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In-situ isotopic and chemical study of pyrite from Chu-Sarysu (Kazakhstan) roll-front uranium deposit.

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Abstract

Pyrite is common in roll-front type uranium deposit in Chu-sarysu basin, Kazakhstan. Combined in-situ microstructural, isotopic and chemical analysis of pyrite indicates variation in precipitation conditions and in fluid composition. Broad-scale $\delta^{34}S$ heterogeneity indicates a complex multi-facet evolution. First generation authigenic framboïdal aggregates are biogenic as demonstrated by the lowest $\delta^{34}S$ values of -48‰ to -28‰. The latest generation pyrites are probably hydrothermal with greater $\delta^{34}S$ variation (-30‰ to +12‰). This hydrothermal pyrite commonly displays variable enrichment of several trace elements especially As, Co and Ni. Strong variation in $\delta^{34}S$ values and variable trace element enrichment is interpreted in terms of continuous variations in fluid composition.

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Keywords: SIMS, LA-ICP-MS, traces elements, sulfur isotopy, pyrite, uranium, roll-front

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1. Introduction

Roll-front uranium deposits in Kazakhstan are characterized by U-bearing minerals systematically mineralized around complex conglomerates of iron sulfides. As pyrite in sands seems to have control on physical and chemical processes for U deposition, they have been separated and studied in detail to define their chemical properties and identify the processes of their formation (bacterial or hydrothermal origin). This study examines pyrite from Chu-Sarysu roll front uranium deposit in Kazakhstan. Microtextural analysis and in-situ microanalysis on a suite of pyrite-bearing samples from a profile across the uranium roll-front provide preliminary constraints on mineralization processes. This study also shows the potential of pyrite to monitor fluid changes in low-temperature hydrothermal systems.

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2. Geological context

Roll-Front uranium mineralization of Chu-Sarysu (Kazakstan) occurs in early Paleocene continental arkosic sands issue of peraluminous garnet and calc-alkaline volcanic rocks alteration. These sands were deposited in fluvial environments varying from braided river systems to alluvial plains covered by organic matter rich swamps. The whole sequence has been subject to shallow burial; temperature probably didn't exceed 50°C, and has not evolved since the last deposit. Uranium deposits occur where there is abundant pyrite[6].

3. Methodology

Sixteen samples representing different host formations and redox states were collected along a profile across the roll-front uranium deposit in Kazakhstan. Unconsolidated sands are separated into different size fractions by sieving. Heavy minerals of the fraction between 400 and 63 µm were concentrated using a bromoform solution and set in epoxy one-inch polished ring.

- Optical and scanning electron microscopy (SEM, JEOL J7600F) in back-scattered electron mode (BSE) was used to characterize pyrite morphology and identify relationships with U bearing minerals en Fe-Ti-oxides.
- Laser-ablation (GeoLas 193nm) inductively coupled plasma mass spectrometer (Agilent 7500 cs) was used to obtained trace element concentrations in pyrites. Major element concentration used for internal calibration was providing with electron probe microanalyser (Cameca SX100).
- Isotope analyses of $\delta^{34}S$ were carried out using an IMS 1270 secondary-ion mass-spectrometer (SIMS) on morphologically distinct type of pyrite. Details of analytical methods, for LA-ICP-MS and SIMS are given elsewhere[10,12].

4. Results

4.1. Morphological and textural observations

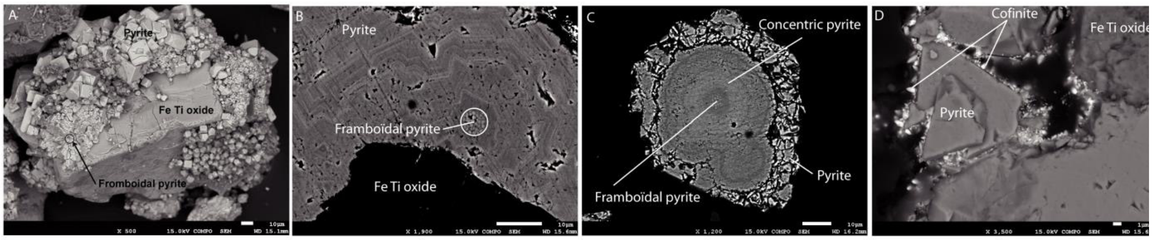

Fig. 1. Back-scattered electron images of pyrites with various morphology and there relations to Fe-Ti oxides and U-bearing minerals. (a) Fe-Ti oxide surrounded by different morphology of pyrite; (b) Polished section of the relation between the different generation of pyrite and Fe-Ti oxide, (c) example of the three main recognizable generation and there relations, (d) zoom on U-bearing mineral mineralized on the surface of pyrite and Fe-Ti-oxides.

Pyrite displays a range of morphologies categorized in this study as: i) framboïdal; ii) concentric and iii) euhedral or cement. The majority of pyrite occur in contact with Fe-Ti oxides (Fig 1, a), and all morphologies are present in all samples.

Framboïds are constituted of densely-packed, spherical aggregates of sub-micrometer-sized pyrite crystals (Fig 1, a, b and c). There can be isolated (Fig 1, c) or clusters of up to several tens of individual framboïds. The framboïds are rarely directly in contact with Fe-Ti oxides. Concentric pyrites exclusively form overgrowths around framboïdal pyrites, and are not found around any other minerals or other pyrite morphology (Fig 1, c). Euhedral or cement pyrite overgrows the two previous generations (Fig 1, c) and frequently link framboidal+concentric pyrite with Fe-Ti oxide (Fig 1 a, b). The morphology of this generation varies widely across the sample suite. Uranium-bearing minerals grow on the surfaces of all types of pyrite and Fe-Ti-oxides (Fig 1, d).