MODEL MULTIPLICATION

Exploring Uncertainty in AVA Amplitude Interpretation

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Model Multiplication

… In forward modelling of AVA seismic data

- My grumbles
- Don’t settle too soon!
- Uncertainty breeds models
- Desktop data crunching with Python
- Model Multiplication - the workflow
- What will you find there? (tutorials)
- Case study (Clapham Area, NNS, UK)

My Grumbles

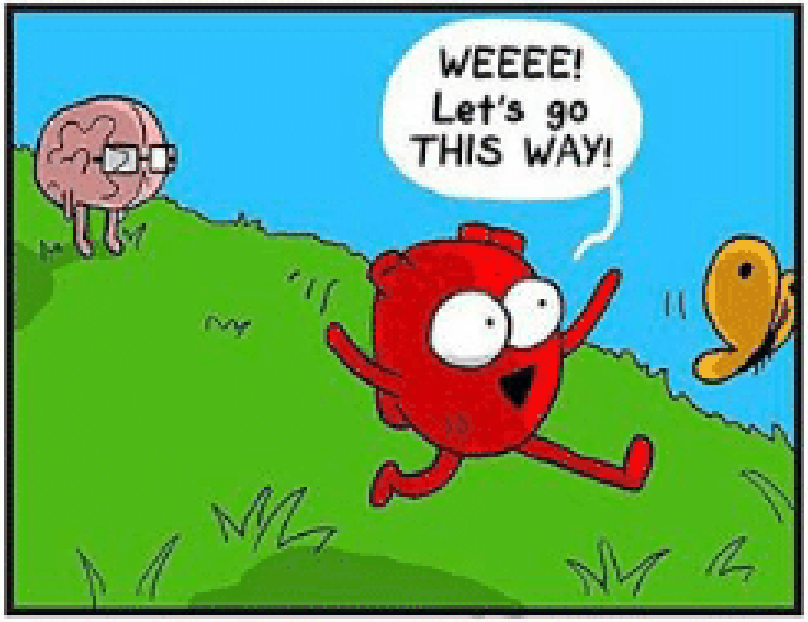
- **ONE model**?!:
  - In early exploration, presenting a single geological model, and a single ‘confirmational’ forward seismic model is not sufficient.
- **Uncertainty** is omnipresent in Exploration – get comfortable and **quantify**!
  - Quantifying uncertainty is frequently a “judgement call” based on confidence in a single model.
  - Constructing statistically significant numbers of models allows us to:

1. Find a quantitative indication of the uniqueness of a response and how confident we can be in our preferred model(s).
2. Explore WHAT ELSE COULD IT BE?

- **Big Data and big compute**:
  - We have so much data and computing power at our fingertips – we frequently do not use these to their full extent.

Don't Settle too Soon!

- Resist adopting restrictive model bounds from the outset
  - that is the way of the single model!

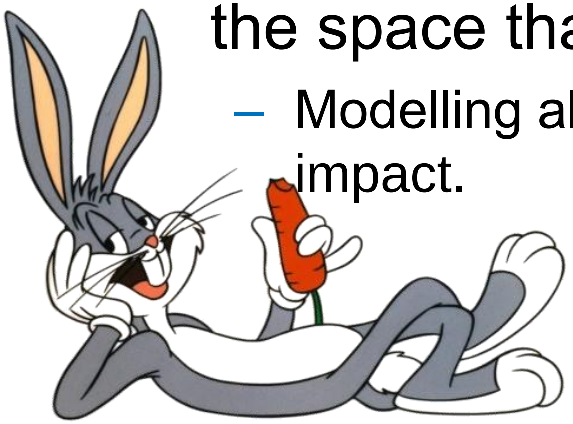


- Discuss – what variables are there? Which are well defined? Which are uncertain or unknown?
- What bounds does the available data place on the geological model? And therefore the rock physics model?

You probably have greater numbers of variables, and wider ranges of variation than you are initially comfortable with…

Uncertainty Breeds Models

- Identify your key variables
  - Those with the biggest uncertainty ranges.
  - …But in particular those to which the rock properties (and therefore the model) are most sensitive.
- The geological model may impose fewer constrains on the rock physics model than you anticipate
  - Small variations in shale content, gas-oil ratio, and internal structure/laminations (particularly at the reservoir interfaces) can have a significant impact on elastic properties.
- The range of uncertainty defined for each variable is the space that is filled with… Models!
  - Modelling allows you to explore these ranges… and their impact.



The Case for Desktop data crunching with Python – dare ye to enter!

https://github.com/jojanna/FORCE

- Ability to automate and iterate
  - No repetitive clicking. Make the most of a computer's ability to undertake repetitive tasks fast and accurately.
- Ability to customise
  - Yes, you can implement that set of variables and test the impact of that empirical constant.
- 'Hands on' with the data – no space for black boxes!
  - What are you actually doing to the data? Is it correct/best practice?
  - What implicit assumptions does it make about the data?
- Replicable workflows
  - Check/duplicate the outcome quickly. Change a parameter, and regenerate the results quickly.
- Handle big, inter-relational databases.
- … and undertake it all freely on your desktop.

The workflow

- Constructs a specified number (100s-1000s) of half space (interface) forward models by sampling from a database created from the fluid substituted wireline logs of all wells supplied.
- Returns the intercept/gradient (Shuey approximation) of all models created, retaining a full trace back of the samples used.
- Requires standard QI inputs i.e. well logs (acoustic and petrophysical), deviation/position, fluid parameters, temperature/pressure.
- Is intended to be iterative, allowing a large number of simulations to be generated rapidly.

The Workflow

1) Assemble data

- Vp, Vs, RhoB,

Vsh, Sw and PhiE.

- QC & clean logs for fluid sub.
- Identify suitable (ranges!) fluid parameters for fluid sub.
- Create TVD logs

2) Implement fluid sub

- Reduce all wells to 100% water.
- Run multiple fluids at multiple saturations/parameters.

3) Review controls on acoustic properties

- Which fluid parameters influence Vp/Vs/RhoB most strongly?
- To what degree are they known/bounded?
- How does this influence your understanding of the uncertainty?

4) Classify discrete facies

- Unsupervised clustering on 100% water case.
- Create database of facies and fluid variations.
- Review on logs – to what degree do the classes reflect geological formations?

5) Generate half space model pairings

- Consider physical constraints/rules on juxtaposed pairs.
- Consider use of depth trends e.g. shale line.

6) Plot and query predicted outcomes

- Scale to your seismic.
- Plot against surface extractions of I/G
- Map data fields from I/G cross plot onto interpreted surfaces

7) Extend modelling to 1D/2D

- If appropriate – to explore impact of the wavelet and tuning.

What will you find there?

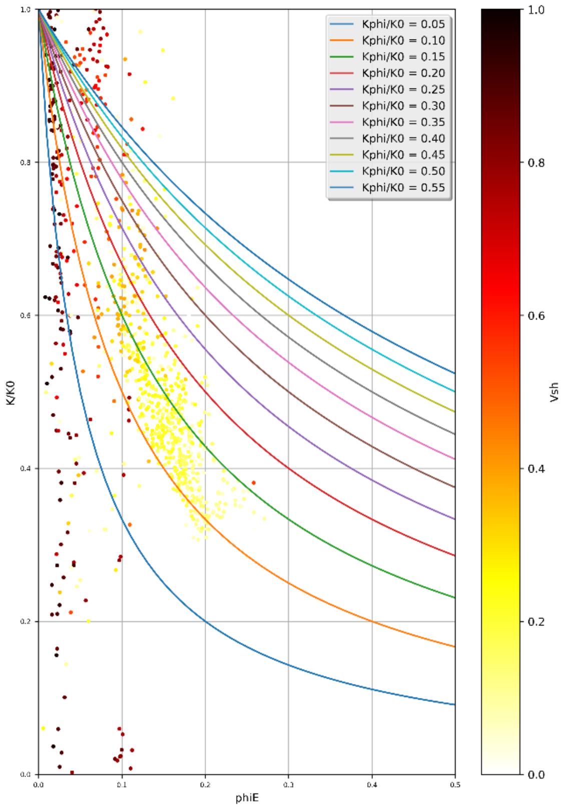
https://github.com/jojanna/FORCE

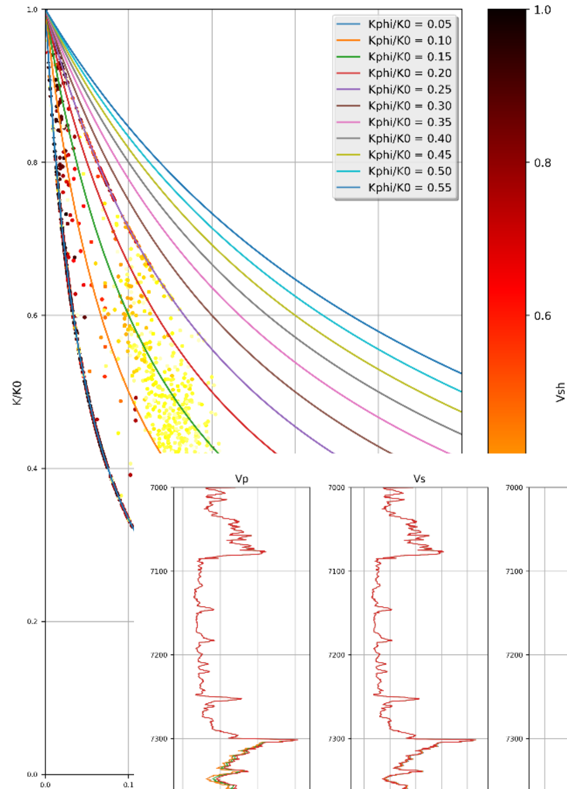
- Tutorials (as interactive Jupyter notebooks):
  - FORCE Tutorial 1 - create TVD logs from deviation
  - FORCE Tutorial 2 - Merge las files
  - FORCE Tutorial 3 – FRM
  - FORCE Tutorial 4 - Clustering Facies
  - FORCE Tutorial 5 - Build Modelling Database
  - FORCE Tutorial 6 - Half Space Forward Modelling
- Python Scripts
- Example well data and parameters files

What will you need?

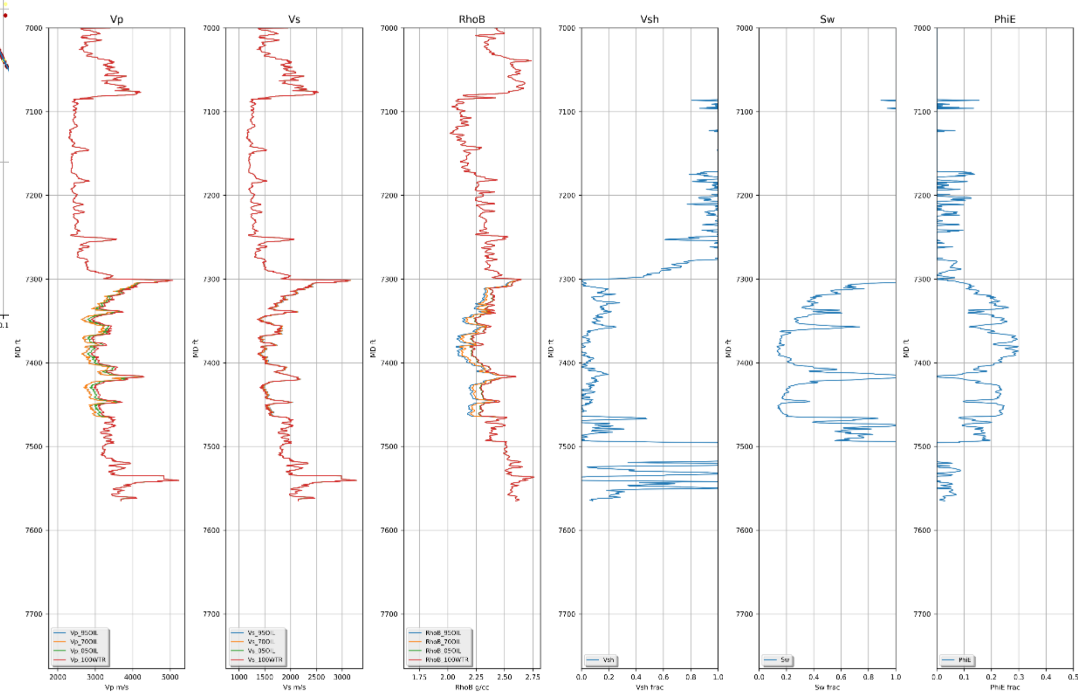
- Recommended Python implementation: Anaconda package (https://docs.anaconda.com/anaconda/install/) with Python 3.3+ (the code will not work with Python 2.7)
- Lasio library (https://pypi.python.org/pypi/lasio)
- Jupyter Notebook (http://jupyter.org/install.html)
- Recommended IDE: Pycharm (https://www.jetbrains.com/pycharm/)

Case Study – Clapham Area, NNS



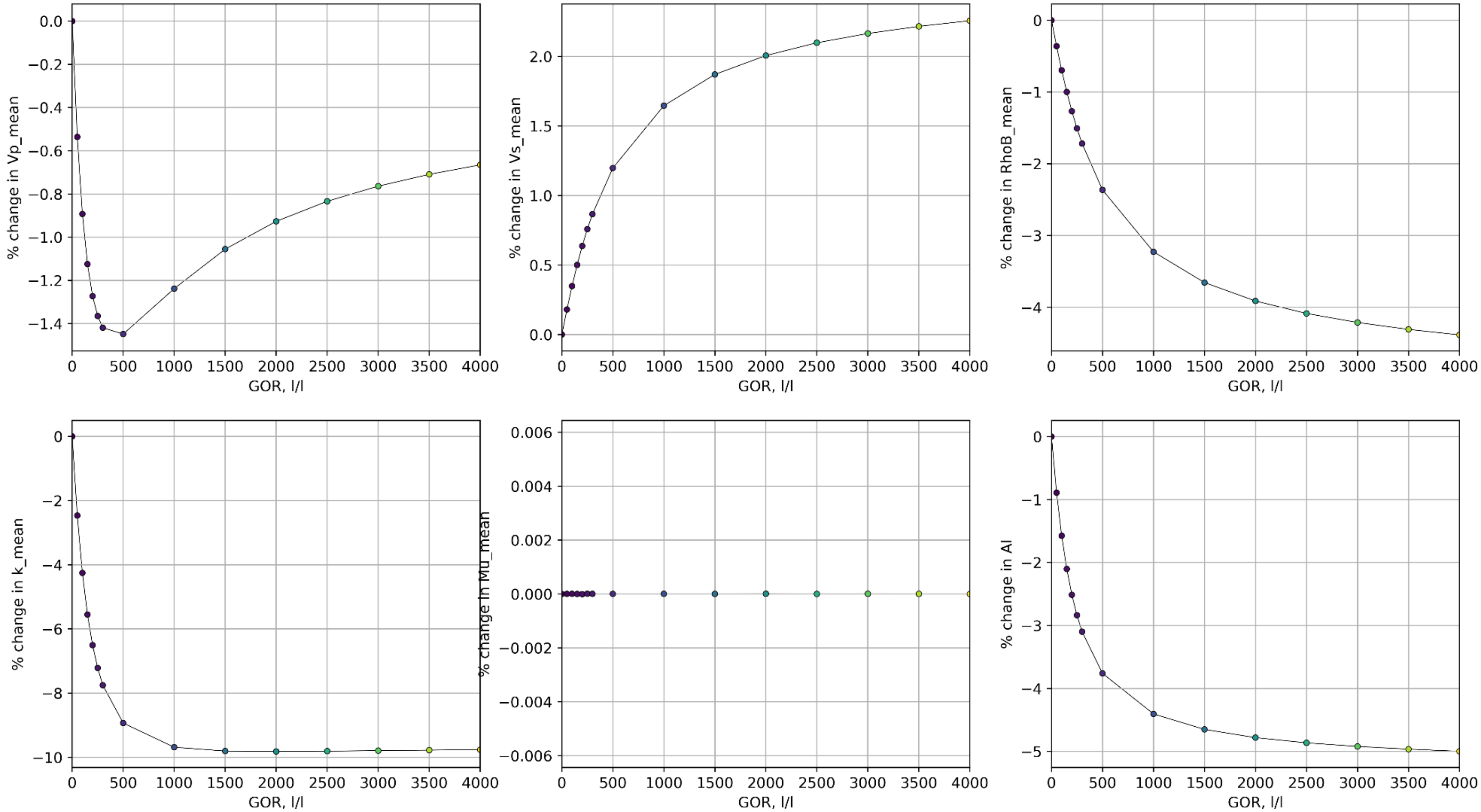


- Bounding the dry rock model for shaly sands.



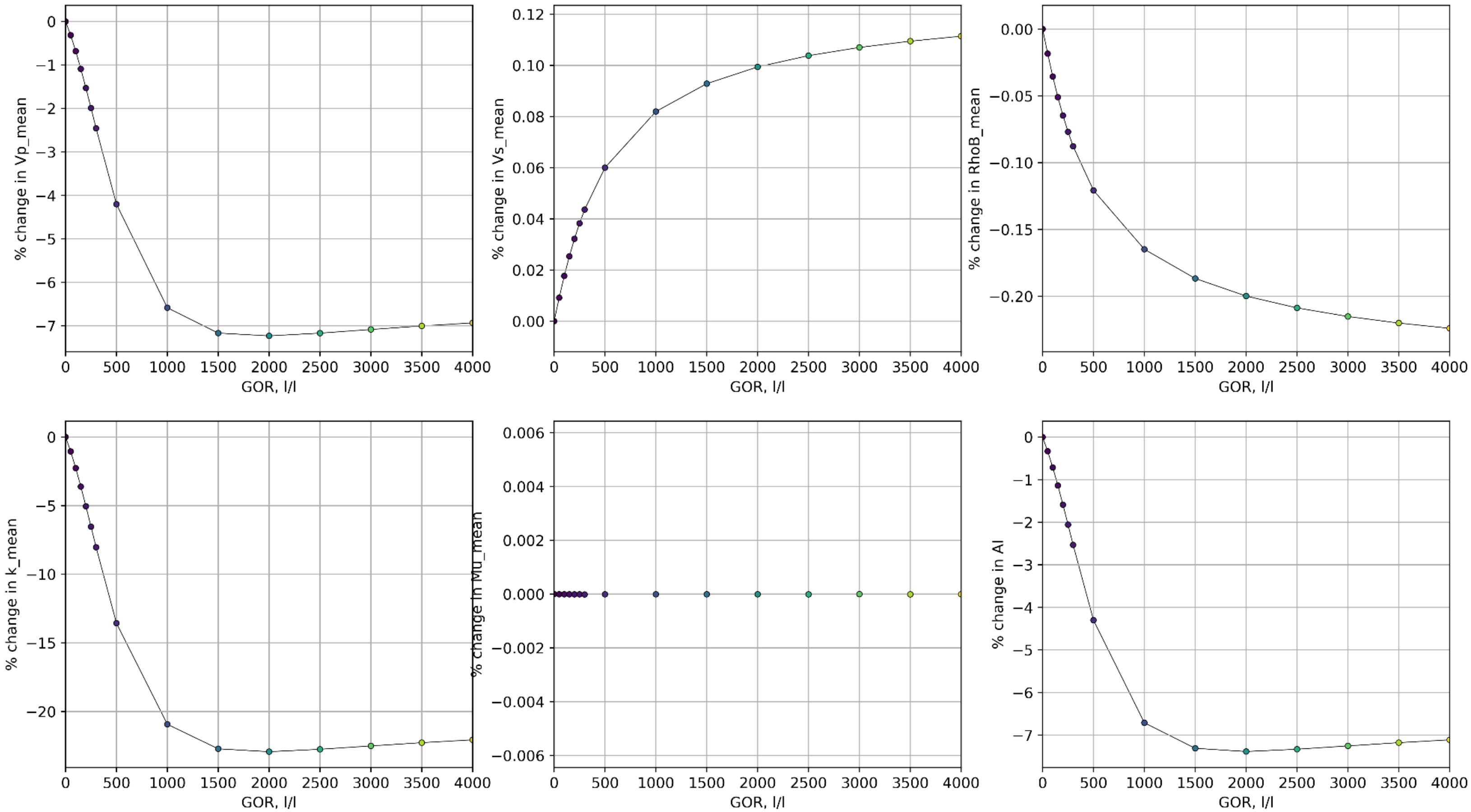
- Fluid substituted logs for 3 oil saturation cases + water case.

Review Sensitivity – e.g. GOR 95% Oil Saturation



- Elastic properties of “dead” oil (i.e. with no dissolved gas) contrast strongly with oil/condensates with significant volumes of dissolved gas.
- High GOR may cause the overall rock properties to resemble a gas rather than oil, particularly at low saturations.

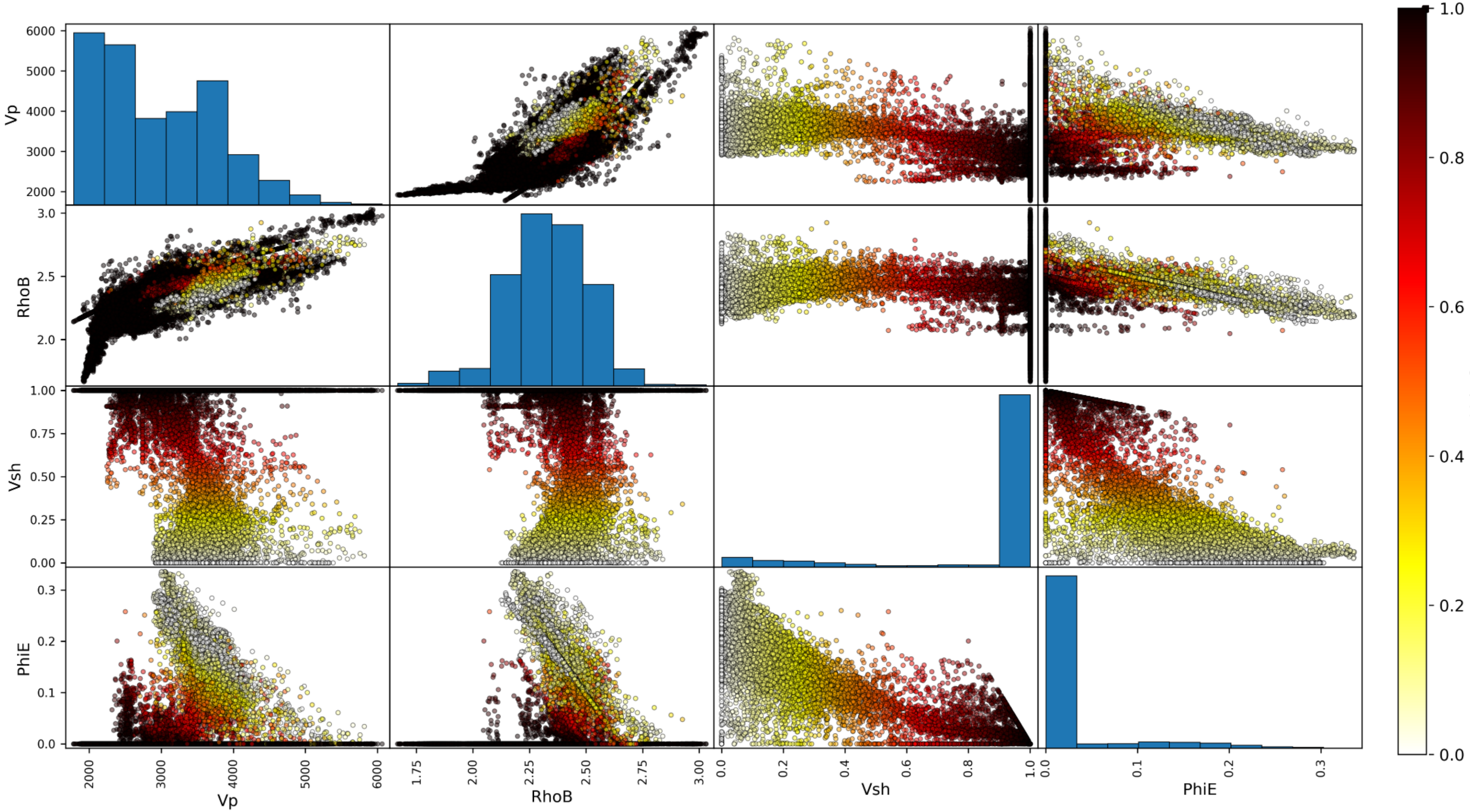
Review Sensitivity – e.g. GOR
5% Oil Saturation



- How robust are your fluid parameters?
- Where do they come from? How many samples? How consistent?
- Consider modelling range of values for fluid sub parameters
- Explore the range, rather than making a rough guess

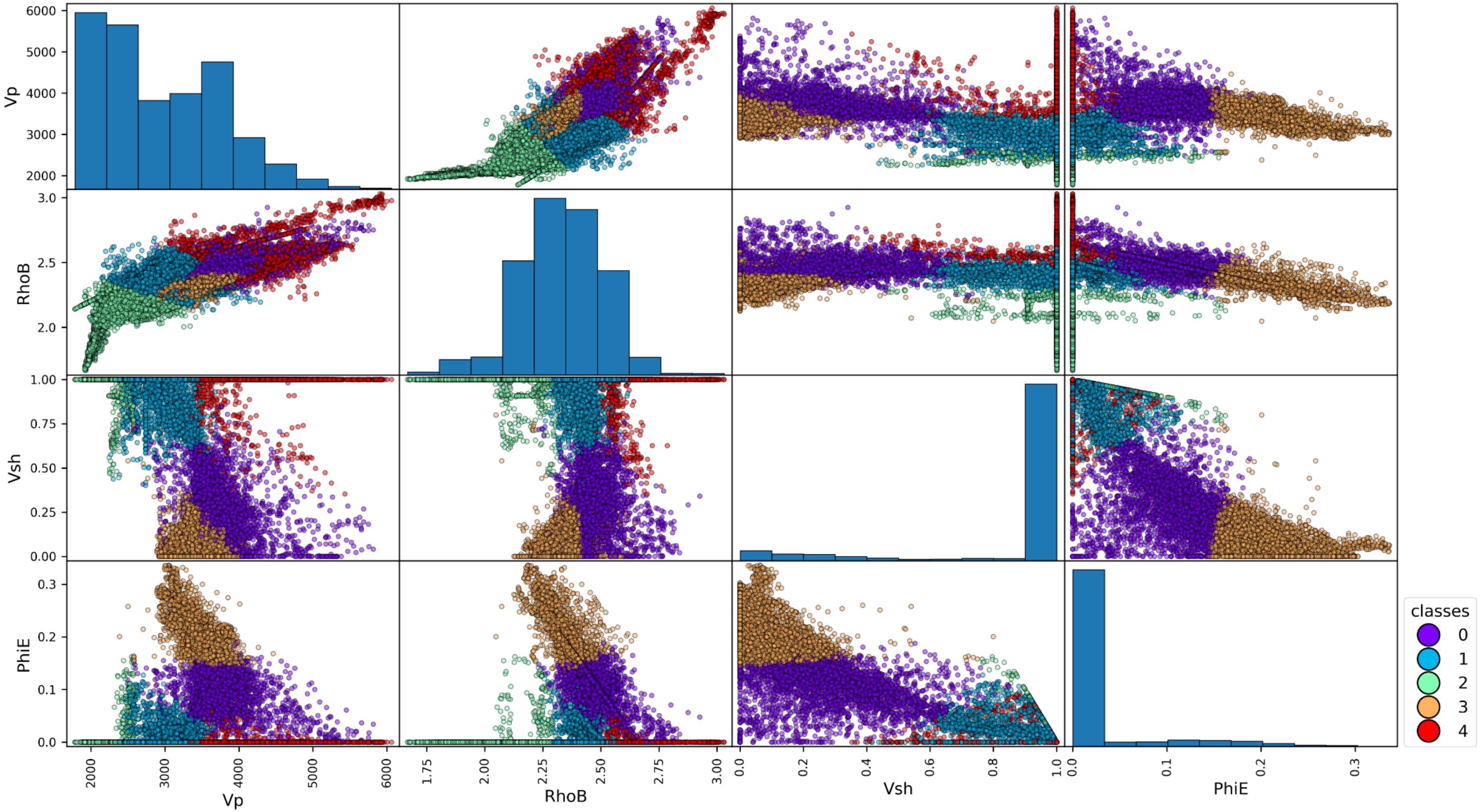
Review Trends/Facies distribution

- Scatter matrix for Vp, RhoB, Vsh and PhiE – these properties have been selected as basis for unsupervised classification of facies (Vs not used due to poor quality)



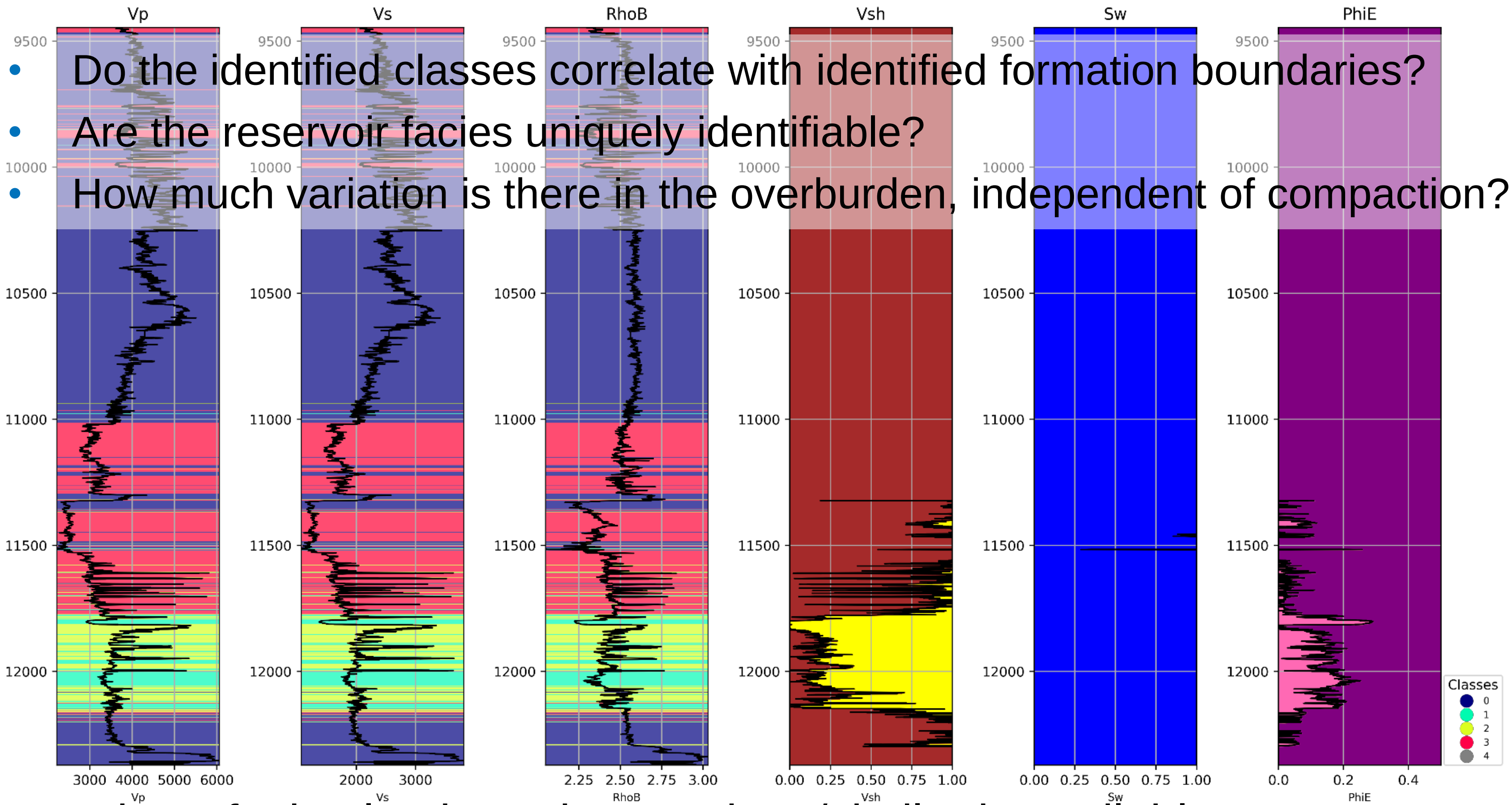
Map Clusters/Facies Classes

- Number of classes identified can be unsupervised or specified.
- 5 classes specified in this case. Classes allow filtering for model generation, and alleviate bias in the models towards the most abundant facies.



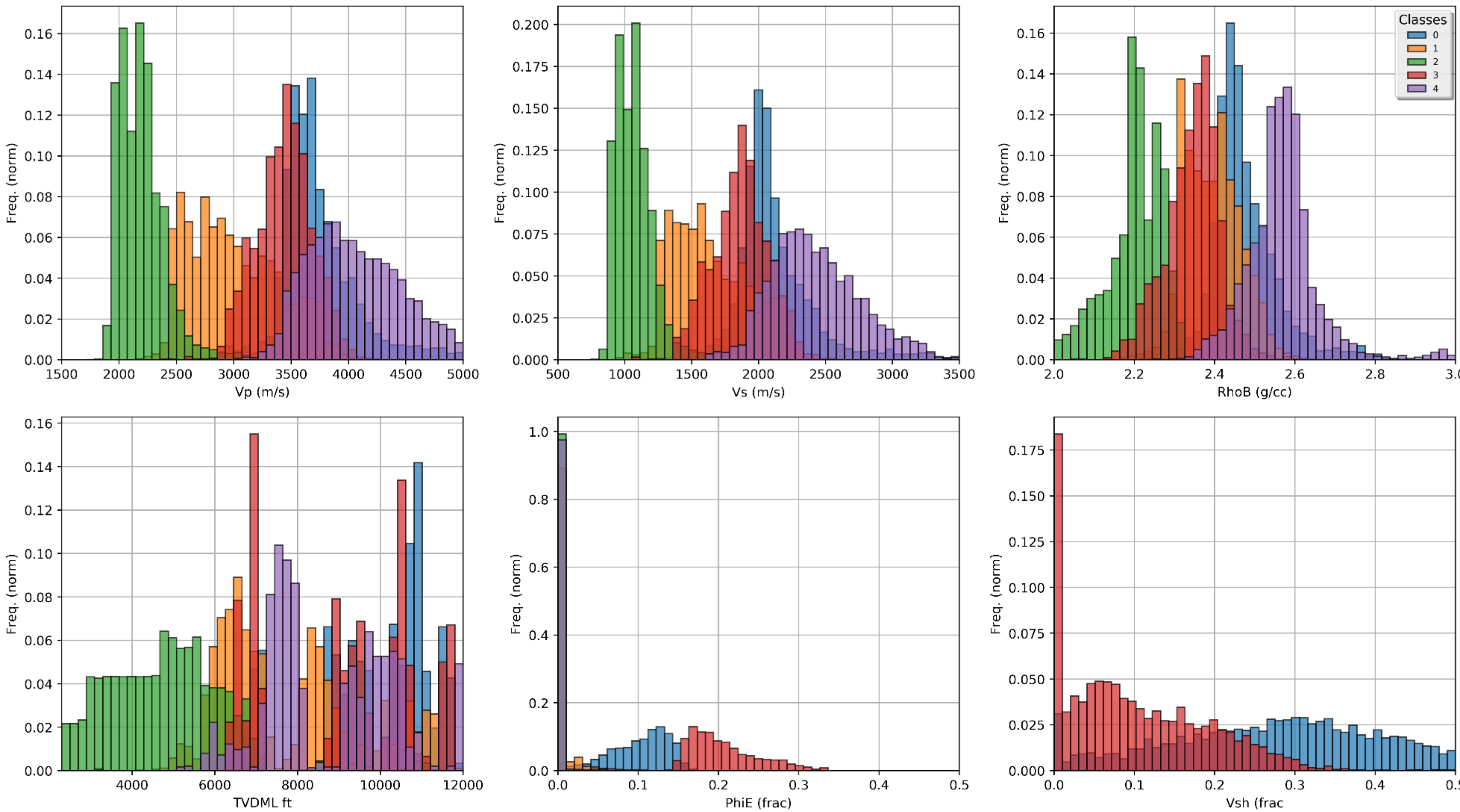
Review in Logs

- Do the identified classes correlate with identified formation boundaries?
- Are the reservoir facies uniquely identifiable?
- How much variation is there in the overburden, independent of compaction?



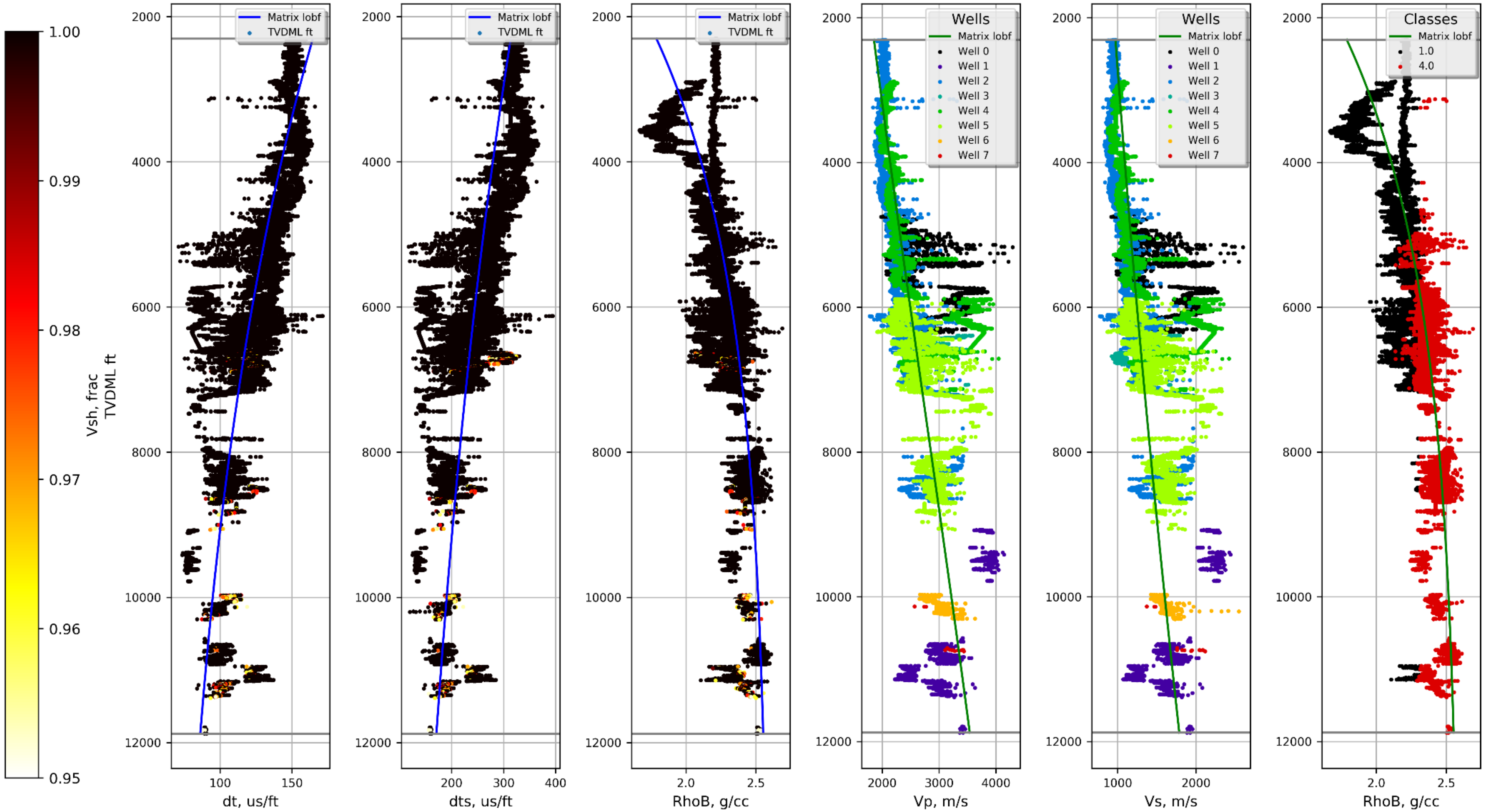
- Where facies log based on cuttings/similar is available, scope to run supervised classification.
- This would potentially allow analogous facies to be identified on un-logged portions of the well, or on inverted data depending on uniqueness of AI/Vp/Vs distribution/data quality.

Statistics



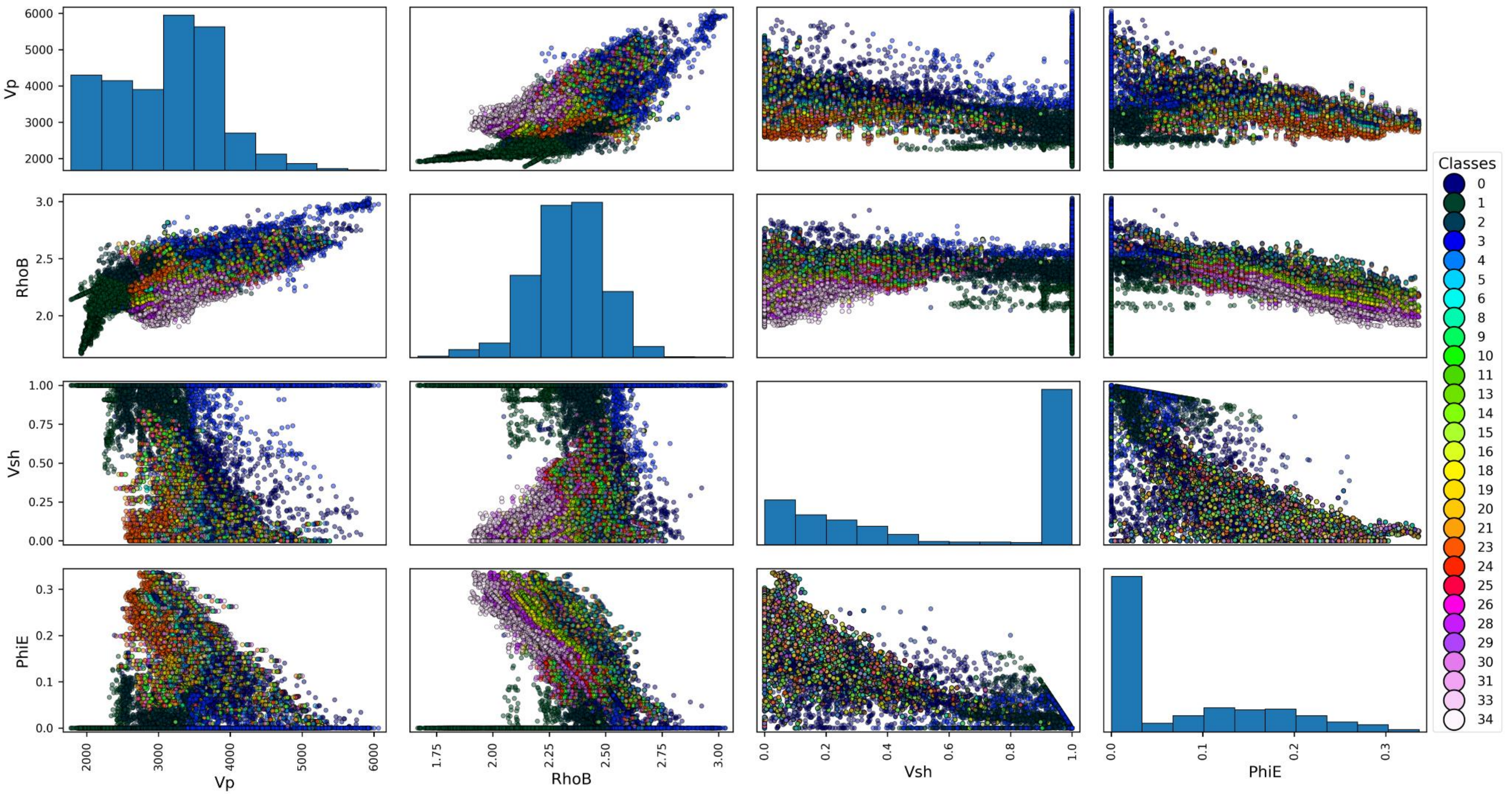
- Readily review distribution/statistics for each class
- Can these be identified as geological facies?
- How do these reflect the ranges/distributions used to estimate the potential hydrocarbon volumes?

Explore the Shale



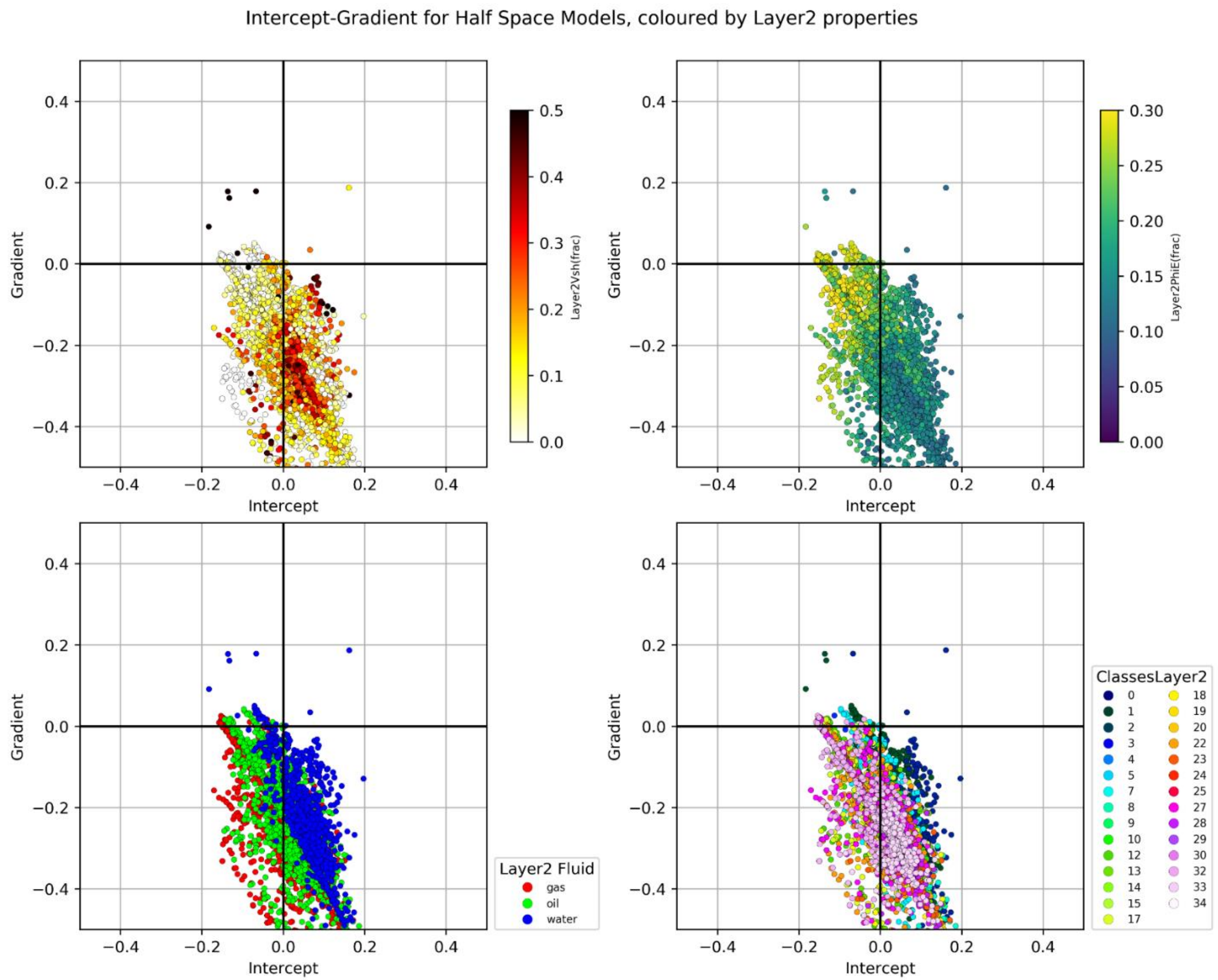
- How predictable are the overburden properties?
- If the overburden is well-constrained, regionally extensive, and has a consistent interface with the reservoir, constraining its properties within an error margin of a depth trend may be justifiable.

Construct Fluid/Facies Database



- In this case, classes assigned by facies and fluid saturation to ensure balanced sampling for forward seismic models.
- The database comprises all logged depths for all wells, with 7 fluid substituted scenarios.

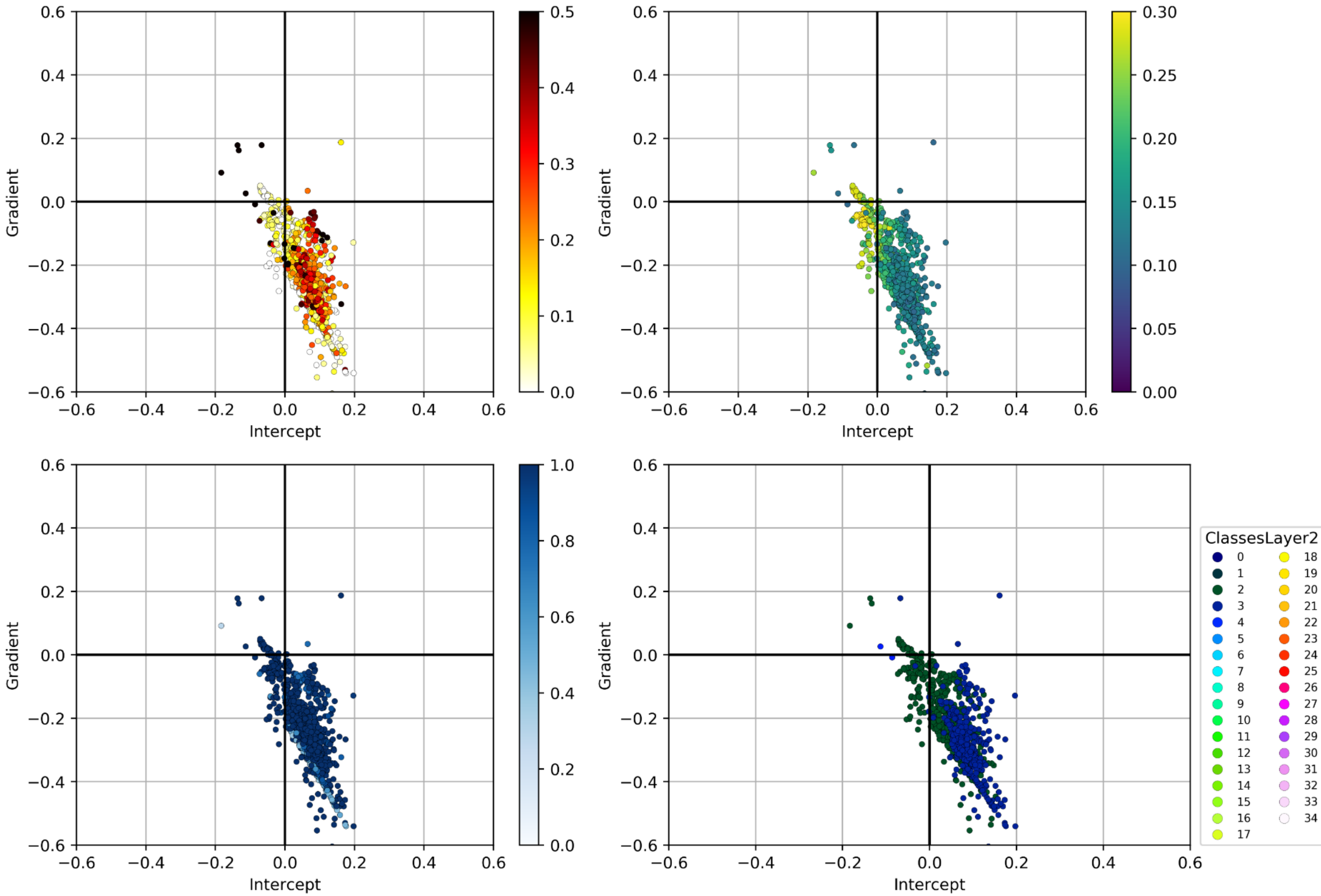
Construct Half Space Models



- 2000 models created by randomly sampling from each facies class, pairing “reservoir” and “overburden”.
- Scope to independently set bounds on definition of reservoir and overburden.
- Bounds applied: Overburden Sw = 1, Vsh > 0.8. Reservoir: Vsh <0.8, PhiE >0.05.

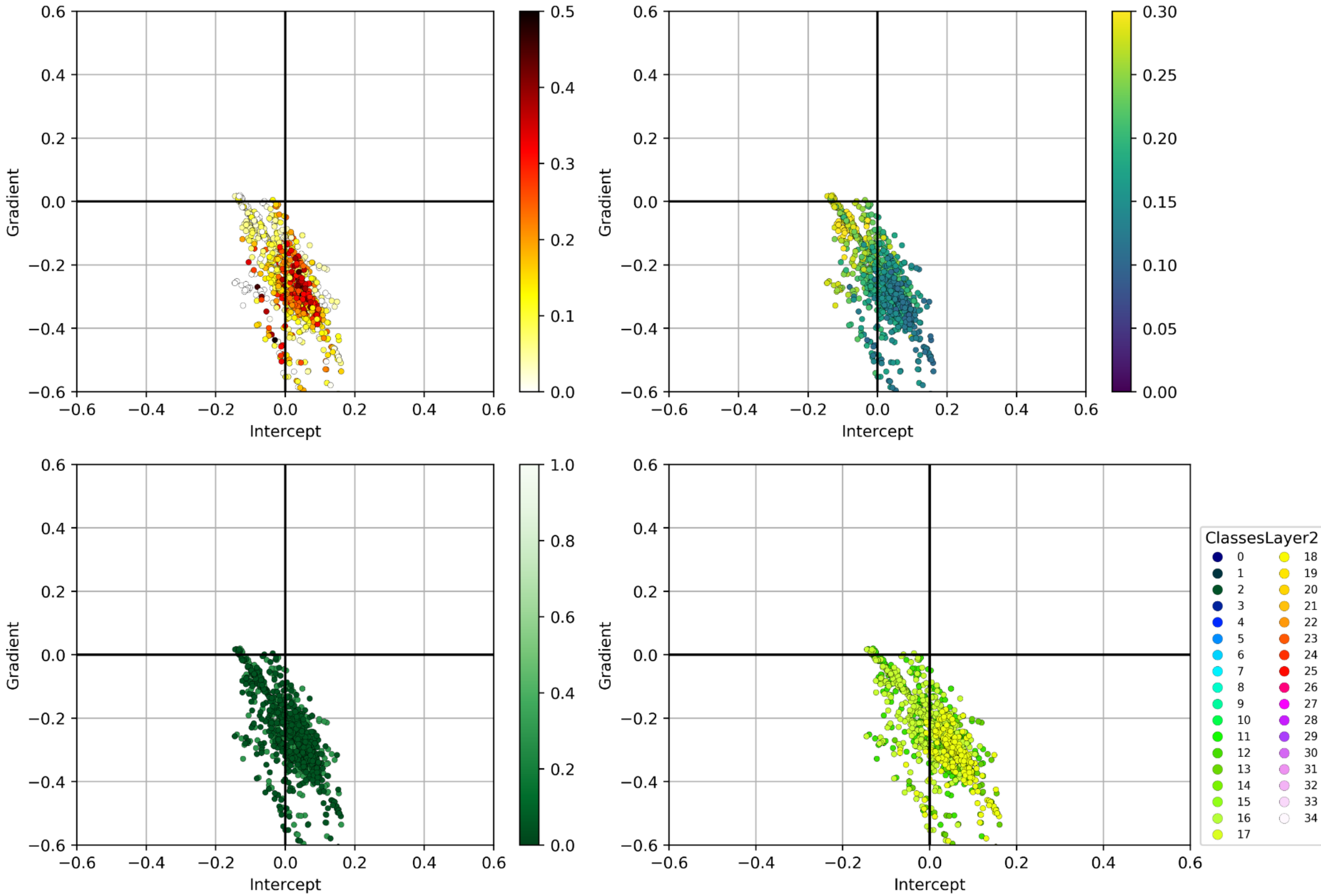
Half Space Models - Water

- Examine each fluid phase…



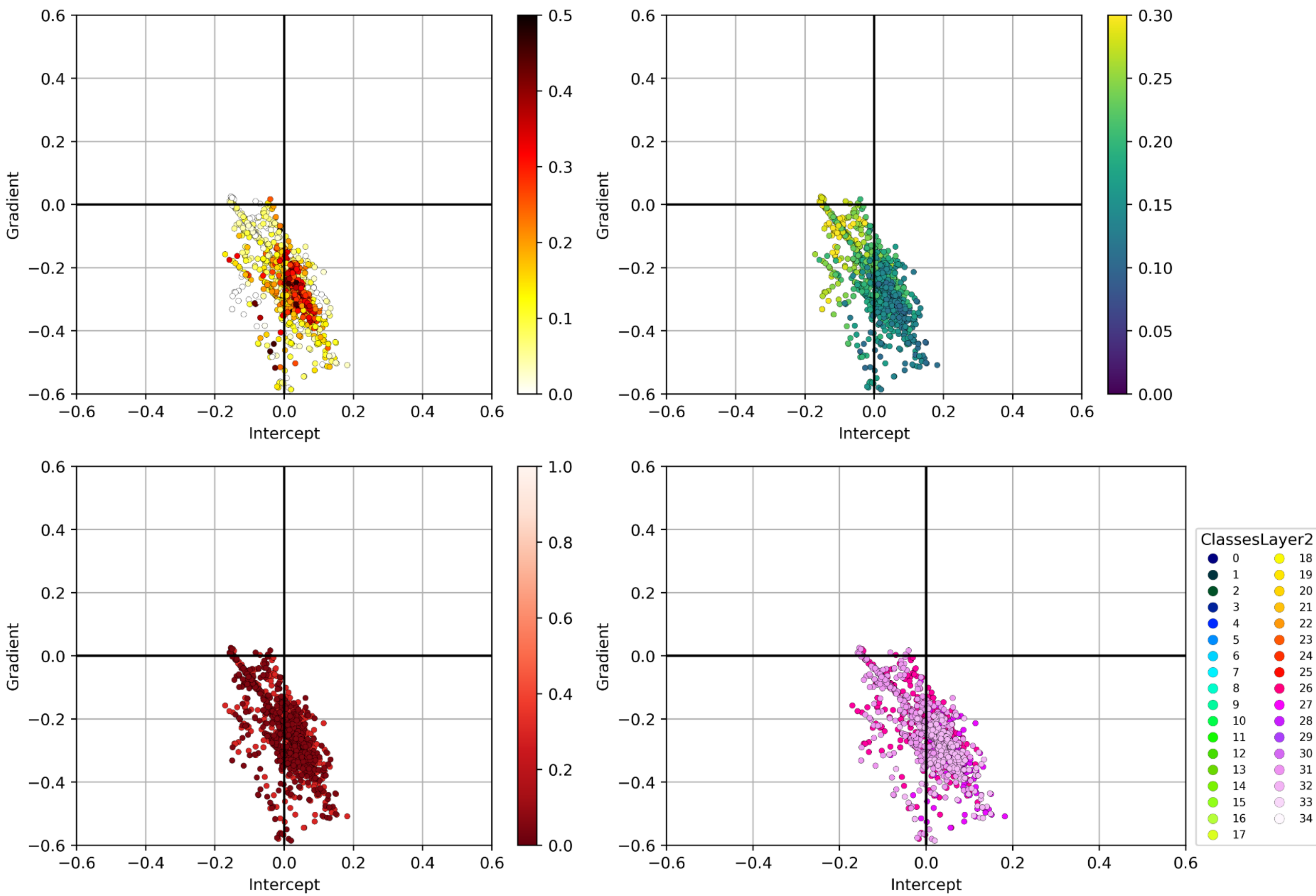
Half Space Models - Oil

- Examine each fluid phase…

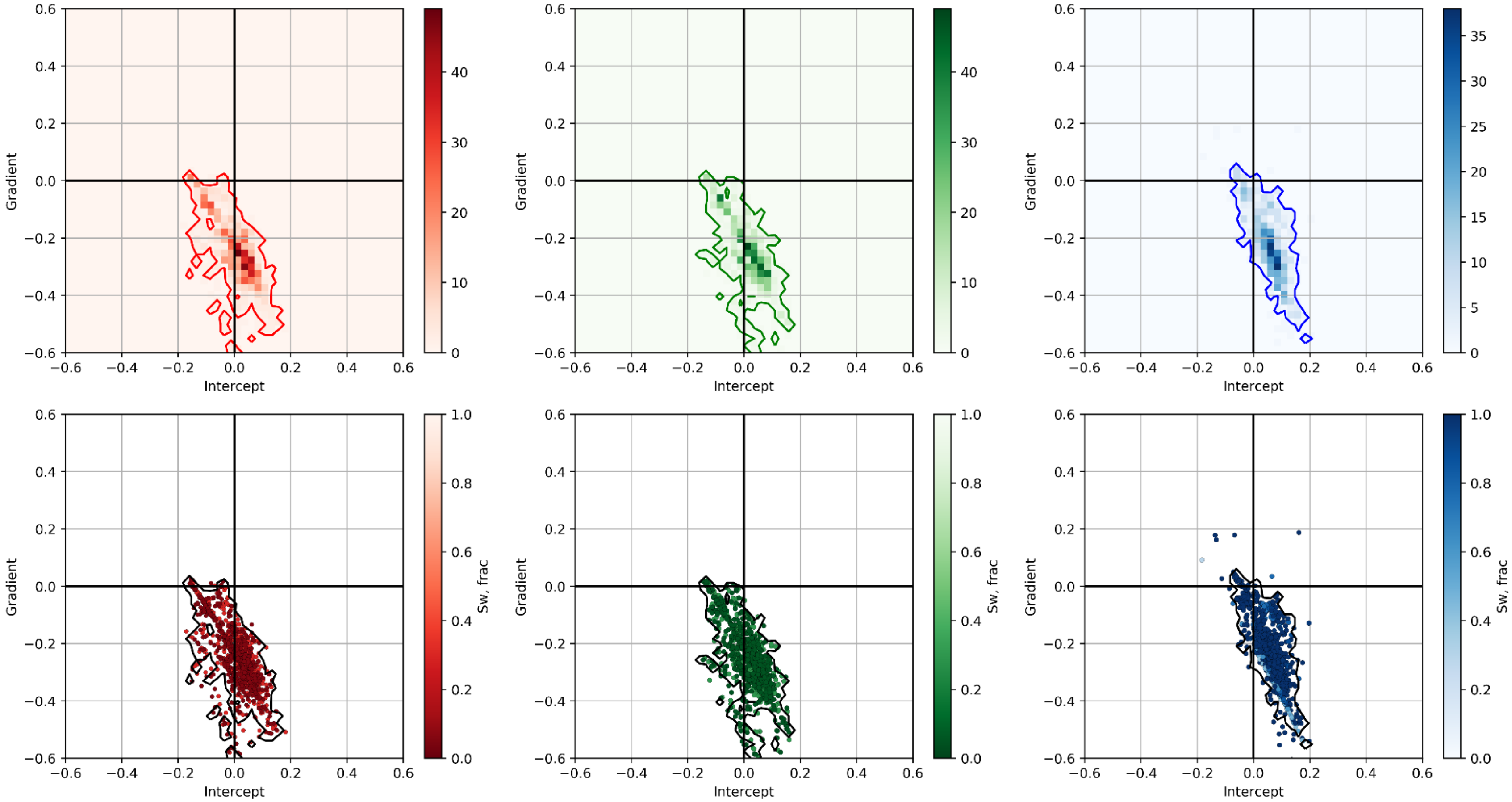


Half Space Models - Gas

- Examine each fluid phase…

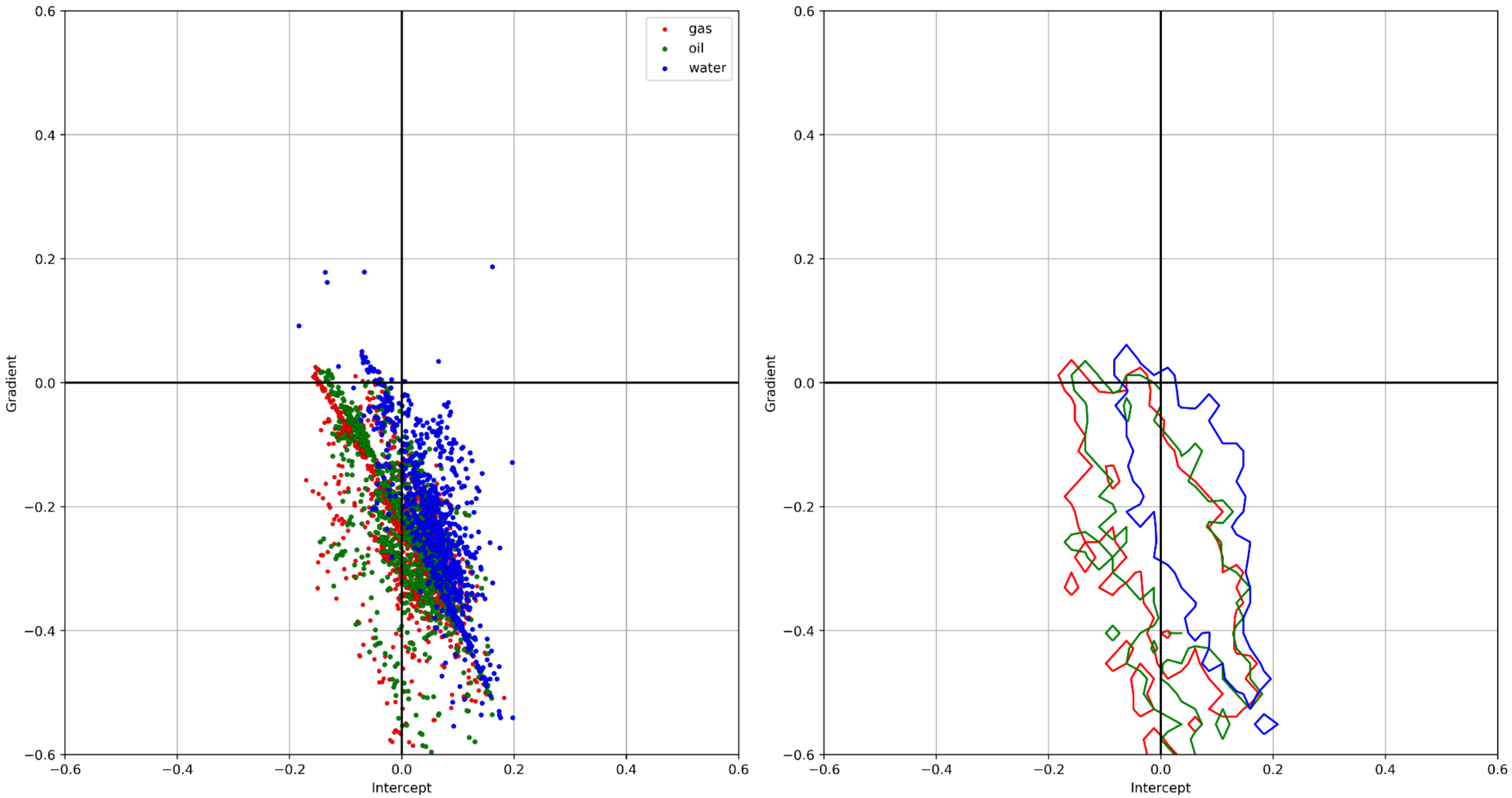


Grid by Point Density and Contour



- To assess distribution of models in I-G space by phase and extract tools to use with our seismic data and interpreted surfaces we can:
  - Grid the models in I-G space to find the model density per bin
  - Isolate the data field with contours

Superimpose Contoured Fields…



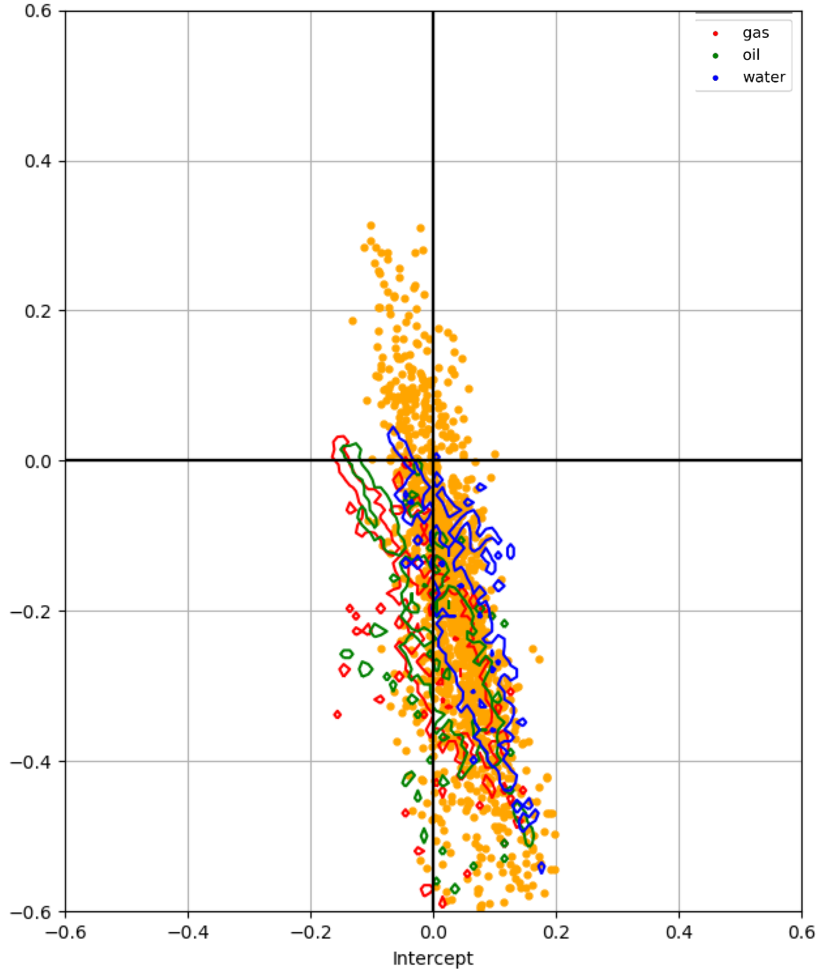
- Superimpose those contoured fields to observe separation…
- Match scale of models to seismic data, and apply polygons to I-G distribution of surface

On Seismic Data

- This result is arguably ambivalent
  - The range spans much of the modelled space
  - Tuning/interference has not been accounted for
  - The scaling should be reviewed
  - The interpretation should be repicked on the intercept and gradient volumes independently.

- However, this is an encouraging result in an area that has resisted identification of hydrocarbons via AVA due to the small differentiation between fluid phases in I-G space, and imaging issues due to tuning and frequency content at reservoir depth.

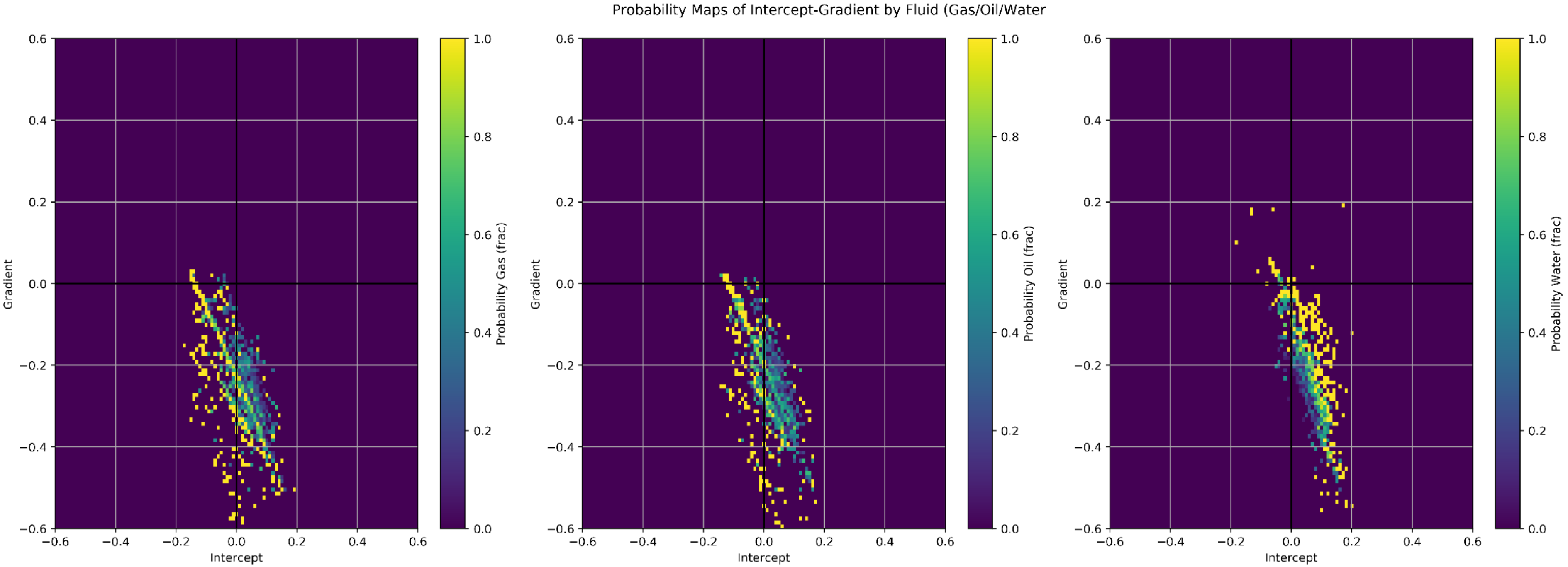
- The combination of GRT depth migration to substantially improve the imaging and amplitude fidelity at reservoir depth, with extensive iterative forward modelling will hopefully allow AVA to meaningfully de-risk exploration activity in the area going forwards.



- The well encountered a small oil column.

Calculate Probability Maps by Fluid…

- Going back to those model density grids…



- Go ahead and map out the probability of a given I-G value representing each phase.
- (But think about your bin sizes vs. number of models)
- Ready for integration into your prospect risking!

Some Notes/Future Possibilities?

- Each sample uses real data points from a single sampled depth.
- The models therefore reflect “observed” facies only – it is unlikely that you have sampled all regional facies, so… expect the unexpected.
- It is possible to map the frequency distributions of the elastic/geological properties and run the workflow “Monte Carlo Style”… with an appropriate rock physics model.
- Scope to use calibrated rock physics models/elastic media models to expand the database beyond the “observed” facies.
- Workflow still makes a gross number of assumptions… in particular:
  - The robustness of the fluid substitution workflow
  - The estimation/extraction of intercept and gradient from the processed angle gathers.
  - How representative a half space model is of the real interface
- Ideas for improvement and expansion welcome!

Any questions/comments?

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