**PROOF OF URANYL DEPOSITION IN UNCONFORMITY-RELATED URANIUM DEPOSITS, ATHABASCA BASIN, CANADA: EVIDENCE FROM SYNCHROTRON XAS AND XPS ANALYSES OF HEMATITE**

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**SUPPLEMENTARY DATA**

This document contains a total of 6 figures and 13 tables.

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Fig. S1. Powder XRD patterns of the original sandstone sample DDH2217-77 containing approximately 3% hematite (middle panel) and hematite separates of low crystallinity from sample DDH2217-77 (upper panel), in comparison witha reference hematite (R110013; bottom panel). Q denotes quartz, H: hematite, and C: chlorite.

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Fig. S2. Plots of UO3 versus various element oxide (Al2O3, MgO, MnO, TiO2, ThO2, and ZrO2) concentrations (wt.%) in uraniferous hematite (data from Tables S1-S11).

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Fig. S3. (a) Reflected-light photomicrograph of an area in sample H737-58 showing hematite inclusions (H3) in quartz overgrowth (Q2) along the margin of a detrital quartz (Qtz); (b-d) μSXRF maps of Fe, U, and Ca in the 100 μm × 100 μm region outlined in (a). The intensities of the elements are scaled from low (blue) to high (red). Note the occurrences of elevated Ca signals in all parts of the quartz overgrowths, while the U hot spots are not associated with the Fe hot spots.

A collage of images of different colors

Description automatically generatedFig. S4. (a) Reflected-light photomicrograph of an area containing disseminated hematite (Hm) in the clay mineral matrix in sample H737-58; (b-d) μSXRF maps of Fe, U, and Mn in the 100 μm × 100 μm region outlined in (a). The intensities of the elements are scaled from low (blue) to high (red).

Fig. S5.**A graph of a graph of energy

Description automatically generated** Representative μSXRF spectra of four uranium-hot spots in samples H737-58 and MAC142-524.9: the uppermost spectrum without visible Ca signals measured on the hematite inclusion (H737-58i) shown in Figure 5; the upper middle spectrum with pronounced Ca signals measured on the hematite inclusion shown in Figure S3; the lower middle spectrum measured on disseminated hematite in the illite-rich matrix (H737-58m) in Figure S4; and the bottom spectrum measured on a hematite inclusion in sample MAC142-524.9i shown in Figure 6.

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Fig. S6. Plot of U Lα1 versus Fe Kα1 intensities measured by µSXRF in the area outlined *in* Figure 6a.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
| Fe2O3(wt.%) | 96.1 | 96.7 | 97.2 | 98.1 | 97.3 | 97.4 | 97.2 | 96.9 | 98.1 | 97.7 | 97.3±0.6 |
| Al2O3 | 0.08 | 0.08 | 0.05 | 0.04 | 0.02 | 0.06 | 0.08 | 0.09 | 0.11 | 0.09 | 0.07±0.01 |
| UO3 | 1.86 | 1.13 | 1.46 | 0.32 | 1.07 | 0.58 | 1.44 | 1.75 | 0.32 | 0.76 | 1.07±0.56 |
| SiO2 | 0.04 | 0.05 | 0.03 | 0.02 | 0.11 | 0.02 | 0.06 | 0.05 | 0.02 | 0.01 | 0.04±0.02 |
| ThO2 | 0.05 | 0.03 | 0.02 | 0.07 | 0.02 | 0.05 | 0.01 | 0.02 | 0.08 | 0.01 | 0.04±0.03 |
| TiO2 | 0.31 | 0.26 | 0.42 | 0.29 | 0.32 | 0.27 | 0.28 | 0.35 | 0.19 | 0.18 | 0.29±0.09 |
| ZrO2 | 0.04 | 0.06 | 0.04 | 0.04 | 0.05 | 0.04 | 0.06 | 0.05 | 0.02 | 0.06 | 0.05±0.01 |
| V2O3 | 0.05 | 0.02 | 0.02 | 0.06 | 0.06 | 0.04 | 0.03 | 0.02 | 0.01 | 0.05 | 0.04±0.01 |
| Cr2O3 | 0.04 | 0.04 | 0.02 | 0.01 | 0.04 | 0.02 | 0.03 | 0.01 | 0.01 | 0.02 | 0.02±0.01 |
| Y2O3 | 0.07 | 0.08 | 0.03 | 0.03 | 0.04 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.03±0.01 |
| MgO | 0.11 | 0.18 | 0.15 | 0.17 | 0.14 | 0.17 | 0.09 | 0.16 | 0.13 | 0.18 | 0.15±0.05 |
| MnO | 0.06 | 0.09 | 0.06 | 0.09 | 0.05 | 0.08 | 0.04 | 0.11 | 0.04 | 0.11 | 0.07±0.04 |
| CoO | 0.08 | 0.11 | 0.09 | 0.11 | 0.09 | 0.07 | 0.11 | 0.09 | 0.08 | 0.07 | 0.09±0.01 |
| Total | 98.9 | 98.8 | 99.6 | 99.4 | 99.3 | 98.8 | 99.5 | 99.6 | 99.1 | 99.3 | 99.2±0.3 |

TABLE S1. COMPOSITION OF DISSEMINATED HEMATITE IN MINERALIZED SANDSTONE FROM THE KEY LAKE MINE (SAMPLE DDH2217-71).

\*Note that the total Fe and U contents are reported as Fe2O3 and UO3, respectively.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
| Fe2O3(wt.%) | 96.2 | 97.1 | 96.6 | 98.1 | 98.3 | 98.2 | 98.3 | 98.1 | 97.9 | 97.7 | 97.7±0.8 |
| Al2O3 | 0.13 | 0.16 | 0.41 | 0.12 | 0.11 | 0.13 | 0.19 | 0.16 | 0.12 | 0.11 | 0.16±0.09 |
| UO3 | 1.56 | 1.44 | 1.78 | 0.78 | 0.26 | 0.44 | 0.82 | 0.97 | 1.01 | 1.11 | 1.02±0.48 |
| SiO2 | 0.05 | 0.07 | 0.05 | 0.04 | 0.05 | 0.05 | 0.05 | 0.06 | 0.01 | 0.03 | 0.05±0.02 |
| ThO2 | 0.03 | 0.04 | 0.03 | 0.06 | 0.05 | 0.04 | 0.03 | 0.11 | 0.06 | 0.03 | 0.05±0.02 |
| TiO2 | 1.05 | 0.76 | 0.77 | 0.54 | 0.53 | 0.47 | 0.46 | 0.38 | 0.45 | 0.25 | 0.57±0.23 |
| ZrO2 | 0.06 | 0.03 | 0.04 | 0.02 | 0.05 | 0.05 | 0.05 | 0.04 | 0.02 | 0.08 | 0.04±0.02 |
| V2O3 | 0.01 | 0.03 | 0.05 | 0.33 | 0.06 | 0.04 | 0.10 | 0.16 | 0.07 | 0.05 | 0.09±0.09 |
| Cr2O3 | 0.21 | 0.11 | 0.07 | 0.08 | 0.05 | 0.03 | 0.04 | 0.04 | 0.05 | 0.04 | 0.07±0.05 |
| Y2O3 | 0.00 | 0.01 | 0.00 | 0.02 | 0.01 | 0.03 | 0.04 | 0.01 | 0.01 | 0.00 | 0.01±0.01 |
| MgO | 0.42 | 0.23 | 0.33 | 0.21 | 0.22 | 0.41 | 0.11 | 0.23 | 0.22 | 0.31 | 0.27±0.10 |
| MnO | 0.29 | 0.08 | 0.06 | 0.02 | 0.08 | 0.07 | 0.13 | 0.15 | 0.22 | 0.21 | 0.13±0.09 |
| CoO | 0,06 | 0.04 | 0.05 | 0.06 | 0.03 | 0.05 | 0.13 | 0.05 | 0.07 | 0.05 | 0.05±0.03 |
| Total | 100.0 | 100.1 | 100.2 | 100.4 | 99.8 | 100.0 | 100.5 | 100.5 | 100.2 | 100.0 | 100.2±0.2 |

TABLE S2. COMPOSITION OF DISSEMINATED HEMATITE IN “BARREN” SANDSTONE FROM THE KEY LAKE MINE (SAMPLE DDH2217-77).

\*Note that the total Fe and U contents are reported as Fe2O3 and UO3, respectively. Note that the term “barren” is often used to describe these samples having only “background” levels of radioactivity when they are measured by hand-held Geiger counters.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
| Fe2O3(wt.%) | 96.5 | 96.4 | 96.8 | 98.1 | 97.1 | 97.6 | 97.7 | 97.2 | 97.4 | 97.6 | 97.2±0.6 |
| Al2O3 | 0.11 | 0.12 | 0.16 | 0.12 | 0.15 | 0.09 | 0.12 | 0.15 | 0.14 | 0.15 | 0.13±0.02 |
| UO3 | 2.16 | 1.98 | 1.35 | 0.43 | 1.75 | 1.32 | 0.94 | 1.56 | 1.32 | 1.34 | 1.42±0.50 |
| SiO2 | 0.05 | 0.02 | 0.05 | 0.06 | 0.06 | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 | 0.04±0.02 |
| ThO2 | 0.04 | 0.02 | 0.04 | 0.05 | 0.06 | 0.02 | 0.06 | 0.05 | 0.03 | 0.02 | 0.04±0.02 |
| TiO2 | 0.16 | 0.12 | 0.23 | 0.24 | 0.22 | 0.09 | 0.26 | 0.21 | 0.22 | 0.12 | 0.19±0.06 |
| ZrO2 | 0.02 | 0.03 | 0.01 | 0.03 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 | 0.02±0.01 |
| V2O3 | 0.13 | 0.16 | 0.06 | 0.11 | 0.13 | 0.11 | 0.16 | 0.11 | 0.09 | 0.11 | 0.12±0.03 |
| Cr2O3 | 0.02 | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02±0.01 |
| Y2O3 | 0.02 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02±0.01 |
| MgO | 0.12 | 0.16 | 0.22 | 0.15 | 0.15 | 0.11 | 0.15 | 0.14 | 0.13 | 0.12 | 0.15±0.03 |
| MnO | 0.11 | 0.11 | 0.12 | 0.09 | 0.1 | 0.09 | 0.11 | 0.06 | 0.08 | 0.07 | 0.09±0.02 |
| CoO | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01±0.01 |
| Total | 99.5 | 99.2 | 99.1 | 99.4 | 99.8 | 99.5 | 99.6 | 99.6 | 99.5 | 99.6 | 99.5±0.2 |

TABLE S3. COMPOSITION OF HEMATITE INCLUSIONS IN Q2 OVERGROWTHS IN ALTERED SANDSTONE FROM THE CIGAR LAKE MINE (SAMPLE WDG1-140-411).

\*Note that the total Fe and U contents are reported as Fe2O3 and UO3, respectively.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
| Fe2O3(wt.%) | 96.5 | 97.3 | 98.1 | 98.1 | 97.4 | 97.4 | 97.4 | 96.7 | 97.6 | 97.4 | 97.4±0.5 |
| Al2O3 | 0.16 | 0.15 | 0.11 | 0.13 | 0.12 | 0.11 | 0.09 | 0.18 | 0.09 | 0.15 | 0.13±0.02 |
| UO3 | 1.74 | 1.52 | 0.48 | 0.78 | 1.65 | 1.36 | 1.44 | 1.83 | 1.26 | 1.56 | 1.36±0.43 |
| SiO2 | 0.03 | 0.04 | 0.03 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02±0.01 |
| ThO2 | 0.03 | 0.04 | 0.04 | 0.02 | 0.04 | 0.01 | 0.01 | 0.02 | 0.02 | 0.04 | 0.03±0.01 |
| TiO2 | 0.21 | 0.33 | 0.32 | 0.18 | 0.22 | 0.15 | 0.17 | 0.16 | 0.14 | 0.22 | 0.21±0.07 |
| ZrO2 | 0.02 | 0.02 | 0.04 | 0.04 | 0.02 | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03±0.01 |
| V2O3 | 0.02 | 0.01 | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.02±0.01 |
| Cr2O3 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 | 0.01 | 0.05 | 0.02 | 0.02±0.01 |
| Y2O3 | 0.02 | 0.01 | 0.03 | 0.1 | 0.02 | 0.02 | 0.03 | 0.01 | 0.03 | 0.03 | 0.03±0.01 |
| MgO | 0.21 | 0.19 | 0.22 | 0.15 | 0.16 | 0.13 | 0.16 | 0.21 | 0.15 | 0.14 | 0.17±0.03 |
| MnO | 0.13 | 0.05 | 0.09 | 0.07 | 0.09 | 0.08 | 0.08 | 0.05 | 0.08 | 0.1 | 0.08±0.02 |
| CoO | 0.11 | 0.09 | 0.12 | 0.08 | 0.12 | 0.1 | 0.09 | 0.08 | 0.11 | 0.08 | 0.10±0.02 |
| Total | 99.2 | 99.8 | 99.6 | 99.7 | 99.9 | 99.5 | 99.6 | 99.3 | 99.6 | 99.8 | 99.5±0.2 |

TABLE S4. COMPOSITION OF HEMATITE INCLUSIONS IN Q2 OVERGROWTH IN MINERALIZED SANDSTONE FROM THE CIGAR LAKE MINE (WDG1-185-441).

\*Note that the total Fe and U contents are reported as Fe2O3 and UO3, respectively.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
| Fe2O3(wt.%) | 95.6 | 96.3 | 96.1 | 96.8 | 95.3 | 97.2 | 97.3 | 96.1 | 96.9 | 96.2 | 96.4±0.6 |
| Al2O3 | 0.16 | 0.11 | 0.26 | 0.09 | 0.21 | 0.08 | 0.06 | 0.22 | 0.33 | 0.22 | 0.17±0.09 |
| UO3 | 2.16 | 1.98 | 1.78 | 1.28 | 1.86 | 0.88 | 0.99 | 1.72 | 1.23 | 1.33 | 1.52±0.39 |
| SiO2 | 0.11 | 0.05 | 0.05 | 0.09 | 0.11 | 0.12 | 0.11 | 0.16 | 0.05 | 0.12 | 0.10±0.04 |
| ThO2 | 0.01 | 0.01 | 0.05 | 0.04 | 0.01 | 0.02 | 0.01 | 0.09 | 0.02 | 0.06 | 0.03±0.03 |
| TiO2 | 0.88 | 0.21 | 0.35 | 0.21 | 0.84 | 0.35 | 0.12 | 0.11 | 0.16 | 0.22 | 0.35±0.23 |
| ZrO2 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01±0.01 |
| V2O3 | 0.21 | 0.15 | 0.14 | 0.16 | 0.17 | 0.11 | 0.15 | 0.13 | 0.17 | 0.12 | 0.15±0.02 |
| Cr2O3 | 0.02 | 0.04 | 0.04 | 0.03 | 0.06 | 0.06 | 0.02 | 0.02 | 0.03 | 0.07 | 0.04±0.02 |
| Y2O3 | 0.01 | 0.05 | 0.02 | 0.02 | 0.04 | 0.01 | 0.04 | 0.02 | 0.02 | 0.01 | 0.02±0.01 |
| MgO | 0.26 | 0.35 | 0.27 | 0.25 | 0.26 | 0.21 | 0.18 | 0.19 | 0.28 | 0.32 | 0.26±0.06 |
| MnO | 0.16 | 0.18 | 0.21 | 0.25 | 0.17 | 0.18 | 0.19 | 0.14 | 0.24 | 0.09 | 0.18±0.05 |
| CoO | 0,02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01±0.01 |
| Total | 99.6 | 99.5 | 99.3 | 99.2 | 99.1 | 99.3 | 99.2 | 98.9 | 99.5 | 98.8 | 99.2±0.2 |

TABLE S5. COMPOSITION OF HEMATITE INCLUSIONS IN Q2 OVERGROWTH IN ALTERED SANDSTONE FROM THE MCARTHUR RIVER MINE (SAMPLE H737-58).

\*Note that the total Fe and U contents are reported as Fe2O3 and UO3, respectively.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
| Fe2O3(wt.%) | 95.9 | 96.8 | 96.6 | 97.1 | 96.6 | 97.8 | 97.3 | 97.2 | 97.1 | 96.6 | 96.9±0.5 |
| Al2O3 | 0.05 | 0.06 | 0.08 | 0.08 | 0.06 | 0.08 | 0.06 | 0.17 | 0.09 | 0.12 | 0.08±0.03 |
| UO3 | 2.02 | 1.68 | 1.56 | 1.28 | 1.46 | 0.47 | 0.86 | 1.65 | 1.19 | 1.27 | 1.34±0.44 |
| SiO2 | 0.03 | 0.02 | 0.02 | 0.02 | 0.05 | 0.06 | 0.02 | 0.02 | 0.04 | 0.03 | 0.03±0.01 |
| ThO2 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.03 | 0.02 | 0.02±0.01 |
| TiO2 | 0.21 | 0.21 | 0.14 | 0.22 | 0.16 | 0.13 | 0.12 | 0.15 | 0.12 | 0.15 | 0.18±0.04 |
| ZrO2 | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 | 0.07±0.06 |
| V2O3 | 0.02 | 0.02 | 0.02 | 0.22 | 0.09 | 0.11 | 0.04 | 0.03 | 0.08 | 0.09 | 0.02±0.01 |
| Cr2O3 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02±0.01 |
| Y2O3 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02±0.01 |
| MgO | 0.18 | 0.12 | 0.17 | 0.15 | 0.13 | 0.16 | 0.08 | 0.09 | 0.09 | 0.06 | 0.12±0.04 |
| MnO | 0.09 | 0.08 | 0.09 | 0.04 | 0.08 | 0.08 | 0.09 | 0.08 | 0.05 | 0.08 | 0.08±0.02 |
| CoO | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01±0.01 |
| Total | 98.6 | 99.1 | 98.8 | 99.2 | 98.7 | 99.0 | 98.7 | 99.3 | 98.9 | 98.5 | 98.9±0.3 |

TABLE S6. COMPOSITION OF HEMATITE INCLUSIONS IN Q1 OVERGROWTH IN ALTERED SANDSTONE FROM THE MCARTHUR RIVER MINE (SAMPLE MAC223-225).

\*Note that the total Fe and U contents are reported as Fe2O3 and UO3, respectively.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
| Fe2O3(wt.%) | 96.3 | 97.2 | 96.6 | 96.8 | 96.8 | 98.2 | 97.4 | 96.6 | 97.1 | 96.6 | 97.0±0.6 |
| Al2O3 | 0.11 | 0.09 | 0.08 | 0.11 | 0.19 | 0.11 | 0.17 | 0.18 | 0.13 | 0.17 | 0.13±0.04 |
| UO3 | 1.46 | 1.38 | 1.86 | 1.32 | 1.84 | 0.37 | 0.78 | 1.82 | 1.16 | 1.76 | 1.38±0.50 |
| SiO2 | 0.04 | 0.03 | 0.02 | 0.02 | 0.03 | 0.05 | 0.03 | 0.02 | 0.02 | 0.04 | 0.03±0.01 |
| ThO2 | 0.01 | 0.02 | 0.03 | 0.02 | 0.04 | 0.01 | 0.01 | 0.02 | 0.03 | 0.05 | 0.02±0.01 |
| TiO2 | 0.43 | 0.27 | 0.21 | 0.12 | 0.32 | 0.44 | 0.35 | 0.26 | 0.27 | 0.28 | 0.30±0.10 |
| ZrO2 | 0.01 | 0.03 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02±0.01 |
| V2O3 | 0.01 | 0.02 | 0.03 | 0.05 | 0.04 | 0.05 | 0.02 | 0.03 | 0.03 | 0.02 | 0.03±0.01 |
| Cr2O3 | 0.03 | 0.02 | 0.03 | 0.02 | 0.06 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.03±0.01 |
| Y2O3 | 0.09 | 0.14 | 0.12 | 0.18 | 0.12 | 0.15 | 0.13 | 0.14 | 0.12 | 0.08 | 0.13±0.03 |
| MgO | 0.26 | 0.15 | 0.13 | 0.16 | 0.17 | 0.16 | 0.15 | 0.13 | 0.18 | 0.17 | 0.17±0.04 |
| MnO | 0.16 | 0.11 | 0.09 | 0.12 | 0.08 | 0.04 | 0.08 | 0.11 | 0.09 | 0.08 | 0.10±0.08 |
| CoO | 0.11 | 0.12 | 0.06 | 0.11 | 0.08 | 0.05 | 0.08 | 0.08 | 0.09 | 0.08 | 0.09±0.02 |
| Total | 99.0 | 99.6 | 99.3 | 99.0 | 99.8 | 99.7 | 99.2 | 99.4 | 99.3 | 99.4 | 99.3±0.3 |

TABLE S7. COMPOSITION OF HEMATITE INCLUSIONS IN Q2 OVERGROWTH IN ALTERED SANDSTONE FROM THE PHOENIX DEPOSIT (SAMPLE WR251-383).

\*Note that the total Fe and U contents are reported as Fe2O3 and UO3, respectively.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | Average |
| Fe2O3(wt.%) | 97.7 | 98.4 | 97.6 | 97.6 | 97.8 | 97.9 | 97.8±0.3 |
| Al2O3 | 0.15 | 0.21 | 0.16 | 0.23 | 0.25 | 0.15 | 0.19±0.04 |
| UO3 | 1.06 | 0.19 | 0.89 | 0.74 | 0.55 | 0.46 | 0.65±0.31 |
| SiO2 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03±0.01 |
| ThO2 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03±0.01 |
| TiO2 | 0.13 | 0.18 | 0.17 | 0.18 | 0.18 | 0.17 | 0.17±0.02 |
| ZrO2 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 | 0.02±0.01 |
| V2O3 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02±0.01 |
| Cr2O3 | 0.02 | 0.01 | 0.01 | 0.02 | 0.03 | 0.02 | 0.02±0.01 |
| Y2O3 | 0.12 | 0.15 | 0.14 | 0.12 | 0.08 | 0.14 | 0.13±0.03 |
| MgO | 0.12 | 0.16 | 0.12 | 0.14 | 0.12 | 0.16 | 0.14±0.02 |
| MnO | 0.06 | 0.08 | 0.06 | 0.04 | 0.08 | 0.06 | 0.06±0.02 |
| CoO | 0.11 | 0.08 | 0.08 | 0.06 | 0.08 | 0.11 | 0.09±0.02 |
| Total | 99.6 | 99.6 | 99.3 | 99.2 | 99.2 | 99.3 | 99.2±0.2 |

TABLE S8. COMPOSITION OF HEMATITE INCLUSIONS IN Q1 OVERGROWTH IN ALTERED SANDSTONE FROM THE BJ PROJECT (SAMPLE MAC121-275).

\*Note that the total Fe and U contents are reported as Fe2O3 and UO3, respectively.

TABLE S9. COMPOSITION OF HEMATITE INCLUSIONS IN Q2 OVERGROWTH IN ALTERED SANDSTONE FROM THE BJ PROJECT (SAMPLE MAC121-275).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Average |
| Fe2O3(wt.%) | 97.5 | 98.2 | 97.8 | 97.6 | 97.9 | 97.9 | 97.5 | 97.6 | 97.8±0.2 |
| Al2O3 | 0.22 | 0.16 | 0.21 | 0.15 | 0.16 | 0.12 | 0.11 | 0.15 | 0.16±0.04 |
| UO3 | 1.28 | 0.21 | 0.56 | 0.88 | 0.63 | 0.44 | 1.02 | 0.76 | 0.72±0.34 |
| SiO2 | 0.02 | 0.02 | 0.04 | 0.01 | 0.01 | 0.03 | 0.01 | 0.04 | 0.02±0.01 |
| ThO2 | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02±0.01 |
| TiO2 | 0.16 | 0.13 | 0.12 | 0.12 | 0.14 | 0.17 | 0.21 | 0.15 | 0.15±0.03 |
| ZrO2 | 0.04 | 0.03 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.03 | 0.02±0.01 |
| V2O3 | 0.02 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02±0.01 |
| Cr2O3 | 0.01 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01±0.01 |
| Y2O3 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02±0.01 |
| MgO | 0.14 | 0.22 | 0.15 | 0.19 | 0.18 | 0.14 | 0.23 | 0.18 | 0.18±0.03 |
| MnO | 0.08 | 0.12 | 0.08 | 0.07 | 0.08 | 0.12 | 0.012 | 0.09 | 0.08±0.08 |
| CoO | 0.15 | 0.11 | 0.1 | 0.12 | 0.15 | 0.12 | 0.11 | 0.09 | 0.12±0.02 |
| Total | 99.6 | 99.3 | 99.2 | 99.2 | 99.3 | 99.1 | 99.3 | 99.1 | 99.3±0.2 |

\*Note that the total Fe and U contents are reported as Fe2O3 and UO3, respectively.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
| Fe2O3(wt.%) | 97.1 | 97.2 | 97.2 | 97.3 | 97.3 | 98.2 | 97.8 | 97.8 | 97.5 | 97.5 | 97.5±0.4 |
| Al2O3 | 0.13 | 0.09 | 0.11 | 0.12 | 0.11 | 0.15 | 0.12 | 0.15 | 0.18 | 0.16 | 0.13±0.03 |
| UO3 | 1.53 | 1.32 | 1.67 | 0.42 | 1.22 | 0.29 | 0.99 | 0.87 | 1.11 | 1.33 | 1.08±0.45 |
| SiO2 | 0.05 | 0.04 | 0.02 | 0.01 | 0.03 | 0.05 | 0.02 | 0.02 | 0.02 | 0.05 | 0.03±0.02 |
| ThO2 | 0.03 | 0.04 | 0.01 | 0.01 | 0.02 | 0.05 | 0.01 | 0.03 | 0.02 | 0.04 | 0.03±0.01 |
| TiO2 | 0.55 | 0.44 | 0.45 | 0.62 | 0.41 | 0.42 | 0.21 | 0.16 | 0.32 | 0.16 | 0.37±0.16 |
| ZrO2 | 0.06 | 0.03 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.05 | 0.02 | 0.03±0.02 |
| V2O3 | 0.01 | 0.03 | 0.02 | 0.03 | 0.03 | 0.01 | 0.03 | 0.05 | 0.08 | 0.03 | 0.03±0.02 |
| Cr2O3 | 0.05 | 0.13 | 0.05 | 0.04 | 0.05 | 0.02 | 0.03 | 0.03 | 0.03 | 0.05 | 0.05±0.03 |
| Y2O3 | 0 | 0.01 | 0 | 0.01 | 0.01 | 0.04 | 0.02 | 0.03 | 0.05 | 0.06 | 0.02±0.02 |
| MgO | 0.33 | 0.23 | 0.33 | 0.32 | 0.43 | 0.25 | 0.23 | 0.31 | 0.32 | 0.16 | 0.29±0.08 |
| MnO | 0.12 | 0.16 | 0.11 | 0.01 | 0.01 | 0.03 | 0.11 | 0.11 | 0.21 | 0.09 | 0.10±0.06 |
| CoO | 0.05 | 0.01 | 0.01 | 0.02 | 0.03 | 0.03 | 0.04 | 0.02 | 0.01 | 0.02 | 0.02±0.01 |
| Total | 100.0 | 99.7 | 100.0 | 98.9 | 99.7 | 99.6 | 99.6 | 99.6 | 99.9 | 99.7 | 99.7±0.3 |

TABLE S10. COMPOSITION OF HEMATITE INCLUSIONS IN Q2 OVERGROWTH IN A SANDSTONE FROM THE ARROW DEPOSIT (SAMPLE AR-14-8-96).

\*Note that the total Fe and U contents are reported as Fe2O3 and UO3, respectively.

TABLE S11. COMPOSITION OF DISSEMINATED HEMATITE IN ALTERED ORTHOGNEISS FROM THE ARROW DEPOSIT (SAMPLE AR-14-25-635).

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
| Fe2O3(wt.%) | 97.3 | 97.2 | 97.2 | 98.1 | 98.5 | 97.5 | 97.6 | 97.7 | 97.8 | 97.4 | 97.6±0.4 |
| Al2O3 | 0.06 | 0.09 | 0.13 | 0.09 | 0.08 | 0.09 | 0.06 | 0.09 | 0.08 | 0.09 | 0.09±0.02 |
| UO3 | 1.35 | 1.16 | 1.47 | 0.56 | 0.35 | 1.09 | 0.86 | 0.95 | 0.77 | 1.05 | 0.99±0.34 |
| SiO2 | 0.02 | 0.01 | 0.01 | 0.01 | 0 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01±0.01 |
| ThO2 | 0.01 | 0.01 | 0.01 | 0.01 | 0 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01±0.01 |
| TiO2 | 0.25 | 0.18 | 0.21 | 0.12 | 0.13 | 0.13 | 0.12 | 0.14 | 0.13 | 0.18 | 0.16±0.04 |
| ZrO2 | 0.06 | 0.02 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02±0.01 |
| V2O3 | 0.01 | 0.02 | 0.01 | 0.03 | 0.03 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02±0.01 |
| Cr2O3 | 0.02 | 0.02 | 0.01 | 0.04 | 0.05 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.02±0.01 |
| Y2O3 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.04 | 0.01 | 0.01 | 0.04 | 0.01 | 0.02±0.01 |
| MgO | 0.13 | 0.14 | 0.13 | 0.12 | 0.13 | 0.12 | 0.12 | 0.16 | 0.14 | 0.12 | 0.13±0.01 |
| MnO | 0.09 | 0.08 | 0.06 | 0.06 | 0.04 | 0.06 | 0.05 | 0.09 | 0.09 | 0.08 | 0.07±0.01 |
| CoO | 0.01 | 0.01 | 0.01 | 0.02 | 0.03 | 0.03 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02±0.01 |
| Total | 99.3 | 99.0 | 99.3 | 99.2 | 99.4 | 99.2 | 98.9 | 99.2 | 99.2 | 99.0 | 99.2±0.2 |

\*Note that the total Fe and U contents are reported as Fe2O3 and UO3, respectively

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
| Fe2O3 (wt.%) | 95.61 | 96.79 | 97.33 | 97.98 | 97.42 | 97.14 | 93.95 | 97.75 | 96.79 | 93.71 | 96.45±1.52 |
| Al2O3 | 0.27 | 0.08 | 0 | 0.02 | 0 | 0.01 | 0.21 | 0.01 | 0.06 | 0.19 | 0.09±0.09 |
| UO3 | 0.02 | bdl | bdl | bdl | bdl | 0.03 | bdl | 0.03 | bdl | bdl | 0.01±0.01 |
| SiO2 | 0.4 | 0.06 | 0.02 | 0 | 0.05 | 0.08 | 0.29 | 0.06 | 0.09 | 0.26 | 0.13±0.128 |
| ThO2 | 0 | 0.05 | 0 | 0.03 | 0 | 0 | 0.04 | 0.11 | 0 | 0.05 | 0.03±0.03 |
| TiO2 | 1.4 | 1.51 | 1.36 | 0.36 | 1.44 | 0.56 | 3.25 | 1.27 | 1.62 | 4.05 | 1.69±1.13 |
| ZrO2 | 0 | 0 | 0 | 0.02 | 0.02 | 0.03 | 0.04 | 0.02 | 0.03 | 0 | 0.02±0.015 |
| V2O3 | 0.07 | 0.12 | 0.03 | 0.1 | 0.04 | 0.03 | 0.04 | 0.05 | 0.08 | 0.13 | 0.07±0.37 |
| Cr2O3 | 0.02 | 0.02 | 0.01 | 0 | 0.02 | 0 | 0.03 | 0.02 | 0.03 | 0 | 0.02±0.12 |
| Y2O3 | 0 | 0.01 | 0 | 0.06 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0.01±0.01 |
| La2O3 | 0.04 | 0 | 0 | 0.04 | 0 | 0.02 | 0.01 | 0 | 0 | 0.03 | 0.014±0.01 |
| Ce2O3 | 0.02 | 0 | 0.03 | 0.01 | 0.03 | 0.01 | 0 | 0 | 0 | 0.04 | 0.01±0.01 |
| MgO | 0 | 0 | 0.01 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0.02 | 0.004±0.007 |
| MnO | 0.16 | 0 | 0.01 | 0 | 0 | 0 | 0.15 | 0.01 | 0.02 | 0.09 | 0.04±0.06 |
| Total | 98.01 | 98.64 | 98.80 | 98.62 | 99.02 | 97.91 | 98.02 | 99.34 | 98.72 | 98.57 | 98.57±0.46 |

TABLE S12. EMPA RESULTS IN wt.% FOR MAJOR ELEMENTS MEASURED IN HEMATITE (HL20-308) FROM HUGHES LAKE.

\*Note that the total Fe and U contents are reported as Fe2O3 and UO3, respectively

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Spot-1 | Spot-2 | Spot-3 | Spot-4 | Spot-5 | Spot-7 | Spot-8 | Spot-9 | Spot-10 | Spot-11 | Spot-12 |
| U | bdl | 16.3 | bdl | 26 | 10.6 | 2.3 | bdl | 4.3 | 3.3 | 4.2 | bdl |
| Mg | bdl | bdl | bdl | bdl | bdl | bdl | 590 | bdl | 260 | bdl | 1130 |
| Al | 4050 | 2460 | 550 | 32500 | 560 | bdl | bdl | bdl | bdl | 410 | 460 |
| Ti | 6430 | 2830 | 6960 | 5500 | 8560 | 690 | 16600 | 5660 | 38800 | 43800 | 33300 |
| V | 517 | 2030 | 1300 | 352 | 347 | 1070 | 453 | 745 | 138 | 177 | 168 |
| Cr | 166 | 730 | bdl | bdl | 216 | bdl | bdl | bdl | 447 | 561 | 640 |
| Mn | 1290 | 132 | 35 | bdl | 227 | bdl | 60 | bdl | 57 | 90 | 89 |
| Co | 50.4 | 36.7 | bdl | bdl | 30.6 | bdl | bdl | bdl | bdl | bdl | bdl |
| Zr | bdl | 100 | bdl | bdl | 86 | bdl | bdl | bdl | bdl | bdl | bdl |
| Nb | 50.2 | 9 | 103 | 51.1 | 140 | 17.7 | 33.8 | 42.1 | 68 | 45 | 37 |
| La | 191 | 7.5 | bdl | bdl | bdl | bdl | bdl | 2.9 | bdl | bdl | bdl |
| Ce | 432 | 11 | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl |
| W | bdl | bdl | 127 | 35 | bdl | 7.1 | bdl | 40.7 | 37.8 | 24.2 | 27.9 |
| Th | 261 | 29.9 | 0 | 15.7 | 10.5 | bdl | bdl | bdl | 16.3 | 17.5 | 11.4 |

TABLE S13. LA-ICP-MS SPOT ANALYSES OF HEMATITE IN ALTERED SANDSTONE FROM THE HUGHES LAKE PROPERTY (SAMPLE HL20-308).