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Characterization of mineralizing fluids and fluid-structural relationships in the Phoenix uranium deposit, southeastern Athabasca Basin, northern Saskatchewan: preliminary core and petrographic studies

K. Wang[1], G. Chi[1], K.M. Bethune[1], Z. Li[1] and C.D. Card[2]

Introduction

The Phoenix deposit, a high-grade unconformity-related uranium deposit associated with a NE-trending moderately SE-dipping reverse fault (WS shear zone), is located 35 km southwest of the world-class McArthur River uranium deposit in the southeastern Athabasca Basin (Fig.1). Previous geological and geochemical studies have revealed features similar to other unconformity-related uranium deposits in the region (e.g. Kerr, 2010; Power et al., 2012; Dann et al., 2014), but the composition, temperature and pressure of the fluids associated with mineralization have not yet been investigated with fluid inclusion techniques. Furthermore, like other well-studied unconformity-related uranium deposits, the structural controls on mineralization , particularly the hydrodynamic relationship between structures (and related stresses) and fluid pressure, are not well understood. The main objectives of this study are to try to determine the fluid composition, thermal conditions and fluid-structural relationships in the Phoenix deposit through a combination of field (drill-core) investigation and petrographic, microstructural and fluid inclusion studies.

Location

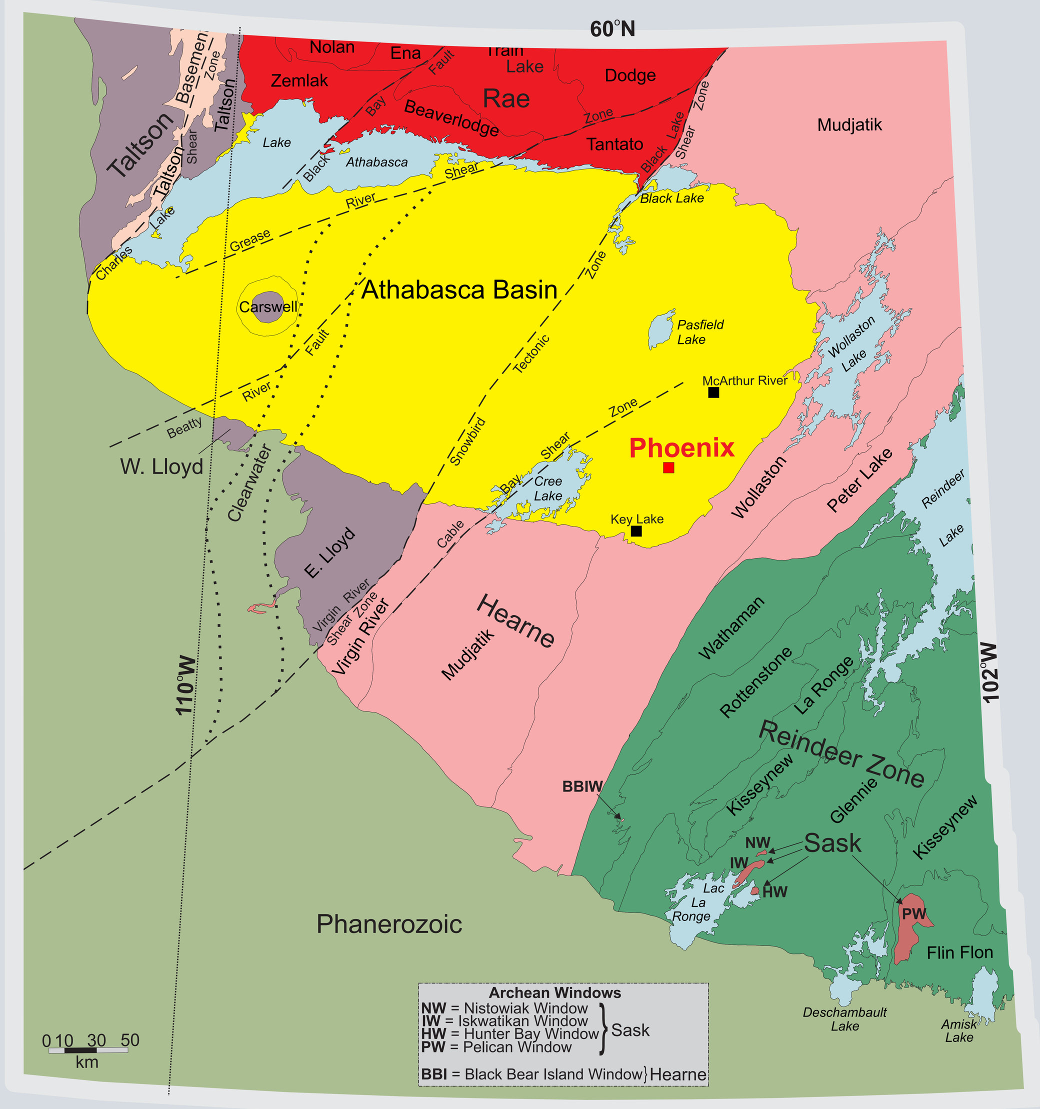


Fig.1: The Phoenix deposit is geographically located in the southeast corner of the Athabasca Basin, 35 km southwest of the McArthur River mine and 25 km northeast of the Key Lake mill (modified from Card et al.2007).

Field drill-core investigation

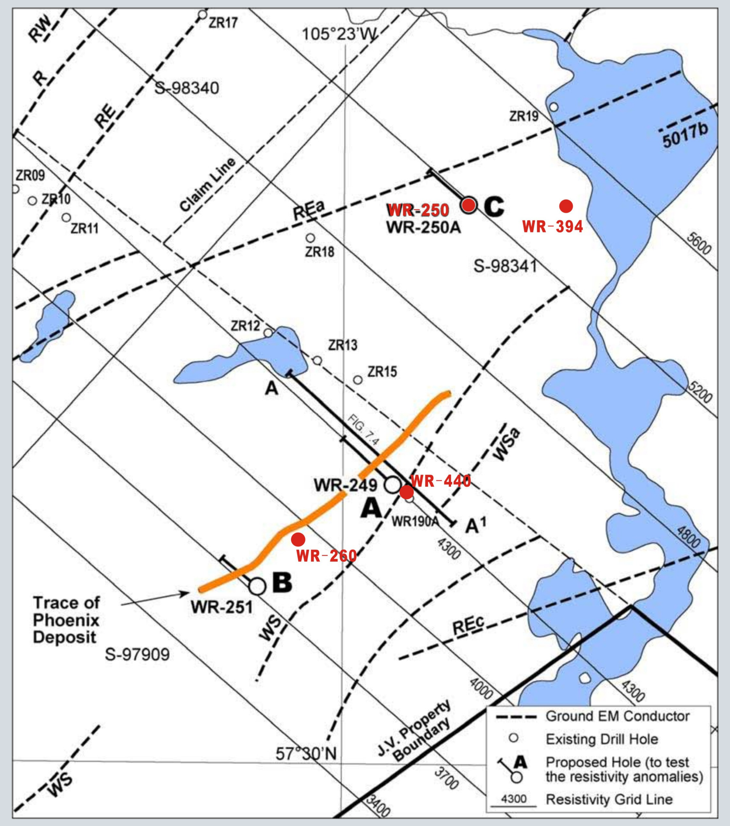


Fig.2: Map locations of studied drill cores, WR-260, WR-440, WR-250, and WR-394 (modified from Arseneau and Revering, 2010)

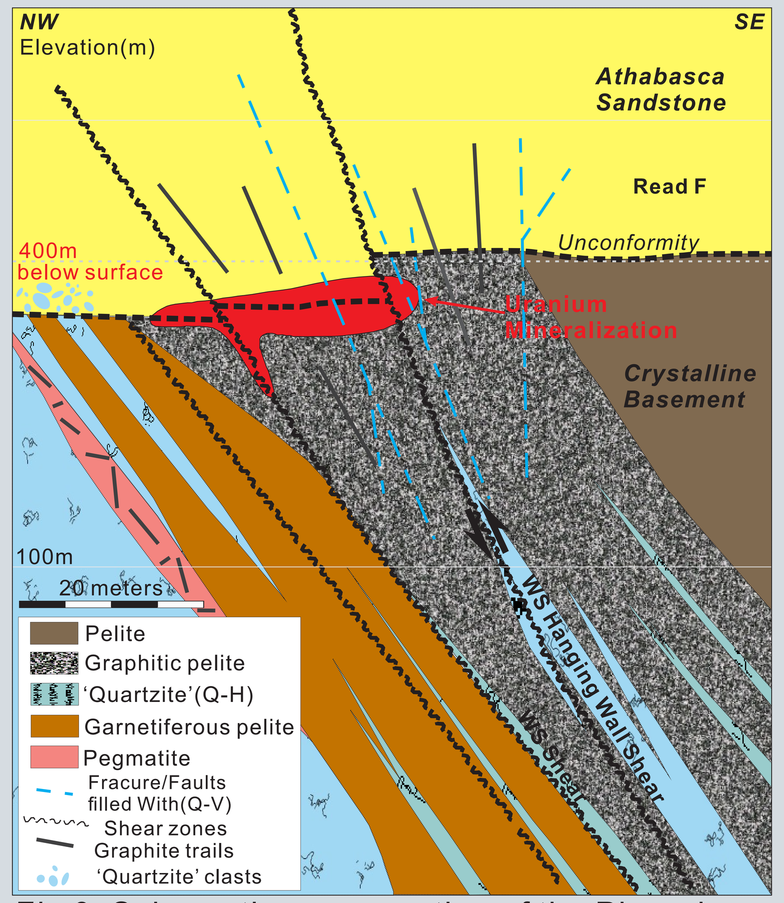


Fig.3: Schematic cross section of the Phoenix deposit, modified from Gamelin et al. (2010)

1) Thirty-five samples were examined from the six drill cores (Fig.2) to determine lithological characteristics and document different varieties of fracture/vein fillings and associated alteration; six of the samples are oriented (Fig.4-B&D);

2) The basement is dominated by granulite grade graphitic pelitic to psammopelitic rocks (Fig.4-A);

3) The pelitic rocks are invaded by dm to m-thick foliation parallel bodies of massive quartz (Fig.4-B) and spatially associated (gradational) pegmatite (Fig.4-C), in places with extensive silicification of host rocks;

4) Graphite of probable hydrothermal origin is abundant in these zones (Fig.4-D);

5) Intense silicification was observed along the unconformity surface, and clasts of 'quartzite' (hydrothermal quartz?, Q-H) were observed in the basal conglomerate of the Athabasca Group (Manitou Falls Fm [Read Fm in Fig.3]);

6) A younger generation of fractures and microbreccia zones, characterized by vuggy quartz infillings, cut both the silicified basement rocks (Fig.4-E) and overlying sandstone (Fig.4-F); Locally these fractures are lined by graphite

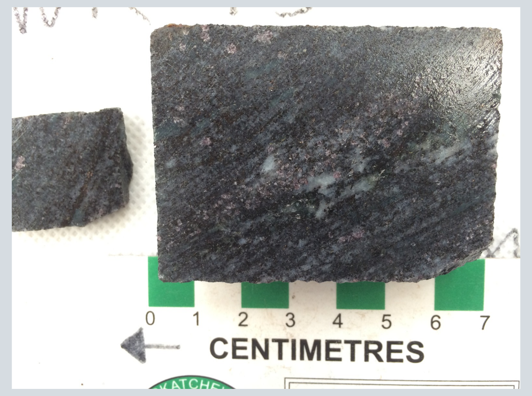


Fig.4-A: Garnetiferous pelite (WR-440)

Fig.4-B: Oriented sample of hydrothermal quartz (WR-440)

Fig.4-C: Pegmatite cut by graphite-filled fractures (WR-440)

Fig.4-D: Hydrothermal graphite vein cutting granite (WR-440)

Fig.4-E: Pelite with hydrothermal quartz cut by vuggy quartz vein (WR-440)

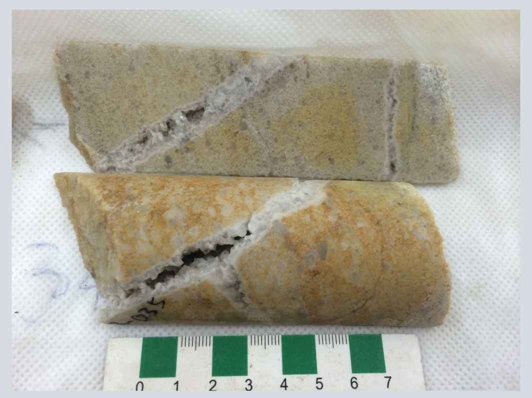


Fig.4-F: Vuggy Quartz cutting sandstone (WR-250)

Petrographic study

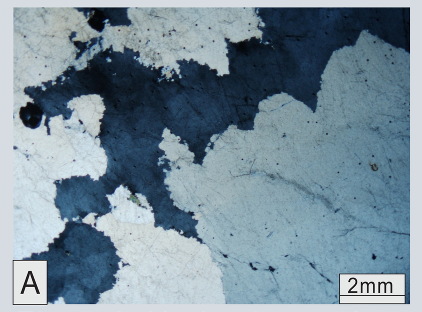


Fig.5-A: Hydrothermal quartz ('quartzite',Q-H, grain size up to 28mm)

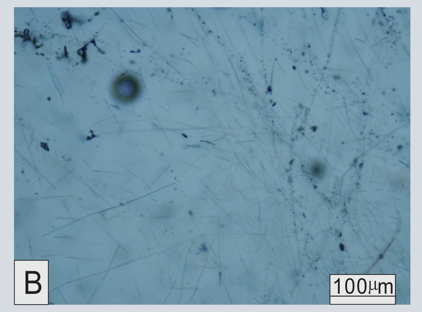


Fig.5-B: Numerous needle-like mineral inclusions (rutile or tourmaline?) in Q-H

Fig.5-C: Garnet-sillimanite bearing pelitic gneiss

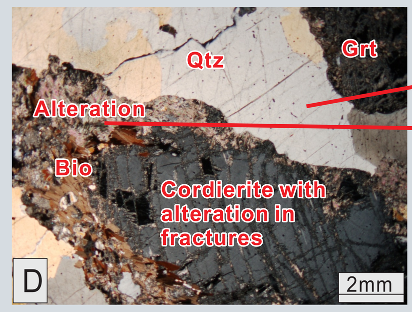


Fig.5-D: Q-H cutting garnet-cordierite-sillimanite-bearing pelitic gneiss

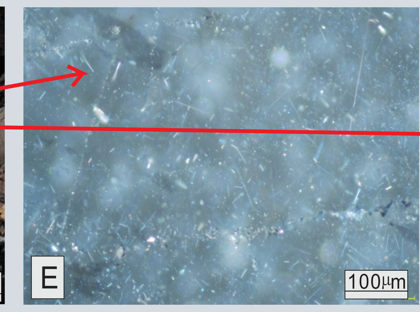


Fig.5-E: Needle-like mineral inclusions in a Q-H vein

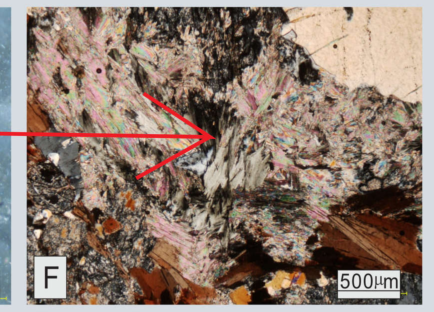


Fig.5-F: Sudoite and muscovite alteration

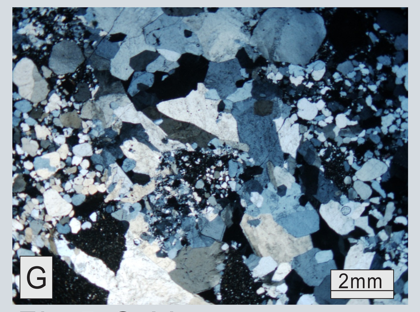


Fig.5-G: Vuggy quartz (Q-V) vein cutting quartz conglomerate

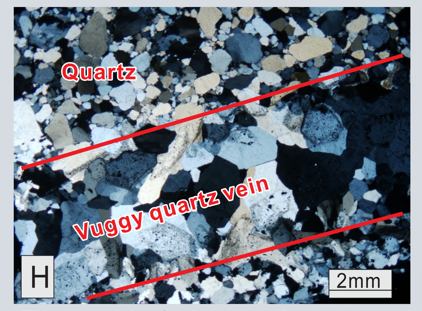


Fig.5-H: Q-V cutting quartz sandstone

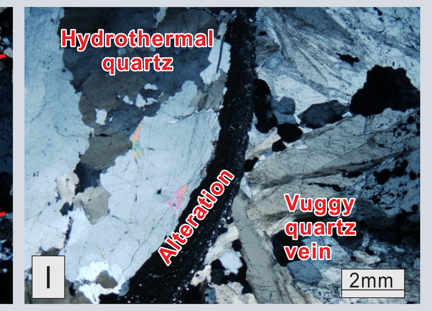
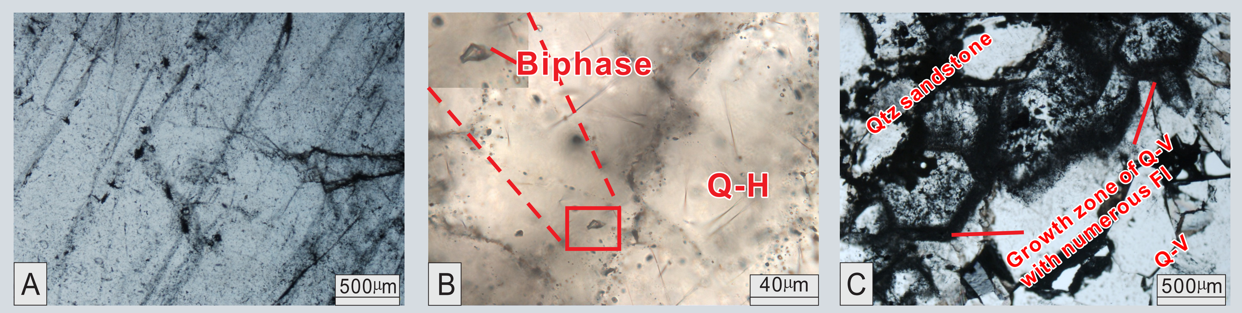
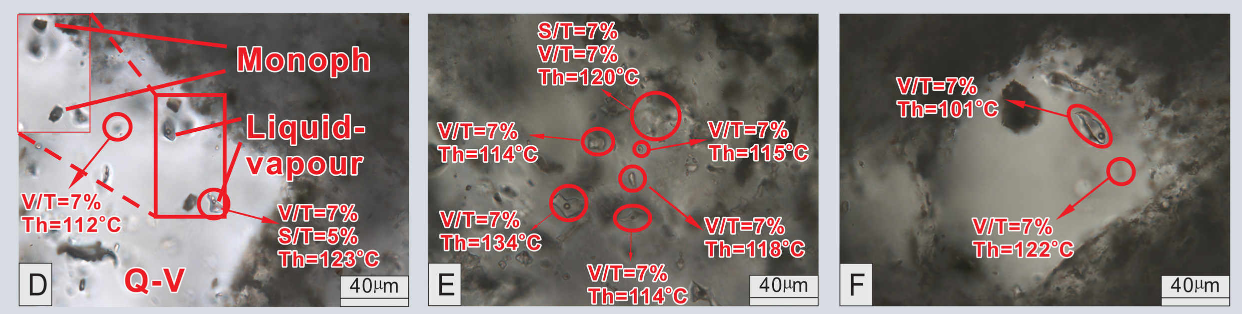


Fig.5-I: Q-V cutting Q-H

Fluid inclusion (FI) study



Figs.6-A&B: CO_2-dominated inclusions are well developed in densely distributed, parallel microfractures in the hydrothermal quartz, which predates mineralization.



Figs.6-C,D,E&F: abundant vapour-only aqueous inclusions found in the euhedral crystals of the secondary vuggy quartz veins and cements.

Summary and conclusions

1) Collectively, the field and petrographic observations, coupled with preliminary fluid inclusion analysis, are consistent with a two-stage history:
   a) extensive pre-Athabasca hydrothermal alteration with associated generation of hydrothermal quartz (Q-H) and pegmatite;
   b) post-Athabasca brittle faulting/fracturing and infiltration of a second generation of quartz (Q-V);
2) Petrographic studies of the quartz-rich rock (Q-H) indicates that the quartz grains are very coarse (up to 28mm) and contain abundant needle-like mineral inclusions (rutile or tourmaline?), suggesting the rock may be quartz generated by hydrothermal activity;
3) CO_2-dominated inclusions are well developed in densely distributed, parallel microfractures in the hydrothermal quartz (Q-H) in the basement, suggesting relatively high fluid pressure;
4) Abundant vapour-only aqueous inclusions were found in the euhedral crystals of the secondary cements and vuggy quartz veins (Q-V) near the unconformity and in the overlying Manitou Falls Formation. This, together with the low homogenization temperatures (101 to 134°C) of co-existing biphase aqueous inclusions, suggests low fluid pressures and probable boiling;
5) The brittle-style deformation associated with emplacement of this secondary quartz contrasts with the ductile deformation in the basement;
6) At present it is uncertain whether or not the fluids represented by these inclusions were directly related to mineralization;
7) Ongoing studies aim to characterize the nature and sequence of structures and related mineralizing fluids (fluid composition, temperature and pressure), as well as to evaluate the stress regime during mineralization, through the orientation of microfractures and fluid inclusion planes.

Acknowledgments

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[1] Department of Geology, University of Regina, Regina, Saskatchewan
[2] Saskatchewan Geological Survey, Regina, Saskatchewan

For more information, please contact Dr. Guoxiang Chi [Guoxiang.Chi@uregina.ca].

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