Adding value to exploration and the mining environment with isotopes

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Isotopes in exploration

Elemental geochemistry has proven invaluable in exploring for undercover ore deposits using a multitude of surface media. The anomalous concentrations of metals and compounds in ore deposits will disperse with geologic time and may result in slight aberrations in the normal background levels in the environs of the deposit. The challenge in exploration geochemistry is in finding those particular elements that reflect this process when the ore deposits reside at some depth below the surface. Most elements of interest have more than one isotope whose ratios can provide the most sensitive and precise way to fingerprint the source of an element, even though the concentration may not differ from backgroud.

The use of isotopes as definitive tracers of the origin of an element is exemplified by radiogenic Pb that has migrated from uranium deposits and non-radiogenic Pb that has migrated from VHMS deposits. The $^{207}Pb/^{206}Pb$ ratios in permeable sandstones, along unconformities or in fractures of cemented lithologies several kms from known sandstone-hosted uranium mineralization are aberrantly low and unsupported by co-existing U. This indicates that radiogenic Pb was introduced from the deposits post-mineralization. Similar results are evident using H, Li, C, N and U isotopes from U deposits. Similarly, low $^{206}Pb/^{204}Pb$ ratios in soils and vegetation above VHMS deposits at depth discriminate mineralized bodies buried ca. 100m below cover from background signals. S, Cu and Zn isotopes have the same response, despite surface media over the deposits and the background having similar elemental concentrations.

Carbon, N, O and S isotopic compositions in conjunction with elemental concentrations differentiate the least-altered from moderately-altered rocks as well as the specific geochemical alteration associated with the ore stage. Isotopic compositions and trace elements of these fluids are recorded in the ores and concomitant alteration and can be used to guide exploration at both regional and local scales.

Use of isotopes in the mining environment

As in exploration, isotopes can be used in the mining environment to fingerprint the origin of elements. For example, explosives used in mining and residual sulfides are potential sources of nitrate and sulfate pollution in the environs mines in S. Africa and Chile. However, isotopes of B, C, N and S indicate that the mine sites contribute only minor amounts of these compounds to the environment, but anthropogenic and agricultural sources of nitrate and sulfates are substantial. Similarly, the isotopic compositions of Cu, Zn and Pb are distinct from mining and anthropogenic activities on local, regional and even global scales.

Conclusion

Isotopes can add value to exploration for all types of ore deposits and provide new avenues to move up learning curves for both effective exploration and targeting of remediation strategies for mining.