Evolution of uraninites at Olympic Dam: Deciphering complex textures, chemistry and temporal history

Edeltraud Macmillan 1,3, Nigel Cook 1, Allan Pring 2, Kathy Ehrig 3 and John Foden 1

1School of Earth and Environmental Sciences, The University of Adelaide, SA, 5000, Australia
2Department of Mineral Sciences, South Australian Museum, Adelaide, SA, 5000, Australia
3Resource Planning & Development, BHP Billiton – Olympic Dam, Adelaide, SA, 5000, Australia

INTRODUCTION AND HYPOTHESIS

Uraninites at Olympic Dam (OD) display a complex history, both chemically and texturally. OD is the largest economic uranium resource in the world, but the genesis of uranium mineralisation remains poorly constrained [1]. The uranium minerals have a complex paragenesis with strong evidence for multiple stages of U dissolution and reprecipitation [2]. This study aims to address a major gap in knowledge with respect to textural and compositional evolution of uraninite. A textural classification system is developed based on detailed mineralogical and micro-analytical investigation of selected samples. A potential pathway for the oxidation of uraninite is postulated. It is hypothesised that the uraninites are multi-generational and can be subdivided into various classes based on differences in chemistry and texture. Furthermore, Pb/U data can be used to distinguish between the main classes of uraninite and thus used as a proxy for chemical age.

METHODOLOGY

1. Selected 24 samples from around the deposit of diamond drill-core to target key mineralogical/chemical variability.
2. Use Scanning Electron Microscopy (SEM) and Mineral Liberation Analysis (MLA) to identify key uranium mineral textural classes.
3. Chemical analysis on each textural class using an Electron Probe Micro-Analyzer (EPMA), Conditions: 15 keV, 100 nA, 1 µm beam size, 28 elements measured.
4. Use X-ray Spectroscopy to determine valency and bonding differences within the various textural classes (XFM, XAS).
5. Statistical analysis of all data to determine relationships between chemistry, texture and Pb/U ratio (proxy for chemical ages).

RESULTS AND CONCLUSIONS

1. Four main classes of uraninite are defined: primary, zoned (Figs. 1 & 2), cob-web/sectorial (Figs. 2 - 4 & 6) and massive (Fig. 5). Primary, zoned and cob-web uraninite represent a textural continuum (Fig. 6) created via an in-situ oxidation process.
2. Primary, zoned and cob-web uraninites are of similar composition and represent the same generation of U-mineralisation compared to the younger, massive uraninites (Figs. 7, 10 & 11).
3. Observed “cog-wheel” uraninite textures found at Oklo, Gabon [3] are similar to the OD “cob-web” textures (Fig. 8).
4. The oxidation process of early uraninite is analogous to the oxidation process of UO₂ in spent nuclear fuel (Fig. 8).
5. Preservation of the various forms of early uraninite has occurred via an influx of Cu-sulphide mineralisation.

REFERENCES AND ACKNOWLEDGEMENTS


Fig.1: BSE-Scatter Electron (SSP) image of zoned uraninite with bombsite and fluorspar precipitated in cracks. Chemical zoning visible in Fig. 2.

Fig.2: BSE image of partially oxidised cubic uraninite (zone) displaying spilitisation textures. Uraninite preserved due to bombsite precipitation.

Fig.3: BSE image of cob-web uraninite which has been preserved by RDX oxidation during precipitation of bombsite.

Fig.4: BSE image of cob-web uraninite displaying morphological change due to oxidation. Remnants of cubic uraninite (centre) and orthorhombic uraninite (rim).

Fig.5: BSE image of massive uraninite highlighting the chemical heterogeneity with darker zones representing higher Ca/Si (brightness and contrast reduced).

Fig.6: BSE image of massive uraninite which has almost completely oxidised. Spilitisation of uraninite on edges, with possible later stage fluorite precipitation.

Fig.7: Box plot highlighting Y₂O₃ variability between the different classes of uraninites.

Fig.8: Oxidation transformation of uraninite. (a) unoxidised crystal of primary uraninite; (b) commencement of oxidation; (c) preferential dissolution of oxidised layer and formation of corrosion rinds; (d) precipitation of alteration products; (e) extended oxidation with fragmentation and separation of oxidised uraninite (spalling due to U₂O₃ morphology change); (f) continued fragmentation and spalling with advanced development of cob-web structure; (g) formation of hexagonal type UO₂ (analogous to spent nuclear fuel); (h) complete oxidation of hexagonal type UO₂ with crystallographic plane-oriented oxidation; (i) formation of orthorhombic type UO₂ (analogous to synthetic UO₂); (j) complete oxidation of orthorhombic type UO₂ with crystallographic plane-oriented oxidation.

Fig.9: EPMA WDS map of zoned uraninite (Fig. 1).

Fig.10: Scatter plot of alteration factor (CaO+SiO₂+Fe₂O₃) versus UO₂ for the different classes of uraninite.

Fig.11: Scatter plot of PbO versus UO₂ for the different classes of uraninite (Lee-Pin) as chemical age proxy.