

Improving Exploration Effectiveness in the Subsalt: Hybrid Gravity Inversion

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Outline



- The Subsalt Modelling Challenge
- VALEM A Hybrid Inversion Approach
- Base of Salt Hybrid Inversion Example
- Offshore Africa Example OMV
- Summary



Use of Gravity Data



- Imaging the base of salt is difficult with seismic alone.
- Interpretation can be improved by using potential field data in conjunction with seismic data.
- The Base of Salt problem is a case where gravity data are used to assist the picking of base of salt horizons.

Reducing uncertainty on the geometry of the base of salt can improve exploration effectiveness



Increasing Confidence in the Seismic Model



Petroleum Problem: Seismic imaging in areas of complex salt geometry



Solution: Successful PSDM



How: PSDM is a model-driven technique



Therefore

Use of gravity data for detailed salt mapping to constrain/enhance initial velocity model in the 3D-PSDM

The Subsalt Modelling Challenge





Limitations of Traditional Modelling Approaches



Frequency domain forward modelling of layer geometry

- Cannot handle 3D density distributions
- No seamless integration with velocity model building process
- Fast but inflexible

How can we build a more efficient and optimized modelling strategy?

Limitations of Traditional Modelling Approaches



Voxel inversion of gravity data

- More flexible, but slow
- Suitable for 3D, complex geometries
- Requires powerful processors
- Non-unique, too smooth

Voxel inversion also has challenges to overcome.



Best of layered Earth modelling and voxel-based inversion

VALEM's Hybrid Inversion Approach



Voxel Inversion of Gravity Data

- Can handle complex 3D distribution
- Constrained with seismic interpretation (not smooth)
- High Performance Computing

Layered Earth Geometries

- Interactive modelling workflow allows effective visualization of gravity and seismic within the same environment
- Potential to enhance the velocity model with improved based of salt interpretation
- Returns discrete geological layers (intuitive model building)

Addressing the Challenge of Non-Uniqueness



Can introduce constraints to the model based on what we know

- Constant or voxel constraints
- Upper & lower density bounds
- Parameter weighting
- Allows inclusion of faults, boreholes, varying uncertainty in starting model, etc.

Use of Iterative Reweighting Inversion (IRI) Focusing to sharpen inversion results

 IRI takes an initial inversion result and uses it as an iterative reweighting constraint in a subsequent inversion.

IRI Salt Focusing: sharpening salt/sediment boundary





GEOSOFT. Inversion Methodology 1 - SEG/EAGE 1996 model 0 0 2000 N 0 ອ

8000

10000

12000

14824

See Aminzadeh et al. (1995)

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Х

6000

2000

Velocity model

4000

Inversion Methodology 2 – Density Model





Density Model – Includes at the Minimum ToS

Inversion Methodology 2 – Gravity Data



3. Observed *Data:* G_z



Inversion Methodology 3 – Reference Model



Bathy and basement represented by grids

Interpolated Fill

Constraints:

- Top of salt
- Active area with salt boundaries
- Top of basement is base of active volume

Demonstrate the maximum that can be achieved with perfect data



Inversion Methodology 4 – Hybrid Model





Inversion Methodology 5





Inversion Methodology 5 – Starting Model



1. Active Inversion Domain

2. Sediment Reference Model









Inversion Result



Before inversion ΔG_z



After inversion ΔG_z



Inversion Result





Inversion Result – Density Misfit

The difference between the SEG model and the model recovered by inversion. Note that the sediment density is correctly determined to an accuracy of ~0.010 g/cm³ and the salt density is exact.





0.158 r



3 IRI Salt Focusing





- 500 m line spacing
- 500 1200 m water depth

"We kept it as the most simple model which explains the data."



 Gravimetric base of salt is currently fed into velocity model building and migration

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Offshore Africa Example – OMV



Summary



Hybrid inversion of gravity data can improve seismic imaging of the subsalt

- Able to recover sharp boundary using constrained voxel based inversion
- Fast, flexible and iterative
- Seamless integration within the seismic workflow
- Reduces uncertainty and produces an improved model for exploration

Potential beyond base of salt ...

 Inversion of gravity gradient and magnetic data for basin analysis and sub-basalt imaging



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