Geological Principles of Imaging Permian Salt Bodies in the North Sea and Irish Sea*

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Abstract

The advent of 3D seismic and then pre-stack depth migration has improved the seismic interpreter’s knowledge of salt bodies and revealed many sub-salt and salt flank hydrocarbon plays. The huge leaps in processing power and introduction of migration algorithms like Reverse Time Migration has helped advance the understanding of many salt features, but this has been at a price. Imaging salt bodies has always been a balance of quality against time and cost. As surveys get bigger and velocity analyses are more automated, then geological quality control becomes an even more critical factor in the processing of seismic and interpretation of structure. However, too often sub-surface professionals rely too heavily upon advanced processing algorithms and automated velocity picking to image and build their structural models. Regrettably, this sometimes results in basic geological principles taking second place to the new technology, which inevitably results in a poorly integrated and geologically questionable subsurface model.

This presentation contrasts salt body interpretation across several basins around the UK and Gulf of Mexico and demonstrates how simple geological understanding can sometimes speed up the construction of complex velocity models and improve the understanding of salt behavior and the subsurface.

Selected References


AAPG Annual Conference April 2011
Integrating New Technology, Geophysics and Subsurface Data

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Gavin Ward

“Where oil is first found is, in the final analysis, in the minds of men...”
Wallace Pratt - One of the founders of the American Association of Petroleum Geologists
Toward a Philosophy of Oil Finding AAPG, 1952
Integrating New Technology, Geophysics & Subsurface Data

Seismic Interpretation is:

1. Sound Geological Principles
2. Subsurface Data
3. New Technology
New Versus Old Technology
New Versus Old Technology

Centrica Energy

Geo Processing company
Seismic Illumination
The Leading Edge (Hubral 1999)

Need to connect the seismic interpreter with:
a) Geologist & geology
b) Processor & velocity

“............the standard reflection-imaging processes PostSDM and PreSDM are not using the full potential that multi-coverage reflection data offer for subsurface reflector imaging.............This (CRS stack surface) can be done without any information about the macro-velocity model other than the near-surface velocity. .......also, important wavefield attributes for the construction of the macro-velocity model can be obtained with only the near-surface velocity and without any ray tracing...........
USA : GOM, West Delta & Deepwater

Plastic & Ductile strata

Figure 1: Sub-salt image generated with conventional technology, showing poor imaging of salt flanks and sub-salt structures.

Figure 2: Sub-salt image generated with RTM technology, showing significant improvement in imaging salt flanks, even beneath the salt body.
USA : GOM, West Delta & Deepwater

Plastic & Ductile strata

- Base of salt reflector
- Salt flank reflector
- Near top of salt reflector
- Prograding sediment wedge/Syn depositional thickening into salt
- Syn depositional thickening related to salt movement

Courtesy of Virtual Seismic Atlas
UK, Norway : N.Sea, Central Graben

Example 1 & 2 : Brittle & lithified strata
Pre-stack depth migration offers a more general imaging solution than Common Reflection Seismic, but successful application is dependent on the ability to define an accurate velocity model in a few iterations. This is a difficult exercise with datasets contaminated with noise and in complex geological settings.
Think Salt! – Thick & Thin


Brittle fracture & conservation of mass
**Example 3**: Brittle & lithified strata

Old velocity model assumed simple velocity field but Halite beds created anomalous velocities not previously recognised.
East Irish Sea – Thin Salt

Extension followed by Late Tertiary compression (eg: Rivers Graben)

Coulomb collapse modified after Hamblin 1965
Example 3: Brittle & lithified strata

U. Triassic Shale & Salt beds

L. Triassic Sandstone

2008 reprocessing of example #5 did not recognise thrust and inversion in basin. Thrust decouples on halite members.
Example 4: Brittle & lithified strata

No conservation of mass

2008 interpretation of Southern Gas Basin (Quadrant 48) salt wall

Courtesy of Virtual Seismic Atlas
Example 4: Processing Solution Only

SEG 2008: “.....the recent rapid increase in available cost-effective computing power has enabled industrial implementation of migration algorithms, particularly reverse-time migration that in principle can image events that reflect more than once on their way from source to receiver.....”

Ian F. Jones, ION GX Technology EAME - Geophysics / Volume 73 / Issue 6 / TECHNICAL PAPERS / SEISMIC MODELING AND WAVE
Example 4: Processing Solution Only

- 2D Time migrated
- 3D Time migrated
- 3D Depth migrated
- PSDM shown with high cut filter to match Reverse Time Migration frequency range
- Reverse Time Migration shown with gain to match Kirchhoff amplitude decay
Back to Basics = Homework

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 44, NO. 9 (SEPTEMBER, 1956), PP. 1819-1846, 23 FIGS.

MECHANISM OF SALT MIGRATION IN NORTHERN GERMANY

F. TRUSHEIM
Hannover, Germany

Brittle fracture & conservation of mass
Modern PrSDM Kirchhoff migration does produce good images in the middle of salt domes where ray-paths are relatively simple, but stack can contain useful information (in hind-sight).
Modern PrSDM Kirchhoff migration does produce good images in the middle of salt domes where ray-paths are relatively simple, but stack can contain useful information (in hind-sight).

Stack shows some preserved Normal ray paths which are migrated out of section.
Failed Salt Wall Development

Southern Gas Basin (Quadrant 48)

Tertiary muds
Cretaceous chalk
Jurassic & U.Triassic mudstones & halite
L.Triassic sandstones
Carboniferous sandstones & mudstones
Permian
Cretaceous
U.Permian halite
L.Permian sandstones

C49/84-23
SALTWALL DEVELOPMENT
Successful Wall Development

Southern Gas Basin (Quadrant 49)

- Jurassic & U.Triassic mudstones & halite
- U.Permian halite
- L.Permian sandstones
- Carboniferous sandstones & mudstones
- L.Triassic sandstones
- Tertiary muds
- Cretaceous chalk

Geological strata and rock formations are shown in the diagram.
Successful Wall Development

Southern Gas Basin (Quadrant 49)

- Jurassic & U.Triassic sandstones & halite
- U.Permian halite
- L.Permian sandstones
- Carboniferous sandstones & mudstones
- Tertiary muds
- Cretaceous chalk
- Jurassic & U.Triassic mudstones & halite
- L.Triassic sandstones
- Salt
- Tertiary
- Cretaceous
- L.Permian
Geology First

Southern Gas Basin (Quadrant 48)

1992 Acquisition (PPCo)
1993 Interpretation
1993 Vel model (PPCo)
1994 PreSDM (PPCo)
1995 Re-Interpretation
Geology First

Southern Gas Basin (Quadrant 48)

1992 Acquisition (PPCo)
1993 Interpretation
1993 Vel model (PPCo)
1994 PreSDM (PPCo)
1995 Re-Interpretation
1996 Drilling (PPCo)
Geology First

Southern Gas Basin (Quadrant 48)

1992 Acquisition (PPCo)
1993 Interpretation
1993 Vel model (PPCo)
1994 PreSDM (PPCo)
1995 Re-Interpretation
1996 Drilling (PPco)
2008 Vel model & Kirchoff PreSDM (CE)
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Virtual Seismic Atlas