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Implications of Elastic Anisotropy in Direct Probabilistic Inversion; Example from Offshore Australia

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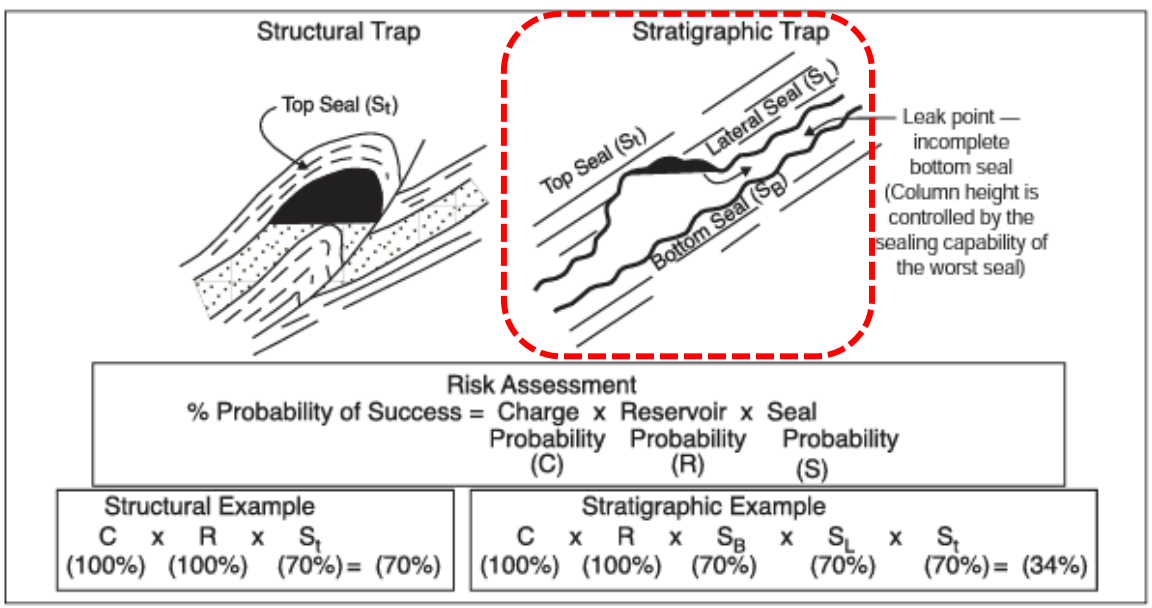
Outline

- Objective
- Isotropic vs. anisotropic media
- Direct probabilistic inversion – DPI
- Study area
- Results
- Conclusions

Objective

- Mapping of *seal* for de-risking stratigraphic play.
- Bottom and lateral continuity of claystone (comprised of high P-wave velocity V_p and low V_p) facies observed as *seal*.



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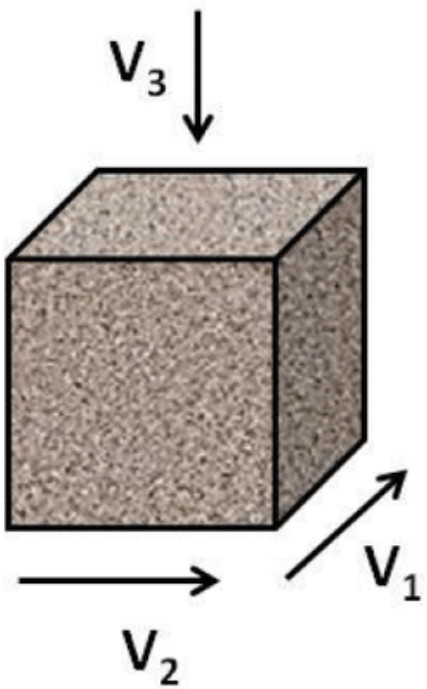
Summary

- Fairly smooth anisotropy models (delta ~ 15%, epsilon ~ 20%) from seismic processing workflow is a reasonable starting point for reservoir characterization.
- Wrong prediction of Calcareous *base seal* facies is overcome by inclusion of anisotropic parameters in seismic inversion engine
- Lateral continuity of *base seal Claystone facies* is well established for the proven stratigraphic traps

Definition

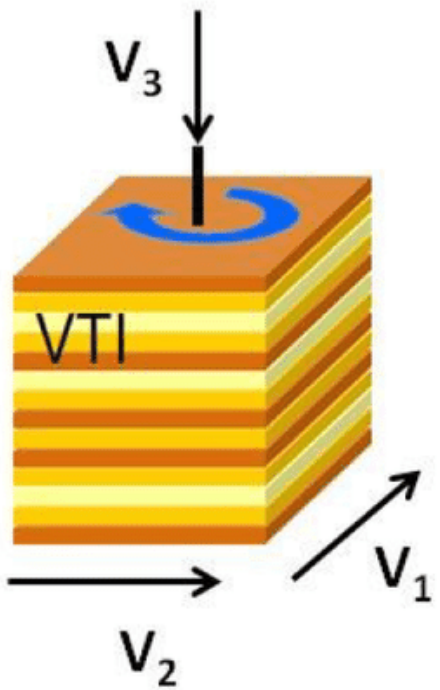
Isotropic media



V1=V2=V3

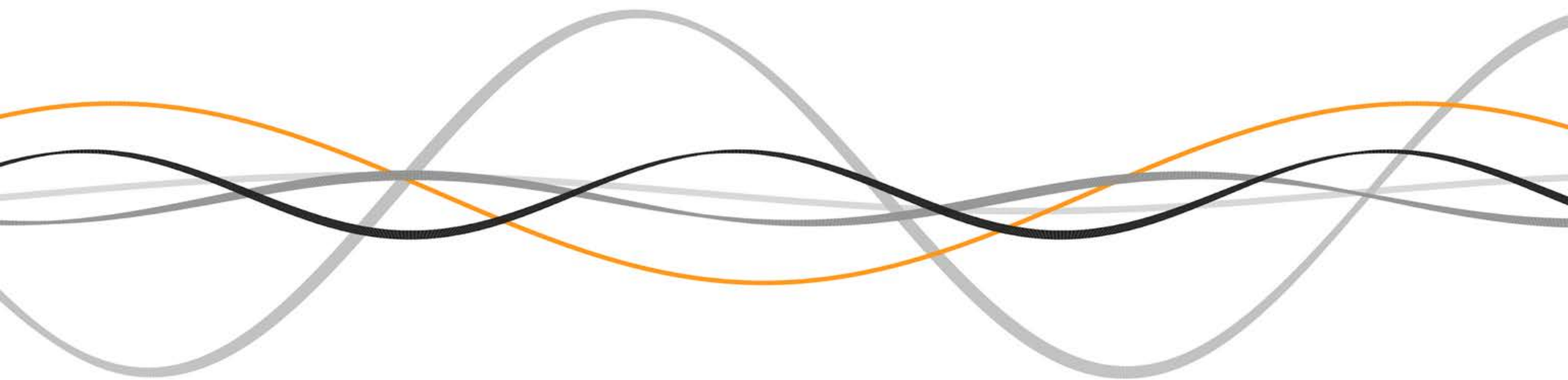
- For shale, average values of Thomsen's parameters (Sams et al., 2018) are - *Delta* ~ 0.14; *Epsilon* ~ 0.25 and *Gamma* ~ 0.24
- Thomsen's *Delta* parameter is crucial over the acquired angle ranges of seismic data

Anisotropic media
Vertical Transverse Isotropic (VTI)
(case for most shales)

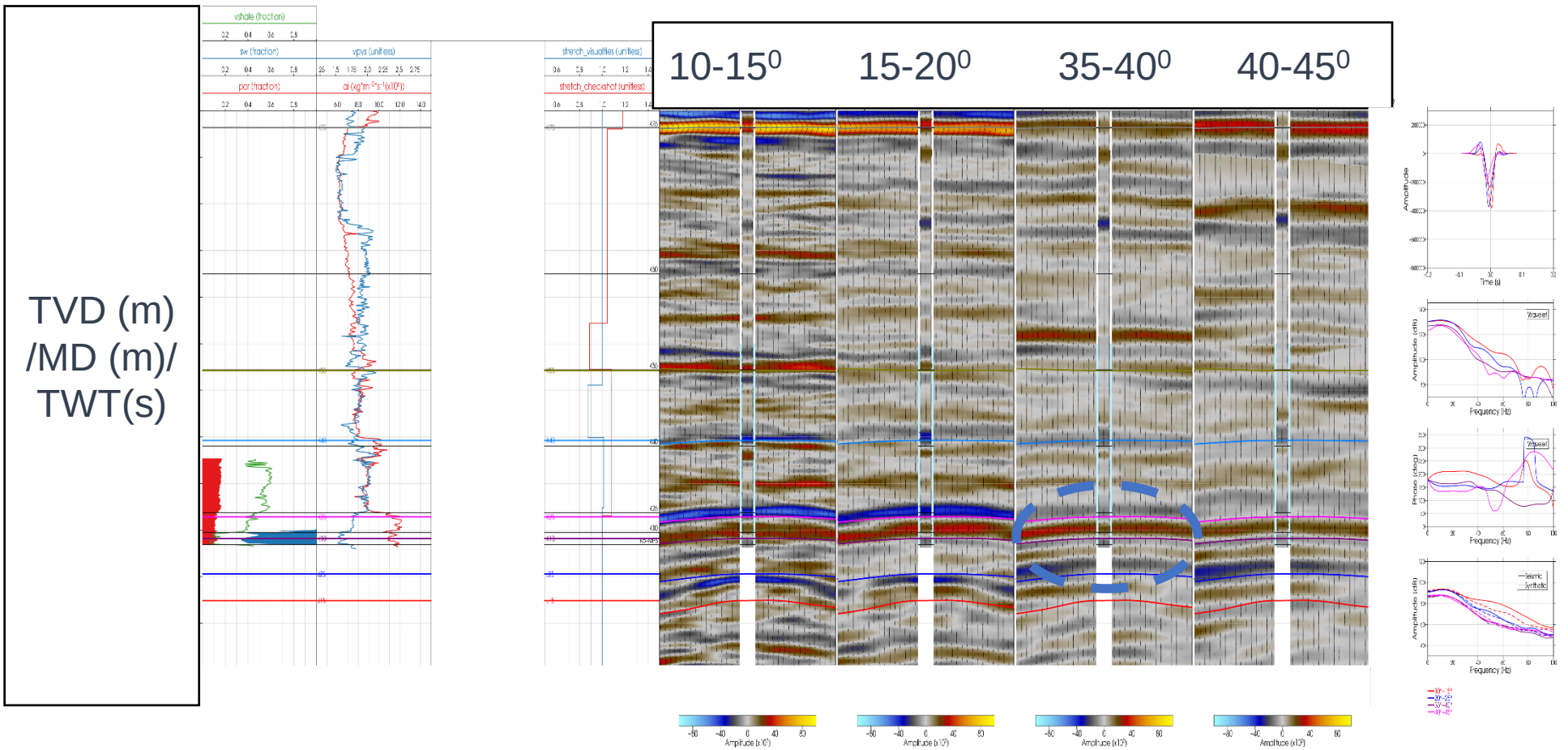


V1=V2>V3

What happens when you do not account for the velocity anisotropy effects on seismic reservoir characterization?



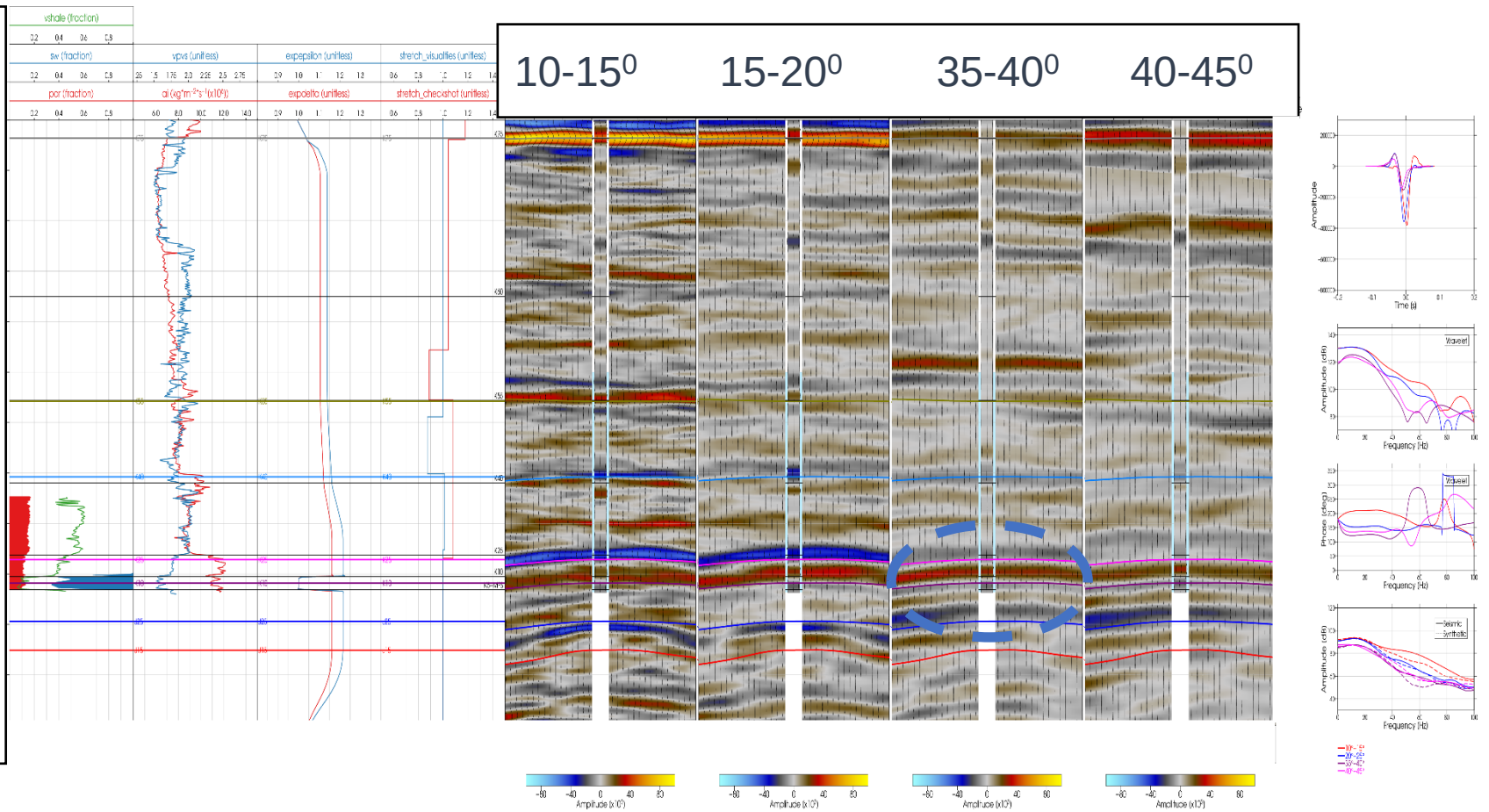
Model assuming isotropic media



Significant amplitude mismatch between seismic data and synthetic seismogram in far-angle stacks.

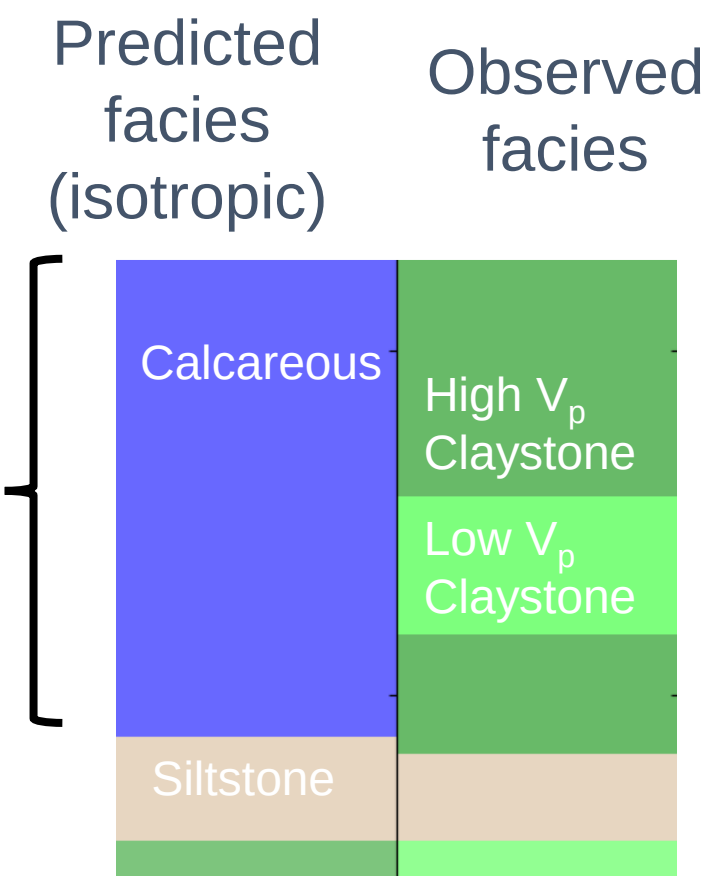
Model assuming anisotropic media

TVD (m)
/MD (m)/
TWT(s)



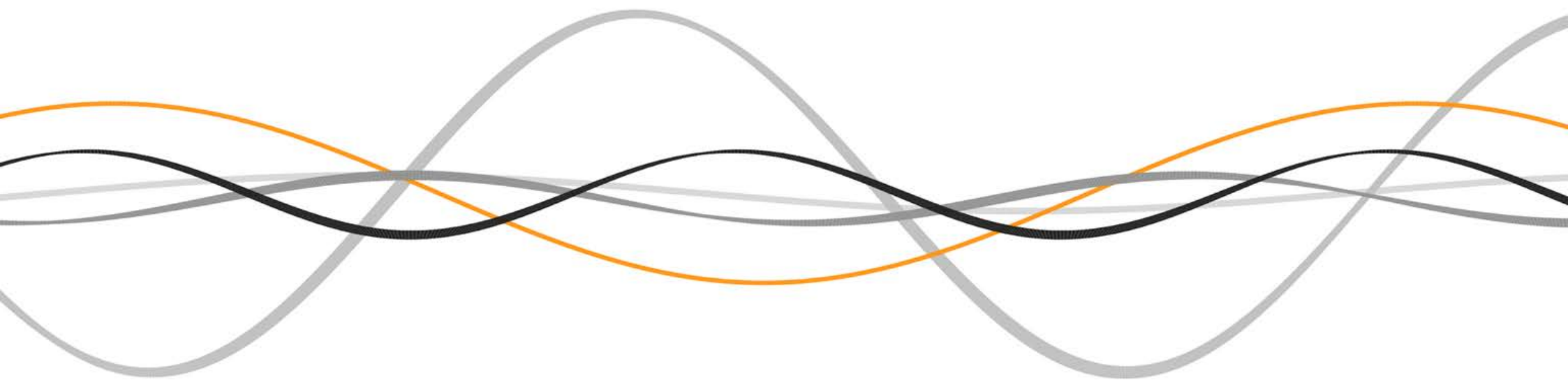
VTI resolves the amplitude mismatch – better AVO modelling

Effect on characterisation results



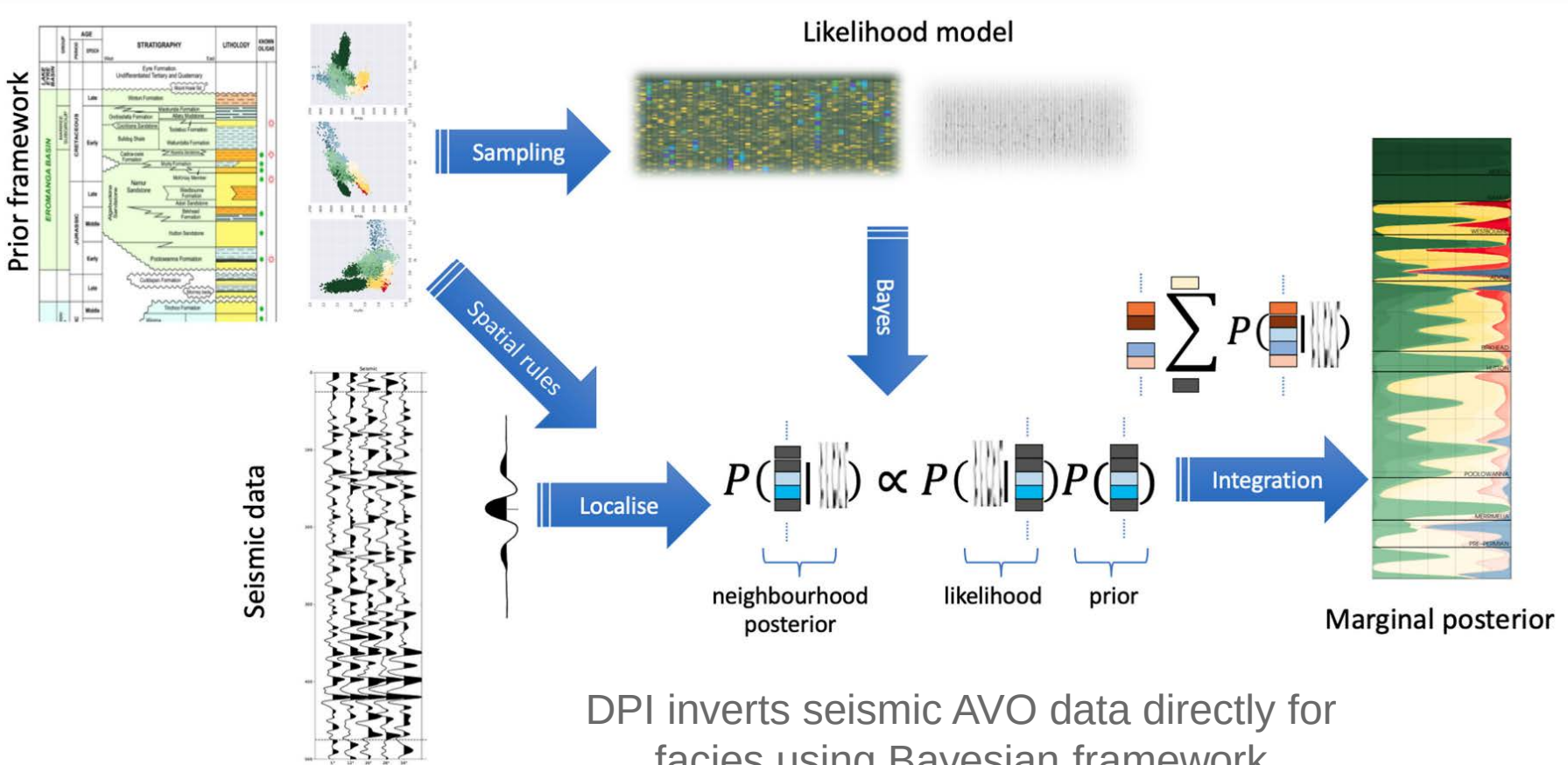
- Facies prediction is poor in the *base seal* interval if we use an isotropic AVO approximation in the seismic inversion.
- A more complex model is needed to capture the anisotropic nature of shale.
- Many of the identified hydrocarbon traps in the studied area are structural/stratigraphic hybrids.
- The correct prediction of the base and lateral seal are crucial.

Direct Probabilistic Inversion (DPI)



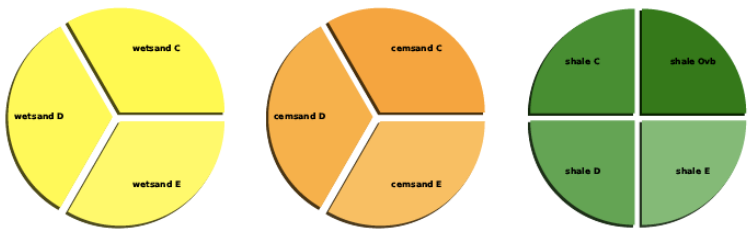
DPI workflow

Geological knowledge used as input to mitigate seismic ambiguities

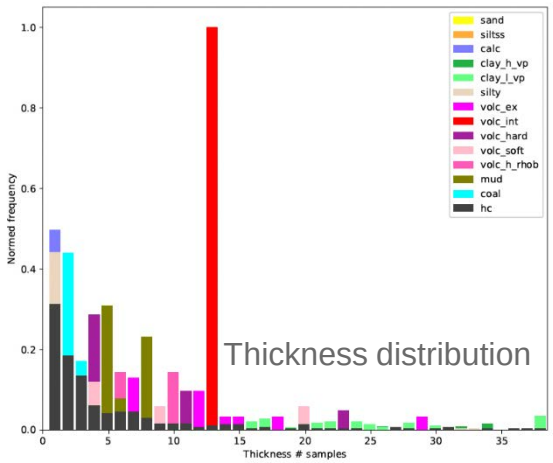


DPI inverts seismic AVO data directly for facies using Bayesian framework

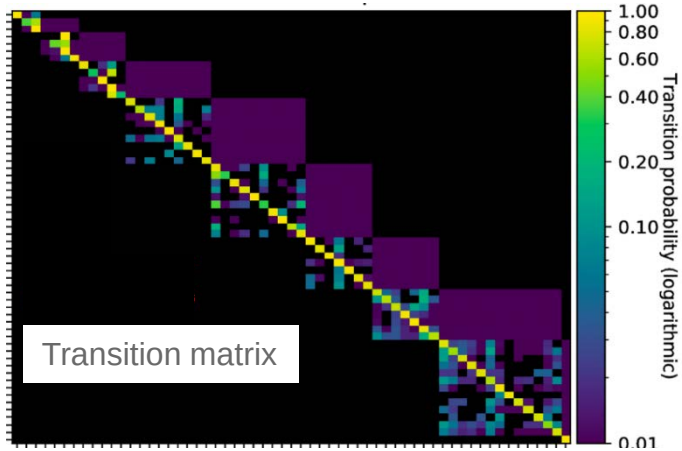
Prior framework – geology based



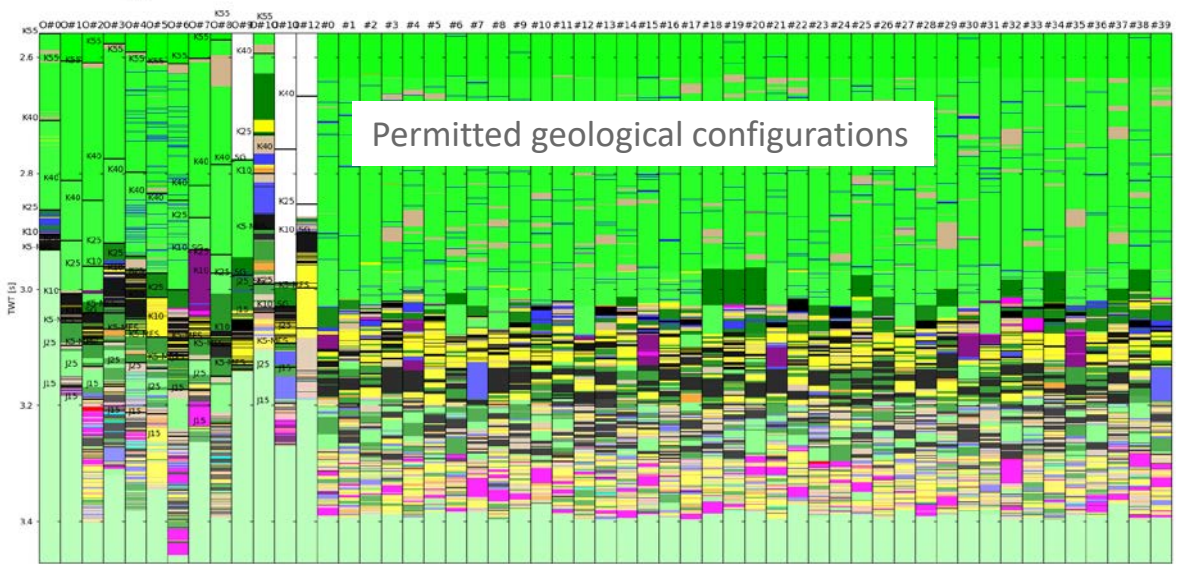
Facies constellation



Thickness distribution

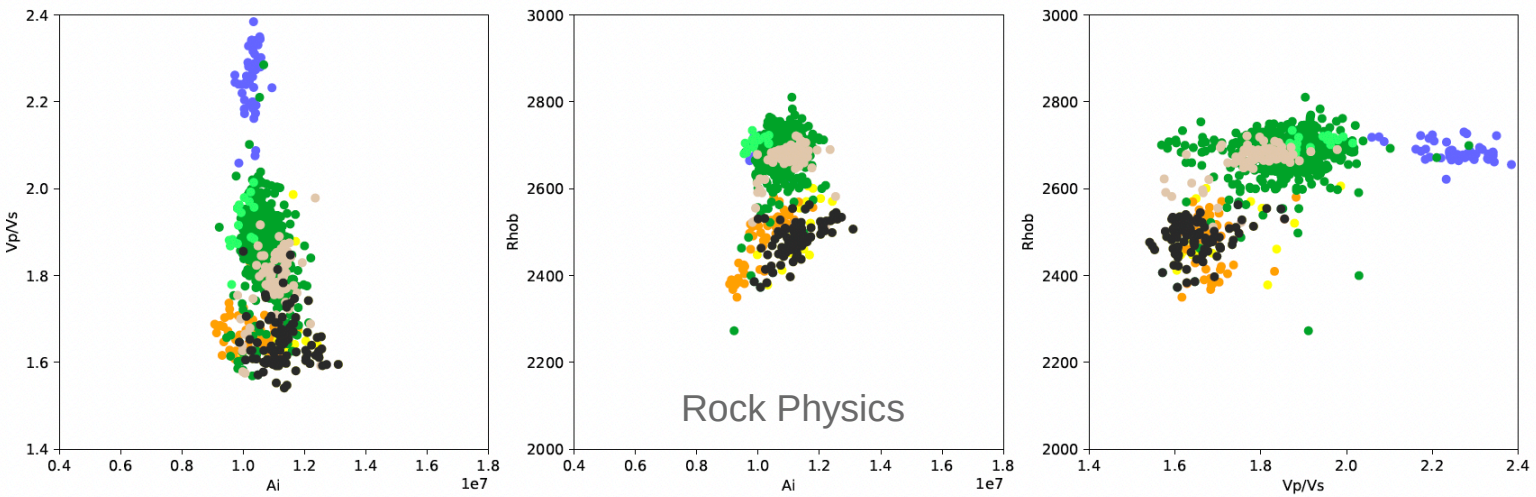


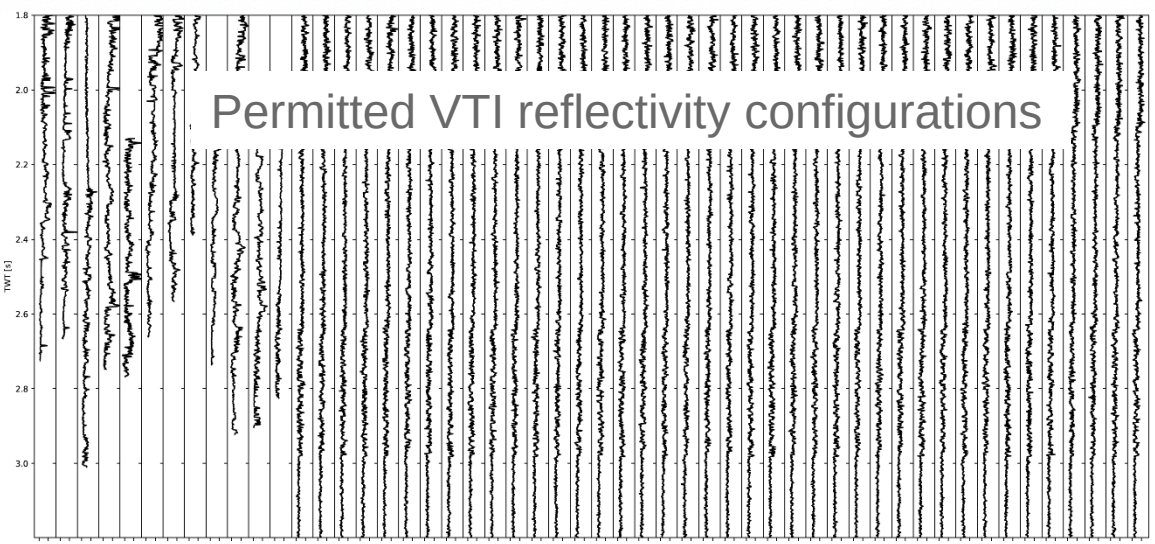
Transition matrix



Permitted geological configurations

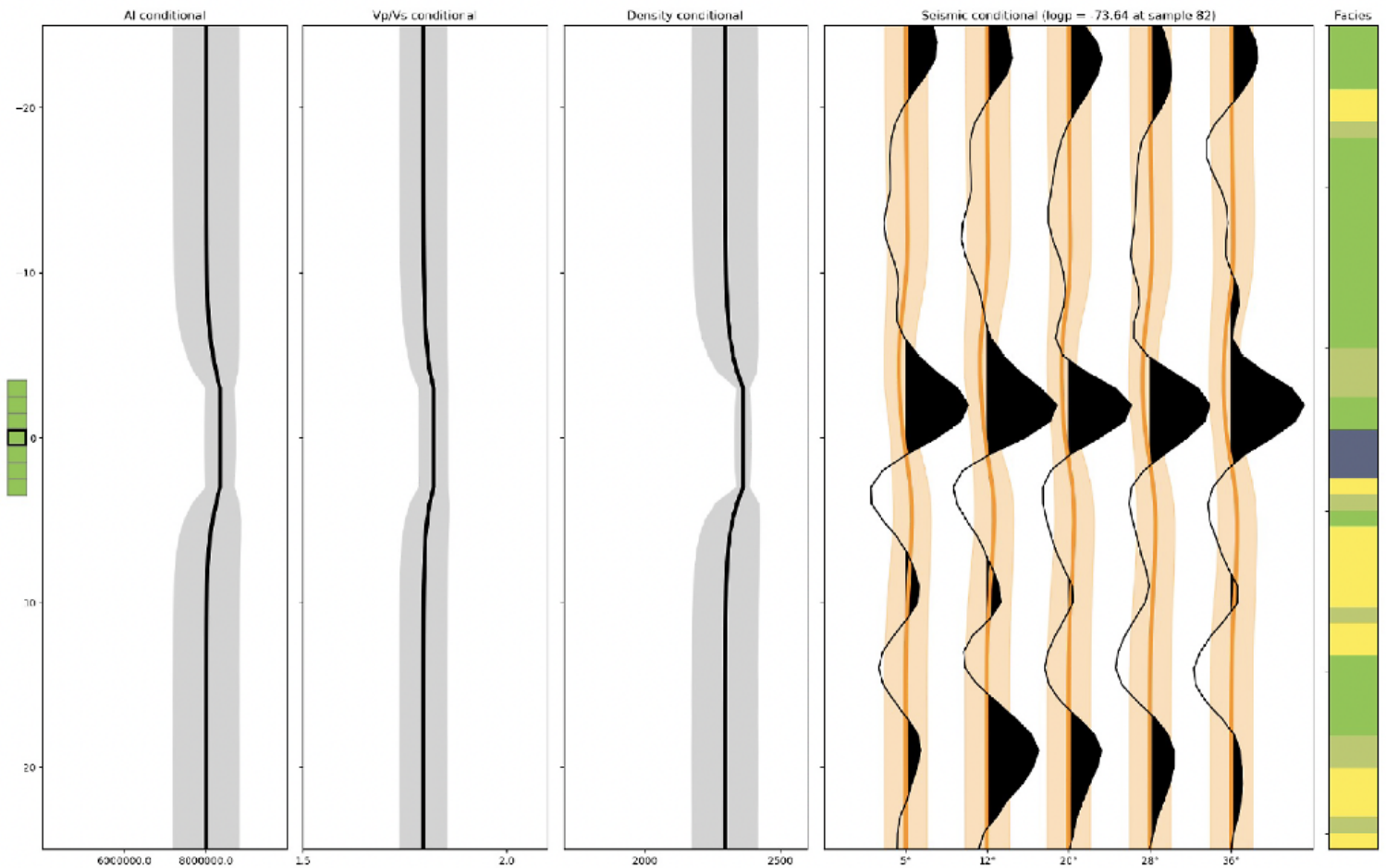
Prior framework – rock physics based





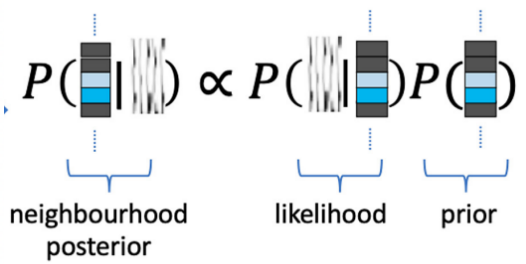
- Isotropic case; Aki &Richards' three-term AVO equation
- Anisotropic case; Ruger's AVO approximation for VTI media as the forward modelling operator
- VTI - additional inputs delta and epsilon

DPI – Likelihood model

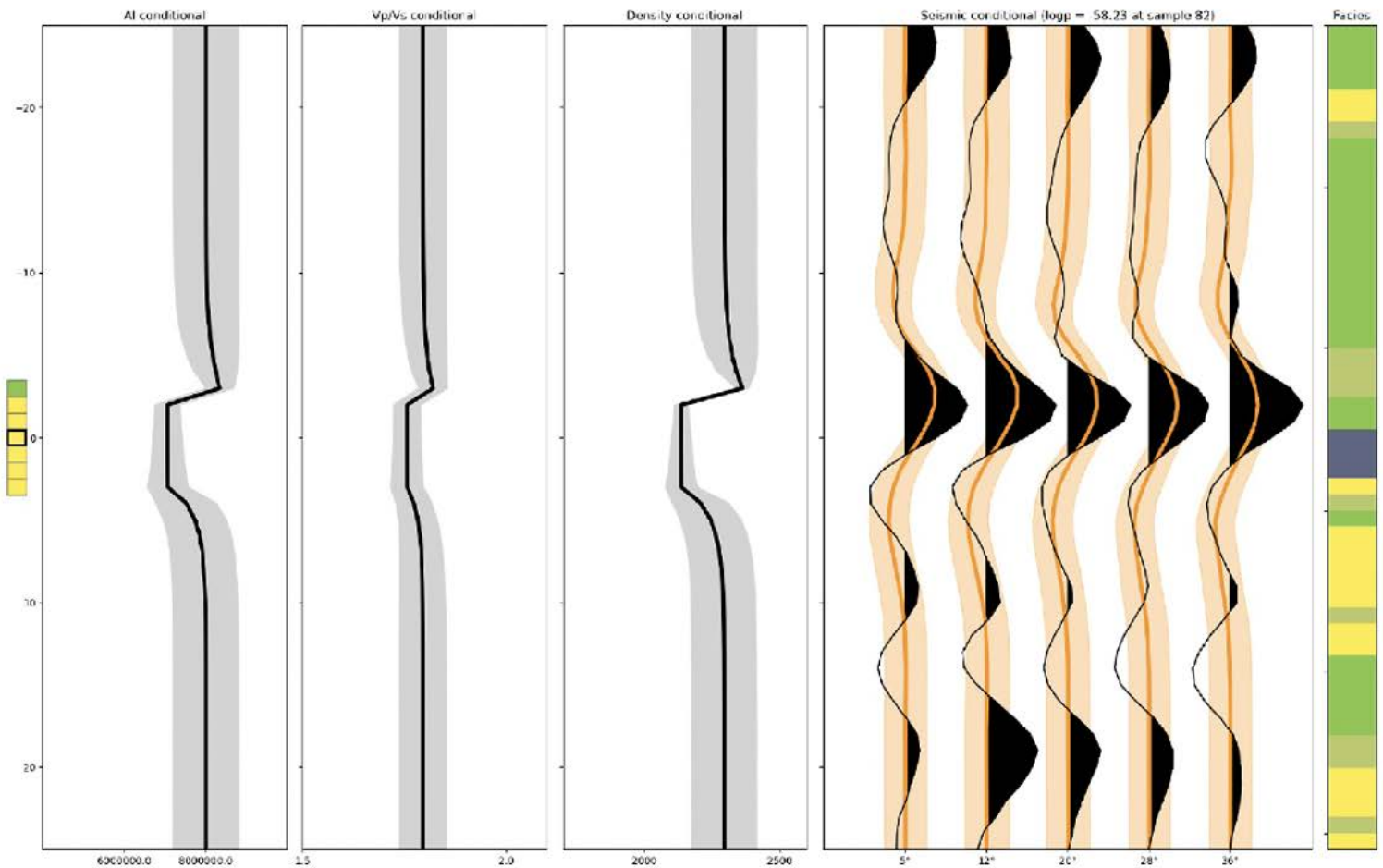


Shale
Silt
Brine sand
Oil sand
Gas sand

- Isotropic case; Aki &Richards' three-term AVO equation
- Anisotropic case; Ruger's AVO approximation for VTI media as the forward modelling operator



DPI – Likelihood model



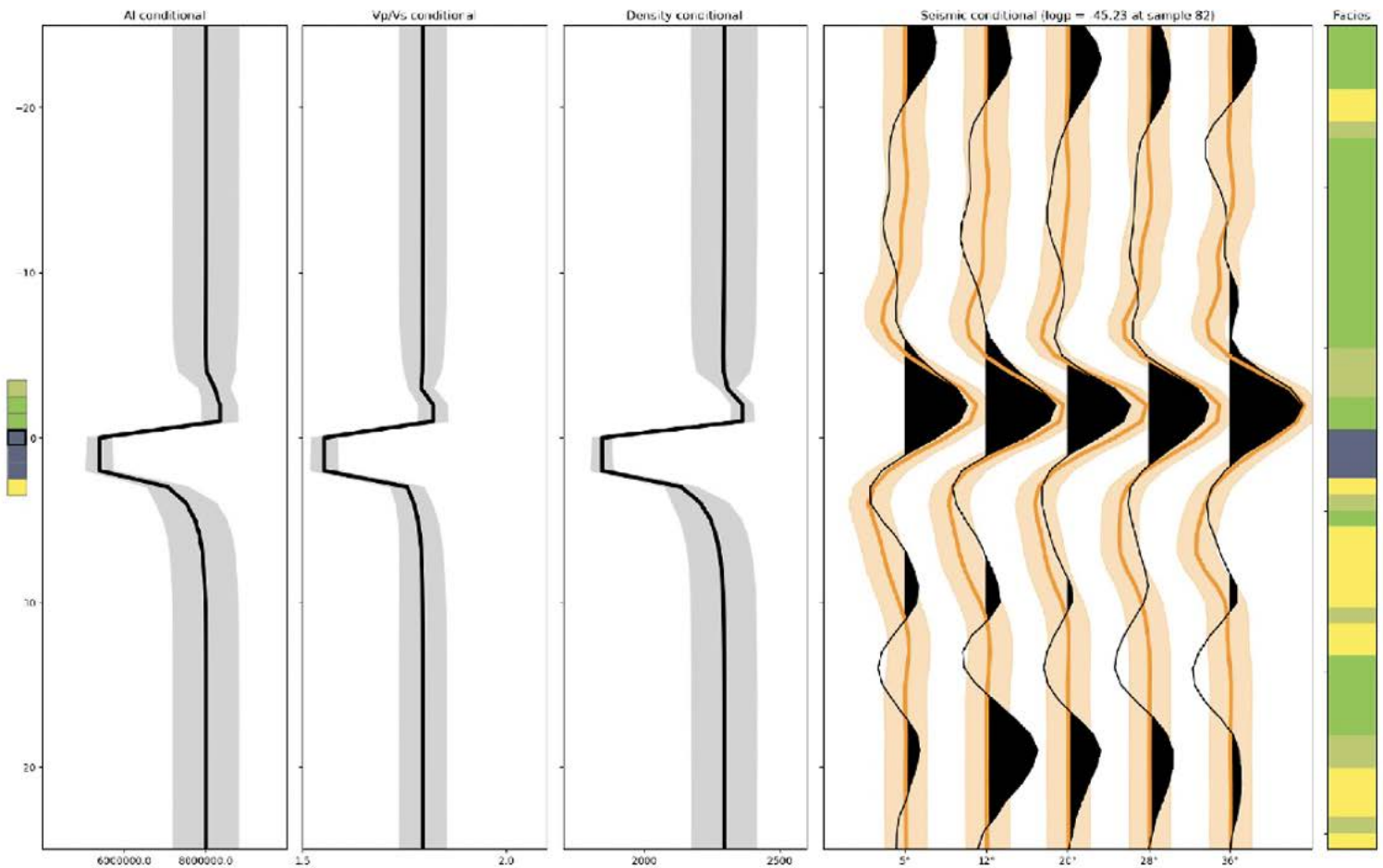
$$P(\text{posterior}) \propto P(\text{likelihood})\,P(\text{prior})$$

neighbourhood posterior

likelihood

prior

DPI – Likelihood model



$$P(\text{posterior}) \propto P(\text{likelihood})P(\text{prior})$$

neighbourhood posterior

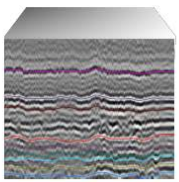
likelihood

prior

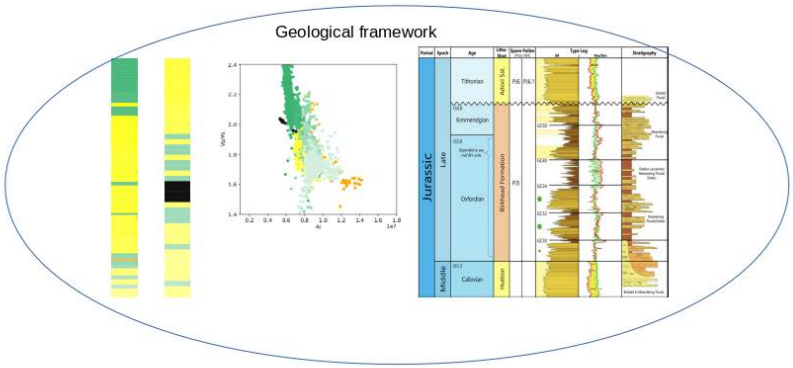
DPI outputs

INPUT

Preconditioned
Angle-stack seismic



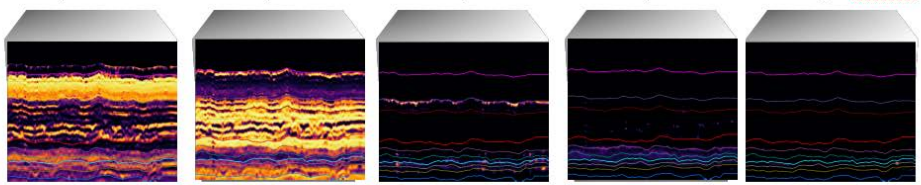
Geological framework



OUPUT

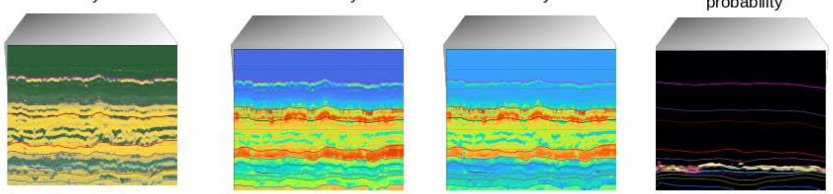
PROBABILISTIC FACIES

Probability of Facies1 | Probability of Facies2 | Probability of Facies3 | Probability of Facies4 | Probability of FaciesN



DERIVED VOLUMES

Most likely facies | Volume of clay | Porosity | Interpreted surface probability



Study area

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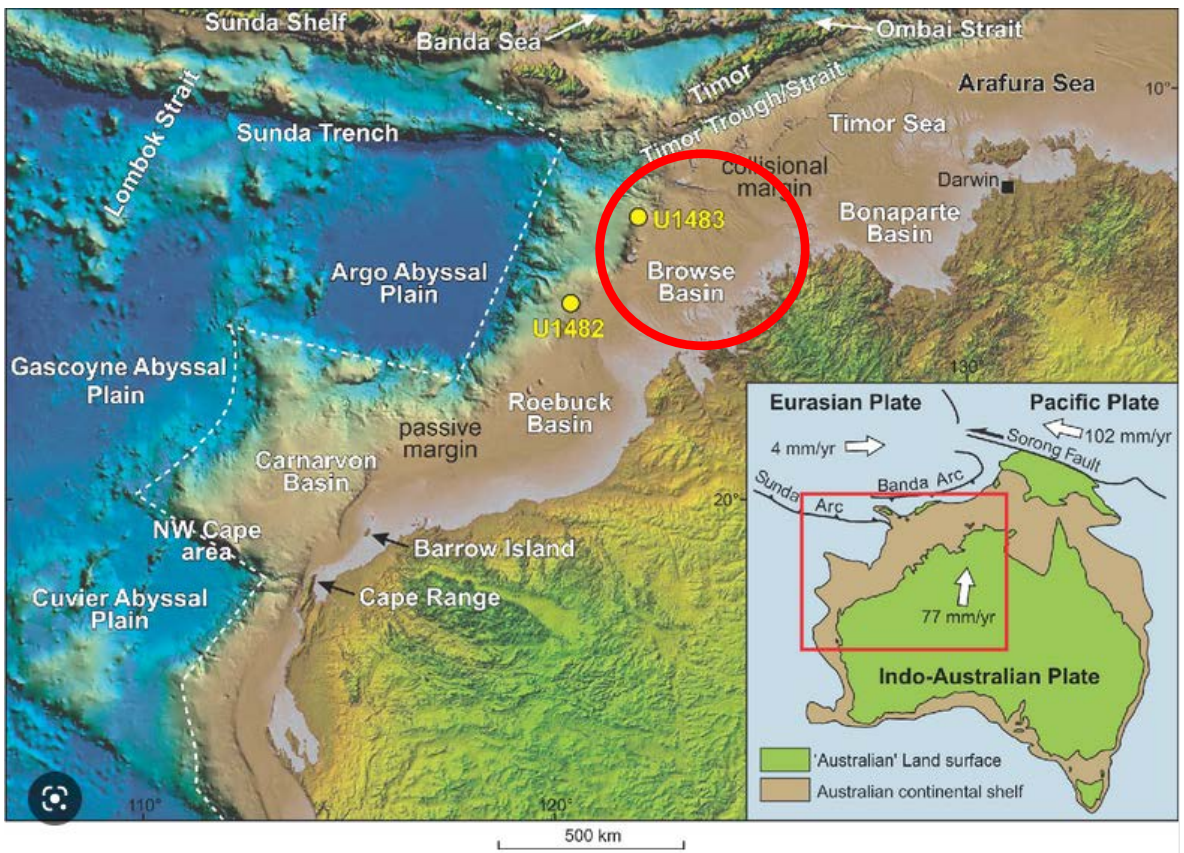
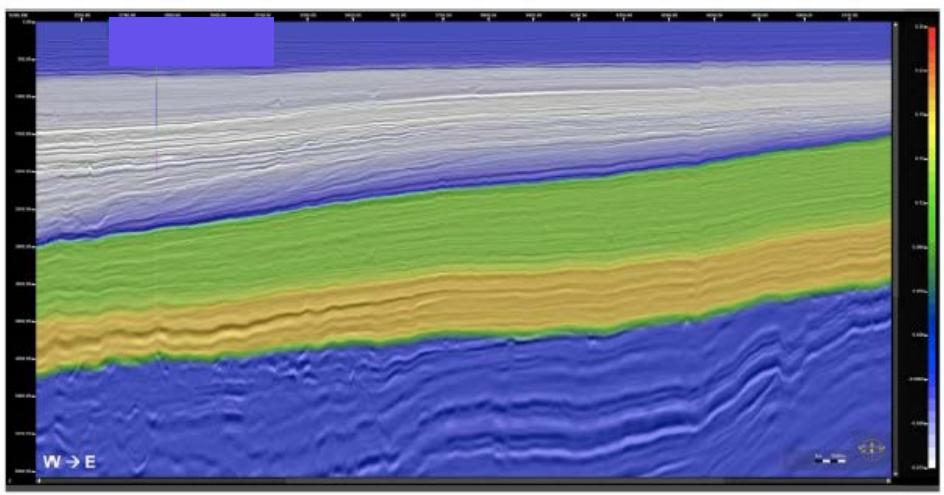
Browse Basin, NW continental shelf of Australia



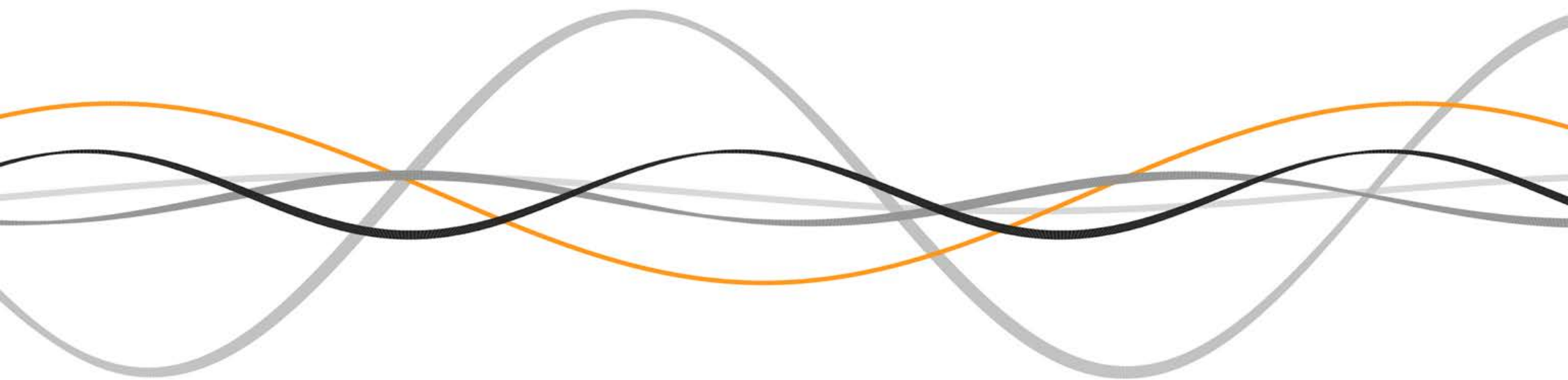
Modified from Keep et al., 2018

Anisotropic parameter (epsilon) obtained from seismic processing

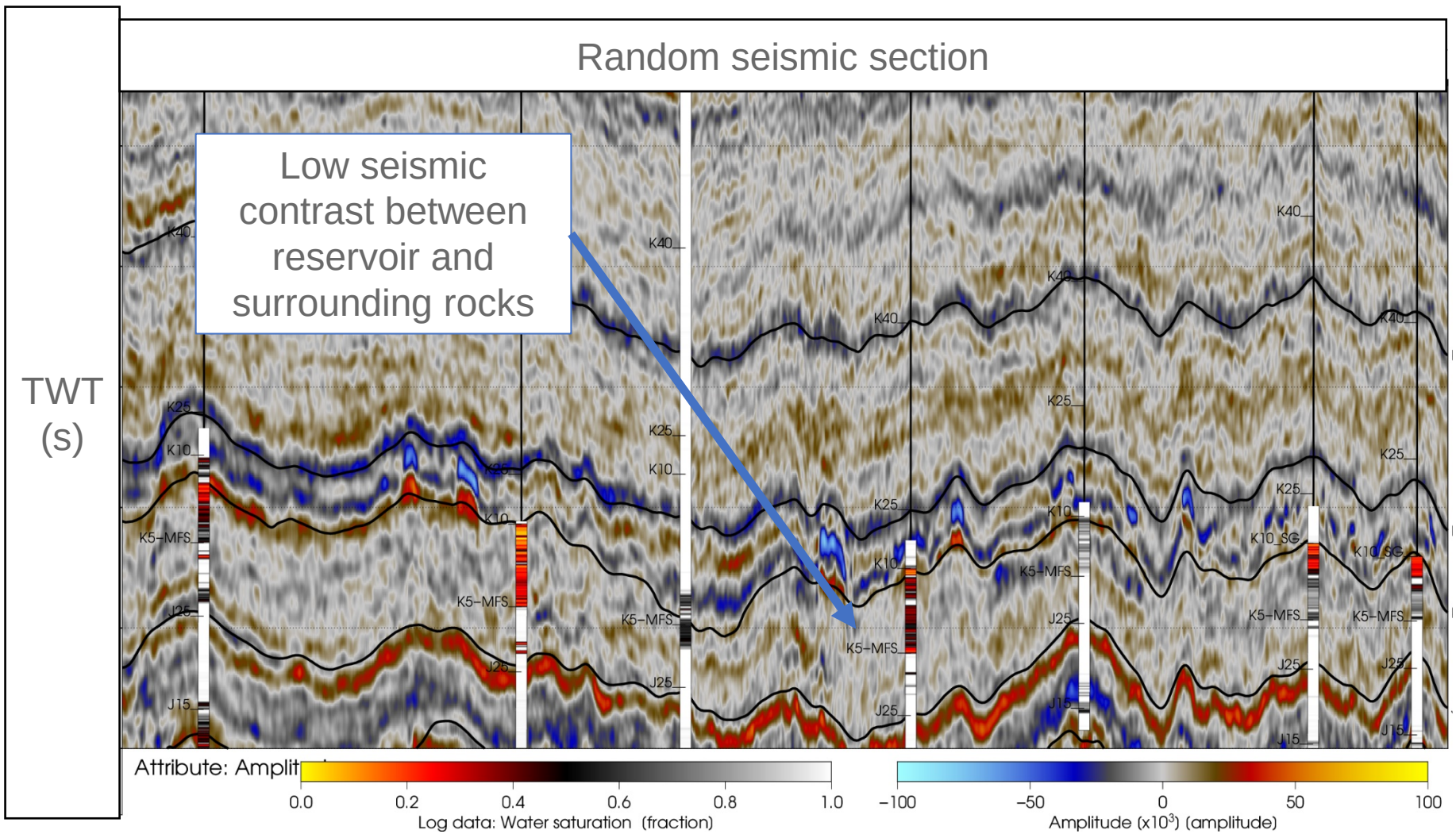


Hot colors = relatively higher anisotropy
Cold colors = relatively lower anisotropy
Delta = 10 – 20 %
Epsilon = 1.3 * Delta
Overburden shale, gas sandstone and underburden shale

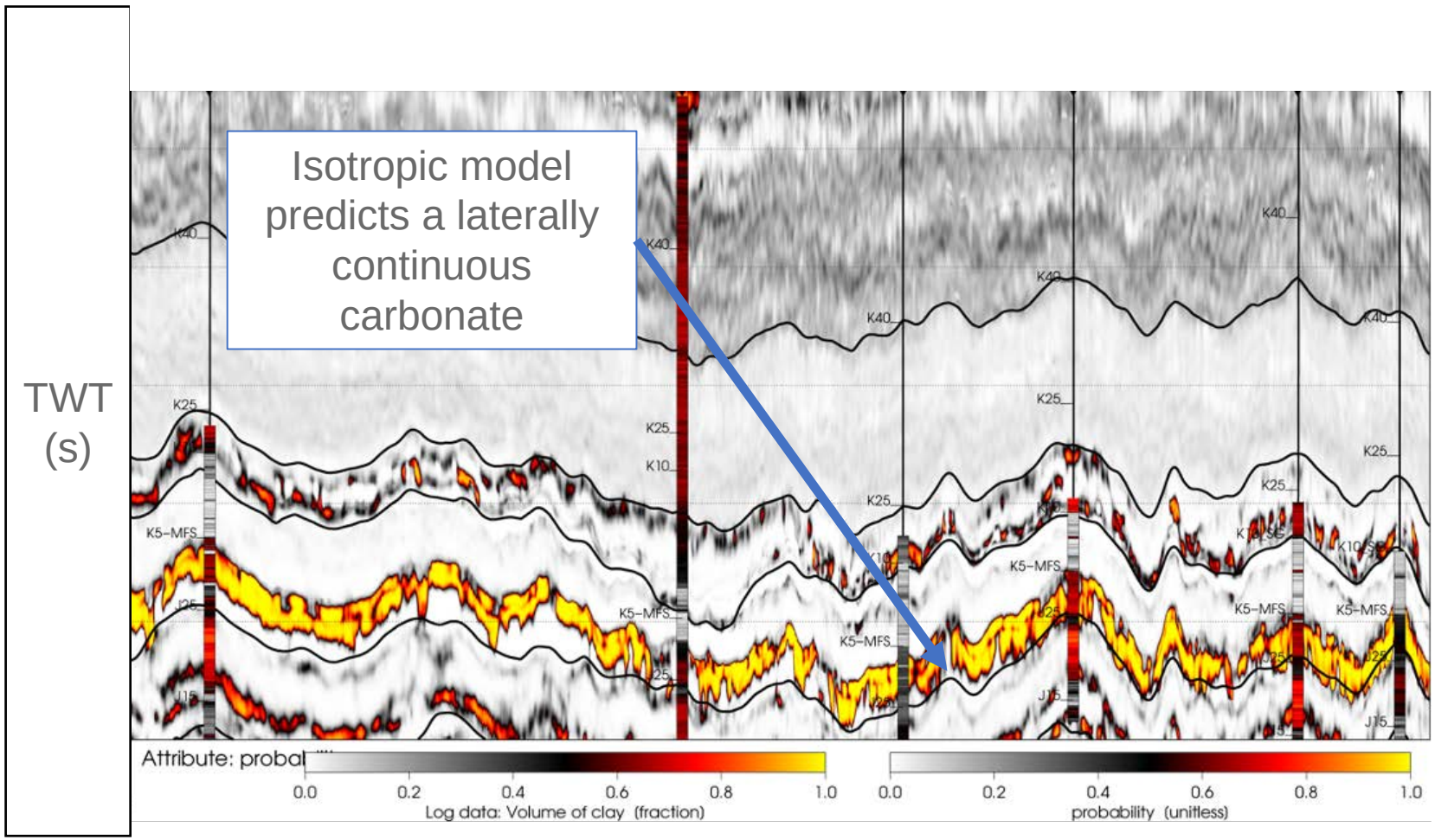
Results
Isotropic vs VTI anisotropic model



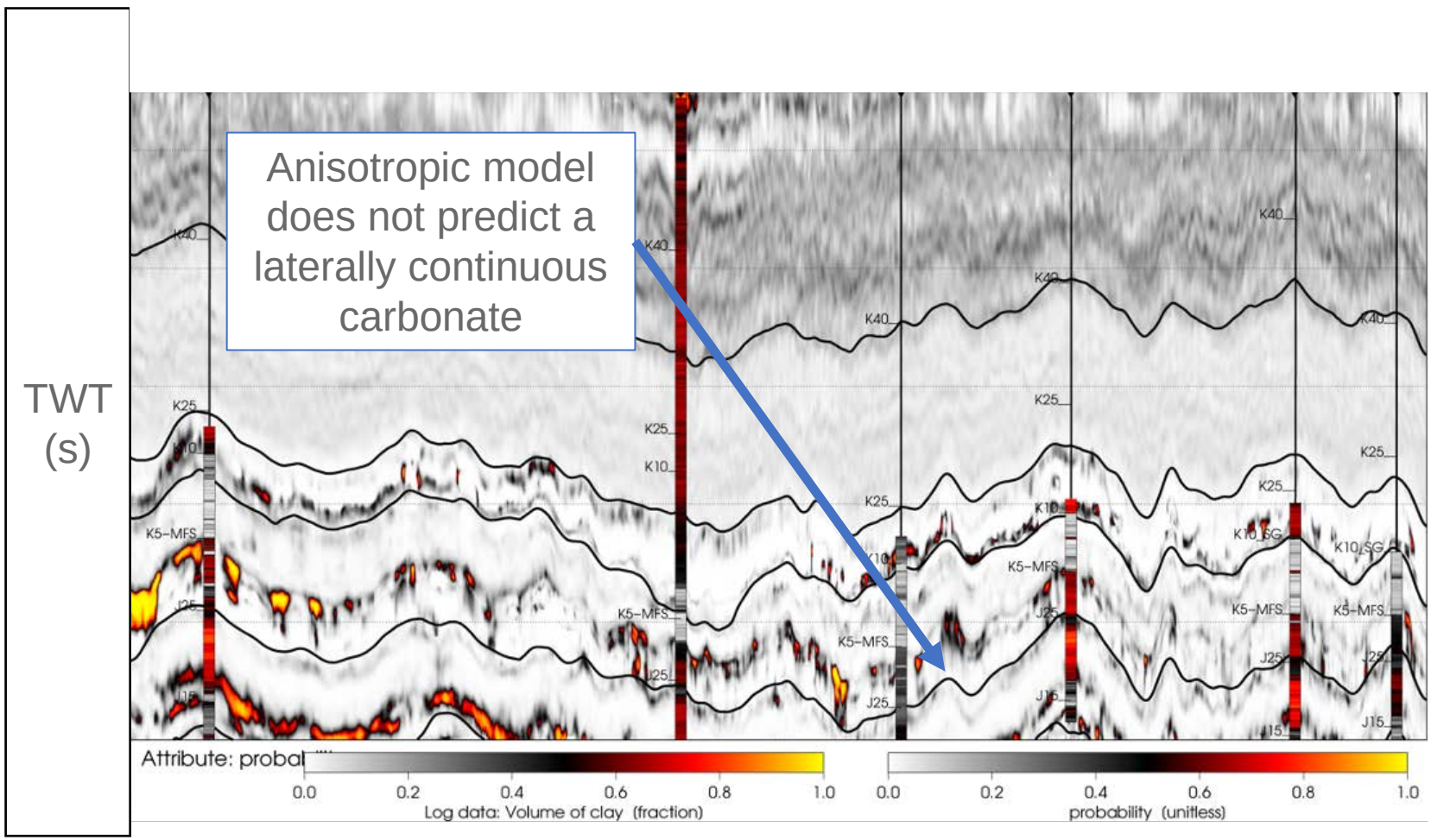
Seismic amplitude



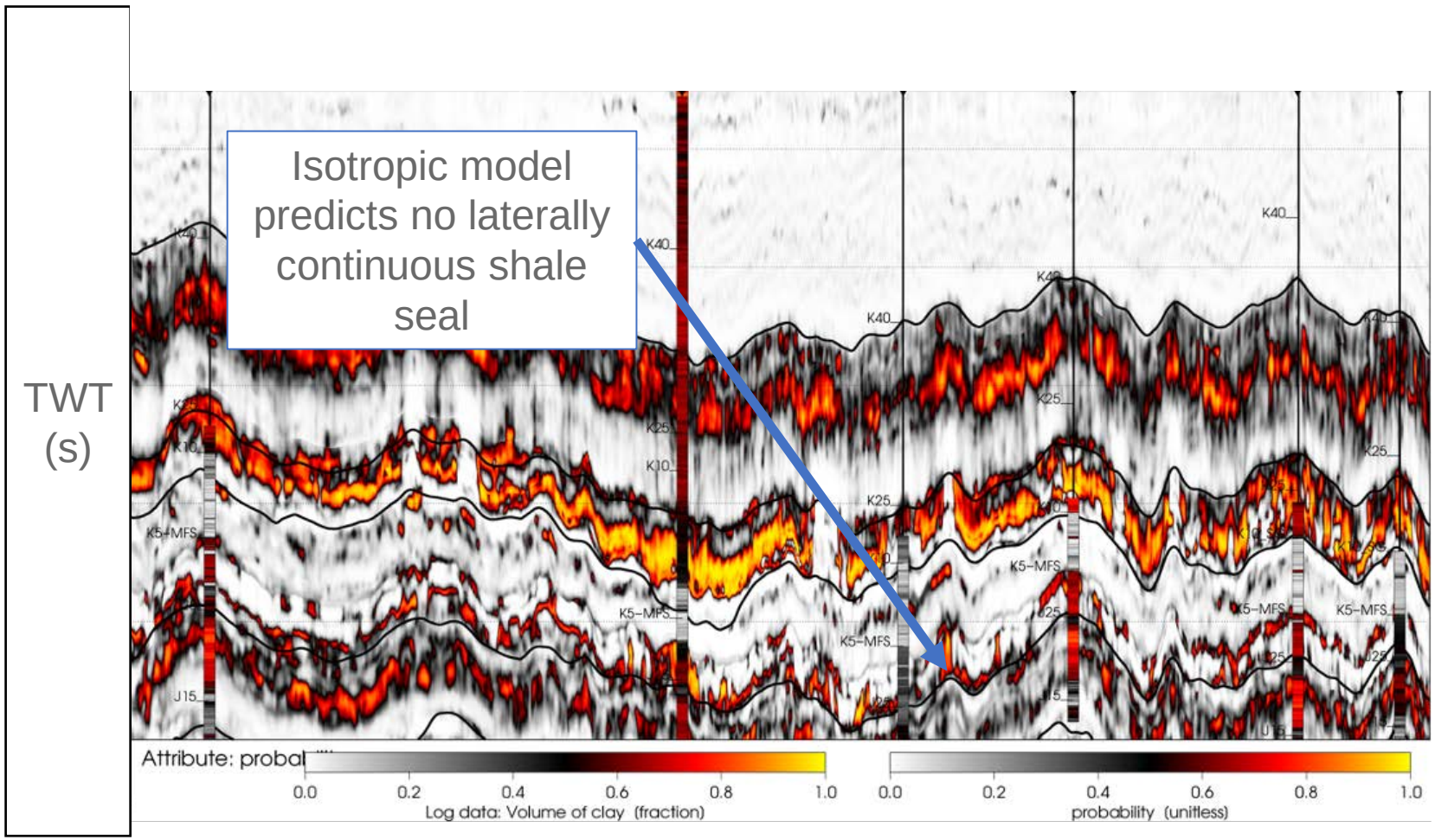
Carbonate probability - isotropic



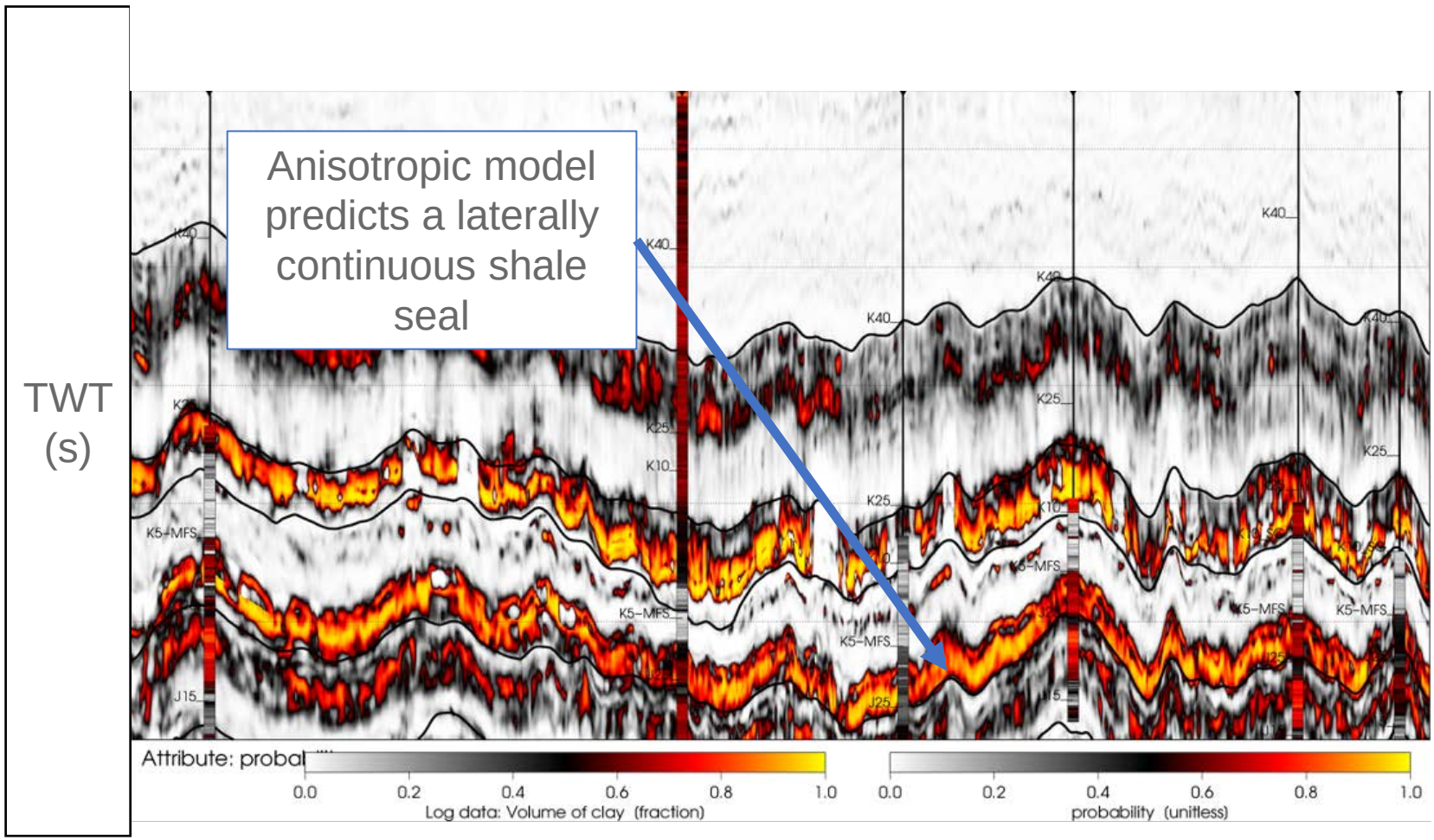
Carbonate probability - anisotropic



Shale probability - isotropic



Shale probability - anisotropic



Conclusions

- Incorporating *anisotropic* effects correctly accounts for changes in the AVO response.
- Including *anisotropic* effects materially improve the inversion results.
- Consequently, the facies are better predicted, especially on the prediction of the lateral and bottom sealing shales.
- The outputs of DPI are probabilities for each facies at each location enabling a more comprehensive statistical analysis of exploration and development risk.

The end

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- The authors would like to thank Santos Limited for permission to use the data

- Questions now – or at the Qeye booth during the breaks

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