American Mineralogist, Volume 107, pages 2128–2142, 2022

The role of graphite in the formation of unconformity-related uranium deposits of the Athabasca Basin, Canada: A case study of Raman spectroscopy of graphite from the world-class Phoenix uranium deposit

Hao Song[1,2], Guoxiang Chi[2,*], Kewen Wang[2], Zenghua Li[3], Kathryn M. Bethune[2], Eric G. Potter[4], and Yongxing Liu[5]

[1]Chengdu University of Technology, Chengdu, Sichuan 610059, China
[2]Department of Geology, University of Regina, Regina, Saskatchewan S4S 0A2, Canada
[3]East China University of Technology, Nanchang, Jiangxi 330013, China
[4]Geological Survey of Canada, Ottawa, Ontario K1A 0E8, Canada
[5]Denison Mines Corporation, Saskatoon, Saskatchewan S4S 0A2, Canada

Abstract

The unconformity-related uranium (URU) deposits in the Proterozoic Athabasca Basin (Canada) represent the richest, and one of the most important, uranium endowments in the world. Most of the URU deposits are associated with pre-existing graphitic basement faults that were reactivated after the formation of the basin. These graphite-rich structures have been widely used as a vector for exploration, but the nature of the association of the URU deposits with graphitic basement faults has been debated for over four decades. Proposed roles of graphite include: (1) as a direct reducing agent to reduce U^{6+} to U^{4+} and precipitate uraninite; (2) as a precursor of hydrocarbons (mainly CH_4) produced in situ or nearby and then used as a reducing agent for uraninite precipitation; (3) as a precursor of hydrocarbons produced at depth that were remobilized to the site of mineralization and acted as a reducing agent for uraninite precipitation; and (4) as a lubricant facilitating faulting and fluid flow that led to uranium mineralization. This paper uses the Phoenix uranium deposit in the southeastern Athabasca Basin as a case study to address these uncertainties. Petrographic studies indicate that there is no direct contact between graphite and uraninite at microscopic scales, and the content of graphite in the graphitic metapelite along the ore-controlling WS Shear Zone does not show a systematic change with the distance from the unconformity surface. Raman spectroscopic studies of graphite suggest that the degree of structural disorder of graphite, expressed by various parameters related to the D bands and G band ratios, does not change systematically with the distance from the unconformity surface either. The minor irregularities in these parameters near the unconformity are better explained by paleo-weathering related to the unconformity and/or diagenetic processes than by hydrothermal activity related to uranium mineralization. Based on these observations and interpretations, the role of graphite as an in situ reducing agent, either directly or as a provider of hydrocarbons, is discounted. It is proposed that hydrocarbons derived from graphite at depth, tapped by episodic reactivation or seismicity of the basement faults that was facilitated by graphite as a lubricant, were responsible for URU mineralization.

Keywords: Raman spectroscopy, graphite, unconformity-related uranium (URU) deposits, Phoenix, Athabasca basin