useful and meaningful results, but will usually show large bias or uncertainty.

LIBS

Laser-induced breakdown spectroscopy was introduced later and brought big promises in overcoming the three classical limitations of pXRF: distance to sample, lower atomic weights, and radioemission permits. However, most current applications of LIBS fall short of the reliability of pXRF on heavier elements. LIBS is indeed the only option for Li and elements lighter than Mg, and some manufacturers claim it can analyse all the elements, but it often needs to be used in combination with pXRF to cover exploration needs. An advantage of LIBS over pXRF is the ability to carry out focused spot measurements and micromapping. Their safety constraints (laser) are less strict than those implied by radiation mitigation for pXRF, hence easier permitting for field operation.

pXRD

XRD instruments are field-portable but bulkier than handhelds. Their applications are constrained by the limitations of optical geometry. They can fill a significant role in exploration mineralogy, especially through the recognition of hydrothermal alteration zones and secondary minerals.

FTIR

Infrared handheld spectrometers can be used for the detection or semi-quantification of organic substances and specific minerals (nIR instruments for humidity and asbestos, mIR instruments for extended mineralogy and organics). They need the development of exploration-oriented libraries. They have a potential for hydrothermal alteration recognition and mapping. Their operation is hampered by water contents and by dark substances, such as organic matter.

µRaman

Micro-Raman handheld spectrometers can also be used for organic substances and minerals, and are less sensitive to water and darkness, but their operation and spectral interpretation are still experimental for exploration applications.

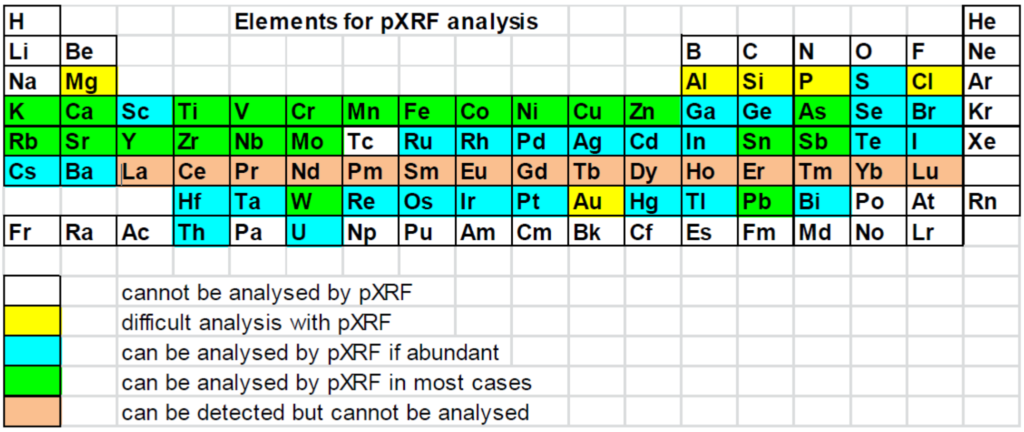

Fig.1. Elements that may be currently analysed by pXRF (as of 2015)

Water analysis

Fluid analyses are not as common as analyses of solid materials, but there are such technologies as ASV, polarography, and ion exchange electrodes allowing analysis of commodity or other important elements. Current applications for water comprise:

- accurate measurement of geochemical properties that are not stable with time and transport,
- fast decision-making measurements and analyses: wastewater treatment or discharge monitoring, including process monitoring and alarm networks,
- catchment mapping and reconnaissance (both for baseline and exploration surveys),
- screening of samples to select which ones will be analysed in the lab,
- improved measurements and analyses for site investigations: catchment or pit lake reconnaissance and monitoring, groundwater logging and monitoring.

Possible issues about sample preparation are less important for water samples than for solid samples, as lab-ready preparation on site is mandatory, and homogeneity is easier to ensure.

They are not yet sensitive enough for advanced hydrogeochemical exploration purposes.

Exploration site technologies

Heavier equipment can be used at a mining exploration camp, even if not on the outcrop. This includes:

- laboratory devices adapted for mobile or rough conditions (XRF, XRD, AAS,...)
- combinations of field sensors around a core scanner, allowing the fast processing of cores at the drilling site, before logging or splitting them for laboratory analyses. Core scanners include hyperspectral, gamma and XRF systems, to build extensive core data sets,
- combination of field sensors or devices around a sample preparation system, such as cuttings separated from drilling fluids (an example is the Lab-at-Rig® technology (CSIRO, Imdex and Olympus within Deep Exploration Technologies CRC).

APPLICATIONS

All these technologies are aimed at providing decision-support results while drilling, or while performing geochemical surveys, in order to optimise the exploration strategy in quasi-real time. Handheld instruments operate on outcrops, or on samples submitted to a very basic preparation, using field-portable devices such as battery-operated mills. Field-transportable lab instruments may be hosted by portable cabins or lab trucks at a camp.

There are many discussions about the quality of field analyses vs. laboratory analyses, with often non-neutral contributions from instrument suppliers and from the laboratory profession. Sample preparation and sample representativeness issues are by far more important than instrument limitations to interpret discrepancies. Documented evidence of field-lab concordance is frequently published, usually by geochemists which paid attention enough to sample preparation and representativeness.

Benefits of field analysis comprise in-situ analysis, without transport issues; ASAP, DSP or Triad (adaptation of sampling strategy along results collection or dynamic sampling plans: Crumbling, 2001; US-DOE, 2001), increase of data density and quality (through larger data sets) and better representation of transient phenomena.

Possible pitfalls include improper interpretation of field data as a result of insufficient understanding of the sampling and measurement processes, use of heterogeneous data sets collected by different methods, and the lack of critical examination of data.

Field and on-site results do not need to achieve absolute accuracy. They only need to achieve the level of confidence expected from the decision (Ramsey & Boon, 2012). Field techniques produce usually denser data sets than more expensive laboratory analyses, which may compensate for lower accuracy. Most mineral exploration decisions are based on flexible thinking rather than on a preset framework of investigations. One of the key benefits of real-time analyses, or short delay analyses (less than a day) is the possibility to adjust sampling plans, test hypotheses based on ongoing results, and make fast decisions on exploration work - especially drilling and sampling. This is particularly important for remote locations, where sample logistics to the laboratory may become long and demanding.

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