Permeability prediction with geostatistical seismic inversion constrained by rock physics

PHD IN PETROLEUM ENGINEERING

ROBERTO MIELE (roberto.miele@tecnico.ulisboa.pt)

Predicting rocks' permeability

Why?
Rocks' absolute permeability (k) describes the ease with which a given fluid can flow through the pores of a rock sample. An accurate prediction about the spatial distribution of k in the subsurface allows for reliable evaluations of risks and monitoring of CO2 gas plumes injected in the subsurface (for carbon capture and storage), or for predictions of production of a hydrocarbon reservoir.

What are the main issues with permeability modelling?
Direct measurements of k on samples are scarce and its values variate strongly over several order of magnitudes. That is why k is usually derived using rocks' porosity (ϕ) data in two ways:

- **Data-driven** approaches: statistical co-simulation of k from the joint distribution of measured ϕ vs. k (Figure 1, left). Lack of physics information can result in geologically implausible models.
- **Rock physics** modelling: predicting k from ϕ using a set of equations that require knowledge on the rocks' structure (e.g., pore shape and tortuosity). The resulting models do not reproduce the real .variability of k.

By linking ϕ to rocks' acoustic impedance (AI), both approaches can be included in a seismic inversion algorithm (deriving rock properties distributions from seismic data; e.g., Sen, 2006, Bosch et al., 2010, Azevedo and Soares, 2017).

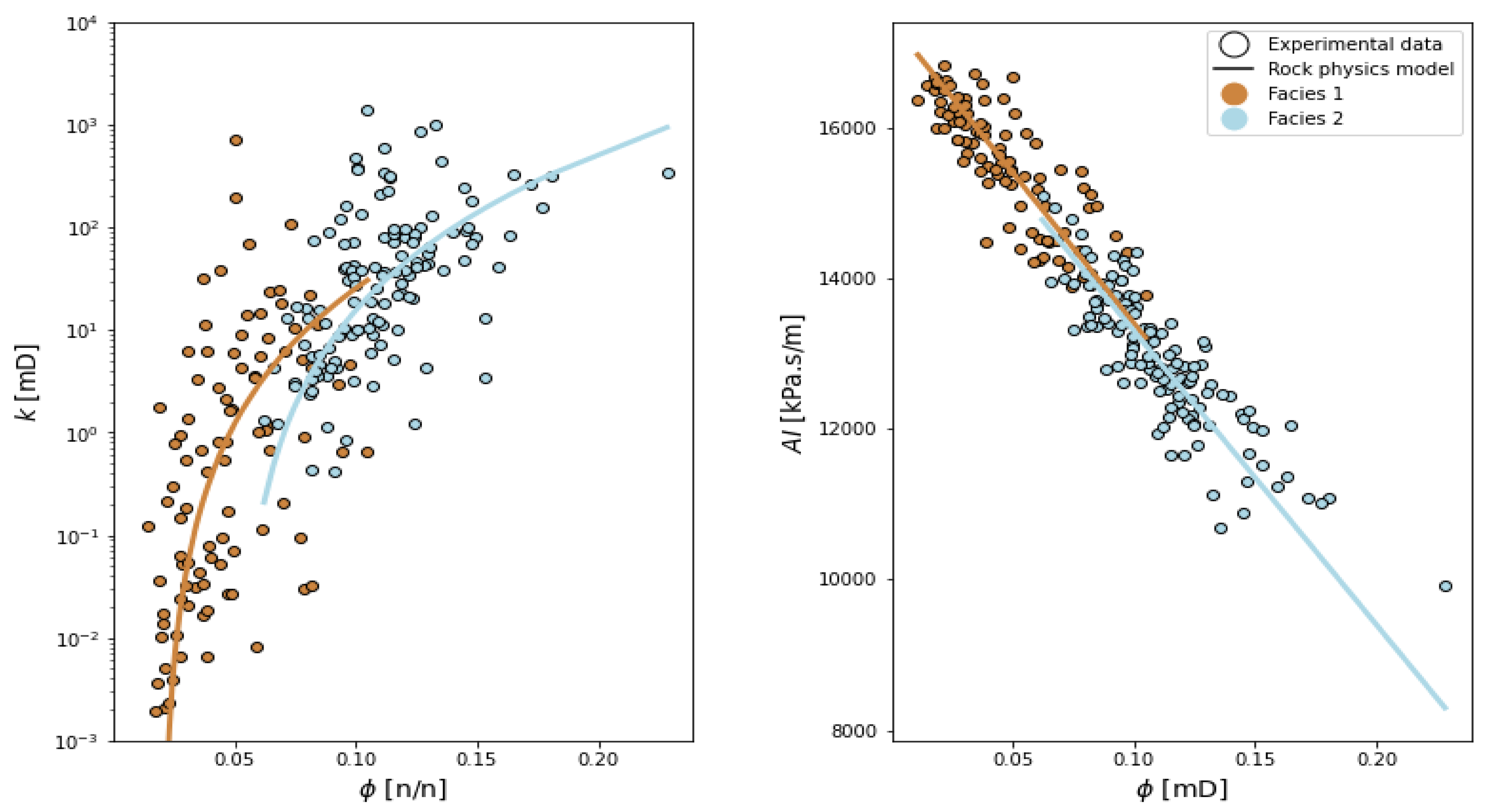

FIGURE 1: Distribution of k vs. ϕ (left) and ϕ vs. AI (right). Calibrated rock physics models are represented by the colored curves.

Proposed solution
We propose an iterative stochastic seismic inversion algorithm to invert for facies (rocks' litho-fluid classes) and k, based on the principles of the global stochastic inversion (GSI) (Soares et al., 2007), and integrating both data-driven and rock physics modelling approaches (Figure 2).

Facies models are generated using Markov Chain Monte Carlo sampling, while stochastic sequential simulation and co-simulation are used to generated k, ϕ and AI. At each iteration, the new generation of models is stochastically updated based on rock physics plausibility and seismic data misfit.

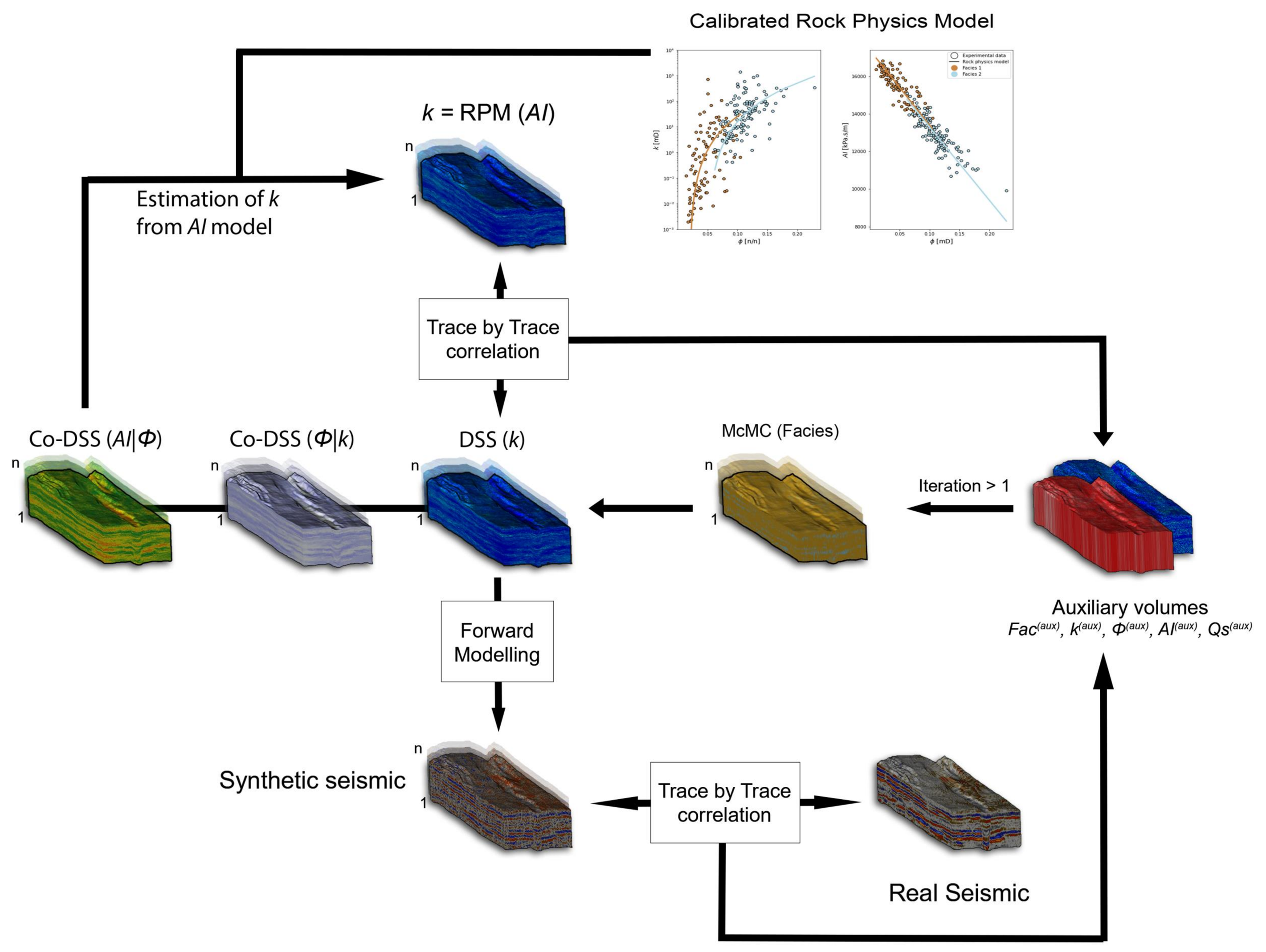

FIGURE 2: Stochastic Seismic Inversion algorithm proposed

Results
We successfully applied the methodology to a synthetic, 1D case, (Figure 3) and compared the results with those of the two other commonly adopted approaches. The methodology proposed outperforms both in the reproduction accuracy of facies and permeability real trends. Similar results were obtained in a real, 3D study case application.

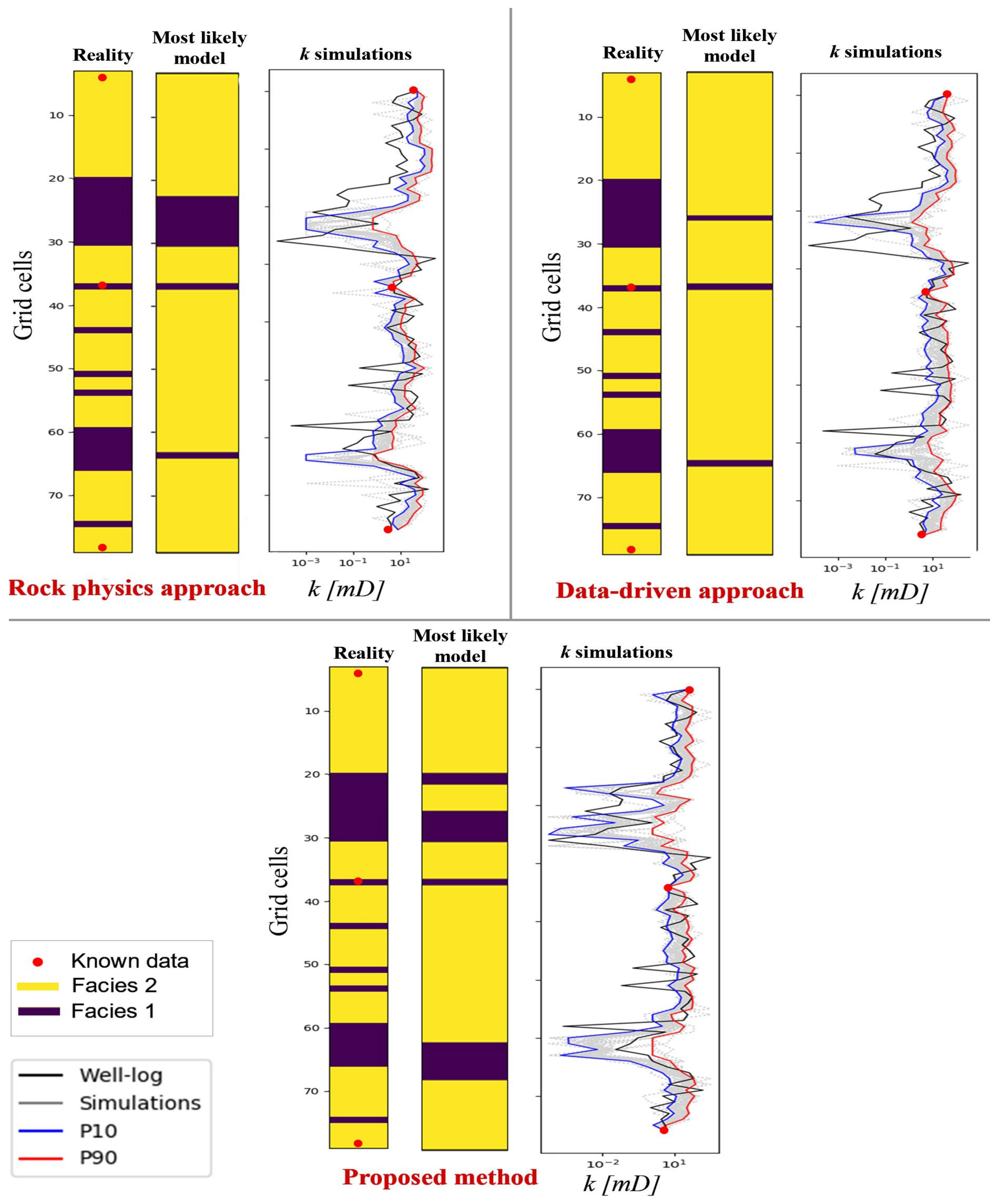

FIGURE 3: Results of the synthetic case application. Red circles are experimental measured data. P10 and P90 are the 10th and 90th percentiles of the simulations' ensembles.