Exploring the ability to quantify reservoir parameters from seismic inversion data using inverse rock physics modelling

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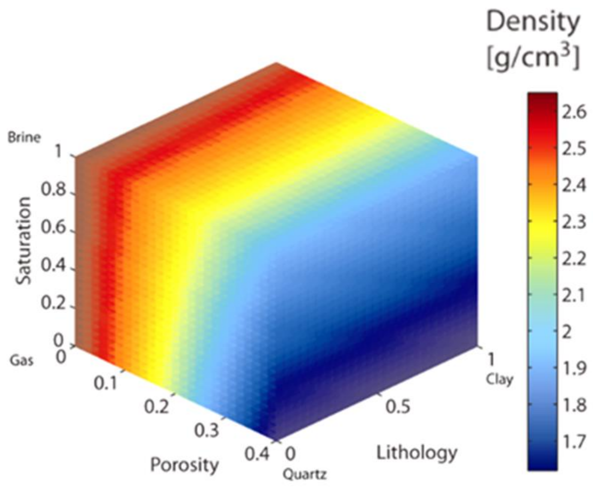
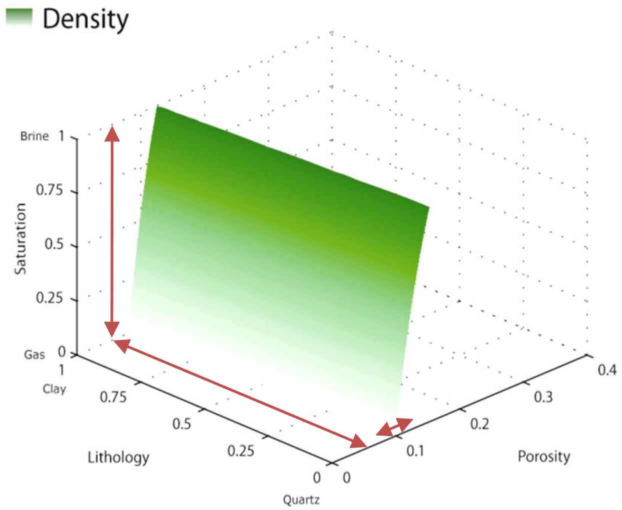
Outline

- Rock Properties vs. Elastic Properties
- Inverse Rock Physics Modelling - IRPM
- Seismic Inversion Feasibility Using IRPM
- Well Log Data vs. Seismic Inversion Data
- Seismic Inversion Analysis Using IRPM
- Conclusions

Rock Properties vs. Elastic Properties

PLF solution space	Solution for 1 observation

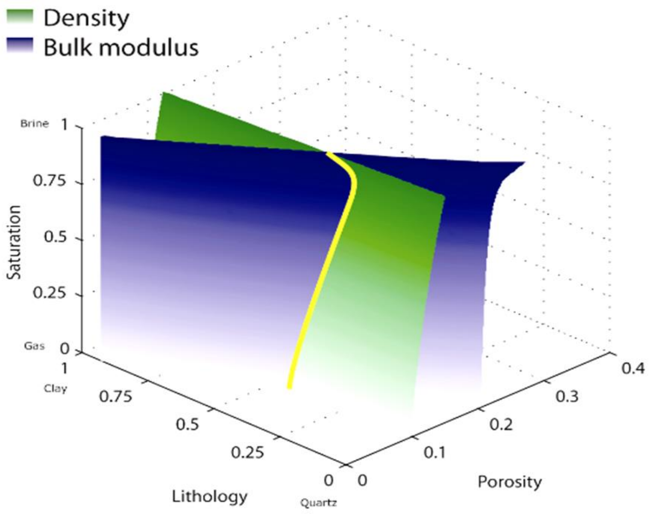


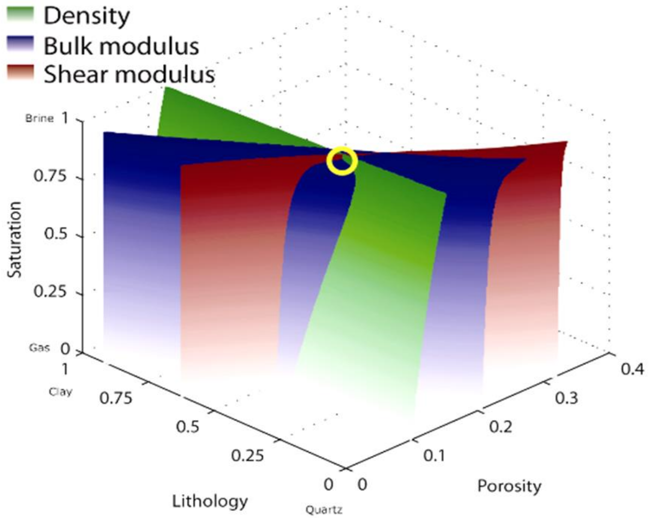


- A Rock Physics Model (**RPM**) can span a Porosity-Lithology-Fluid (PLF) solution space for all types of observations.
- Each observation can be viewed as an iso-surface in the PLF-space.
- All combinations of PLF values on the surface is a solution consistent with the RPM.

Rock Properties vs. Elastic Properties

Solution for 2 observations	Solution for 3 observations





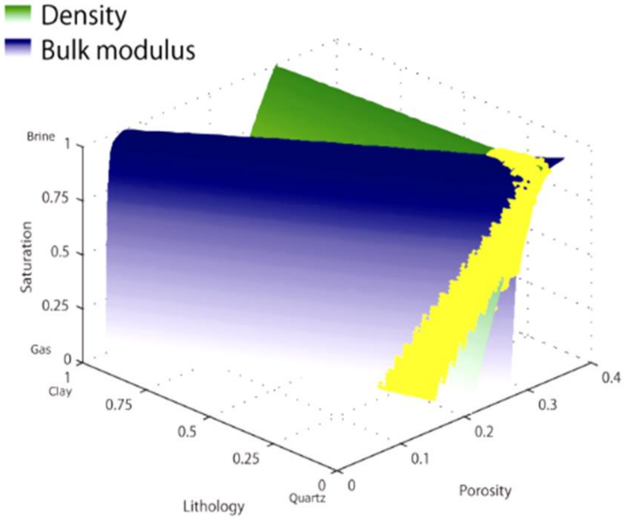
For exact solutions assuming exact data and exact model:

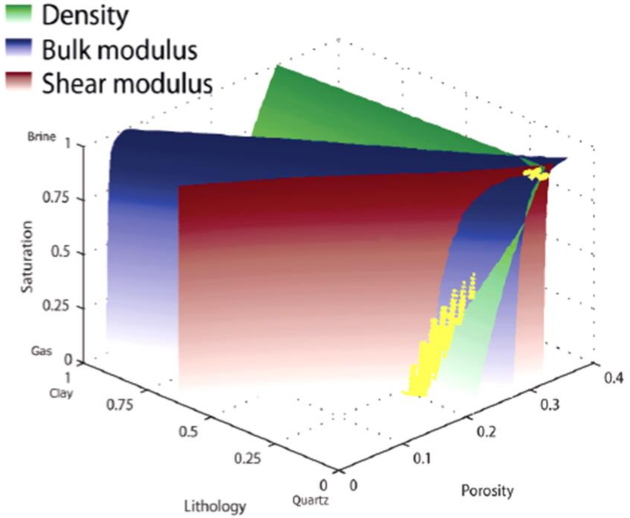
- 2 observations define an intersection line of consistent solutions.
- 3 observations define intersection point(s) of consistent solutions.

ROCK PHYSICS TECHNOLOGY

Rock Properties vs. Elastic Properties

Solution for 2 observations	Solution for 3 observations





- Uncertainties in data define point clouds of consistent solutions.
- Uncertainties in model/model parameters define thicker surfaces.

Inverse Rock Physics Modelling – IRPM

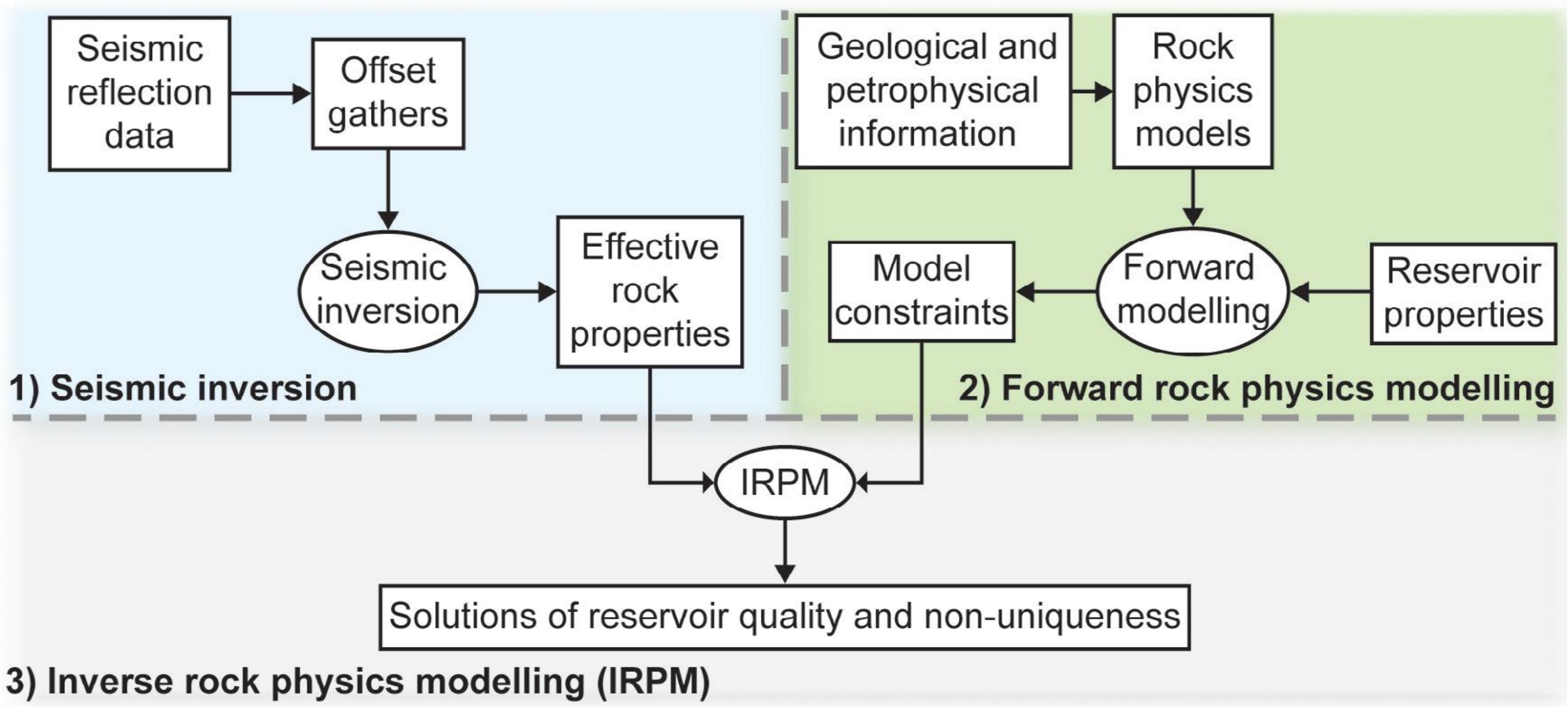
Predict rock properties by an exhaustive search in the PLF solution space spanned by forward modelling using a RPM.

Key features:

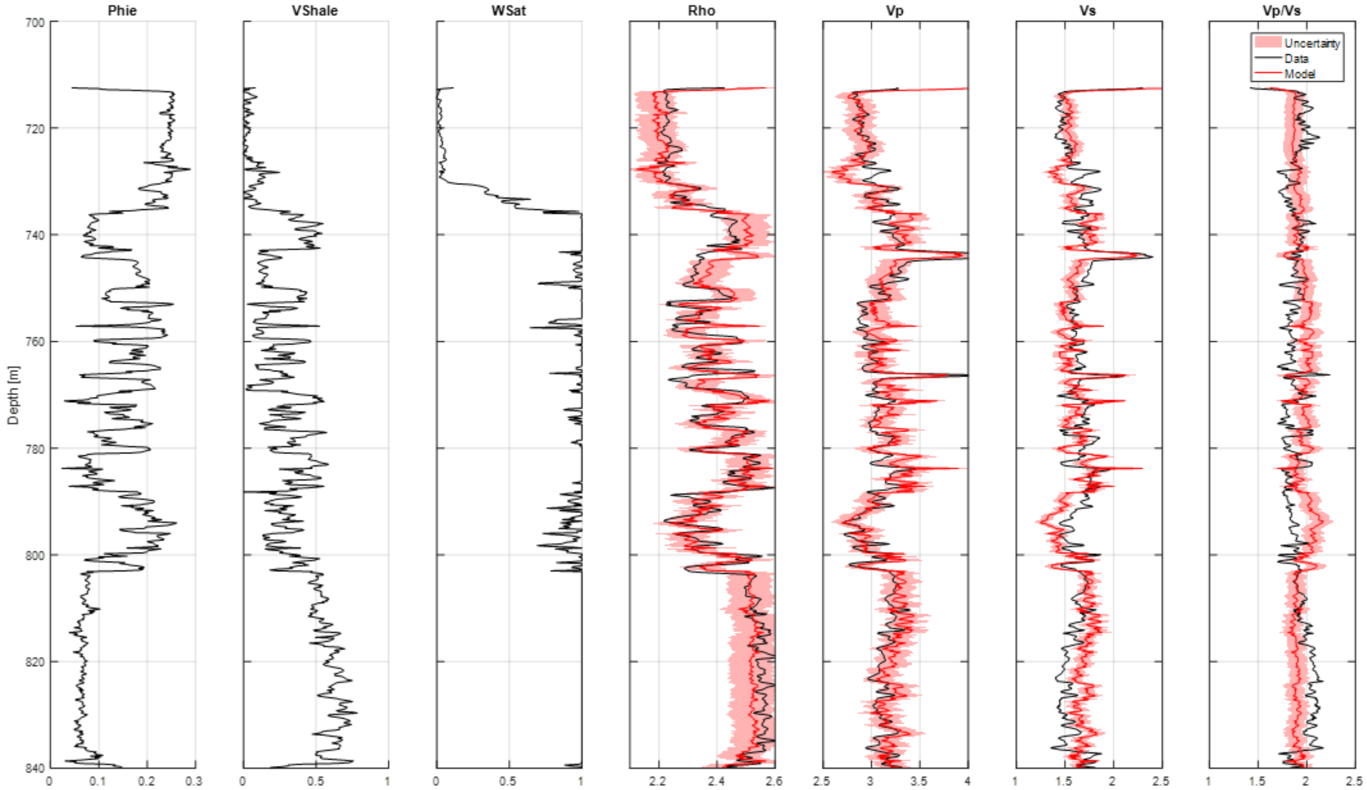
- Use **fit-for-purpose rock physics** models, not limited to a specific theory.
- **Honour complex, non-linear relationships** between properties.
- **Capture non-uniqueness** in relationship between rock properties and elastic properties.
- **Integrate uncertainties** in data and model parameters.
- **Predict uncertainties** in reservoir properties and model quality.

- Concept introduced by Johansen et al. (2013). Further shown by Bredesen et al. (2015), Jensen et al. (2016, 2017).
- Implemented and developed at the Department of Earth Science, University of Bergen.
- Applications demonstrated in various geological environments through theses and projects.

IRPM workflow

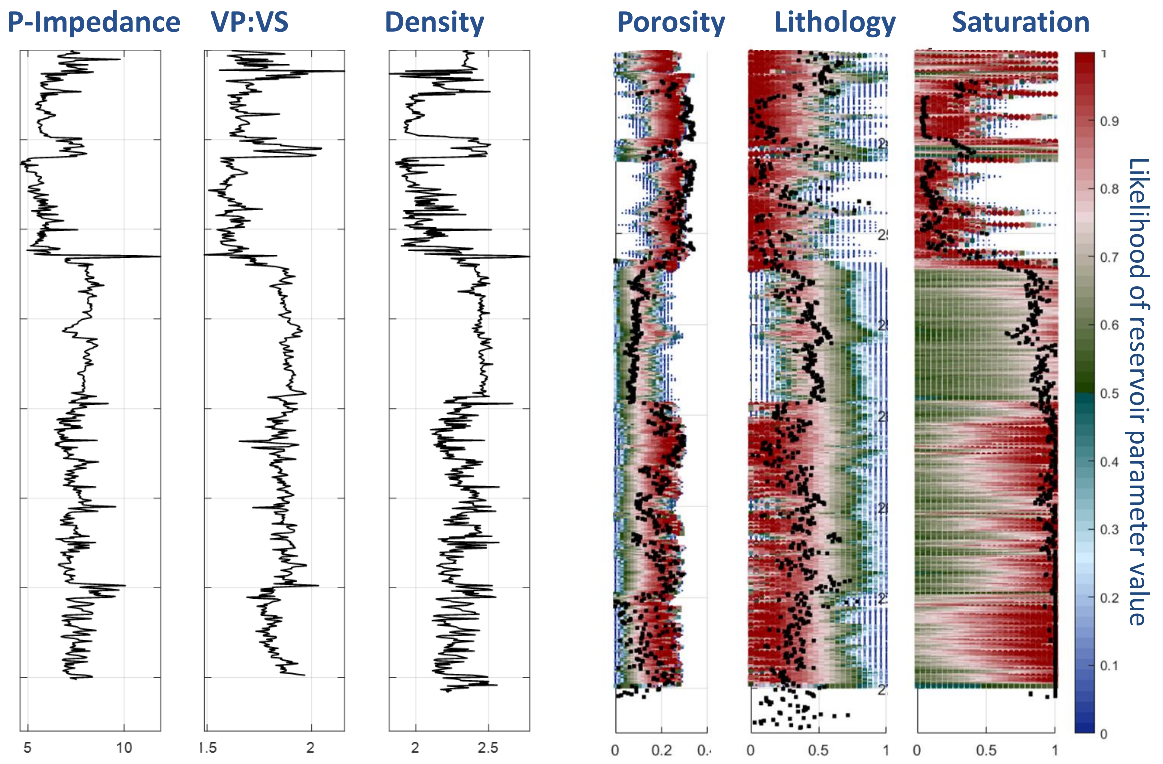


Forward Modelling of Elastic Well Logs with Uncertainties



IRPM Predictions on Well Log Data

ELASTIC INPUT DATA → RESERVOIR PARAMETERS



Black dots represent the well log data. These are not used in the IRPM method and are only plotted as QC of the predictions.

Coloured dots represent all possible IRPM predictions. The colour scale is the likelihood of that value, i.e. red dots have high likelihood, blue dots have low likelihood.

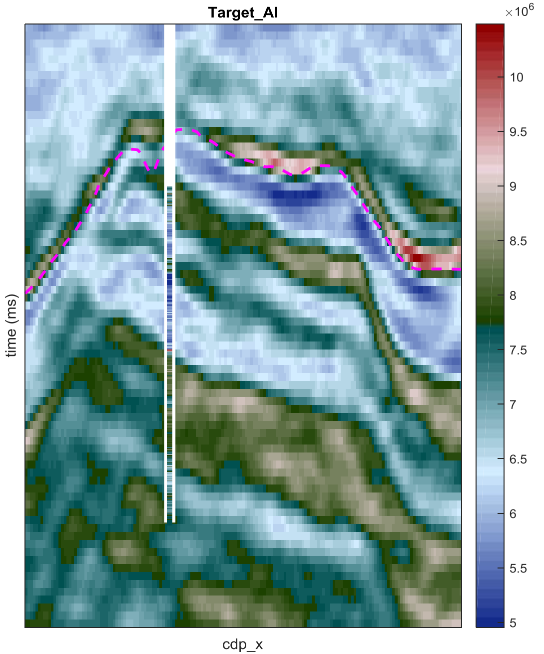
Blank areas means no consistent values are found using the current RPM and the assumed data uncertainties.

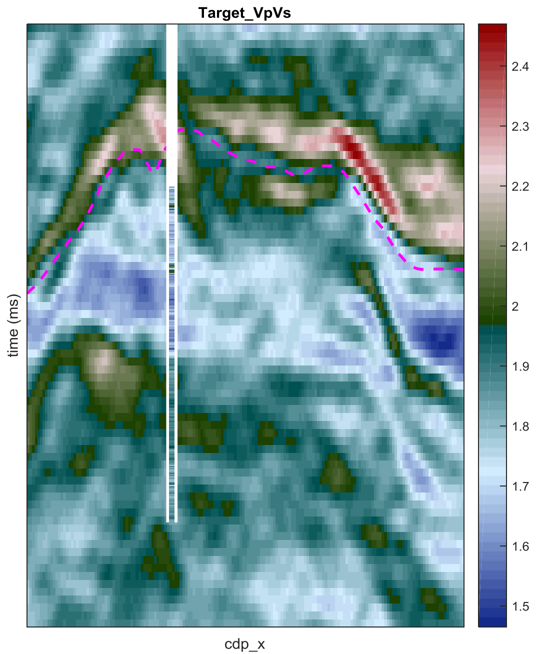
High likelihood predictions coincide well with data indicate good match between model and data.

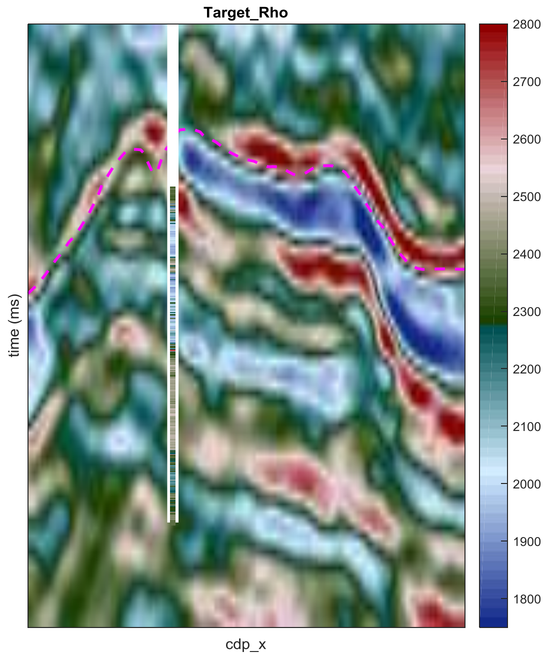
High/intermediate likelihood predictions that cover a wide range indicate high uncertainty in the predicted values.

Well Log Data vs. Seismic Inversion Data

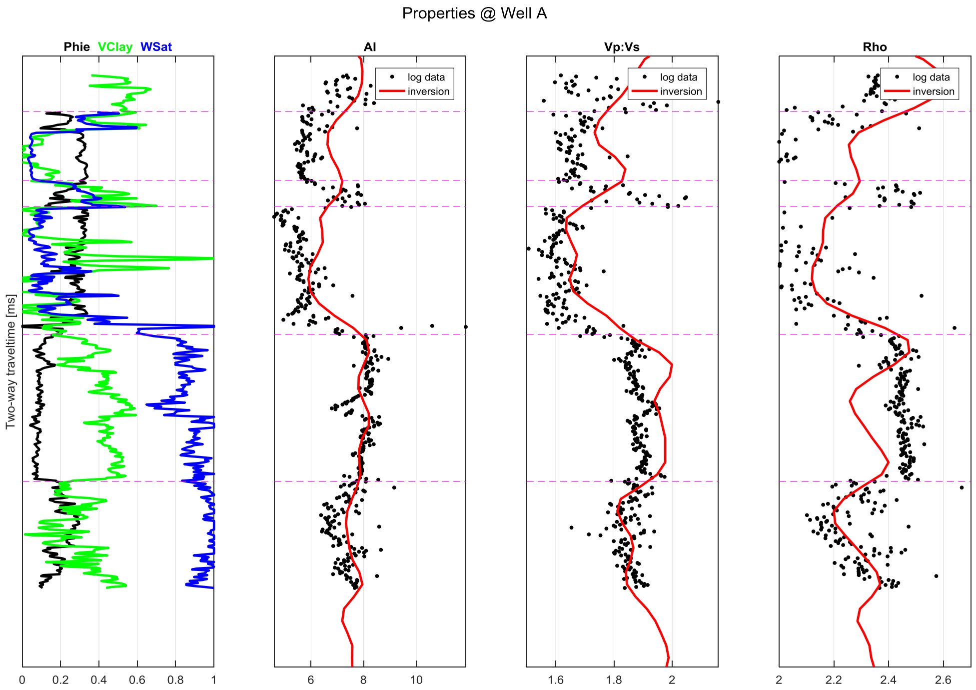
P-Impedance	VP:VS	Density

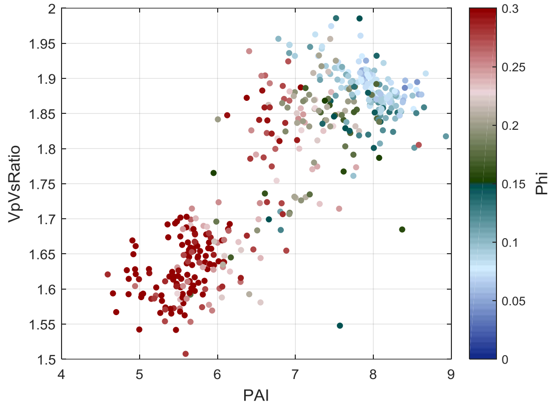


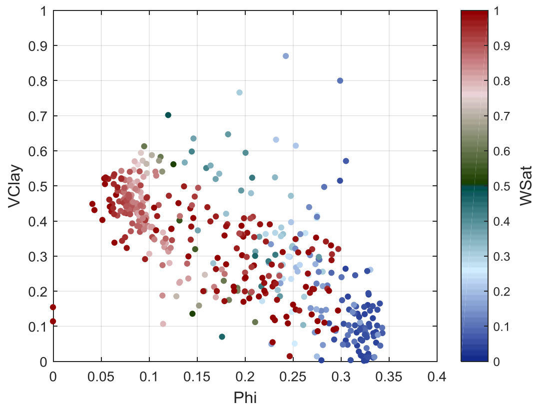




Well Log Data vs. Seismic Inversion Data





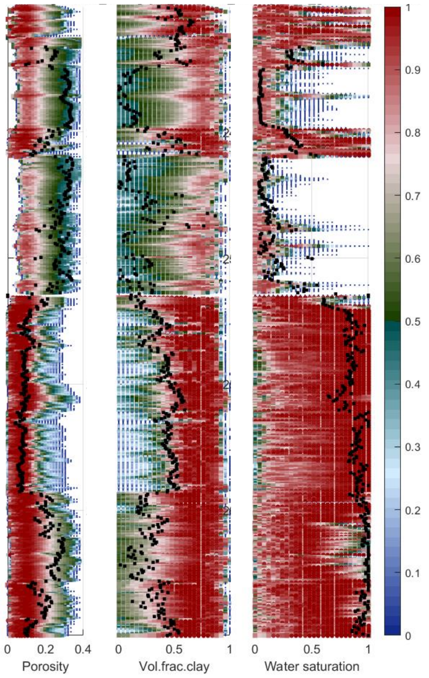


● **Log data** — **Inversion data**

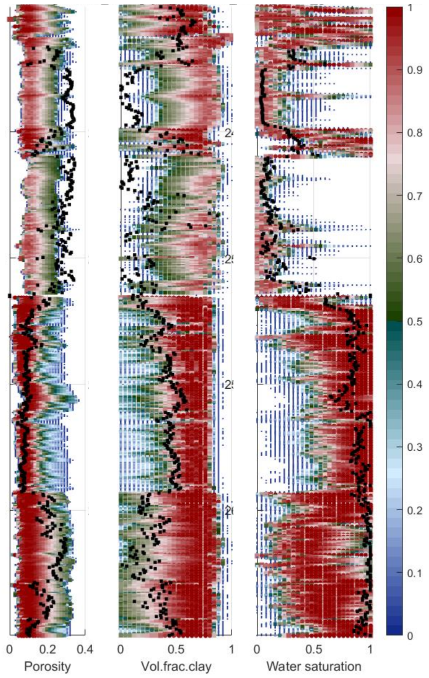
IRPM Predictions on Well Log Data

Input: [AI, VP:VS]	Input: [AI, VP:VS, RHO_est]	Input: [AI, VP:VS, RHO]

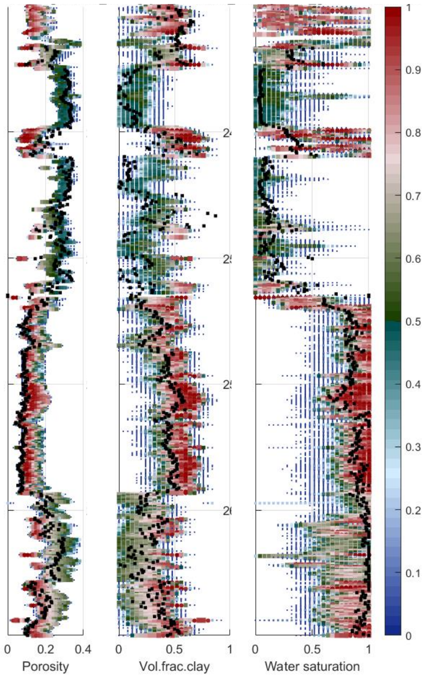
Porosity Lithology Saturation



Porosity Lithology Saturation



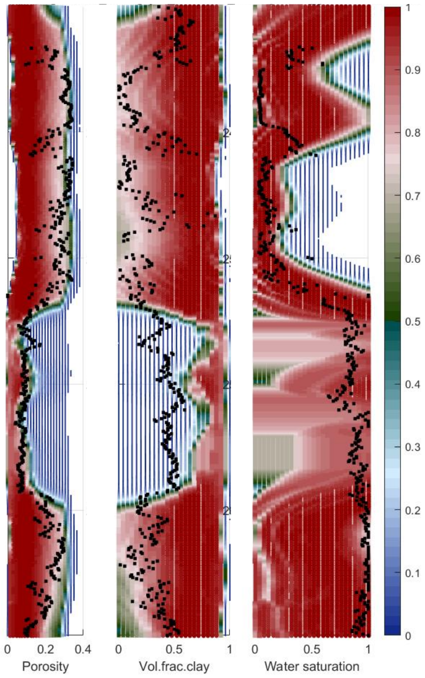
Porosity Lithology Saturation



IRPM Predictions on Seismic Inversion Data

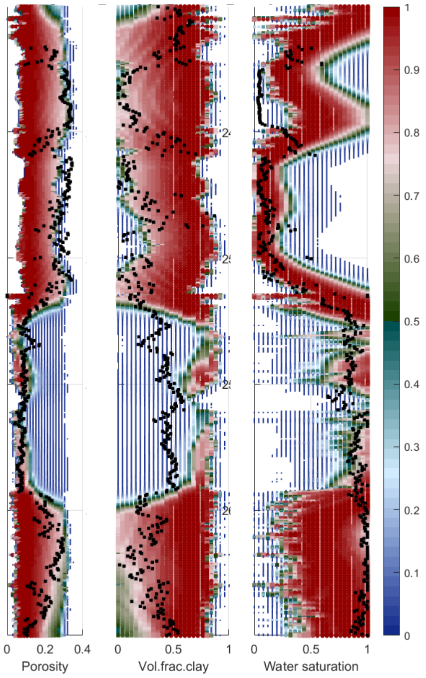
Input: [AI, VP:VS]

Porosity Lithology Saturation



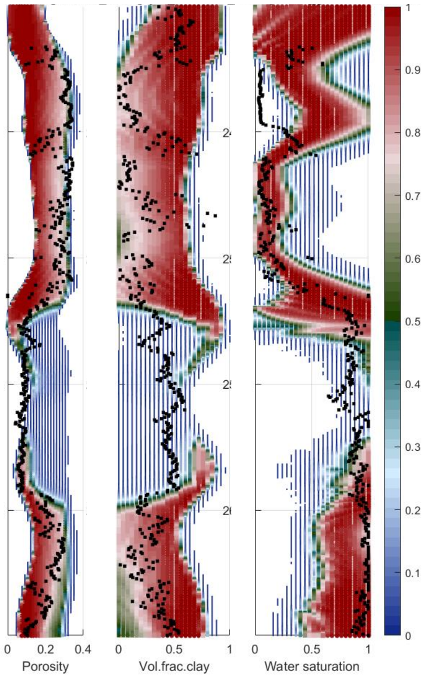
Input: [AI, VP:VS, RHO_est]

Porosity Lithology Saturation



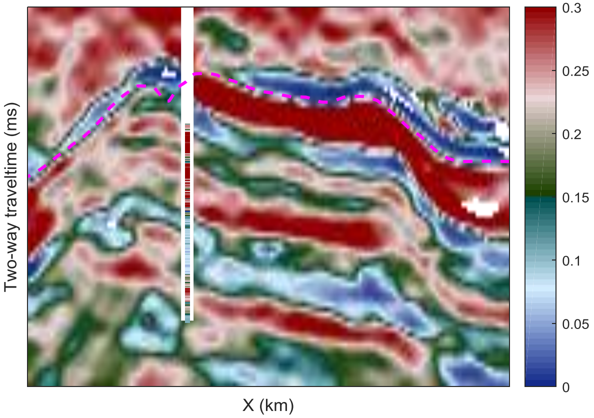
Input: [AI, VP:VS, RHO]

Porosity Lithology Saturation



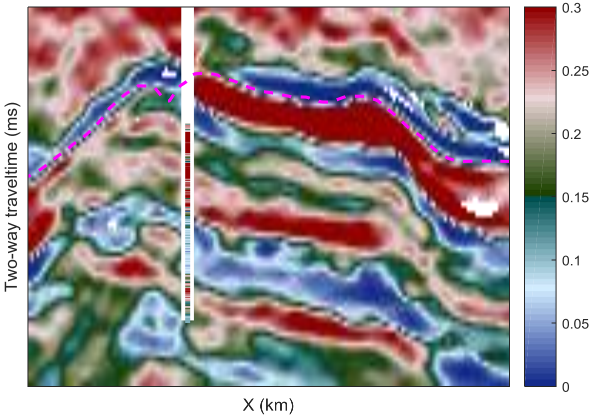
IRPM calculates a spectrum of solution types

Porosity: Mean Value



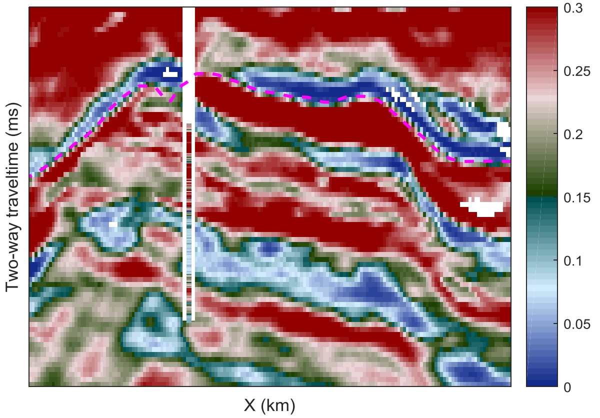
Average solution

Porosity: Model Weighted Mean



Average solutions weighted using model likelihood

Porosity: Posterior Mean

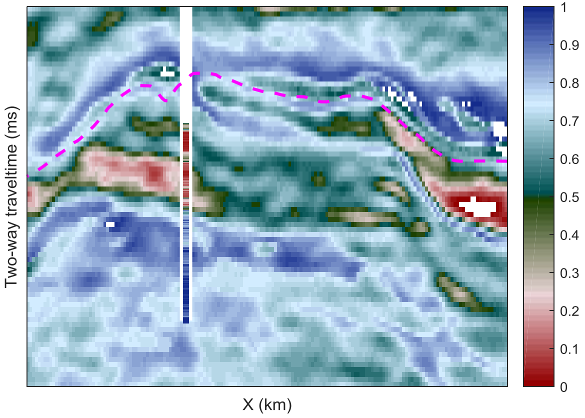


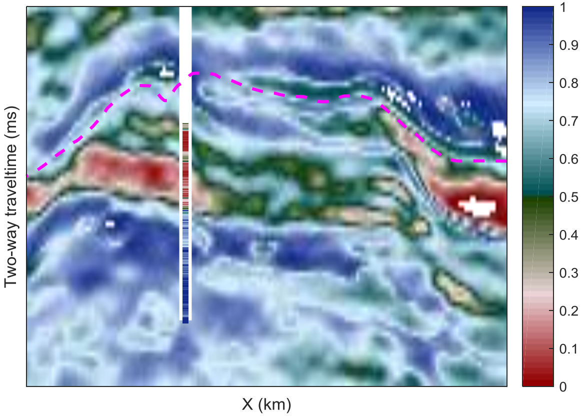
Average solution weighted using Bayesian probability;

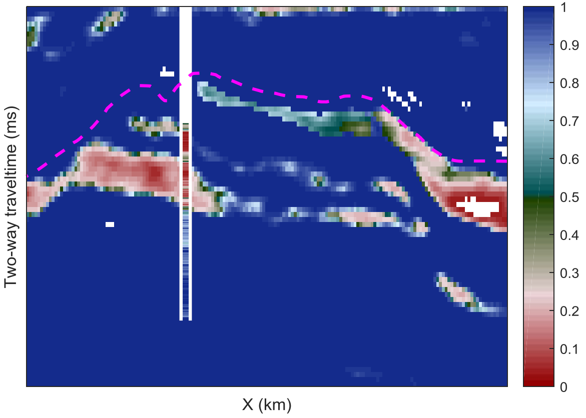
a priori = most likely water saturated

IRPM calculates a spectrum of solution types

Saturation: Mean Value	**Saturation**: Model Weighted Mean	**Saturation**: Posterior Mean







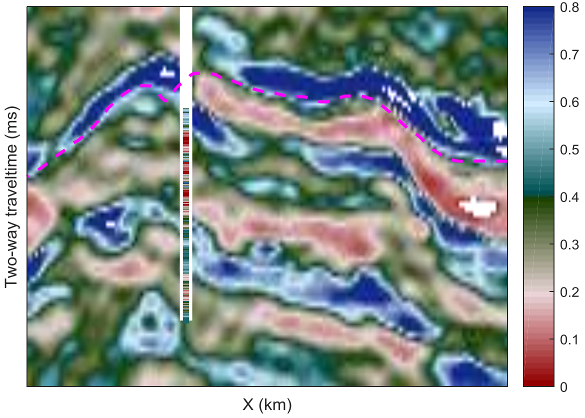
Average solution

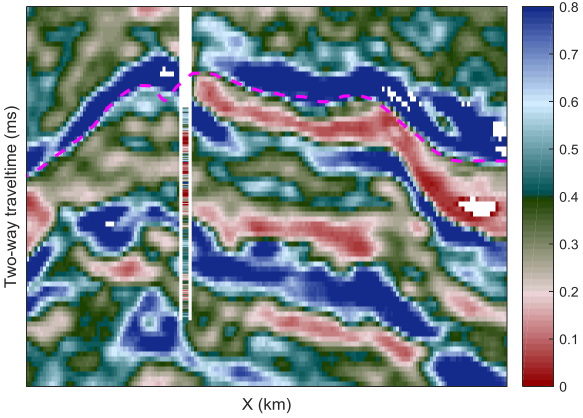
Average solutions weighted using model likelihood

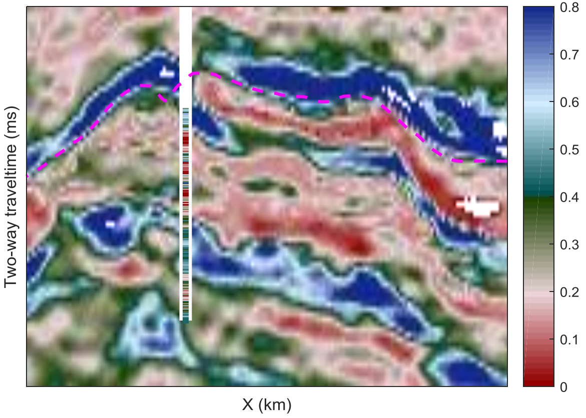
Average solution weighted using Bayesian probability;
a priori = most likely water saturated

IRPM calculates a spectrum of solution types

Lithology: Mean Value	Lithology: Model Weighted Mean	Lithology: Posterior Mean







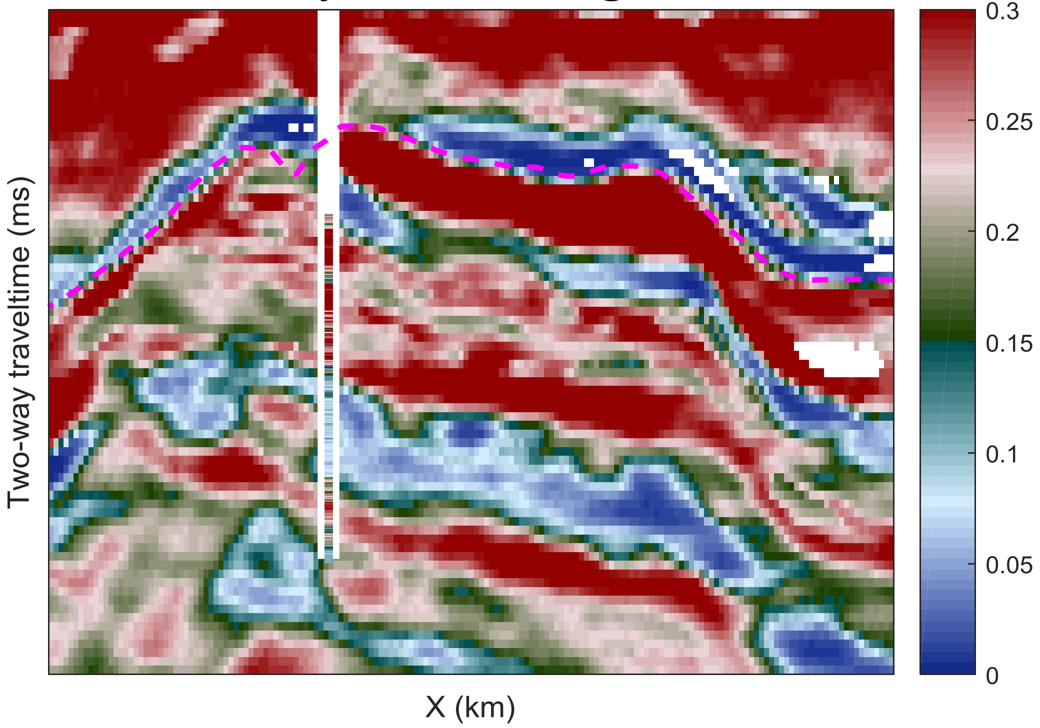
Average solution

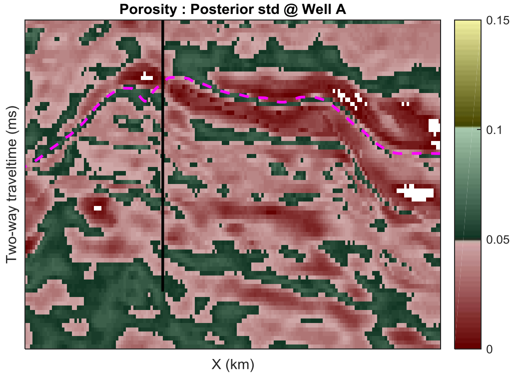
Average solutions weighted using model likelihood

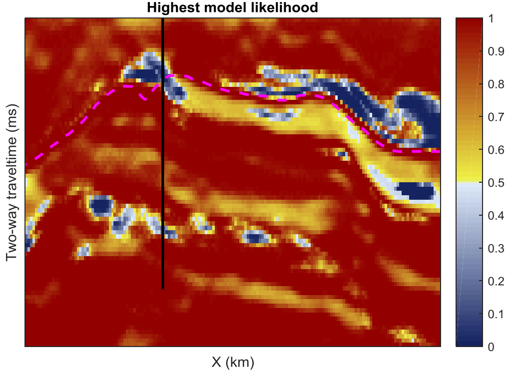
Average solution weighted using Bayesian probability;
a priori = most likely water saturated

Porosity Prediction

Posterior mean at well A







Conclusions

- IRPM allows consistent handling of fit-for-purpose rock physics models.
  - Honours non-uniqueness and non-linear relationships
  - Allows for error propagation
- IRPM can be used in feasibility studies for seismic inversion to investigate:
  - Sensitivity to error levels in the observations
  - Sensitivity to different data combinations
- IRPM allows integration of geological constraints:
  - Explore different scenarios
  - Consequences of different hypotheses

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