Supplementary Material

Supplementary figures

Figure S1. Petrography of the arsenopyrite-bearing replacement-style hydrothermal alteration and mineralization from the Cochenour mine complex, Red Lake district, Canada. PPL (a), BSE (b), and RL (c) images of the hydrothermally altered Balmer basalt located outside of the zone of mineralization. Biotite is chloritized (a-b) and chlorite is sericitized (b). A veinlet of tourmaline is surrounded by quartz, biotite, chlorite, and white mica (b). Sulfide globules consisting of pyrrhotite and chalcopyrite are partly corroded (c). XPL (d-e), and RL (f) microphotographs of mineralized samples. A veinlet of carbonate-quartz-white mica is surrounded by quartz, white mica, arsenopyrite, biotite, and quartz (d). The white rectangle in (d) represents the area used for the laser ablation ICP-MS map (see Fig. 5). A blow up of the quartz-white mica alteration with adjacent sulfide globules and arsenopyrite is shown in ©. A partly corroded sulfide globule is replaced with arsenopyrite in (f). Asp arsenopyrite; BSE back scattered electron image (scanning electron microscope); Bt biotite; Chl chlorite; Cpy chalcopyrite; Po pyrrhotite; PPL plane-polarized light; Qz quartz; RL reflected light; SG sulfide globule; Tur tourmaline; WM white mica; XPL crossed polars light.

Figure S2. Petrography of the quartz-actinolite vein-style hydrothermal alteration and mineralization from the Cochenour mine complex, Red Lake district, Canada. XPL (a-b) and B©(c) images of the hydrothermally altered basalt located outside of the zone of mineralization. Mildly chloritized biotite is interspersed with a mixture of epidote-albite-quartz, and cut by veinlets of quartz-carbonate-sulfides (a). Former ferromagnesian silicate minerals are altered to a mixture of actinolite, epidote, carbonate, quartz, and biotite, and surrounded by biotite, chlorite, actinolite, and epidote (b-c). Sulfide globules consisting of pyrrhotite and chalcopyrite are partly corroded. XPL (d) and PPL (e-f) photomicrographs of the mineralized samples. Outside of the quartz veins, the basalt is intensely pervasively altered to quartz and actinolite, with minor amounts of epidote and white mica (d-f). In some areas, the hydrothermal alteration is dominated by quartz and white mica (f). Ab albite; Act actinolite; BSE back scattered electron image (scanning electron microscope); Bt biotite; Cal calcite; Chl chlorite; Ep epidote; FM ferromagnesian silicate mineral; Po pyrrhotite; PPL plane-polarized light; Py pyrite; Qz quartz; Ser ‘sericite’ (white mica); SG sulfide globule; XPL crossed polars light.

Figure S3. Optical photomicrographs (a-d) and laser ablation ICP-MS maps (labeled with analyzed elements) showing the mineralogy/textural relationships and the distribution of major/trace element concentrations in the barren-, replacement-style hydrothermal alteration, at the Cochenour mine complex, Red Lake district, Canada. (a,d) PPL; (b) XPL; (c) RL. The inset rectangles in (a-c) depict the area shown in (d) which was mapped using laser ablation ICP-MS (LA-ICP-MS). The LA-ICP-MS maps are color-coded according to the concentration of selected major/trace elements in ppm. Chl chlorite; Chl-Cr Cr-rich chlorite; Cpy chalcopyrite; Po pyrrhotite; PPL plane-polarized light; RL reflected light; Ser-Chl sericitized chlorite; Ttn titanite; WM white mica; XPL crossed-polarized light. Sample 18RL-165.

Figure S4. Optical photomicrographs (a-d) and laser ablation ICP-MS maps (labeled with analyzed elements) showing the mineralogy/textural relationships and the distribution of major/trace element concentrations in the mineralized replacement-style hydrothermal alteration, at the Cochenour mine complex, Red Lake district, Canada. (a,d) PPL; (b) XPL; (c) RL. The inset rectangles in (a-c) depict the area shown in (d) which was mapped using laser ablation ICP-MS (LA-ICP-MS). The LA-ICP-MS maps are color-coded according to the concentration of selected major/trace elements in ppm. Asp arsenopyrite; Bt biotite; Cal calcite; Chl chlorite; Cpy chalcopyrite; Po pyrrhotite; PPL plane-polarized light; Qz quartz; RL reflected light; WM white mica; XPL crossed-polarized light. Sample 18RL-207.

Figure S5. Optical photomicrographs (a-d) and laser ablation ICP-MS maps (labeled with analyzed elements) showing the mineralogy/textural relationships and the distribution of major/trace element concentrations in the barren-, quartz-actinolite vein-style hydrothermal alteration, at the Cochenour mine complex, Red Lake district, Canada. (a,d) PPL; (b) XPL; (c) RL. The inset rectangles in (a-c) depict the area shown in (d) which was mapped using laser ablation ICP-MS (LA-ICP-MS). The LA-ICP-MS maps are color-coded according to the concentration of selected major/trace elements in ppm. Ab albite; Bt biotite; Cal calcite; Ep epidote; Po pyrrhotite; PPL plane-polarized light; Py pyrite; Qz quartz; RL reflected light; XPL crossed-polarized light. Sample 18RL-320.

Figure S6. Optical photomicrographs (a-d) and laser ablation ICP-MS maps (labeled with analyzed elements) showing the mineralogy/textural relationships and the distribution of major/trace element concentrations in the mineralized part of the quartz-actinolite hydrothermal alteration, at the Cochenour mine complex, Red Lake district, Canada. (a,d) PPL; (b) XPL; (c) RL. The inset rectangles in (a-c) depict the area shown in (d) which was mapped using laser ablation ICP-MS (LA-ICP-MS). The LA-ICP-MS maps are color-coded according to the concentration of selected major/trace elements in ppm. Act actinolite; Ap apatite; Au native gold; Cpy chalcopyrite; Chl chlorite; Ep epidote.

Fig. S7. Variation in modeled bulk rock δ7Li values over distance, as a result of varying mineral Li concentrations and isotopic ratios, for the replacement-style alteration and mineralization. Mineral proportions are fixed (Fig. 12b). Measured (analyzed) values are in red circles and modeled values are in empty circles. When not visible, the 2σ SD error bars for the measured δ7Li values are smaller than the symbols. Bt biotite, Chl chlorite, WM white micas.

Fig. S8. Variation in modeled bulk rock δ7Li values over distance, as a result of varying mineral proportions, for the replacement-style alteration and mineralization. Mineral proportions vary over ±50 % of the values originating from the regression curves (Fig. 12b), which are also those of the best fit (Fig. 13a). Mineral Li concentrations and isotopic ratios are fixed, and are also those of the best fit. Measured (analyzed) values are in red circles and modeled values are in empty circles. When not visible, the 2σ SD error bars for the measured δ7Li values are smaller than the symbols. Bt biotite, Chl chlorite, WM white micas.

Fig. S9. Variation in modeled bulk rock δ7Li values over distance, as a result of varying mineral Li concentrations and isotopic ratios, for the quartz-actinolite vein-style alteration and mineralization. Mineral proportions are fixed, and are those that were observed and measured (Table 1). Measured (analyzed) values are in blue circles and modeled values are in empty circles. When not visible, the 2σ SD error bars for the measured δ7Li values are smaller than the symbols. The scales of the y axes have been kept as in Fig. 12 to avoid any confusion. Bt biotite, Chl chlorite, Qz quartz.

Fig. S10. Variation in modeled bulk rock δ7Li values over distance, as a result of varying mineral proportions, for the quartz-actinolite vein-style alteration and mineralization. Mineral proportions vary over ±50 % of the observed (measured) values, which are also those of the best fit (Fig. 13b). Mineral Li concentrations and isotopic ratios are fixed, and are also those of the best fit. Measured (analyzed) values are in blue circles and modeled values are in empty circles. When not visible, the 2σ SD error bars for the measured δ7Li values are smaller than the symbols. The scales of the y axes have been kept as in Fig. 12 to avoid any confusion. Bt biotite, Chl chlorite, Qz quartz white micas.

Figure S11. Binary plots showing the correlation and R2 values of Li with Ti, Cr, and V in hydrothermally altered basalts from the Cochenour mine complex, Red Lake district, Canada.

Supplementary tables

Table S1. Complete trace element composition of hydrothermally altered basalts from the Cochenour mine complex, Red Lake district, Canada. MLD minimum limit of detection.

Table S2. Analytical accuracies and limits of detections for laser ablation ICP-MS major/trace element concentration maps, based on the analysis of NIST610 standard and comparison with accepted values. The limits of detections are given in ppm for the elemental forms of the analytes (K not K2O) whereas the accuracies are given for the oxide forms of the analytes when the analytes are indicated as oxides (K2O not K; Ti not TiO2).