Improved estimation of density enabled by PP–PS simultaneous inversion of multicomponent seismic data

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Roadmap

- Motivation
- Case study
  - Amplitude calibration
  - Event registration
  - Inversion results
- Lesson learned
- Recommendations for future work
- Q & A
Motivation

- OBS undergoing a renaissance
- Recent technical (efficiency) advances
  - Handling
  - Large sensor inventory
  - Battery life
  - Blended sources
  - Compressive sensing
- Reduction in unit cost of data
- High end PP–PS imaging and improving QI value proposition
  - New and existing data
  - Can address some common challenges in SEA
    - Gas obscured zones
    - Density as a proxy for gas saturation
Case study

- Production asset offshore peninsular Malaysia
- Density is observed to be a strong predictor of gas charge
- Difficult area for seismic
- Can a QI workflow accurately:
  - Map the PS data to the PP data to aid interpretation?
  - Tie blind well log data?
  - Produce stable and reliable density inversion results?
Input data

- Four wells
- PP and PS imaged anglestacks
- 14 anglestacks covering ~60 sqkm
- PP and PS RMS velocities
- PP horizons X 4
- PS horizons X 1
- Gamma field
Key steps

- Preconditioning
  - Amplitude calibration
  - Event registration
  - Angle stack conditioning
- Inversion parameterisation
  - Angle ranges / weighting
  - Spatial and component weights per angle stack
Case study – preconditioning
Effect of shallow gas on reservoir amplitudes

PP fullstack

PS fullstack

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Case study – preconditioning
Full stack amplitude calibration
Case study – preconditioning
Full stack amplitude and spectral balancing

raw RMS PP

amplitude balanced RMS PP

amplitude correction field

RMS spectral matched PP data

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Case study – preconditioning

Event registration

1. Apply supplied gamma field
2. Calculate a laterally smooth timeshift field to align provided PP and PS horizon
3. Pick additional PS horizons

   Calculate additional non linear timeshifts to align event between co-picked PP & PS horizons
   Update timeshift field, smooth and QC
   Update timeshift field, smooth and QC

   Calculate additional linear timeshifts to align additional horizons and PS horizons
   Remove imaging artifacts around faults
   Update timeshift field, smooth and QC

Seapex 2019
Case study – preconditioning
Cross correlation PP to PS (in PS time)
Case study – preconditioning
Cross correlation PP to PS (in PP time from supplied gamma)

Seapex 2019
Case study – preconditioning
Cross correlation PP to PS (gamma plus residual alignment using supplied PS horizon)

Seapex 2019
Case study – preconditioning
Cross correlation PP to PS (gamma plus residual alignment using picked PS horizons)
Case study – preconditioning
Cross correlation PP to PS (after final event registration)
### Case study – preconditioning

**PP seismic section (reference)**

<table>
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<tr>
<th>Attribute: Amplitude</th>
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**TWT (s)**

| TWT (s) | 2731 | 2739 | 3139 | 5100 | 2771 | 2751 |

**Qeye**

Seapex 2019
Case study – preconditioning
PS seismic (raw)

Attribute: Amplitude

Amplitude \[\times 10^3\] [amplitude]
Case study – preconditioning
PS seismic (in PP time from supplied gamma)

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Amplitude [x10^3] [amplitude]

Seapex 2019
Case study – preconditioning
PS seismic (gamma plus residual alignment using supplied PS horizon)
Case study – preconditioning
PP seismic section (reference)
Case study – preconditioning
PS seismic (gamma plus residual alignment using picked PS horizons)
Case study – preconditioning
PP seismic section (reference)

Attribute: Amplitude

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Seapex 2019
Case study – preconditioning
PS seismic (after final event registration)

Attribute: Amplitude

Seapex 2019
Case study – preconditioning
PP seismic section (reference)

Attribute: Amplitude
Case study – preconditioning

Angle stack conditioning

- Final PP time to PS time correction field now applied to anglestacks
- Anglestacks within each component then aligned to the component full stack
  - All anglestacks in PP time
  - All anglestacks flattened
- Raw PP anglestacks require amplitude calibration
  - Repeat similar workflow to the full stack calibration anglestack by anglestack
  - Amplitude effects are angle specific
  - Only correct amplitudes, spectral variations between stacks and components will be corrected by wavelets
Case study – preconditioning
Angle stack amplitude calibration and intra-component alignment

Raw PP anglestack

Amplitude calibration field

Displacement field

Calibrated anglestack
Case study – preconditioning
25° to 35° PP anglestack amplitude calibration

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Case study – preconditioning
Scalar fields by PP anglestack for amplitude calibration
Case study – preconditioning
25° to 35° PP anglestack event alignment
Case study – preconditioning
25° to 35° PP anglestack event alignment
Case study – preconditioning
25° to 35° PP anglestack phase mismatch before event alignment
Case study – preconditioning
25° to 35° PP anglestack phase mismatch after event alignment
Case study – preconditioning
25° to 35° PP anglestack Xcorrelation vs max displacement before event alignment
Case study – preconditioning
25° to 35° PP anglestack Xcorrelation vs max displacement after event alignment
Case study – preconditioning
Lower window PP anglestack Xcorrelation vs max displacement before event alignment
Case study – preconditioning
Lower window PP anglestack Xcorrelation vs max displacement after event alignment

5°–15°

25°–35°

25°–40°

30°–45°

35°–45°

35°–50°

40°–55°

45°–55°
Case study – inversion parameterisation
Final multiwell wavelets – wavelets without preconditioning shown for comparison

PP wavelets after warp
PP wavelets before warp
PS wavelets after warp
PS wavelets before warp
Case study – inversion parameterisation
Component weighting

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Case study – inversion
Final inversion PP

Acoustic impedance
Vp/Vs
Density

Seapex 2019
Case study – inversion
Final inversion PPPS

Acoustic impedance

Vp/Vs

Density

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Case study – calibration vs blind wells
Final inversion PP

Calibration wells

Blind wells
Case study – calibration vs blind wells
Final inversion PPPS

Calibration wells

Blind wells

Seapex 2019
Conclusions

- A focus on preconditioning, and especially event registration, produced a more geologically consistent density volume.
- Acoustic impedance is relatively robust and, after amplitude calibration, PP inversions showed limited improvement with the addition of PS data.
- Vp/Vs improvements are smaller than you might expect. This is consistent with results seen on other projects.
Lessons learned and recommendations

- You can get good density results from simultaneous PPPS AVO inversion
  - It does require care and attention – but it can be done
  - You need to parameterise such that there is no cross talk between the terms

- The PS data does not improve all components equally
  - Where the PP data was already good, the addition of the PS data can downgrade the results

- Frame the question
  - The workflow and the focus depends on the question asked
  - In this case density was important and it required the PS data in the gas obscured areas
  - This workflow combines easily with others – e.g. thin bed resolution, time lapse, etc.
Lessons learned and recommendations

- Process the PS data
  - This workflow leverages the excellent quality PS image

- Depth process the data
  - The PP and the PS data are spatially different in this case despite being depth processed
  - This is particularly apparent around the faults

- Preserve the azimuth information
  - Most modern OBS geometries are naturally full azimuth
  - This information increases inversion resolution
  - This information contains the stress/fracture signature
Acknowledgements

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  - Christian Proud – Qeye
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- Seapex organisers and technical committee
- Audience
  - As long as the questions are not too difficult!