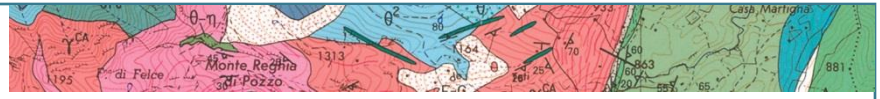

Field and site geochemical techniques Relevance for decision making in mineral exploration

Real time decision based on field analyses - benefits for efficiency and cost-effectiveness

Bruno LEMIERE, Yulia UVAROVA

BRGM – French GeoSurvey

CSIRO Mineral Resources, Australia

Getting the lab on the field, why ?

> Is Field Analysis a key innovation of the Decade ?

- Existed in 2007 (Glanzman & Closs, 2007), but not routinely used
- One of the most promising routes for today's geochemical exploration (Agnew, 2017)

photo USGS

> Relevance for exploration

- flexibility: operate anywhere
- reactivity: instant results and on-site decisions
- improve the efficiency of lab sampling

> But how far can it replace lab results ?

- Quality, accuracy, reliability ?
- Replace, or complement lab results ?

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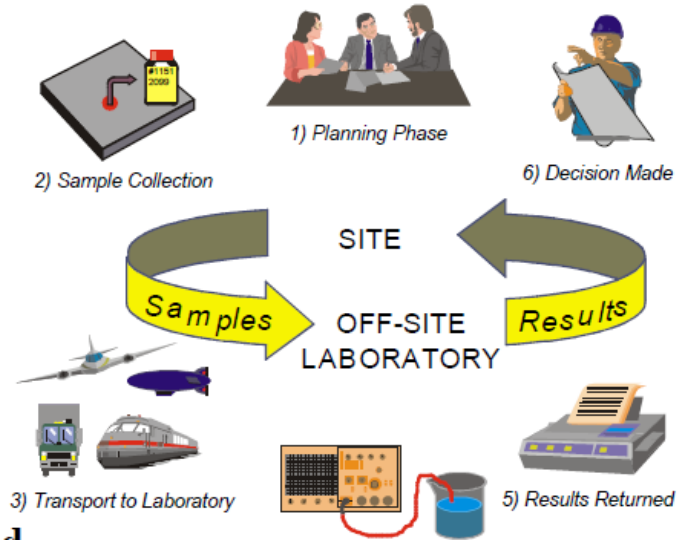
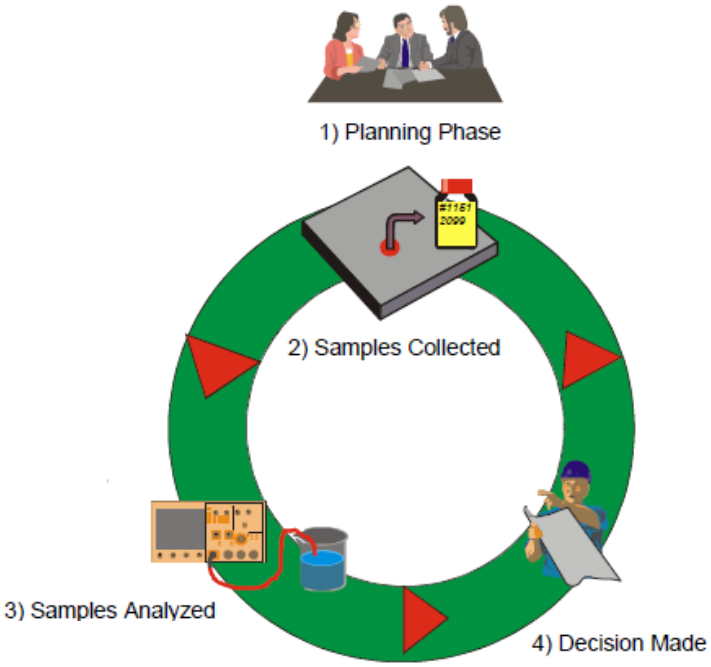
Field analytics where they offer reactivity

> ASAP, DSP

- Adaptive sampling and analysis
- Dynamic sampling plans





- On-site decision making: on areas to be sampled or gridded, on drill-core progress and sampling

=>diagrams from Johnston, FRTR 2003

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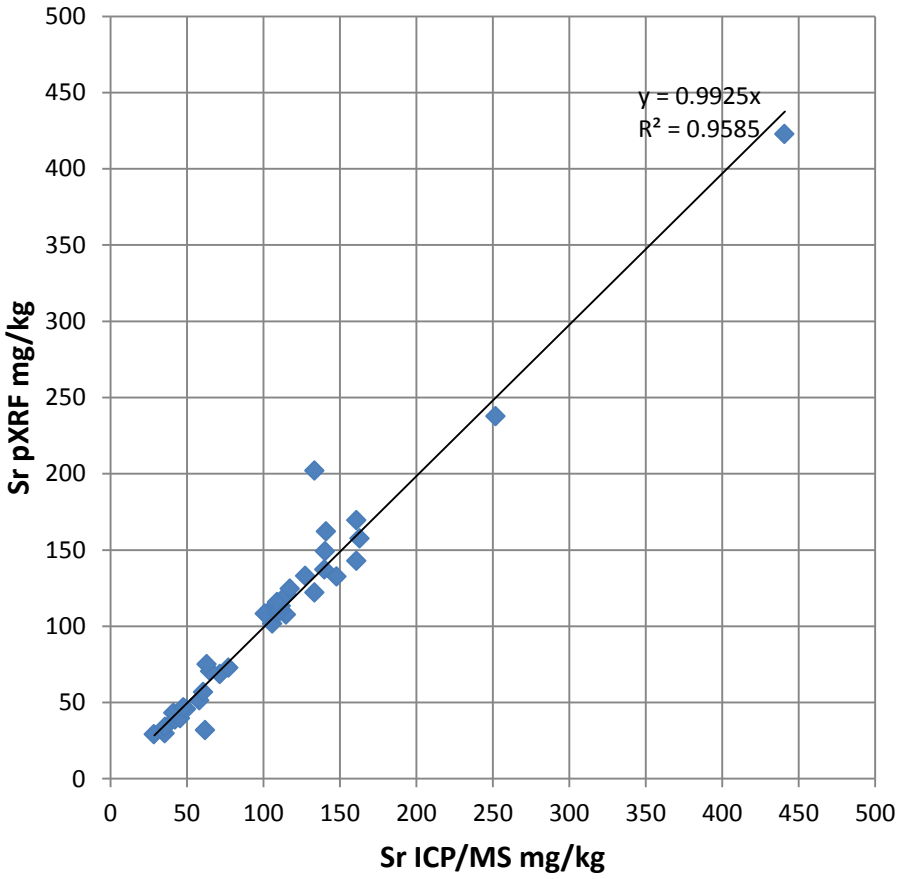
pXRF: accuracy or sensitivity ?

> Accurate results

- lab-type sample preparation mandatory
- quality control by systematic lab samples
- homogeneous matrix composition
- pXRF analyses allow larger data sets and better data quality
- But lower analytical levels will not compete with high sensitivity lab analyses



Example from strontium in sandstone

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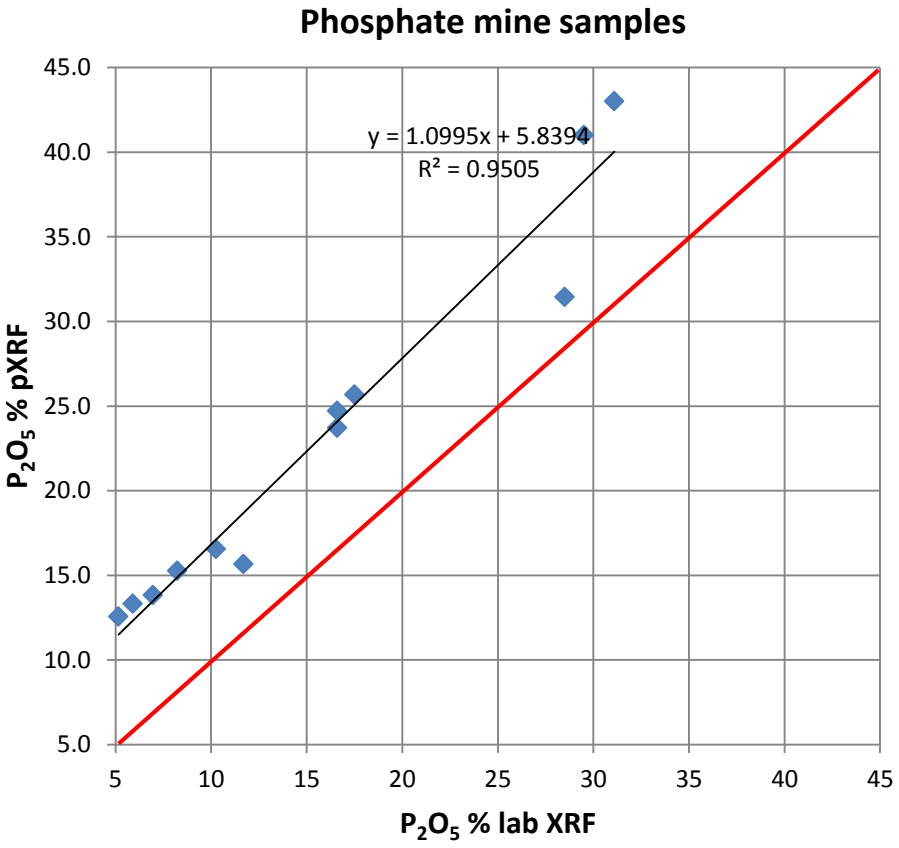
pXRF: accuracy or sensitivity ?

- **Biased results with reproducibility and sensitivity**
  - Decision thresholds may be deduced from correlation graphs
  - Systematic lab controls needed
  - Results must be called “measurements” and not “analyses”
  - Never mix results from both methods



Example from phosphate in limestone

Field decisions during exploration: commodity elements ? pathfinders ? geochemical signatures ?

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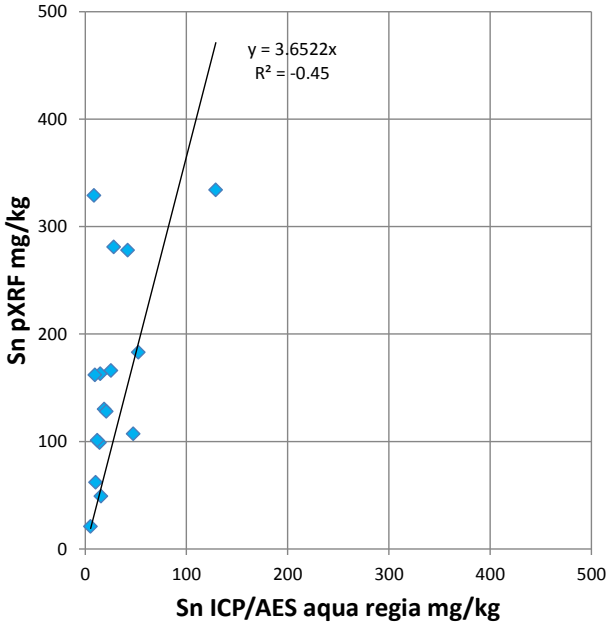
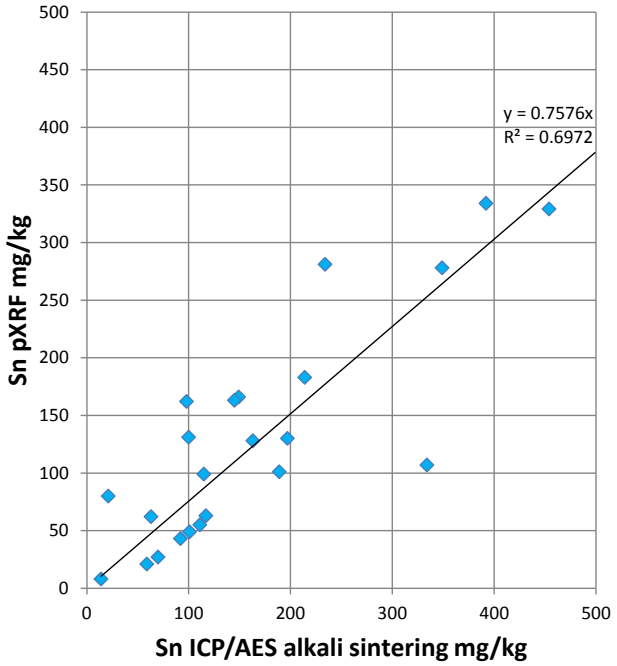
pXRF analyses: are they always inferior ?

- Bias depends on the type of digestion to which pXRF is compared
- pXRF results often higher than aqua regia analyses for refractory minerals such as cassiterite (Sn), wolframite (W) or rutile (Ti).
- pXRF analyses carried out on laboratory standard pulps often more accurate than standard laboratory analyses, unless total digestion techniques are used





Example from soils near a Sn-W deposit

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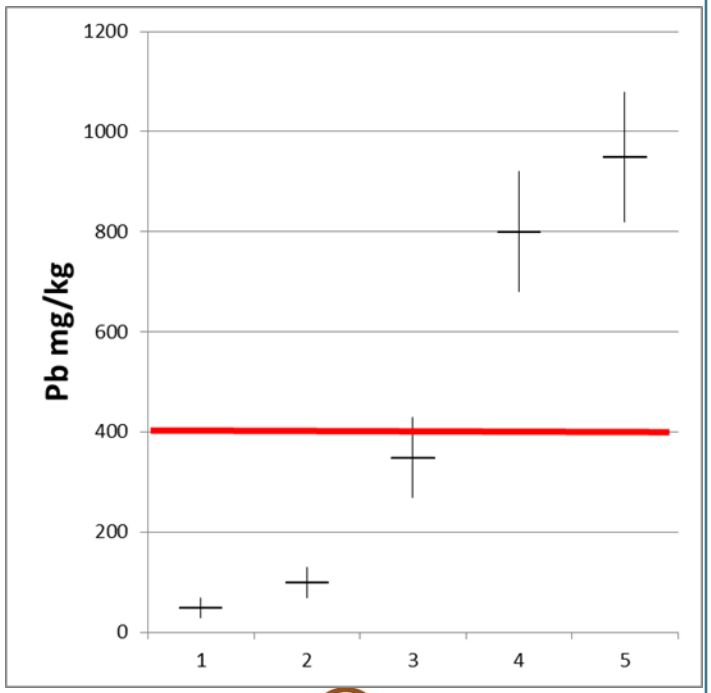
Geoscience for a sustainable Earth

Real time decisions based on field analyses Benefits for efficiency and cost-effectiveness

Field results are representative enough of the actual concentrations of the key elements to allow on-site decisions without waiting for lab results in most cases

> Decision making and real-time measurements

- Decision is based on your own calculated threshold value, with a safety margin for sampling and analysis errors
- On this example, only sample 3 is inconclusive with pXRF data
- No compliance data based upon your field measurements
- Potential large cost savings from not waiting for laboratory results
- and...



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Field analytics: Fitness for purpose

> Data quality, or fit-for-purpose ability

Ramsey M.H., & Boon, K.A. - Can in situ geochemical measurements be more fit-for-purpose than those made ex situ? Applied Geochemistry 27 (2012) 969–976

- A measurement of how far the geochemical data set is representative of the explored object, and how far exploration decisions based on it will be reliable, in terms of effectiveness and financial consequences
- The usually lower quality of field analyses is more than balanced by the much larger number of analyses made possible by on-site methods
- Higher sampling density
- No conservation concerns
- Matrix homogeneity may be appreciated and understood on site
- Quantification of heterogeneity is best done on site
- Automated operations in the lab allow longer measurement time
- On site measurements carried out on smaller sample volumes

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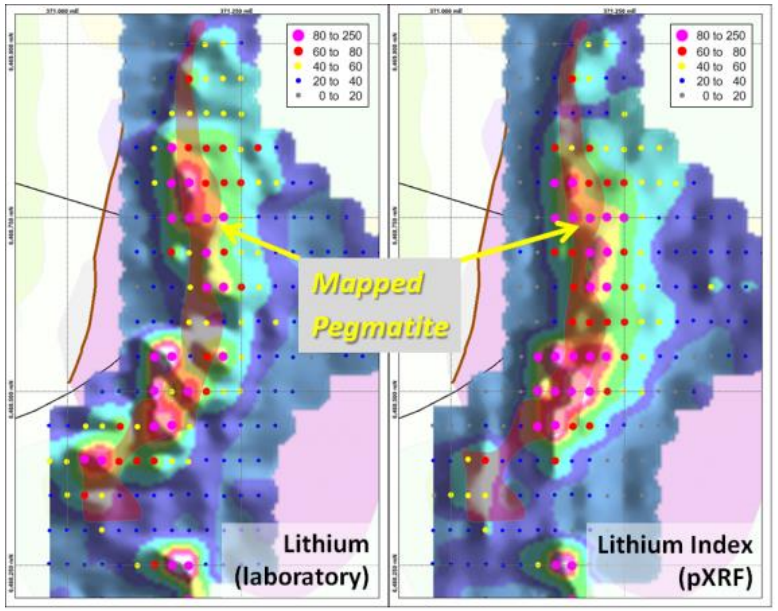
Field analytics: Fitness for purpose

> Data quality, or fit-for-purpose ability

The geochemist has the final say to decide which is best adapted for his purpose (taking into account DQO, confidence in decision, compliance, but also time and budget)

Best global results usually achieved through a clever combination of field and lab data



From Portable XRF Services (www.pxrfs.com.au)

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Field analytics where they cooperate with the lab

> Reliability of decisions based on either method

- Better analytical accuracy from the lab, but fewer samples
- Lower accuracy from field analysis, but known uncertainty
- Sampling errors for both methods >> analytical errors: Never forget sampling and preparation uncertainties when dealing with lab results
- Large data sets and representative grids with field methods

> Improving both methods by cooperation

- Use field methods for lab sample selection and screening
- Use field methods to control the representativeness of the samples you will send to lab (assess heterogeneity by multiple shooting)
- Improving field calibration with lab analyses
- Never forget sampling and preparation uncertainties when dealing with lab results

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Groundbreaking Lab-at-Rig® technology

> Making decisions in near real time

Top of Hole Assay - DD

Lab-at-Rig®

- Manual Proof of concept of workflow and sub-systems (TRL4), communications and data integration systems
- Delivered near-real time assay information from diamond drilling with excellent depth fidelity and resolution

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Field analytics: quality and strategy ?

- **The need for a laboratory control scheme**
  - Protocols for field measurements, based on orientation survey
  - QA/QC scheme and monitoring of field measurements
- **The need for relevant standards**
  - Some lab standards may be applied on field (water analyses)
  - Pioneering EPA-6200 and recent ISO-13196:2013 for pXRF
- **The need for relevant reference materials**
  - Some lab CRMs may be used on field (non-destructive) – but project-specific SRMs will be more helpful
- **Integrate measurement uncertainties in data**
  - Benefits for mining or environmental global data management
  - Easy integration with geometallurgy and geostatistics
- **Benefits for data set quality**
  - Data density vs discrete samples accuracy

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Open discussion: place of field analysis in 2017

- **Where you really need it:**
  need for immediate results, remote locations, or where no other budget would fit
  => but keep some resources for QA/QC and lab controls
- **Where it brings a real benefit:**
  orientation surveys, adaptive investigations, lab sample screening, data collection by skilled geoscientists
- **Requirements:**
  close cooperation between data user, geochemist, and field operators – traceable protocols, sample and quality data
  close cooperation between the geochemist, the instrument supplier... and the labs !

Successful applications over the last decade, will be mainstream in the next one !

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