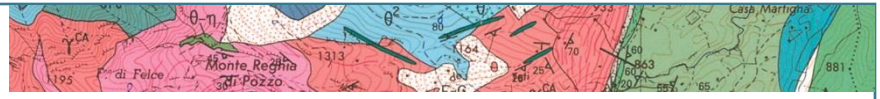


# New developments in field portable geochemical techniques and site technologies and their place in mineral exploration

Bruno LEMIERE, Yulia UVAROVA

BRGM – French GeoSurvey

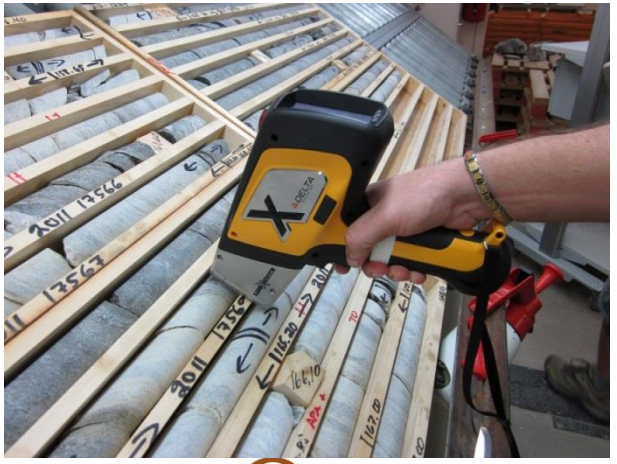
CSIRO Mineral Resources, Australia

# Field analytics where they offer flexibility

## > Exploration: sample screening and selection

- Identification of targets for new commodities
- Quick selection of prospects
- Quick ranking of samples and lab analysis of a smaller number of relevant samples
- Grid mapping and lab confirmation
- Dynamic sampling plan based on observations and measurements
- Fewer lab samples, but covering the whole grade range
- Focus on lab samples near the decision level

Thermo Niton XL3t 500 hand-held XRF analyser =>



photos Olympus =>

## > Mining camp operations

- Drill-hole monitoring and decisions
- Re-logging previous cores

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# New hardware developments in the last decade

## Handheld instruments derived from lab ones

- **LIBS** Elemental analysis, even LE
  see Andrew's and Mohamad's talks

photo SciAps

- **Infrared (SWIR or nIR)**
  - Terraspec 4 & Halo : mineral identification
  - other manufacturers coming

photo ASD

- **Infrared (MWIR) Exoscan**

photo Agilent

- **µRaman** Mineral analysis
  see Adam's talk

photo Jan Jehlička

**Component miniaturisation and development of field applications**

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# Previous hardware with new development

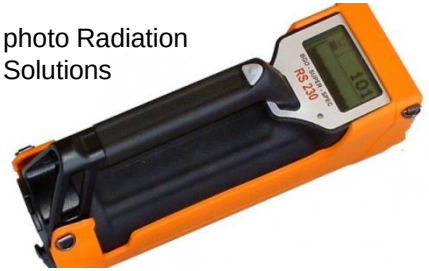
- **pXRF:** elements from Mg to U
  the most operational equipment
  in exploration (see Peter's talk)

- **pXRD:** minerals identification
  (see Aaron's talk)

photos Olympus

- **Spectral gamma handheld**
  a proxy for K, U, Th

photo Radiation Solutions



- **Hydrogeochemistry**
  - Anodic Stripping Voltammetry
  - Ion Specific Electrodes

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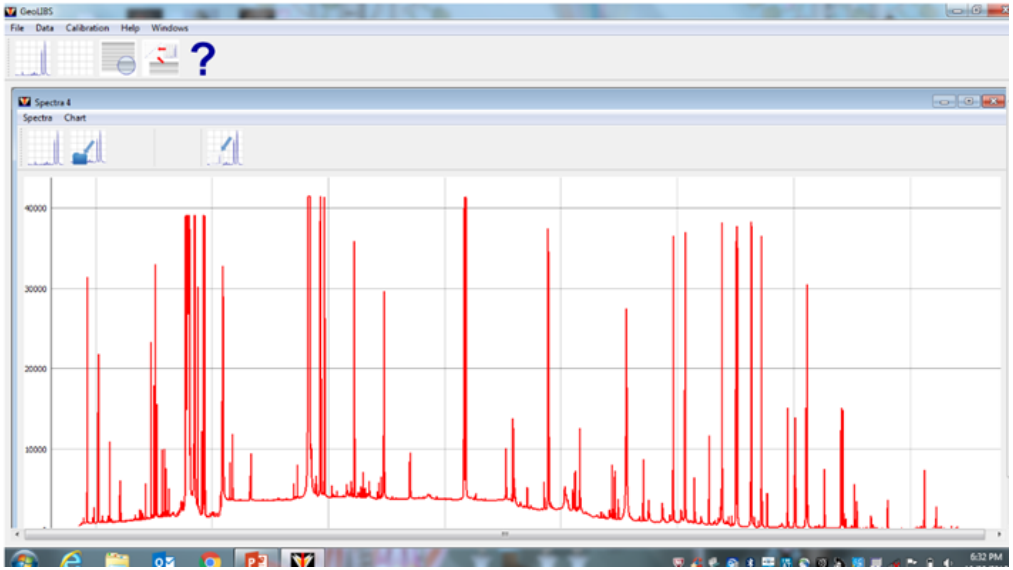
# Improvements in software

- **Novel or improved software technologies in the last 10 year allowing new applications, DLs, etc**
- **Advanced use of such methods as chemometrics, machine learning and artificial intelligence**

  Not easy to calibrate one absorption band for a mineral or element ? Use mathematical analysis of the whole spectrum

  Predict other properties from collecting one dataset

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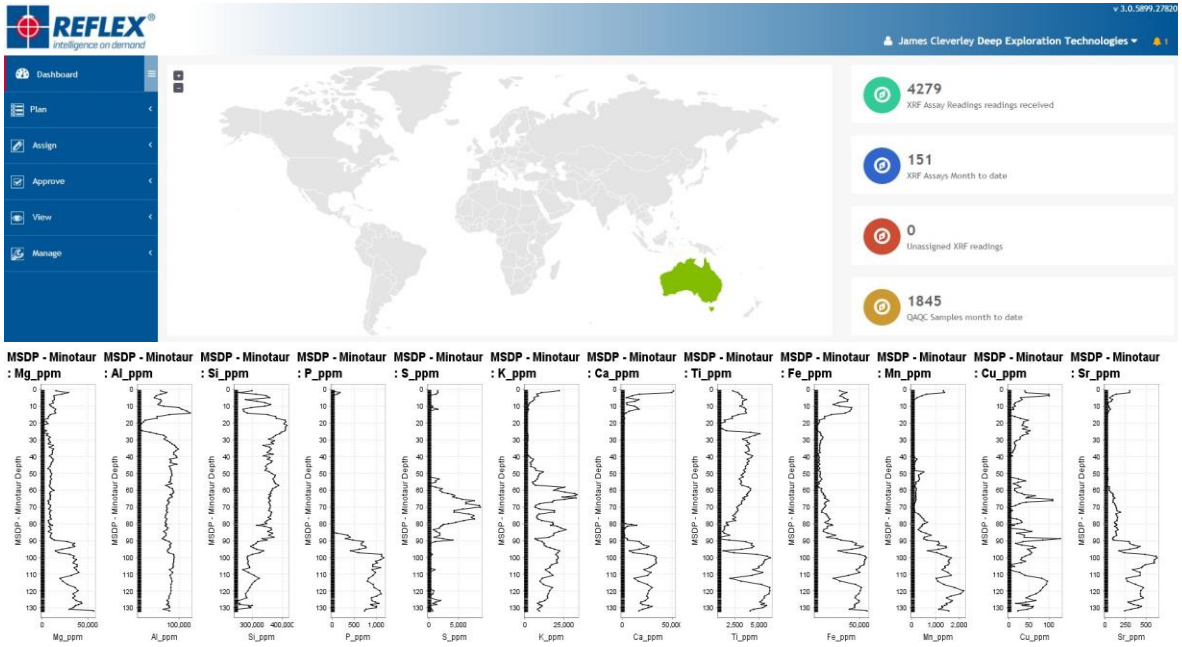
# Integrating sensors and cloud-based software applications in new platforms providing global services

- **Real-Time cloud based data delivery (e.g. REFLEXHUB-IQ)**
- **Core scanners**
- Solids on line for continuous flows (spectral gamma, neutron activation, PGNAA, PFTNA,NITA, LIBS, UV/VIS & NIR spectroscopy, XRF, EDXRF




Geoscience for a sustainable Earth

# Integrating sensors and software applications in new platforms providing global services

- **Lab-at-Rig®**
- **Samples preparation system (REFLEX)**

## Top of Hole Assay - DD

Lab-at-Rig®

Trial deployment with Barrick as part of Kickstarter partnership

- 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: solids analysis

## > Elemental analysis

- pXRF (handheld X-ray fluorescence): most widely used field instrument after pH/EC meter
- LIBS: for lighter elements, still experimental
- Spectral gamma, radiation-based proxy for K, Th, U

LIBS - photo IVEA

## > Minerals analysis

- pXRD (portable diffraction): A first screening of mineralogy
- FTIR: organics & minerals
- µRaman: organics & minerals

pXRD
photo Olympus

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# Field analytics, inorganic: What is pXRF ?

## > element range (as of today)

| | | | | Elements for pXRF analysis | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | | | | | | | | | | | | | | | | | He |
| Li | Be | | | | | | | | | | | B | C | N | O | F | Ne |
| Na | Mg | | | | | | | | | | | Al | Si | P | S | Cl | Ar |
| K | Ca | Sc | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | Ga | Ge | As | Se | Br | Kr |
| Rb | Sr | Y | Zr | Nb | Mo | Tc | Ru | Rh | Pd | Ag | Cd | In | Sn | Sb | Te | I | Xe |
| Cs | Ba | La | Ce | Pr | Nd | Pm | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | |
| | | | Hf | Ta | W | Re | Os | Ir | Pt | Au | Hg | Tl | Pb | Bi | Po | At | Rn |
| Fr | Ra | Ac | Th | Pa | U | Np | Pu | Am | Cm | Bk | Cf | Es | Fm | Md | No | Lr | |

- cannot be analysed by pXRF
- difficult analysis with pXRF
- can be analysed by pXRF if abundant
- can be analysed by pXRF in most cases
- can be detected but cannot be analysed

photos Bruker, Thermo Niton =>

- portable X-Ray Fluorescence spectrometer, allowing to perform easily multi-element analyses in 30 to 120 seconds
- robust grid mapping structures (with absolute concentrations validation in the lab)

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# Field analytics: pXRF


- **the early days: source instruments**
  - Constraints on use, but better penetration
- **modern instruments: X tubes**
  - Less constraints, but focused and surficial measurements
- **point and shoot vs. sample preparation**
  - pXRF as a diagnostic tool vs. pXRF as a portable analyser
- **limitations and assets**
  - heavier elements only, but no speciation or digestion issues
  - shallow investigation depth, variable with elements (1 to 0.05 mm)
  - limited area (less than 1 $cm^2$)
  - may overcome heterogeneity with multishooting

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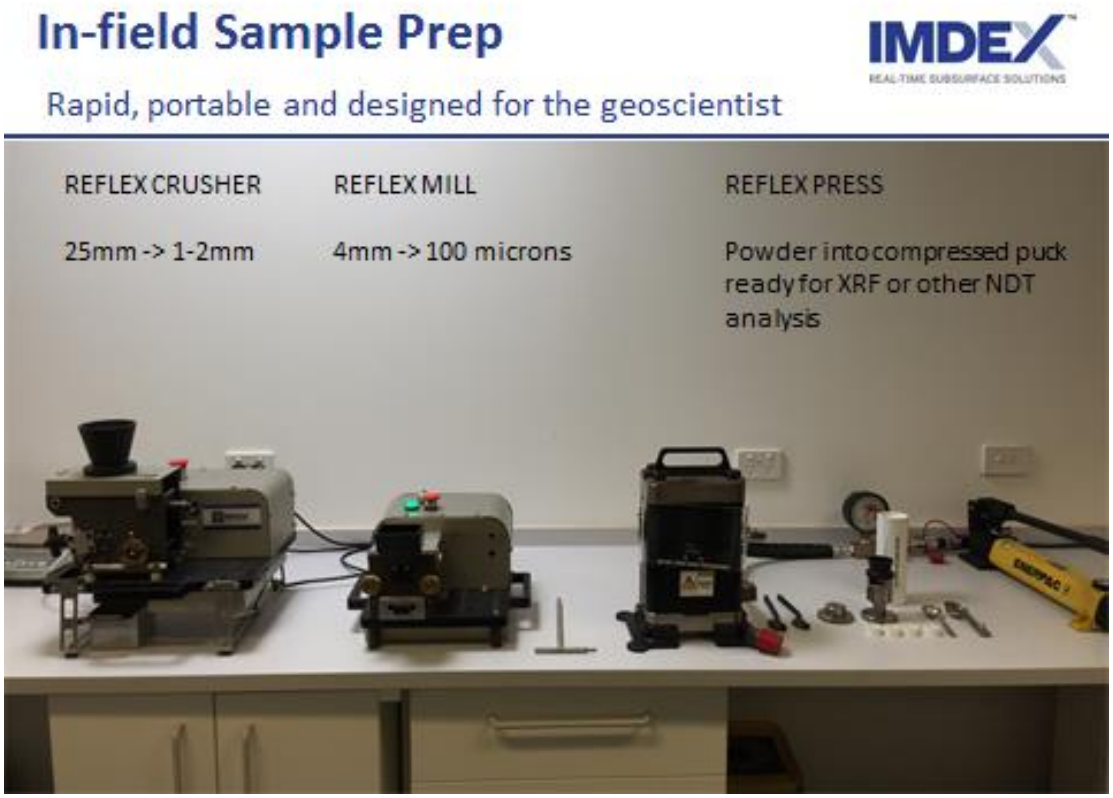
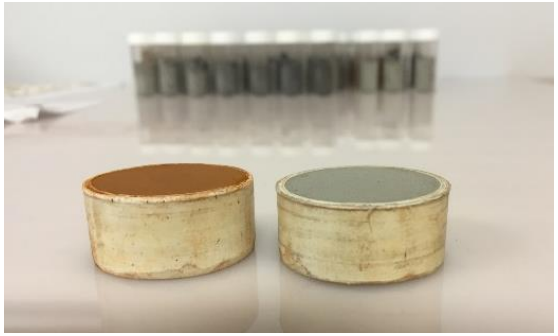
# Field analytics: sample preparation

- **Soil or sediment homogenisation**
- **Site grinding and milling for rocks**
  - Getting near lab-quality pulps anywhere

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# Field analytics: water analysis

## > Elements or species analysable on site

- Methods without sample preparation considered only here
- Mendeleev's table for field methods (from literature review)

| | | | | Elements for field analysis of water | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | | | | | | | | | | | | | | | | | He |
| Li | Be | | | | | | | | | | | B | C | N | O | F | Ne |
| Na | Mg | | | | | | | | | | | Al | Si | P | S | Cl | Ar |
| K | Ca | Sc | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | Ga | Ge | As | Se | Br | Kr |
| Rb | Sr | Y | Zr | Nb | Mo | Tc | Ru | Rh | Pd | Ag | Cd | In | Sn | Sb | Te | I | Xe |
| Cs | Ba | La | Ce | Pr | Nd | Pm | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | |
| | | | Hf | Ta | W | Re | Os | Ir | Pt | Au | Hg | Tl | Pb | Bi | Po | At | Rn |
| Fr | Ra | Ac | Th | Pa | U | Np | Pu | Am | Cm | Bk | Cf | Es | Fm | Md | No | Lr | |

| | |
|---|---|
| | cannot be analysed by usual field methods, or out of scope |
| | may be analysed with ISE technologies |
| | selected ionic species can be analysed |
| | may be analysed on site by voltamperometry, voltammetry or polarography |
| | may be analysed by voltamperometry, voltammetry or polarography if abundant |
| | may be analysed on site with specific equipment |

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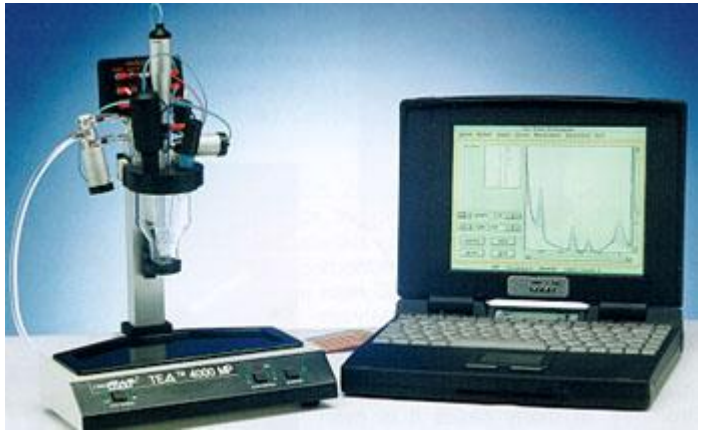
# Field analytics: water analysis

## > Electrochemical techniques usable on site

- Ion selective electrodes (ISE)
- Voltammetric and voltamperometric (VAM) methods
- Anodic stripping (ASV) or cyclic voltammetry
- Polarography



^ GAT 4000 polarography/voltammetry system, photo TOPAC

in situ voltammetric probe – photo Idronaut >

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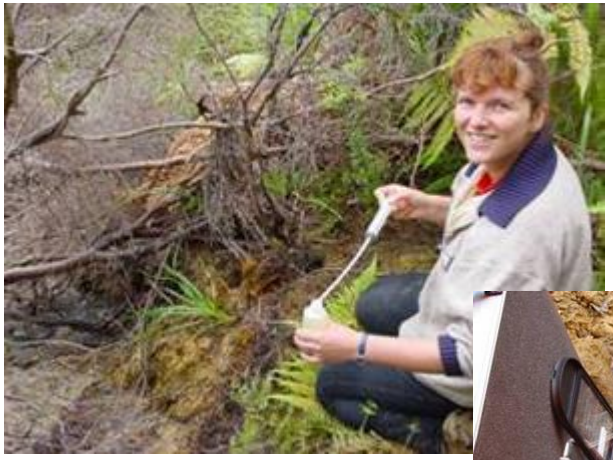
# Field analytics: water analysis

## > Traces on site (electrochemistry)

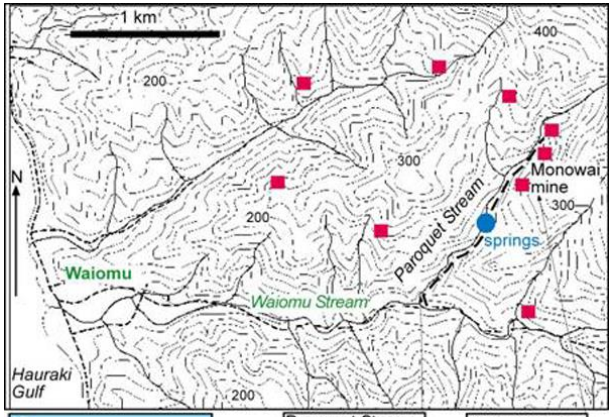
- Ore elements, pathfinders (exploration)
- High sensitivity needed – and possible



Ionic species: ISE

Trace elements:
ASV, polarography

pictures Univ. of Otago, NZ





| Paroquet Stream | L/sec | 18 | 140 |
|---|---|---|---|
| | | µg/L | µg/L |
| Cu | | 1.2 | 5 |
| Pb | | 7 | 4.7 |
| Cd | | 0.5 | 0.3 |
| Zn | | 120 | 44 |

| Monowai mine | L/sec | 0.8 |
|---|---|---|
| | | µg/L |
| Cu | | 500 |
| Pb | | 350 |
| Cd | | 20 |
| Zn | | 2000 |


http://www.otago.ac.nz/envscience/research/CoromandelSprings.html

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# Thank you for your attention

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