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, Industry

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 fifteen 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 allow 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 high efficiency. It has been applied successfully to synthetic cases.

The main objectives of this study are to:

i) apply 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) investigate the potential and feasibility of using simplified geochemical models aka proxies for faster computation.

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

Skills

- Doctorate (Ph.D) degree (or engineer with a first experience) with solid background in mathematics/physics and numerical optimization;
- Experience in numerical optimization, machine learning, with advanced skills in python and associated scientific libraries (numpy, scipy, pandas, matplotlib, pyvista)
- Strong motivation for team work with the industrial partners;
- High level in English, intermediate level in French is desirable.
- Skills in geosciences and geochemistry is a plus.

Workplace and contract

This project is part of a collaboration between Centre for Geosciences of Mines Paris - PSL and Orano. Centre for Geosciences conducts projects with major economic and societal implications, such as sustainable supply of primary resources, underground storage of energy and waste, and environmental impacts on water resources. Orano is the French national nuclear fuel cycle company, the third largest producer of uranium in the world.

The position will be based at Centre for Geosciences in Fontainebleau (77), with regular travel to ORANO's headquarters in Châtillon (92) and potential trip to the mining sites of ISR in Kazakhstan.

Duration: 12-month fixed-term contract at Mines Paris - PSL.

Starting date: from the second semester 2025.

CONTACTS

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HOW TO APPLY ?

Please send the following documents to the above contacts (pdf format):
- CV
- Motivation letter
- Any supporting research documents (publications, thesis, report, etc.)
- Recommandation lettres/referee contacts

BIBLIOGRAPHY

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