First Impressions Count: Applications of field portable X-ray diffraction to environmental monitoring of mine sites

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The development of portable X-ray diffractometers is enabling researchers to conduct detailed qualitative and quantitative mineralogical analysis in the field. Portable X-ray diffraction (XRD) is a valuable technique for analysis of samples such as mine tailings, which traditionally have posed a challenge for mineral identification in the field. Here, we detail two case studies using field observations and portable XRD data to provide a "first look" at the mineralogy of several derelict mine sites. We used portable XRD to quantify the mineral carbonation potential of mine tailings at the Woodsreef Chrysotile Mine, NSW, Australia and to investigate the formation of arsenic-bearing efflorescences at the Ottery Arsenic-Tin Mine, NSW, Australia.

The Woodsreef Chrysotile Mine was the site of Australia's largest tonnage chrysotile mine, producing 500,000 t of long fibre chrysotile as well as 100 Mt of mineral waste from 1972 to 1983. The serpentinite tailings at Woodsreef are highly reactive and were potentially sequestering atmospheric CO_2 via the formation of stable carbonate minerals.[1, 2] Portable XRD was used in the field to reliably identify the mineralogy of the tailings, as in many cases samples were too fine-grained for identification from hand specimens. XRD results show that the tailings contain serpentine, magnetite and multiple carbonate-bearing minerals including pyroaurite [$Mg_6Fe^{3+}_2(CO_3)(OH)_{16}{\cdot}4H_2O$] and hydromagnesite [$Mg_5(CO_3)_4(OH)_2{\cdot}4H_2O$]. Quantitative phase analysis was performed on portable XRD patterns using the PONCKS methodology to account for the disordered structures of the serpentine minerals.[3] Crusts forming on the surface of the tailings contained ~5.8 wt% hydromagnesite and ~2.1 wt% pyroaurite, indicating that passive carbon mineralisation reactions are occurring at the site and sequestering atmospheric CO_2.

The Ottery Arsenic-Tin Mine is a heritage listed historic site that contains mineral wastes and a ruined processing plant. The formation of mineral efflorescences is causing degradation of the brickwork in the arsenic processing plant and is likely a source of arsenic contamination in local soils and waterways. Portable XRD was used to help identify the mineralogy of the efflorescences, determining the key minerals that control As release and contamination. A distinct mineralogical change was observed in efflorescences between exposed walls on processing buildings and walls that were still sheltered by the remains of a roof: efflorescences on exposed walls contain mainly gypsum whereas those on sheltered surfaces were coated with historical efflorescences dominated by the As_2O_3 polymorphs arsenolite and claudetite. Thus, ensuring that historical arsenic-rich efflorescences remain sheltered is a key strategy for preventing the future release of As from the Otter Mine.[4]

Portable XRD instruments are powerful tools for the initial investigation of field sites. Although not a replacement for high quality laboratory based instruments, portable XRD allows researchers to obtain detailed mineralogical data as soon as they enter the field. This provides unprecedented opportunities to modify sampling strategies on the fly and to ensure that the most representative samples are collected during a field campaign, thus reducing the likelihood that subsequent field trips will be necessary to close knowledge gaps.

1. Oskierski, H. C.; Dlugogorski, B. Z.; Jacobsen, G., Sequestration of atmospheric CO_2 in chrysotile mine tailings of the Woodsreef Asbestos Mine, Australia: Quantitative Mineralogy, isotopic fingerprinting and carbonation rates. *Chemical Geology* **2013**.
2. Turvey, C. C.; Wilson, S. A.; Hamilton, J. L.; Southam, G., Field-based accounting of CO_2 sequestration in ultramafic mine wastes using portable X-ray diffraction. *American Mineralogist* **2017**.
3. Scarlett, N. V. Y.; Madsen, I. C., Quantification of phases with partial or no known crystal structures. *Powder Diffraction* **2006,** *21*, (04), 278-284.
4. Hebbard, E. R.; Wilson, S. A.; Jowitt, S. M.; Tait, A. W.; Turvey, C. C.; Wilson, H. L., Regrowth of arsenate–sulfate efflorescences on processing plant walls at the Ottery arsenic–tin mine, New South Wales, Australia: Implications for arsenic mobility and remediation of mineral processing sites. *Applied Geochemistry* **2017**.