

Introduction

The McArthur River deposit is the largest high-grade uranium deposit in the world. The focus of this study is to describe the compositions of the various generations of pyrite within and near the McArthur River deposit. This work builds on previous sulphur isotopic studies of Athabasca deposits (e.g. Bray et al., 1982; Wallis et al., 1985; Kotzer & Kyser, 1992) through the application of in-situ trace element analysis coupled with isotopic analysis.

Geological Setting

The McArthur River uranium deposit is located along the unconformity between the Athabasca Group sandstones and underlying crystalline basement rocks.

The basement is comprised of upper facies metasedimentary rocks that contain pyrite, especially in the graphitic metapelite units. In the sandstones and conglomerate of the Athabasca Group, pyrite occurs along fractures and disseminations between detrital quartz grains.

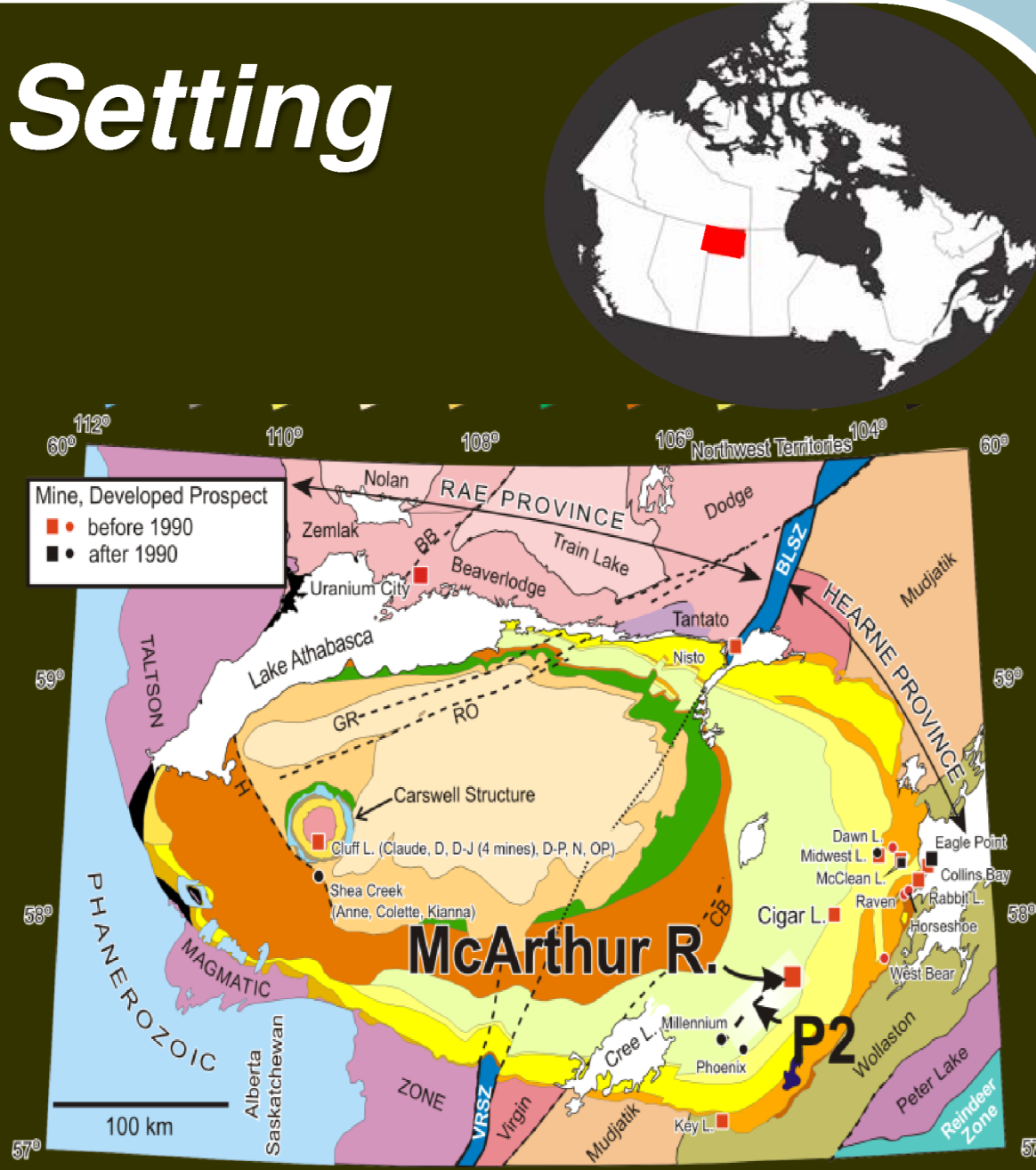


Fig. 1: (a) Location of the Athabasca basin and (b) McArthur River deposit, after Jefferson et al., (2007).

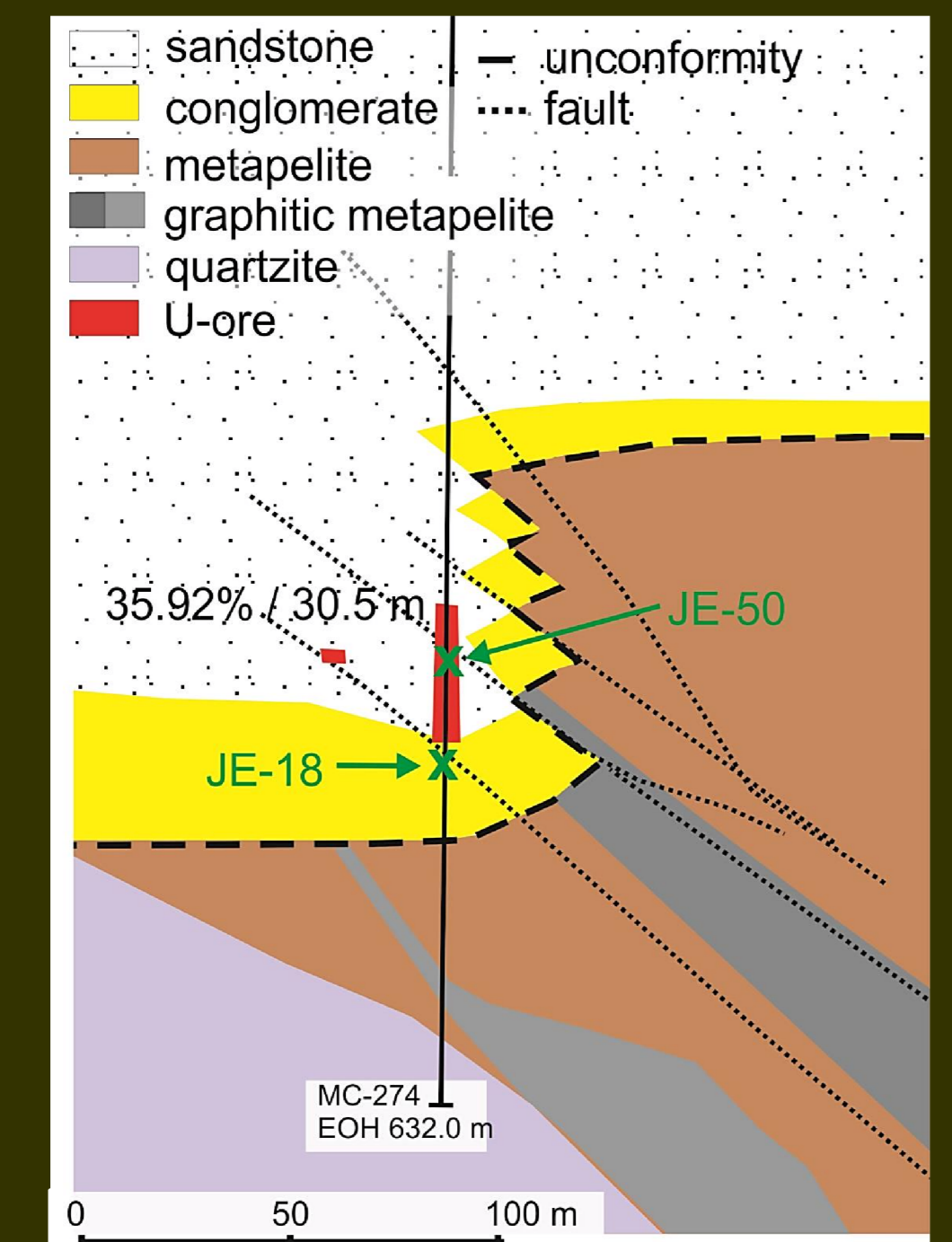


Fig. 2: Cross section of DDH MC 274, which intersected high grade ore in the zone B ore body. Abundant graphite is present in the dark grey layer. Sample s JE-18 & JE-50 were taken from this drill core. Simplified map courtesy of Cameco Corporation.

Sampling and analytical methods

1. Core samples were collected along the P2 fault. Samples include high grade ore, weakly mineralized and background samples, taken far from mineralization.
2. Transmitted and reflected light microscopy was used to identify sulphide minerals and examine textural relationships with alteration minerals.
3. Micro-drilling of selected grains of pyrite for sulphur isotope analysis by ICP-MS
4. Scanning electron microscopy to obtain back-scattered electron images (BSE).
5. Major and minor element analysis using an electron microprobe analyzer (EMPA).
6. Trace element analysis using laser ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS).

Petrography of pyrite

Pyrite was classified into the following categories.

- **Pyrite in sandstone & conglomerate (Fig. 3):** Fracture-filling grains (<0.2 mm in width) or along grain boundaries.
- **Fracture-hosted pyrite (Figs. 3a & c):** Euhedral to anhedral grains along fractures (1 – 2 mm in width) that cut foliation.
- **Large euhedral pyrite in pelite (Figs. 3b & d):** Euhedral grains (0.5 – 10mm) forming mono-mineralic bands or isolated crystals.
- **Disseminated pyrite in pelite (Figs. 4a & c):** Subeuhedral to euhedral grains (< 0.05 mm) disseminated in pelitic rocks.
- **Pegmatite-hosted pyrite (Fig. 5):** Subeuhedral to euhedral grains (0.05 – 1 mm) as isolated or disseminated.
- **Ore-hosted pyrite (Fig. 6):** Disseminated grains (0.01-1mm) in association with uraninite.

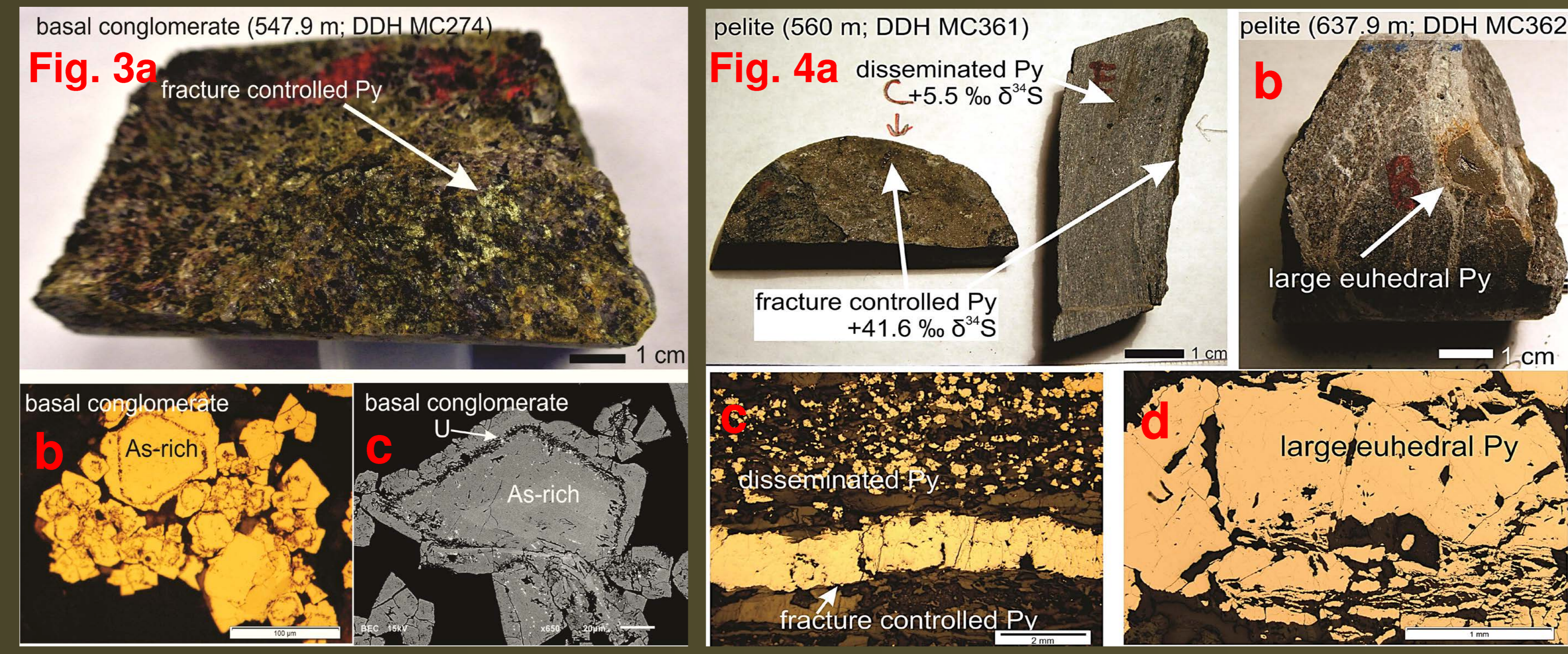


Fig. 3b reflected light photomicrograph, 3c BSE Figs. 4c & d reflected light photomicrograph

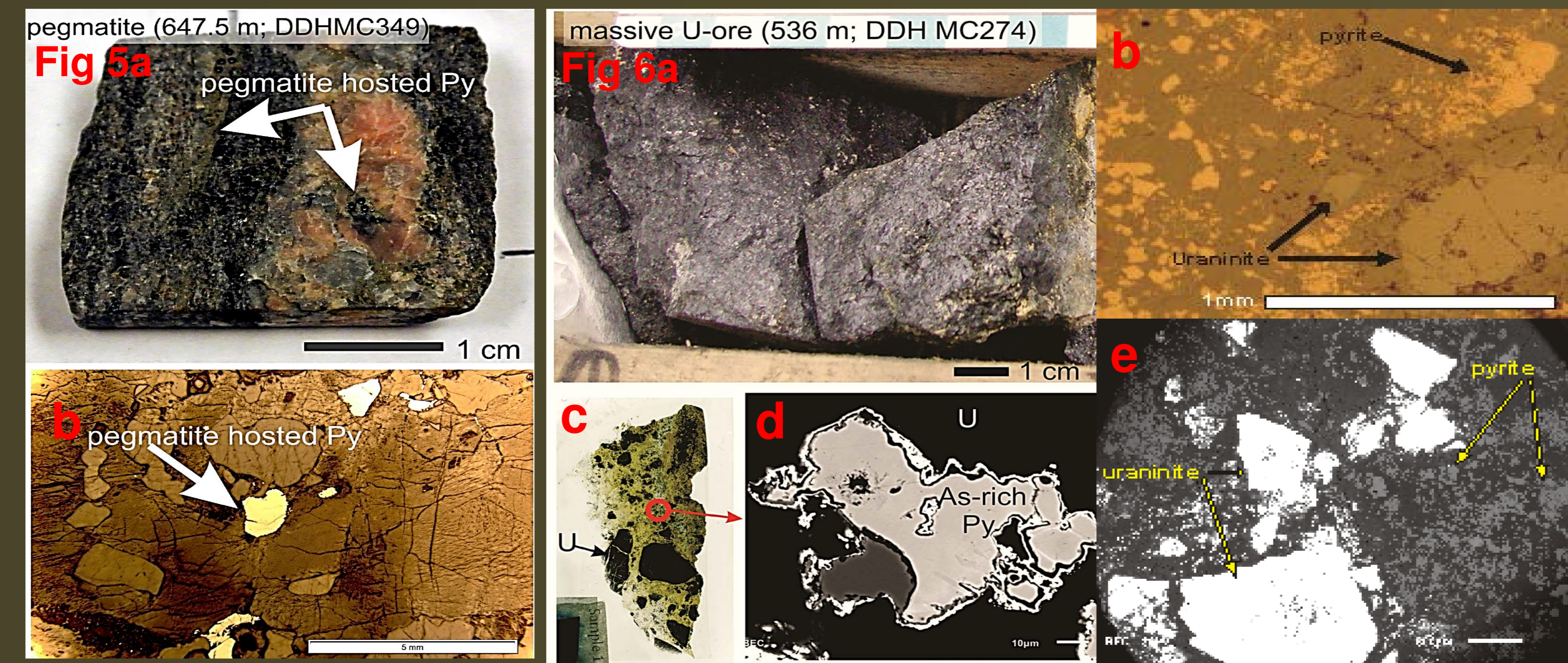
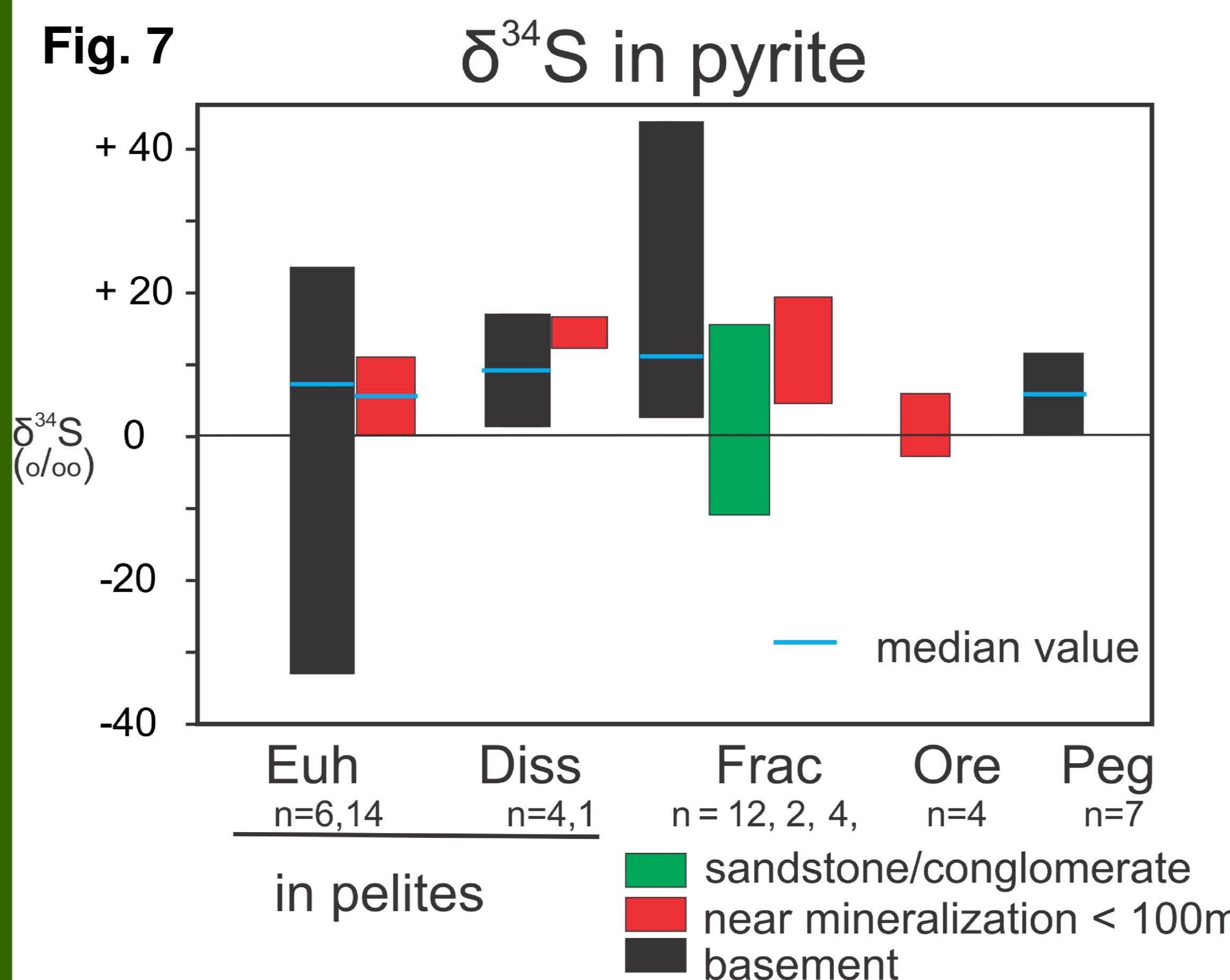


Fig. 5b reflected light photomicrograph Fig. 6b reflected light photomicrograph, 6c transmitted light photomicrograph, 6d & e BSE

Sulphur isotope compositions

Pyrite disseminated and along fractures in metapelite yield a large variation in $\delta^{34}\text{S}$ values, ranging from + 5 to + 40 ‰, and from - 30 to + 20 ‰, respectively (Fig. 7). Although the spread is large, the median values are similar. Furthermore, pyrite proximal to the mineralization in the McArthur River deposit contains a restricted range of $\delta^{34}\text{S}$ values from 0 to + 15 ‰, regardless of its occurrence. This includes As-rich pyrite associated with uraninite. The results indicates that the S in uraniferous hydrothermal fluids was well-mixed and that the fluid to rock ratios were high.



Arsenic-rich pyrite in association with uraninite

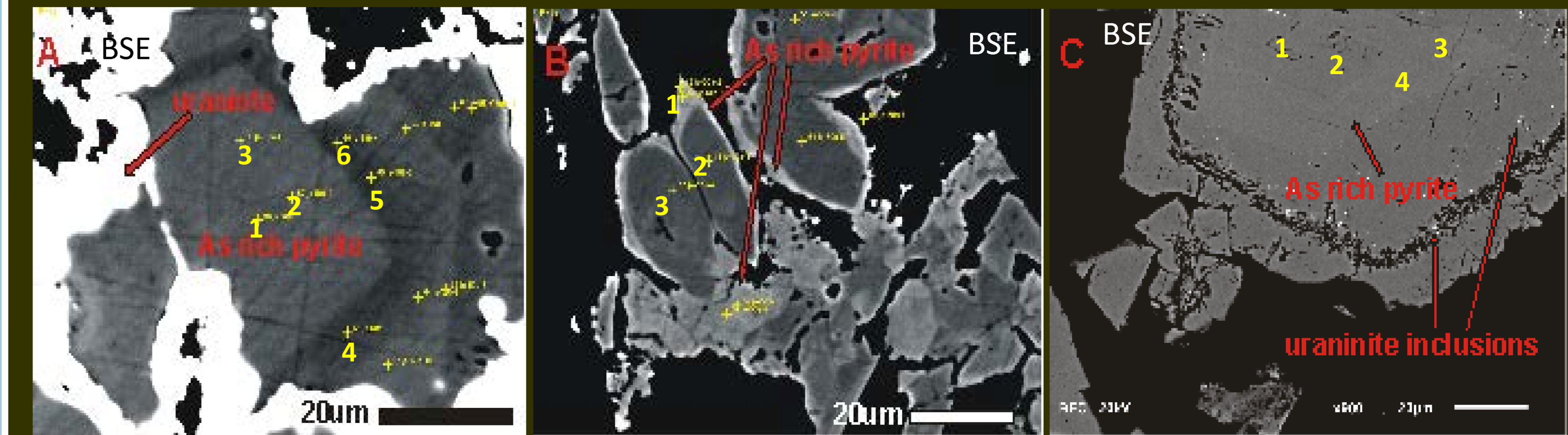


Fig. 8 A : BSE-image from sample JE-50, hole MC274 at 536m depth. Pyrite is rimmed by uraninite and has prominent zoning which consists of alternating light and dark areas. The light zone of the core has high As, with areas 1, 2 and 3 containing 2.80, 2.85 and 2.78 wt.% As, respectively. Just outside this zone is a dark band where analyses at points 4, 5 and 6 yield lower As values of 1.63, 1.14 and 1.92 wt.%, respectively. In Fig. 8B, also from sample JE-50, pyrite has rims (position 1) with high As contents of 1.48 wt.% while the cores have lower As contents of 0.06 and 0.04 wt.% respectively. Fig. 8C is from sample JE-18, hole MC274 at 547.9 m depth. The brighter zone just outside the core has higher As levels of 0.82 and 1.00 wt.% at positions 3 and 4 respectively. The darker core has lower As contents of 0.28 and 0.29 wt.% (positions 1 and 2, respectively).

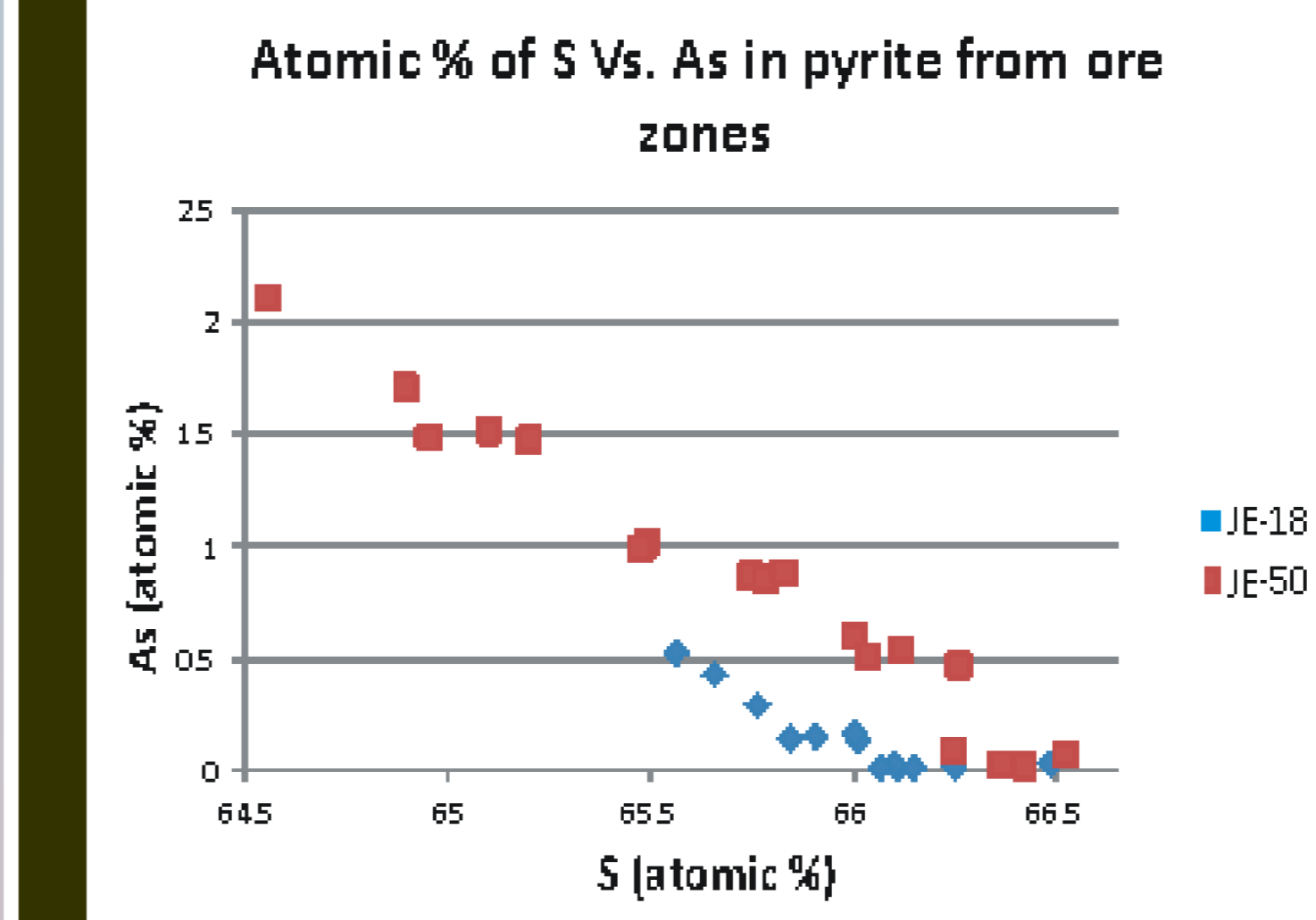


Fig. 9: Individual points on the graph represent the value of S and As for one area. The inverse correlation between S and As indicate that the As is replacing S in pyrite forming an AsS dianion.

²⁰⁶Pb- and As-rich pyrite as late cement

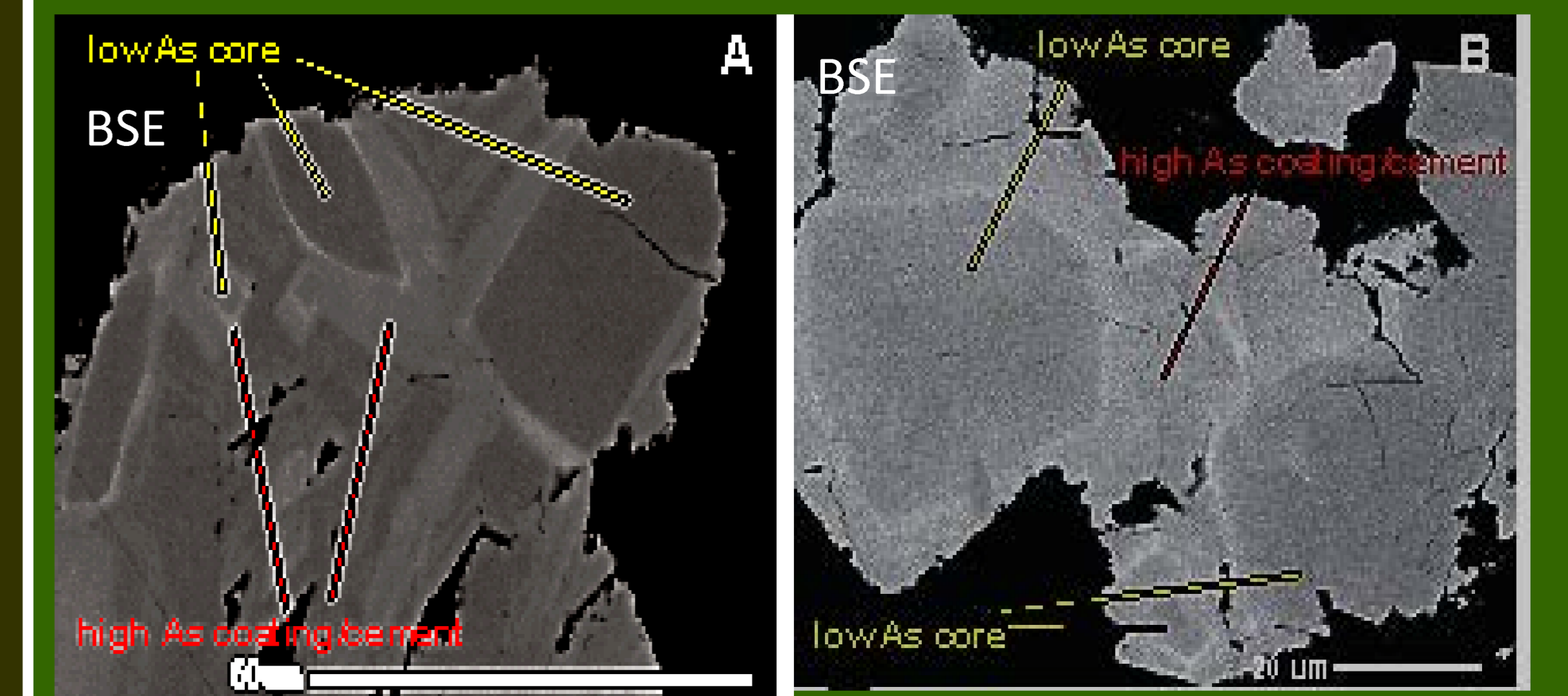


Fig. 10: BSE-images from sample JE-50, Hole MC274 at 536.0 m depth. Dark euhedral pyrite grains (As-poor) are surrounded by brighter pyrite with higher As contents. LA-ICP-MS analysis of pyrite shows that this As-rich pyrite also contains essentially no ²⁰⁶Pb, but elevated values of ²⁰⁶Pb (up to 2.0 wt.%), indicating that the As-rich pyrite formed after uraninite.

Summary

1. High contents of As (up to 4.0 wt. %) are observed in pyrite spatially associated with the U mineralization.
2. High As has been noted in the McArthur River deposit. This study suggests that pyrite is a likely host of As in the deposit.
3. Zoning in pyrite, due to varying As contents, in the basal conglomerate of the Athabasca Group records fluctuating fluid compositions.
4. Early As-poor pyrite grains are coated and cemented by later As-rich pyrite. This As-rich pyrite contains elevated ²⁰⁶Pb contents (up to 2.0 wt.%), indicating that some As-rich pyrite formed after uraninite.
5. There is a large variation in S-isotopic compositions for pyrite within the deposit, from -30 to + 40 ‰, but the values for pyrite associated with the U mineralization exhibit a narrow range. The evidence suggests a well mixed, homogenous source of S for the mineralization.

Acknowledgements

Cameco Geologists: Gerard Zaluski, Tom Kotzer, Aaron Brown, Doug Adams, Remi Labelle, and Brian McGill for all of their assistance during field work. Glenn Poirier of the Museum of Nature for his help during SEM analysis. Paul Middlestead of the University of Ottawa for his help with S-isotope analyses. Simon Jackson and Zhaoqing Yang of the Geological Survey of Canada for their help during LA-ICP-MS analysis. This study was supported by a Targeted Geoscience Initiative Four (TGI-4) grant through Natural Resources Canada to K. Hattori and critically reviewed by Eric Potter.