History Matching in Reactive Transport. Application to U-ISR.

KEYWORDS
History Matching, physics-based and data-driven optimization, inverse problem, adjoint state, reactive transport, ISR

GENERAL CONTEXT AND OBJECTIVES

In situ recovery (ISR) has recently become the main mining technique for uranium production: it is used for roll-front deposits occurring in medium deep aquifers. Compared to conventional techniques (open pit and underground mining), ISR is faster to implement, less expensive and offers reduced environmental footprint. However, as for oil&gas field, ISR has not a direct access to the deposit within the reservoir and suffers from strong uncertainties about the initial estimate of reserves and the assessment of their evolution over time.

For the past ten years, the Center of Geosciences of Mines Paris PSL and ORANO Mining have been developing a deterministic approach to simulate ISR operations using the reactive transport code HYTEC. The model is based on a 3D geological description (porosity/permeability maps and distribution of reactive mineral phases) coupled with a geochemical model describing the interactions between the leaching solution and mineral phases. In addition, the geometry of the well-field (coordinates and screen position) is fully described as well as operating scenarios. The feasibility and robustness of reactive transport modelling for ISR were demonstrated, especially at KATCO, a mining site in Kazakhstan. It has been shown that HYTEC accurately reproduces uranium recovery at the "technological block" scale (about 15 producer wells and 60 injectors) with manual calibration of the direct model performed on a few geochemical parameters. However, large discrepancies may remain, particularly when analysis is made at the scale of the individual producer well. At this scale, improving the history matching results requires local adjustments of geological/geochemical models through optimization methods.

Gradient-based methods allows for efficient optimization by integrating well data in the inverse problem. The adjoint state method is a well-known approach for parameter estimation in hydrogeology, seismic imaging, and reservoir simulation. The adjoint state is implemented in HYTEC and several regularization technics demonstrate a higher efficiency of the developed method comparing with derivative-free stochastic approaches such as PCGA, ESMDA, and SIES.

The main objectives of this study are to:
   i)   extend the developed adjoint-based history matching to real production at large scale, production forecast for mining plan, estimation of production potential, and reconciliation between production and initial estimate of reserves;
   ii)   derive and implement the adjoint method for complex geochemical systems to explore major parameters of ISR-U (distribution of geochemical facies and in particular, acid consumers).

The results will be published in journals of applied mathematics and reactive transport and presented in major conferences and workshops of the field.

Duration: 12-month fixed-term contract at Mines Paris – PSL
Missions: scientific conferences, missions on the mining sites of ISR in Kazakhstan
Access to specific data bases: mining data of the ISR sites in Kazakhstan

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