

Ruth Griffiths

Senior Consultant, Geochemistry



Education: Ph.D. Environmental Geochemistry, 2009
MSc. Environmental Monitoring and Analysis, 2005
BSc (Hons). Environmental Earth Science, 2004.

**Registrations/
Professional
Memberships** Chartered Geologist, 2013
European Geologist, 2016
Fellow of the UK Geological Society
Member of the International Mine Water Association
Member of the UK Mineralogical Society
MSHA 24-Hour New Miner Safety Training

Specialisation:

Environmental geochemistry, including geochemical characterisation of mine wastes, waters and soils, Acid Rock Drainage and Metal Leaching (ARDML) assessments and the application of geochemical modelling to mining environments.

Expertise:

Ruth Griffiths (CGeol, EurGeol, PhD, MSc, BSc) is a Senior Geochemistry Consultant specialising in the application of environmental geochemistry to a range of mining projects. Ruth's areas of expertise include the geochemical characterisation of mine waste, waters and soils, field and laboratory based analytical geochemistry and the application of geochemical modelling to mining environments. Ruth is a Chartered Geologist and has over 8 years' experience working on mine waste characterisation projects in base and precious metals in Africa, Europe, Asia and the Americas and is particularly involved with the geochemical evaluation of gold projects in Nevada. Ruth also provides technical geochemical input to soil and water baseline studies and mine closure plans.

Employment Record

April 2013 - present	SRK Consulting UK Ltd, Senior Geochemist
Jan 2010 – March 2013	SRK Consulting UK Ltd, Consultant Geochemist
Oct 2004 – Dec 2009	Aberystwyth University Department of Geography and Earth Science. Postgraduate Tutor and Demonstrator
Jul 2004 – Sept 2004	Aberystwyth University Department of Geography and Earth Science. Research Assistant on EU funded BIOMAN mine water remediation project.
June 2003 – Sept 2003	Applied Environmental Services, Colchester, Essex. Research Assistant

Languages: English (fluent), German (basic), French (basic)

Key Project Experience: Geochemical Characterisation and Acid Rock Drainage and Metal Leaching (ARDML) Assessment

- Stibnite, Idaho (2015 – present) – baseline geochemical characterisation of development rock, ore, tailings and legacy mine waste to support project permitting.
- Sakatti, Finland (2016 – present) – static and kinetic geochemical characterisation of waste rock and tailings to support the PFS.



- Los Filos, Mexico (2015 - 2017) – preparation of waste rock management and monitoring plans and completion of field sampling campaign for geochemical characterisation to support mine closure planning.
- Long Canyon, Nevada (2012 – present) – field sampling of pulp and core materials to support the waste rock characterisation study and preparation of geochemical characterization report.
- Round Mountain, Nevada (2012 – present) – completion of a field sampling exercise and the interpretation and reporting of geochemical static and kinetic data as part of the waste rock geochemical characterisation programme for the proposed pit expansion.
- Chernogorskoye, Russia (2014) – project manager for geochemical characterisation study of waste rock and tailings from proposed open pit nickel-platinum mine.
- Wadi Gabgaba, Sudan (2014) – due diligence review and Acid Rock Drainage and Metal Leaching assessment of waste rock, ore and process residues for a proposed gold project.
- Tambao, Burkina Faso (2013 – 2014) – primary author of the pre-feasibility level ARDML assessment of waste rock.
- Tasiast, Mauritania (2012 – 2014) – project manager for the waste rock geochemical characterisation study for the Phase 2 pit expansion.
- Comstock, Nevada (2012 – present) – completion of field sampling exercise, data assessment and reporting as part of the waste rock geochemical characterisation programme.
- Corcoesto, Spain (2012 – 2013) – project manager for gap analysis and ARDML assessment of waste rock and tailings associated with the project.
- Kiaka, Burkina Faso (2011 – 2013) – project manager and primary author of PFS and FS ARDML assessments of waste rock, tailings and low-grade ore.
- Gemfield, Nevada (2011 - 2014) - sample collection, data assessment and reporting as part of the waste rock characterisation study.
- Gold Bar, Nevada (2011 – 2014) - involved in completing the field sampling exercise and waste rock characterisation report for ARDML and mineralogical assessment of waste rock.
- Karchiga, Kazakhstan (2011 – 2012) – feasibility study ARDML assessment, involving sample collection and the co-ordination of the static and kinetic laboratory testwork programmes for characterisation of waste rock and tailings.
- Thar Block VI, Pakistan (2011 – 2012) – geochemical and mineralogical characterisation study of waste rock and coal. Responsible for co-ordinating sample collection and implementation of static and kinetic geochemical laboratory testwork programmes.
- Bozshakol, Kazakhstan (2011) - assessment of the ARDML potential of waste rock from the Bozshakol copper-gold porphyry deposit.
- Hannukainen, Finland (2011) – involved in reporting, budgeting and sample selection for ARDML and mineralogical assessment of waste rock from the Hannukainen IOCG deposit.
- Copper Flat, New Mexico (2010 – present) – pre-feasibility waste rock and tailings characterisation program, including field sampling, data assessment and reporting.

Also involved geochemical predictions of future water quality associated with the mine facilities (pit lake, waste rock disposal facility and tailings facility).

- Kaplan, Turkey (2010 - 2012) - ARDML assessment of waste rock and predictive geochemical modelling to assess potential pit lake and waste rock dump run-off and seepage water quality. Involved arranging sample analysis and co-ordination with contract laboratories.
- Reko Diq, Pakistan (2010) – involved in the completion of a geochemical characterisation study to assess the ARDML potential of waste rock and tailings from a copper porphyry deposit.
- Malmbjerg, Greenland (2010) – completion of a geochemical assessment to determine the ARDML potential of waste rock from a climax-type molybdenum deposit.

Key Project Experience: Geochemical modelling

- Stibnite, Idaho (2015 – present) – site-wide predictive geochemical modelling of surface water and groundwater associated with the waste rock dumps, tailings storage facility, pit lakes and backfilled pit.
- Long Canyon, Nevada (2014 - present) – predictive modelling of waste rock dump seepage and pit wall run-off/pit lake chemistry to support project permitting.
- Round Mountain, Nevada (2015 - 2017) – predictive geochemical modelling of future pit lake chemistry to support project permitting.
- Copper Flat, New Mexico (2012 – present) - predictive modelling of future potential water quality associated with the waste rock dump, tailings storage facility and pit lake, undertaken in support of permitting.
- Round Mountain, Nevada (2014) – predictive geochemical modelling carried out to support the design and construction of a new tailings cell.
- Coeur Rochester, Nevada (2014 – 2015) – modelling assessment of management options for potentially acid generating waste rock.
- Gemfield, Nevada (2014 - present) – predictive modelling of future pit lake chemistry, including assessment of alternatives.
- Kiaka, Burkina Faso (2013) – predictive modelling carried out as part of the Feasibility Study to assess run-off and seepage water quality for the ore stockpiles, tailings storage facility and waste rock dumps during life of mine and post closure.
- Daisy project, Nevada (2013) – predictive modelling carried out as part of closure planning to assess groundwater chemistry below the evapo-transpiration cell.
- Oromin Joint Venture Group, Senegal (2011) – PHREEQC predictions to assess whether evaporative process will increase salinity in a freshwater reservoir.
- Hycroft, Nevada (2011) – use of PREEQC to predict waste rock dump seepage and run-off water quality.
- Karchiga, Kazakhstan (2011) – application of predictive geochemical modelling to assess liner requirements for the waste rock dump and tailings storage facility.
- Turquoise Ridge Joint Venture, Nevada (2010 - 2011) – application of geochemical predictive modelling to determine cover requirements for the backfilled pits. Fate and transport modelling also undertaken to determine implications of leachate/groundwater interactions.

Key Project Experience: Soils geochemistry

- Tasiast Sud, Mauritania (2015) - completion of a soil baseline soil study to assess existing soil chemical and physical conditions as part of the project ESIA.
- Gemfield, Nevada (2014) – completion of a Rotasonic drill program, field sampling and XRF analysis and to delineate constituent migration from historic tailings material.
- Suralco Project Sites, Suriname (2012) – technical lead for the design and implementation of a soil characterisation study carried out in support of mine closure planning. Involved training of on-site technicians and interaction with government agencies.
- Comstock, Nevada (2012) – statistical analysis of soil and ore geochemistry data to assess the relationship of mercury, lead and arsenic in the South Comstock mineral district.
- Marampa, Sierra Leone (2011 - 2012) – completion of a soil and geomorphology baseline soil study to assess soil and sediment chemistry at the mine site for the Marampa iron ore project.
- Kiaka, Burkina Faso (2011) – completion of a soil and geomorphology baseline soil study to assess soil and sediment chemistry at the mine site for the Kiaka gold project.
- Reko Diq, Pakistan (2010) – completion of baseline soils physical and geochemical investigation of mine site and transport corridors for the Reko Diq copper porphyry deposit.
- Zanaga, Republic of Congo (2010) – completion of a baseline soil characterisation study to assess soil and sediment chemistry for the Zanaga iron ore deposit.

Key Project Experience: Hydrochemistry

- Manhattan Pit Lake Study, USA (2015) – review of historic geochemical and hydrologic data to assess effect of dewatering activities from neighbouring site.
- Confidential project, USA (2014 - 2015) – assessment of natural attenuation of antimony to assist with defining acceptable performance criteria for discharge.
- Suralco, Suriname (2011 – 2015) – co-ordinated the design and implementation of a pit lake, surface water and groundwater characterisation study as part of mine closure planning. Developed site-specific water quality objectives for long-term water quality monitoring.
- Kiaka, Burkina Faso (2011 - 2012) – involved in the day-to-day management of 12-month water baseline monitoring program and laboratory testwork program. Involved consultation with local, in-country consultants to ensure timely completion of baseline study.
- Sintoukola, Republic of Congo (2012 – 2013) – co-author of the baseline water quality study, which included as assessment of baseline surface water and groundwater quality.
- Goldstrike, Nevada (2011) – compilation and statistical analysis of surface- and groundwater data to assess controls on arsenic geochemistry at the Goldstrike gold mine.
- Reko Diq, Pakistan (2010) – co-author of the baseline water quality study, which included hydrochemical assessment of baseline groundwater quality.

- Zanaga, Republic of Congo (2010) – assisted in the quarterly reporting of baseline surface- and groundwater monitoring at the Zanaga iron ore project.
- Dusel Steel (2010) – assessment of groundwater chemistry and the potential for steel corrosion and scaling in a flooded mine shaft.

Key Project Experience: Closure

- AMAK, Saudi Arabia (2016) – co-ordinated the conceptual closure assessment and costing for the Al Masane operations.
- Los Filos, Mexico (2016 – 2017) – conducted a geochemical characterisation assessment for closure of the waste rock dumps, heap leach pads and underground operations.
- Suralco, Suriname (2011 – 2015) – co-ordinated the design and implementation of a pit lake, surface water, groundwater and soil characterisation study as part of mine closure planning. Developed site-specific water quality objectives for long-term water quality monitoring.

Publications (under maiden name of Warrender):

- **Warrender, R.**, Prestia, A., Bowell, R., Brough, C., Donkervoort, L. and Dixon, J. (2018). Environmental Geochemistry of the Round Mountain Gold Mine and Mineralogical Controls on Acid Generation. Society of Economic Geologists Special Edition on the Environmental Geology and Geochemistry of Mining and Mineral Deposits, manuscript submitted.
- Donkervoort, L., Prestia, A., **Warrender, R.**, Bowell, R., Fallowfield, K. and Barr, M. (2018). Environmental Geology of Barite Deposits in Nevada. Society of Economic Geologists Special Edition on the Environmental Geology and Geochemistry of Mining and Mineral Deposits, manuscript submitted.
- Charles, J., Barnes, A., Bowell, R., Brough, C., **Warrender, R.**, Declercq, J. (2018). Environmental Geochemistry of Sulfide Bearing Iron Oxide Deposits in Scandinavia. Society of Economic Geologists Special Edition on the Environmental Geology and Geochemistry of Mining and Mineral Deposits, manuscript submitted.
- Declercq, J., Charles, J., Bowell, R., **Warrender, R.**, and Barnes, A. (2017). Comparison of thermodynamic equilibrium and kinetic approach in the predictive evaluation of waste rock seepage quality in Northern Finland. In: Wolkersdorfer, C.; Sartz, L.; Sillanpää, M. & Häkkinen, A.: Mine Water & Circular Economy (Vol I). – p. 664 – 672; Lappeenranta, Finland (Lappeenranta University of Technology).
- Declercq, J., Charles, J., Bowell, R., **Warrender, R.** and Barnes, A. (2017). Comparison of thermodynamic equilibrium and kinetic approach in the predictive evaluation of waste rock seepage quality in Northern Finland. In Conference Proceedings – IMWA 2017
- Charles J., Declercq J., Bowell R., Barnes A., and **Warrender R.** (2016). Prediction of Source Term Leachate Quality from Waste Rock Dumps: A Case Study from an Iron Ore Deposit in Northern Sweden. In Proceedings of the International Mine Water Association 2016.
- Brough, C., Strongman, J., Bowell, R., **Warrender, R.**, Prestia, A., Barnes, A. and Fletcher, J. (2016). Automated Environmental Mineralogy: The Use of Liberation Analysis in Humidity Cell Testwork, Minerals Engineering 107, pp112-122

- Bowell, R., Declercq, J., **Warrender, R.**, Prestia, A., Parshley, J., and Barber, J. (2016). Geochemical Prediction of Arsenic Attenuation from Infiltrated Heap Leach Drainage, Daisy Mine, Nevada. *Geochemistry, Exploration, Environment, Analysis*, in press.
- Tait, D. and **Warrender, R.** (2015). Using Water Monitoring Data Wisely, *Mining Magazine*, July 2015
- Brough, C., **Warrender, R.**, Dey, M. (2015). Optimising Mine Waste Geochemical Assessments, *Mining Magazine*, April 2015
- Barnes A., Bowell R., **Warrender R.**, Sapsford D., Sexsmith K., Charles J., Declercq J., Santonastaso M. and Dey B. (2015). Comparison between long-term Humidity Cell testing and static Net Acid Generation (NAG) tests: Potential for NAG use in preliminary mine site water quality predictions. In *Proceedings of the 10th International Conference on Acid Rock drainage*.
- Charles, J.C., Barnes, A., Declercq, J., **Warrender, R.**, Brough, C. and Bowell, R.J. (2015). April. Difficulties of interpretation of NAG test results on net neutralizing mine wastes: initial observations of elevated pH conditions and theory of CO₂ disequilibrium. In *Proceedings of the 10th International Conference on Acid Rock Drainage and IMWA Annual Conference*.
- Brough, C., **Warrender, R.**, Bowell, R., Barnes, A. and Parbhakar-Fox, A. (2013). The process mineralogy of mine wastes. *Minerals Engineering* 52, pp125-135
- **Warrender, R.**, Bowell, R., Prestia, A., Barnes, A., Mansanares, W. and Miller, M. (2012). The application of predictive geochemical modelling to determine backfill requirements at Turquoise Ridge Joint Venture, Nevada. *Geochemistry, Exploration, Environment, Analysis* 12, pp339-347
- Bowell, R.J., Rees, S., Barnes, A., Prestia, A., **Warrender, R.** and Dey, M. (2013). Geochemical assessment of arsenic toxicity in mine site along the proposed Mineral Tramway Project, Camborne, Cornwall. *Geochemistry, Exploration, Environment, Analysis* 13(2), pp145-157
- Prestia, A., Bowell, R., **Warrender, R.**, Barnes, A and Lassiter, D. (2013). Environmental Geochemistry of the Hycroft Mine: A case study on the limitation of Sobek style acid generation predictions. *Geochemistry, Exploration, Environment, Analysis* 13, pp171-182
- **Warrender, R.**, Pearce, N., Perkins, W., Florence, K., Brown, A., Sapsford, D., Bowell, R.J., and Dey, M. (2011). Field trials of low-cost reactive media for the passive treatment of circum-neutral metal mine drainage in mid-Wales, UK. *Mine Water and the Environment* 30(2), pp82-89. From issue entitled 'Special Issue: Mine Water and Innovative Thinking – Invited articles based on the best papers at the 2010 IMWA Symposium'
- **Warrender, R.**, Pearce, N., Perkins, W., Florence, K., Brown, A., Sapsford, D., Bowell, R., and Dey, M. (2010). Field trials of low-cost reactive media for the passive treatment of circum-neutral metal mine drainage in mid-Wales, UK. In: C. Wolkersdorfer and A. Freund (eds): *Mine Water & Innovative Thinking*, pp. 291 – 295; Sydney, Nova Scotia (CBU Press).
- **Warrender, R.** and Pearce, N. (2007). Remediation of circum-neutral, low-iron waters by permeable reactive media. *Water in Mining Environments*, R. Cidu and F. Frau (eds). p289-294. IMWA Symposium, 2007, Cagliari, Sardinia.

Conference Presentations:

- Keynote speaker, 12th Finnish Geochemistry Days Workshop, Turku, Finland, April 2016: '*Navigating the Jungle of Best Practices in Mine Waste Characterisation*'
- EU Workshop on Best Practices on Mining Policies and Technologies, Brussels, October 2015: '*Mine Waste Management – Best Practice Examples*'
- EU Workshop on Best Practices on Mining Policies and Technologies, Brussels, October 2015: '*Mine Waste Management – A Global Perspective*'

- International Applied Geochemistry Symposium, Tucson AZ, April 2015: *'The Importance of Mineralogy in Mine Pit Lake Water Quality Predictions'*
- International Applied Geochemistry Symposium, Tucson AZ, April 2015: Workshop presenter - *'Environmental Applications of Portable XRF'*
- Mine Closure, Eden Project UK, September 2013: *'Defining an Approach for Contaminated Land Management in the Historic Comstock Mining District, Nevada, USA'*
- International Applied Geochemistry Symposium, Rovaniemi Finland, August 2011: *'The Application of Geochemical Modelling to Determine Backfill Cover Requirements at Turquoise Ridge Joint Venture, Nevada'*
- Frontiers in Environmental Geoscience, Aberystwyth, June 2011: *'Field Trials of Low-Cost / Waste Materials for Passive Treatment of Metal Mine Drainage in Mid-Wales, UK'*
- International Mine Water Association Symposium, Nova Scotia, September 2010: *'Field trials for passive treatment of circum-neutral metal mine drainage in mid Wales, UK'*
- International Mine Water Association Symposium, Cagliari, May 2007: *'Remediation of circum-neutral, low-iron waters by permeable reactive media'*
- Mineralogical Society Research in Progress Meetings, 2008 (London), 2007 (Manchester) and 2006 (London)