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

Gavin H. Ward[1]

Search and Discovery Article #40779 (2011)
Posted July 26, 2011

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Houston, Texas, USA, April 10-13, 2011.

[1]Subsurface, Centrica, Windsor, United Kingdom. (gavin.h.ward@centrica.com)

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

Hamblin, W. K., 1965, Origin of "reverse drag" on the downthrown side of normal faults: GSA Bulletin, v. 76, p. 1145-1164.

Hubral, P., G. Hoecht, and R. Jaeger, 1999, Seismic illumination: Leading Edge, v. 18/11, p. 1268-1271.

Jones, I.F., 2008, A modeling study of preprocessing considerations for reverse-time migration: Geophysics, v. 73/6, p. T99-T106.

Penge, J., J.W. Munns, B. Taylor, and T.M.F. Windle, 1999, Rift-raft tectonics: examples of gravitational tectonics from the Zechstein basins of northwest Europe *in* A.J. Fleet, and
S.R. Boldy, (eds.) The Petroleum Geology of NW Europe: Proceedings of the Fifth Conference, Geological Society of London, p. 201-213.

Tearpock, D., and R. E. Bischke, 1991, Applied subsurface geological mapping:, Prentice-Hall, Englewood Cliffs, New Jersey, 648 p.

Trusheim, F., 1960, Mechanism of Salt Migration in Northern Germany: AAPG Bulletin v. 44/9, p. 1519-1540.

AAPG Annual Conference April 2011

Integrating New Technology, Geophysics and Subsurface Data

Geological Principles Of Imaging Salt Bodies In The North Sea And Irish Sea

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

centrica energy
Upstream

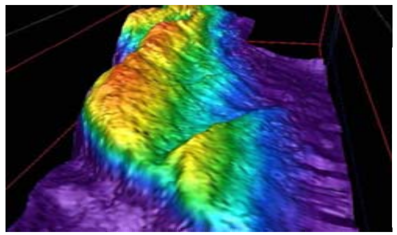
Integrating New Technology, Geophysics & Subsurface Data

MAKING THE NEXT GIANT LEAP IN GEOSCIENCES
AAPG 2011 Annual Convention & Exhibition
10-13 April 2011 • Houston

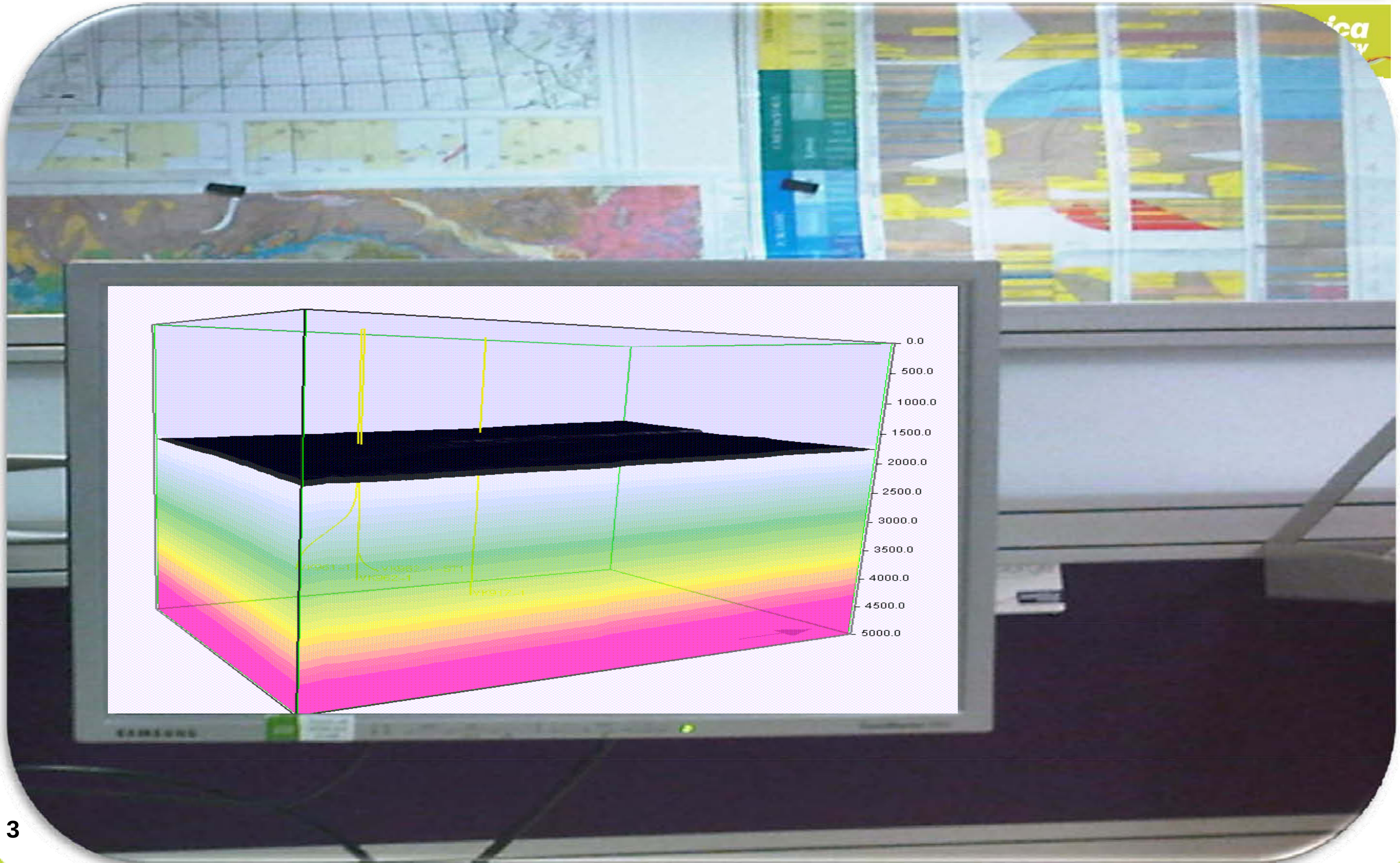
centrica energy

Seismic Interpretation is:

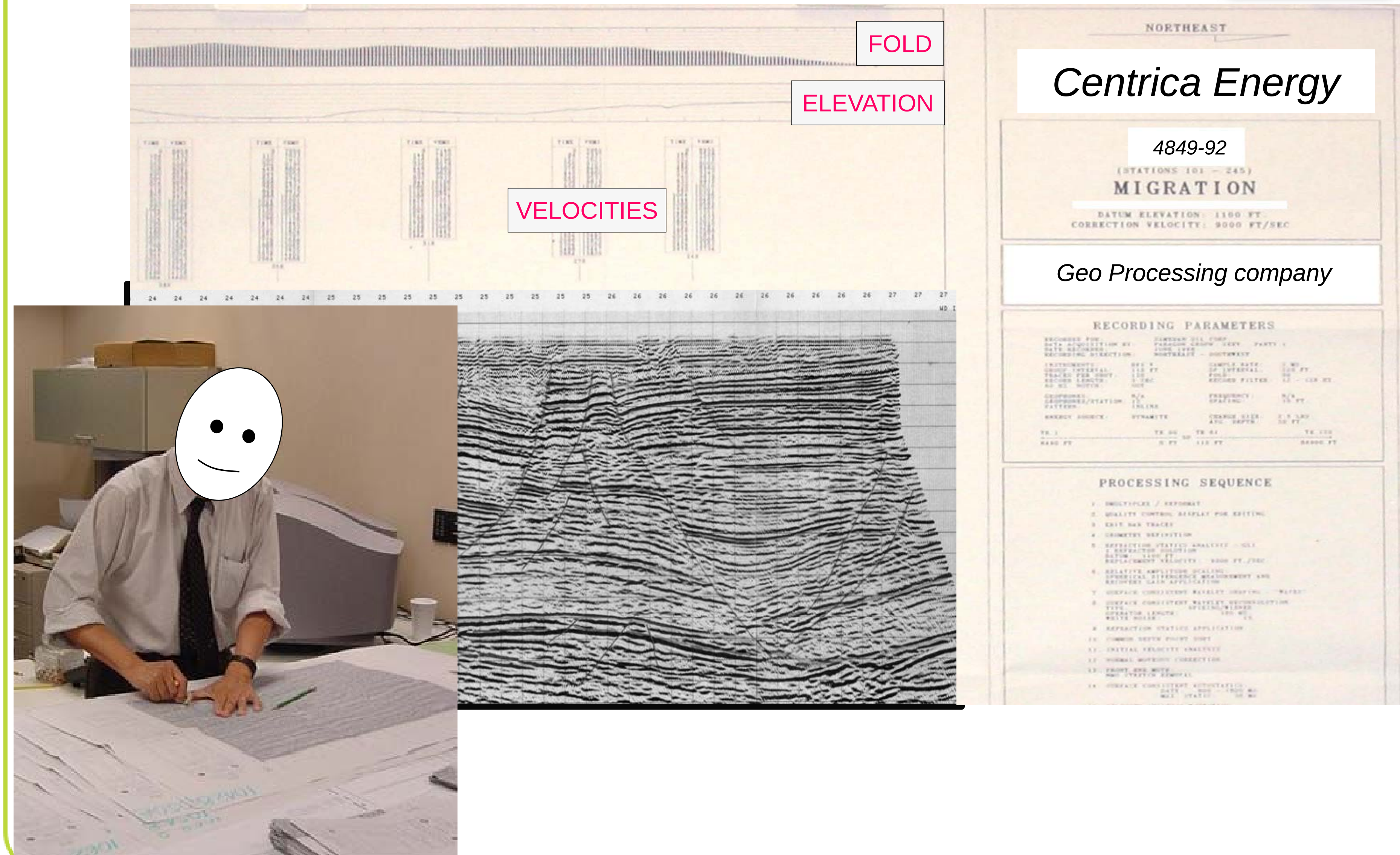
1. **Sound Geological Principles**
2. **Subsurface Data**
3. **New Technology**



New Versus Old Technology



New Versus Old Technology



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.........*

SEG/EAGE workshop "Macro-model independent reflection imaging" in Karlsruhe, Germany, Feb 1999 (CRS = Common Reflection Seismic)

USA : GOM, West Delta & Deepwater

Plastic & Ductile strata

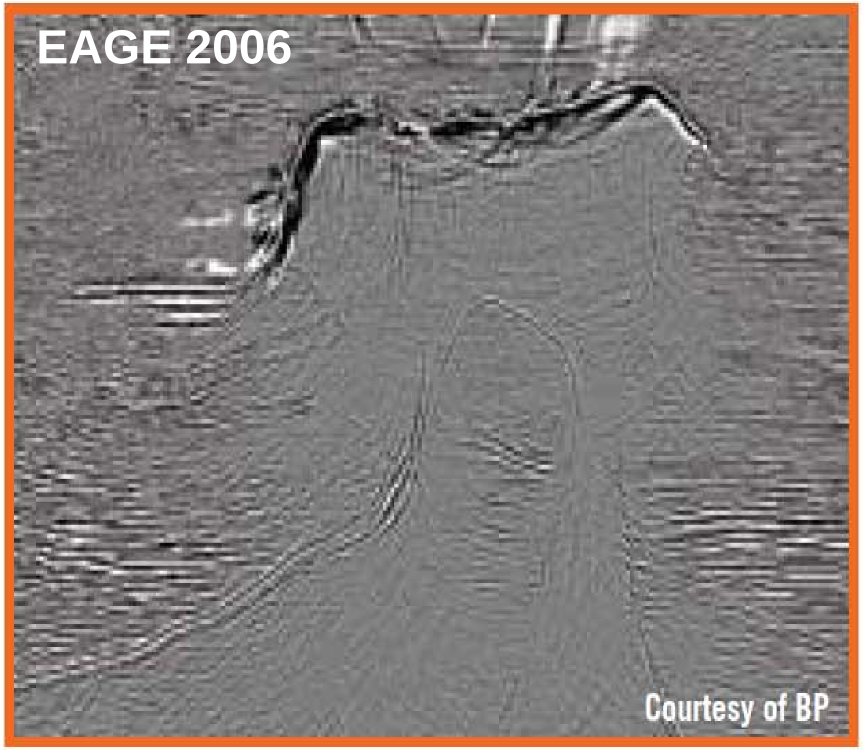
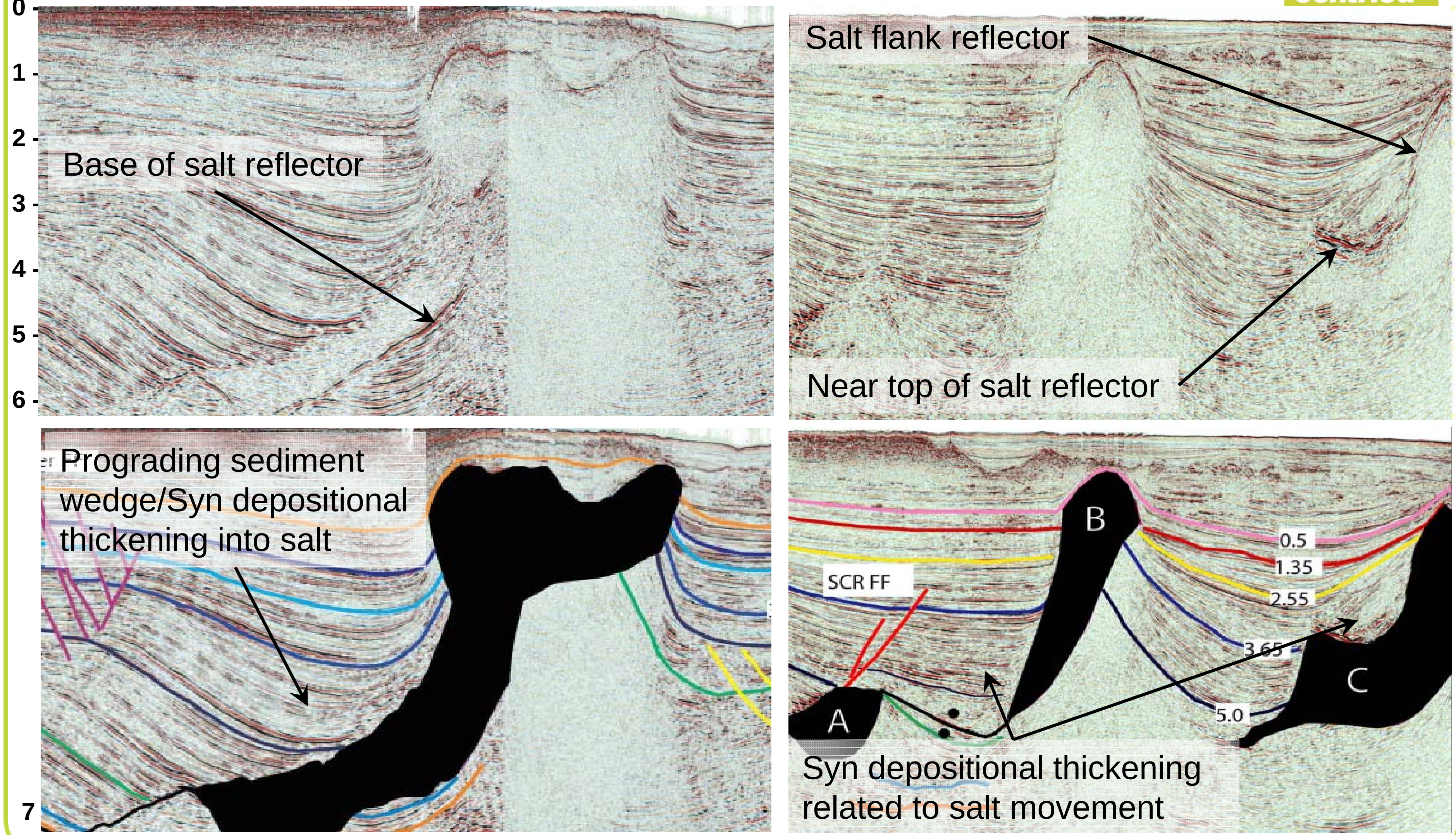


Figure 1: Sub-salt image generated with conventional technology, showing poor imaging of salt flanks and sub-salt structures.

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

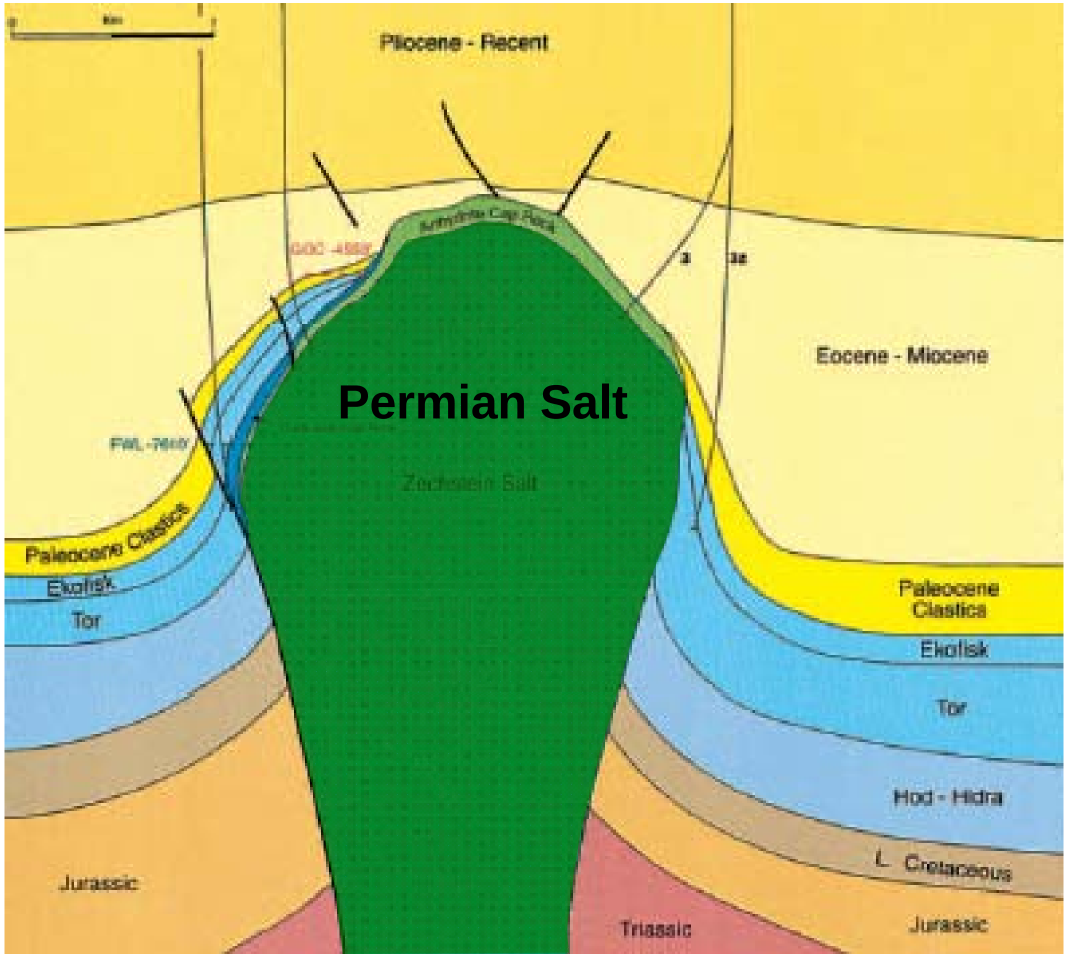
Plastic & Ductile strata

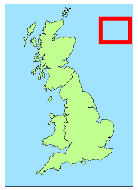


Courtesy of Virtual Seismic Atlas

UK, Norway : N.Sea, Central Graben

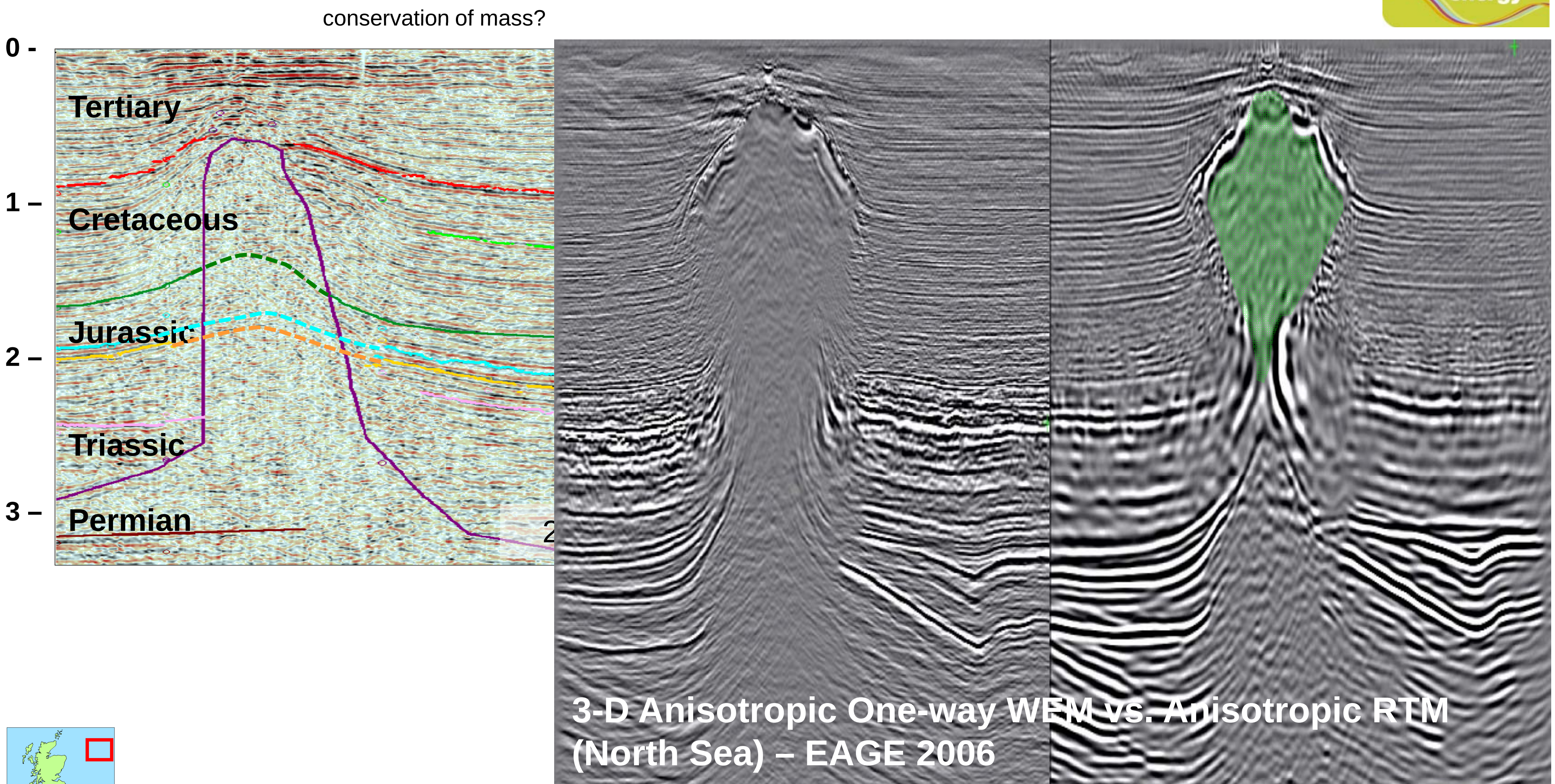
Example 1 & 2 : Brittle & lithified strata

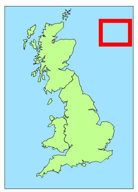




UK, Norway : N.Sea, Central Graben

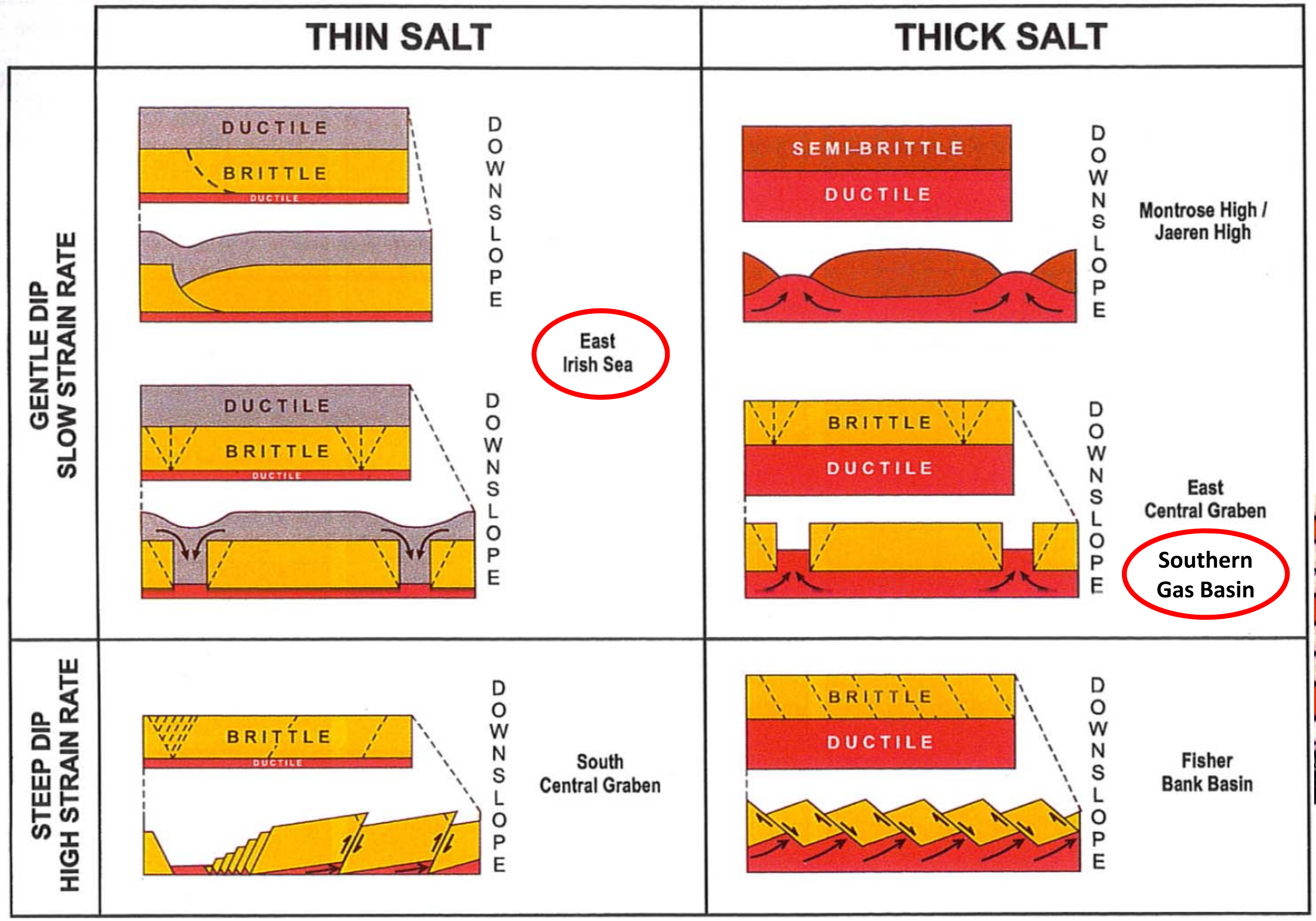
Example 1 & 2 : Brittle & lithified strata

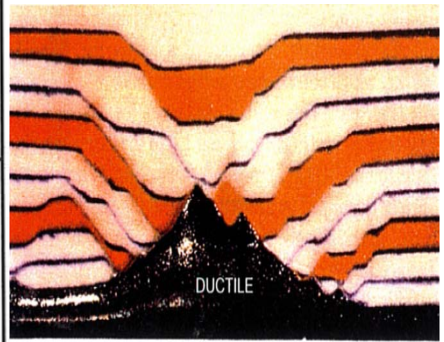




Pre-stack depth migration offers a more general imaging solution than Common Reflection Seismic, but successful application is dependent on the ability to define an accurate velocity model in a few iterations. This is a difficult exercise with datasets contaminated with noise and in complex geological settings.

Think Salt ! – Thick & Thin



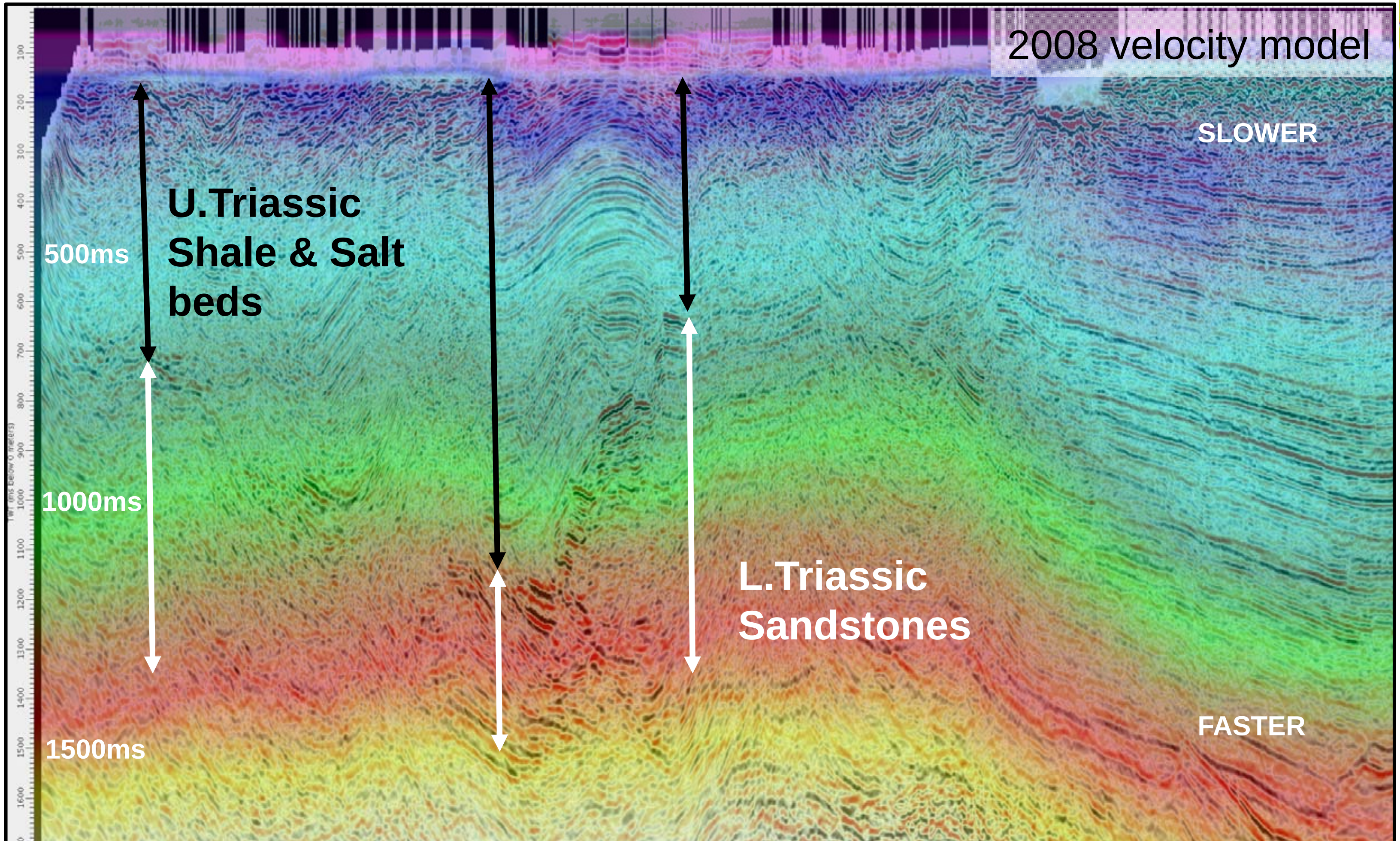


Rift-Raft tectonics of gravitational tectonics from the Zechstein basins of northwest Europe, Petroleum Geology Conference Series, 5 P201-213. Penge J, Munns J, Taylor B, & Windle T

Brittle fracture & conservation of mass

UK : East Irish Sea, Non-Geological velocity field

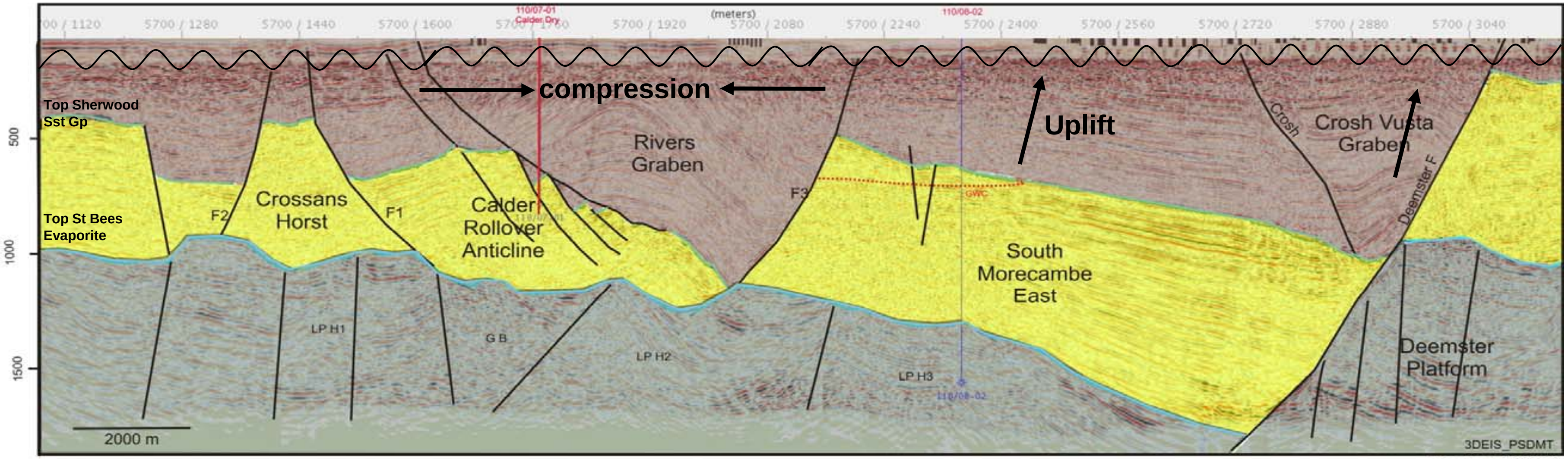
Example 3 : Brittle & lithified strata



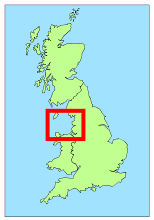
Old velocity model assumed simple velocity field but Halite beds created anomalous velocities not previously recognised

East Irish Sea – Thin Salt

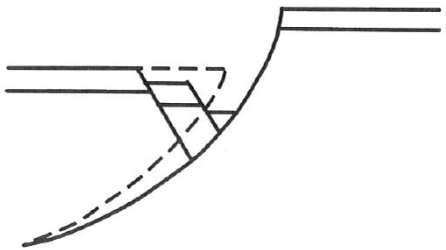
Extension followed by Late Tertiary compression (eg: Rivers Graben)



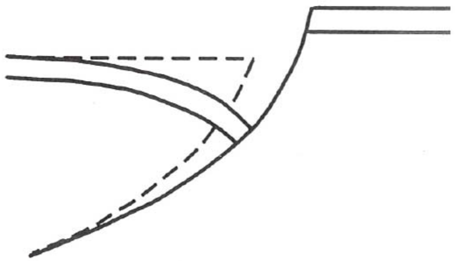
Courtesy of CGGV



COULOMB COLLAPSE



VERTICAL COLLAPSE

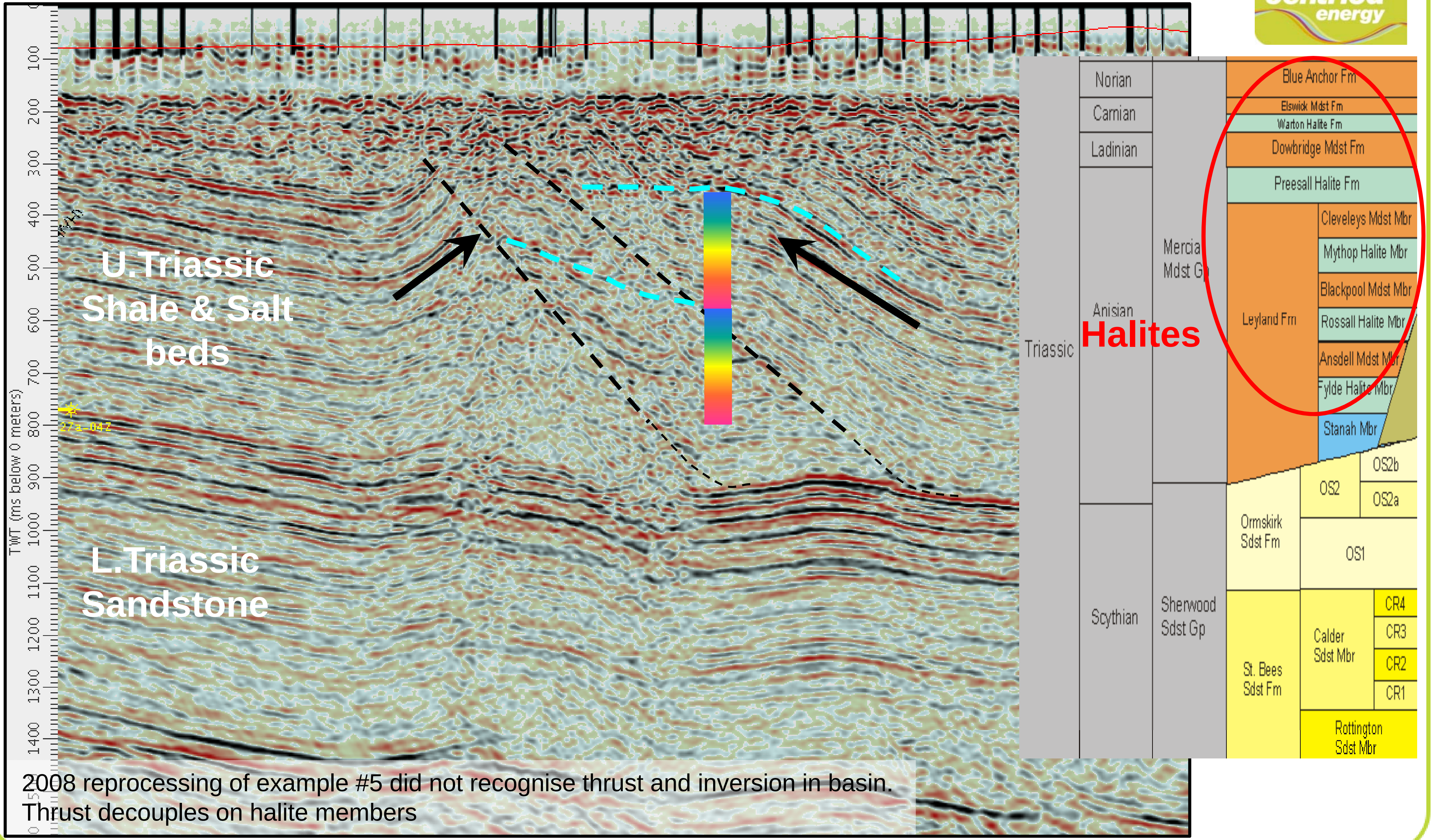


Brittle on Ductile & Thin salt

Coulomb collapse modified after Hamblin 1965
Applied Subsurface Geological Mapping - D.Tearpock & R.Bisckhe (1990)

UK : East Irish Sea, Recognition of structural regime

Example 3 : Brittle & lithified strata

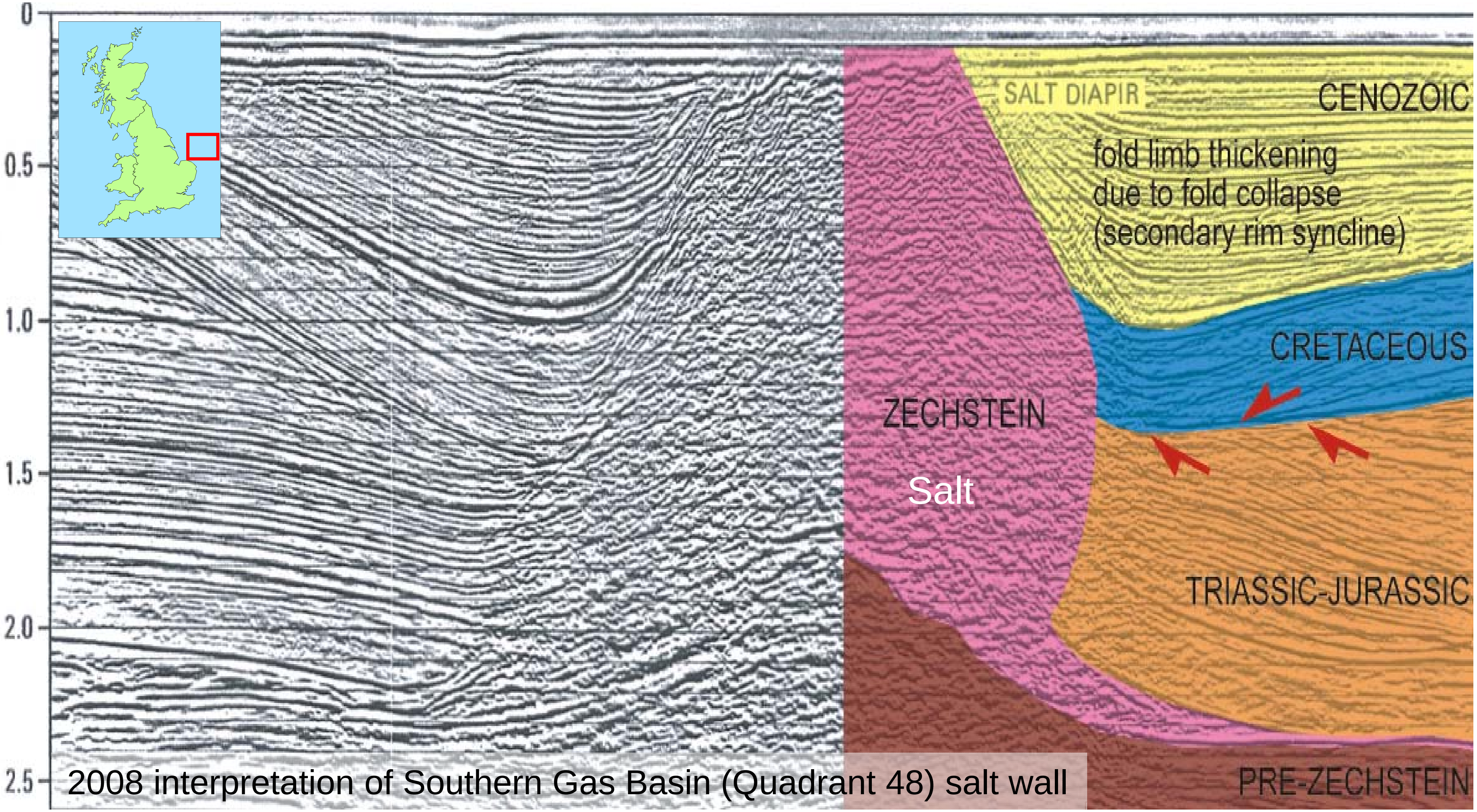


2008 reprocessing of example #5 did not recognise thrust and inversion in basin.
Thrust decouples on halite members

UK : North Sea, Southern Gas Basin

Example 4 : Brittle & lithified strata

No conservation of mass

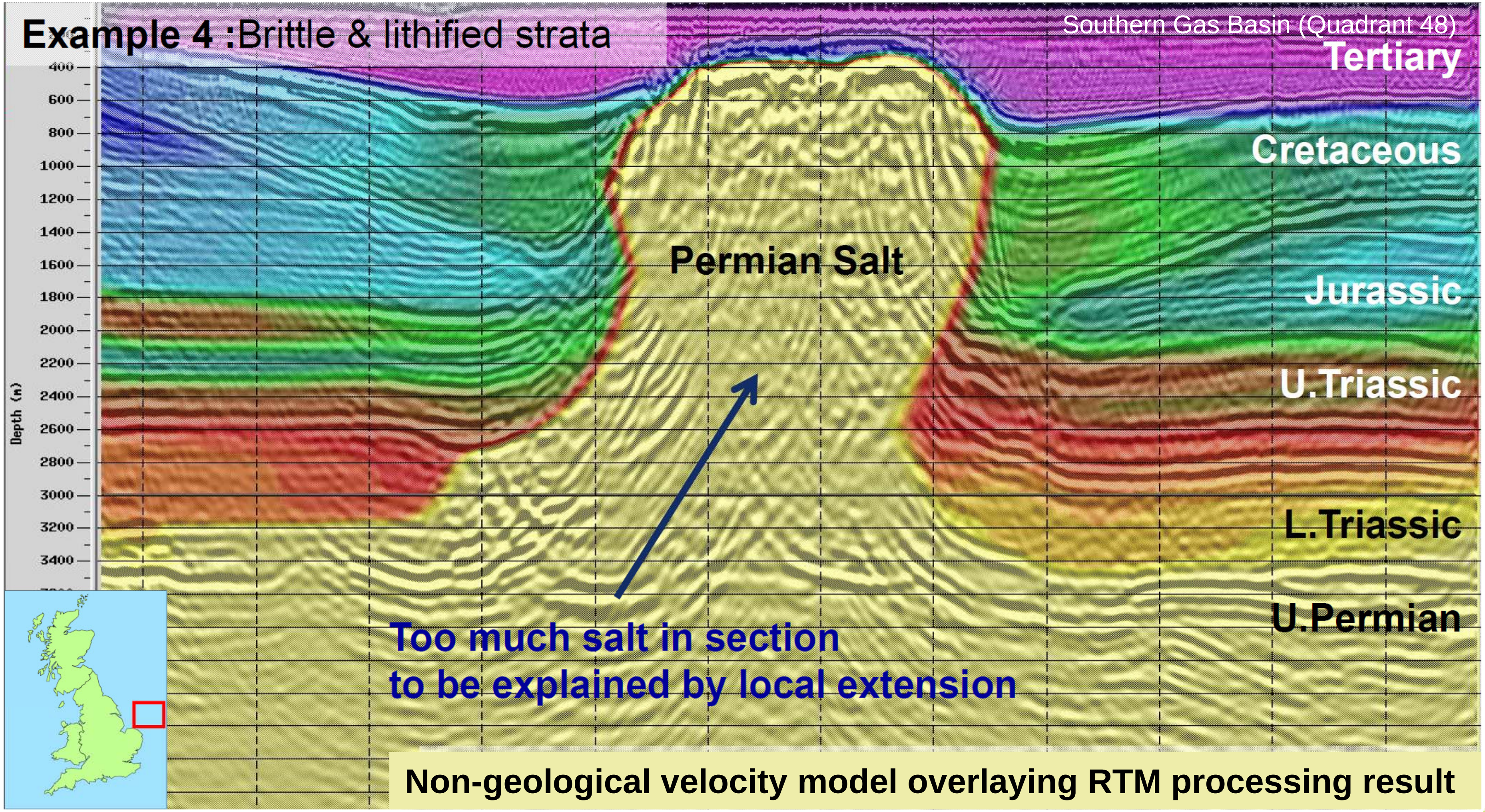


Courtesy of Virtual Seismic Atlas

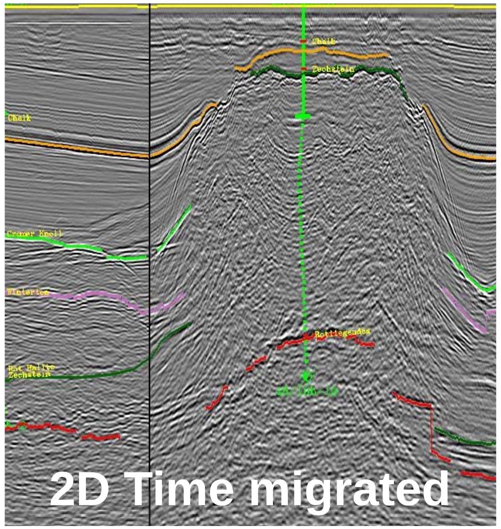
Example 4 : Processing Solution Only

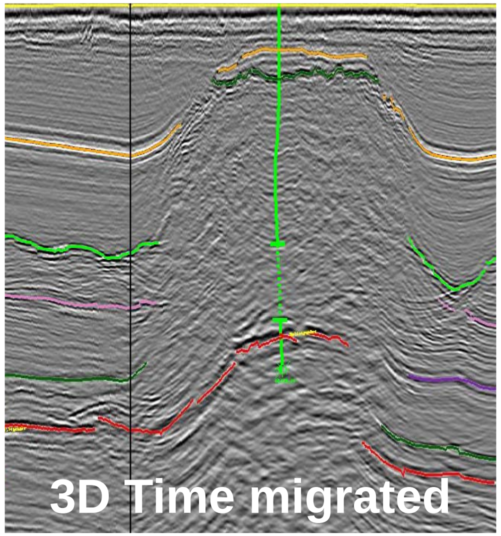
SEG 2008: ".....the recent rapid increase in available cost-effective computing power has enabled industrial implementation of migration algorithms, particularly reverse-time migration that in principle can image events that reflect more than once on their way from source to receiver....."

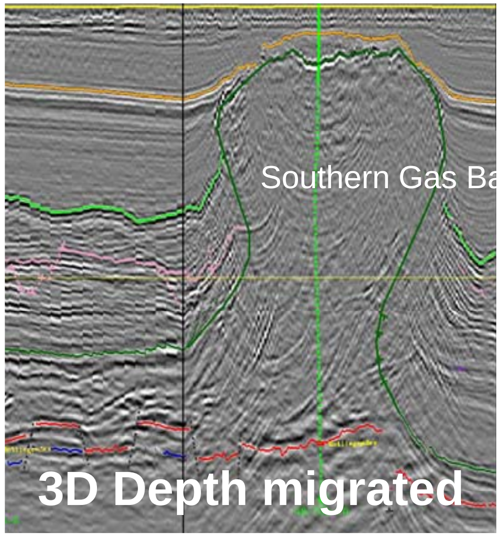
Ian F. Jones, *ION GX Technology EAME* - Geophysics / Volume 73 / Issue 6 / TECHNICAL PAPERS / SEISMIC MODELING AND WAVE

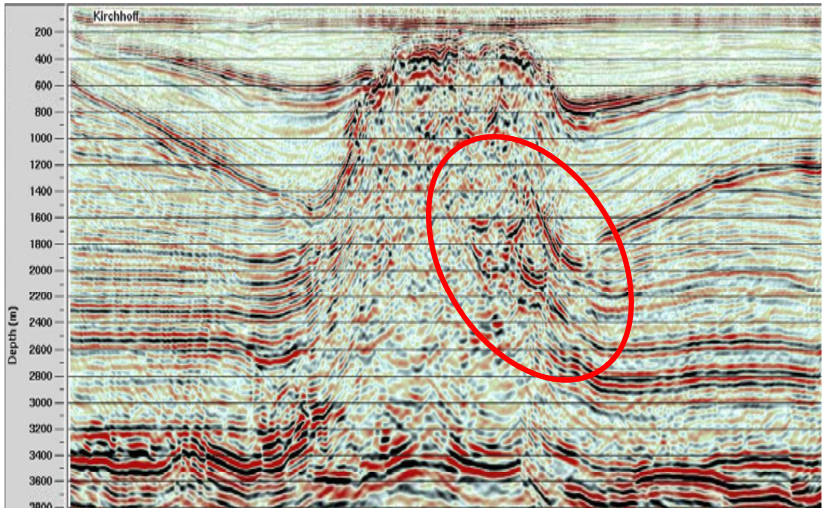


Example 4 : Processing Solution Only

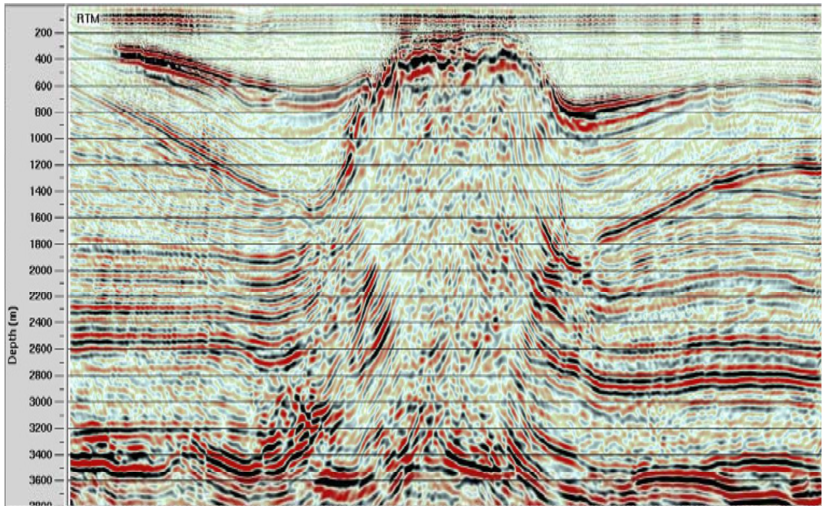






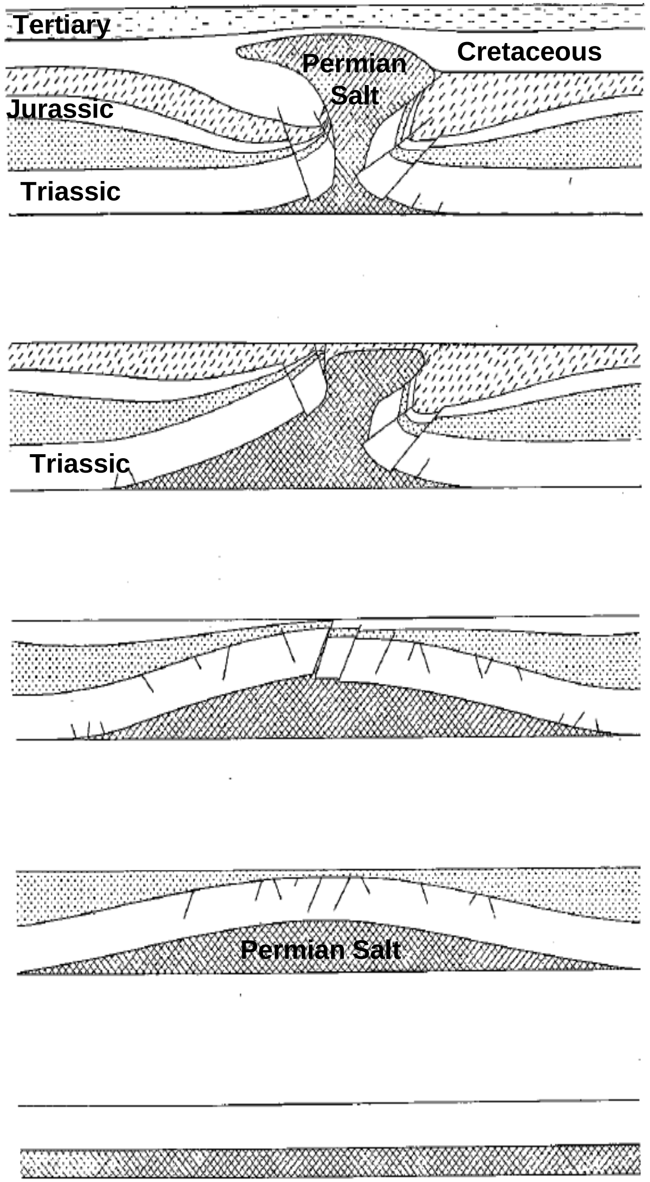


PSDM shown with high cut filter to match Reverse Time Migration frequency range



Reverse Time Migration shown with gain to match Kirchhoff amplitude decay

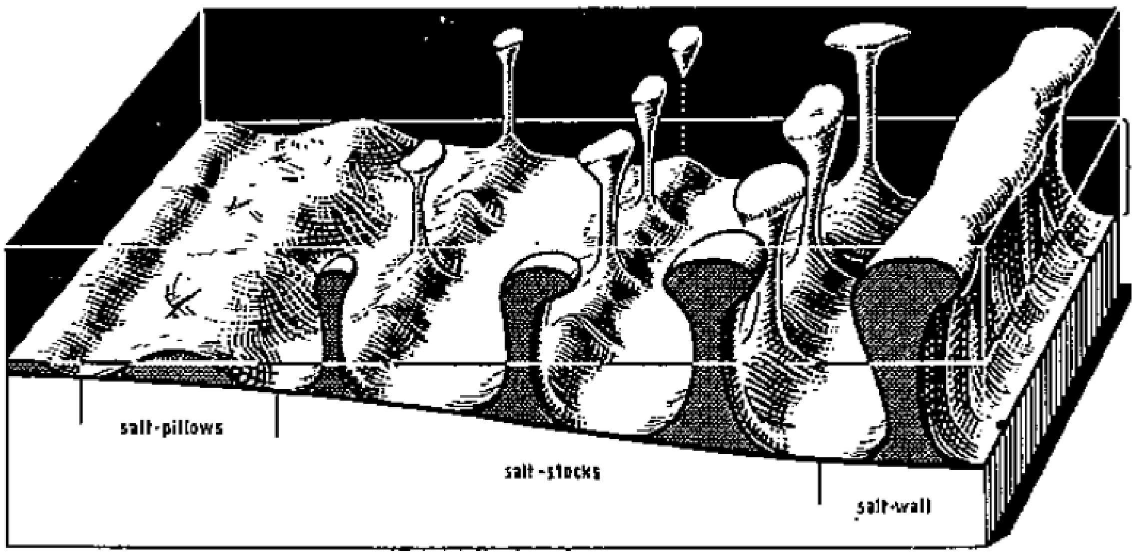
Back to Basics = Homework



BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 44, NO. 9 (SEPTEMBER, 1960), PP. 1519-1540, 23 FIGS.

MECHANISM OF SALT MIGRATION IN NORTHERN GERMANY[1]

F. TRUSHEIM[2]
Hannover, Germany



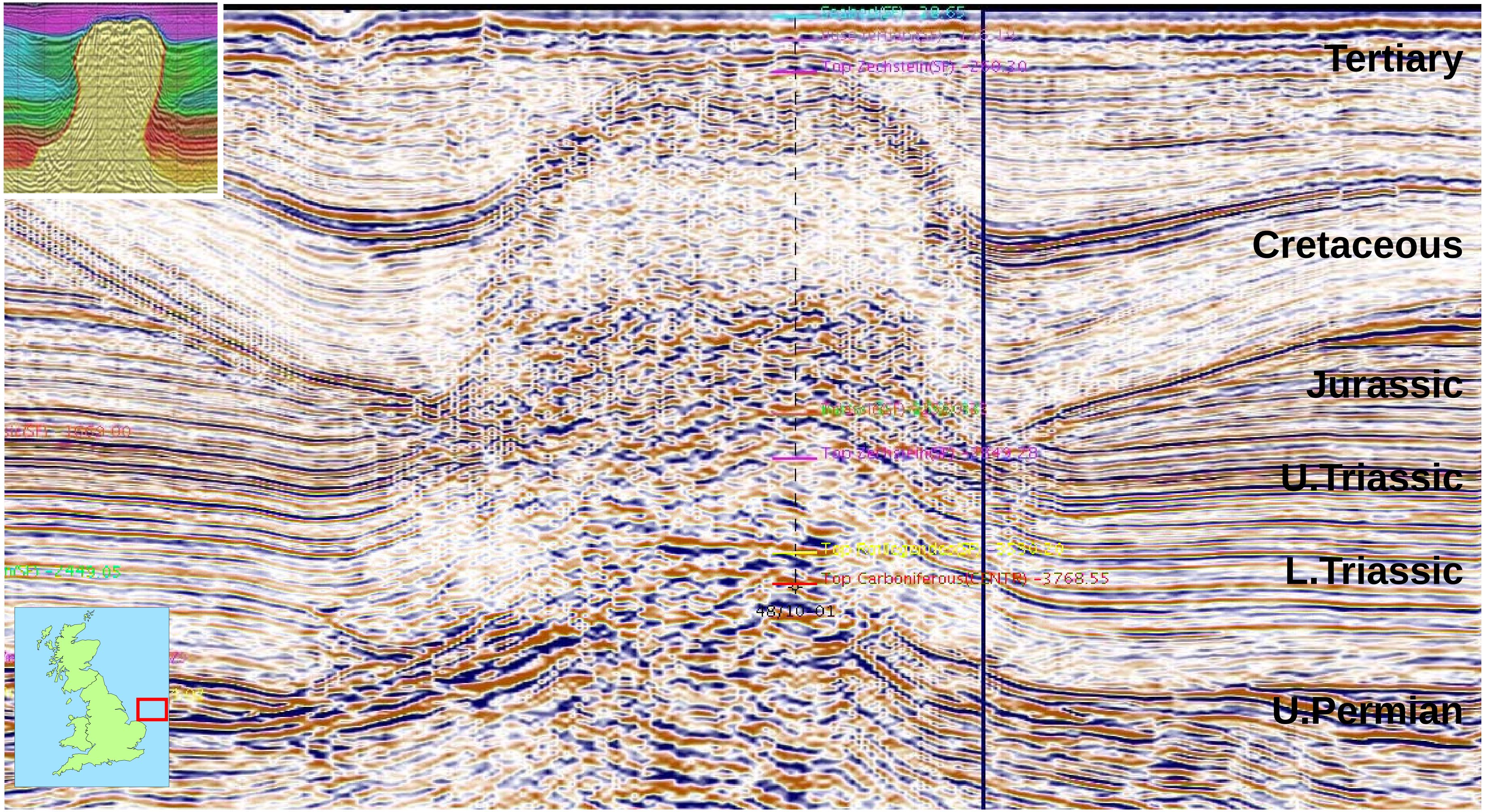
Brittle fracture & conservation of mass

Model What You See?

Migration & Stack

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)

48/10-1

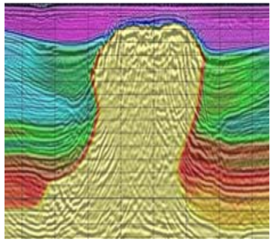


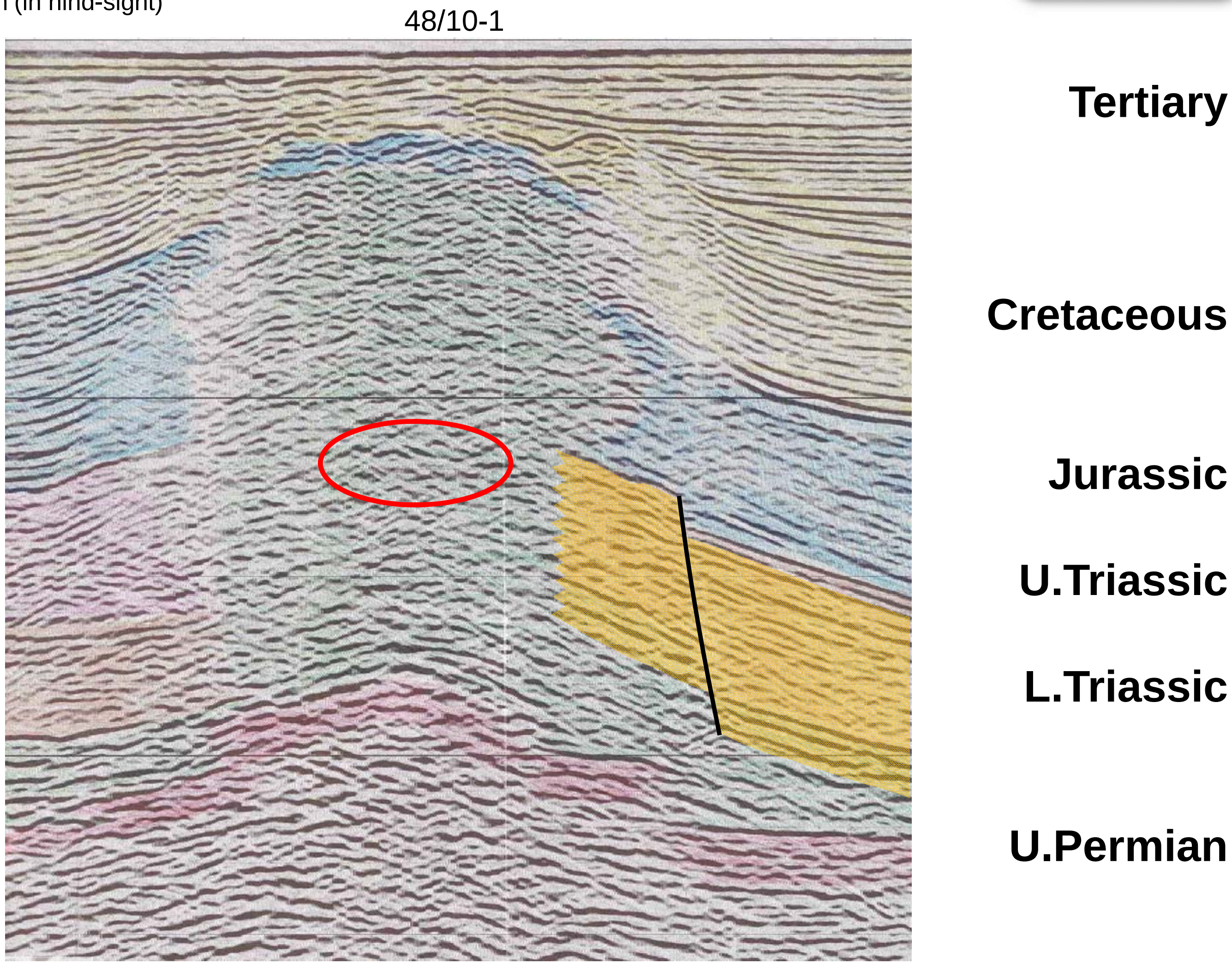
Southern Gas Basin (Quadrant 48)

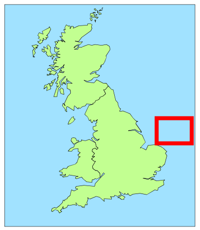
Model What You See?

Migration & Stack

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)





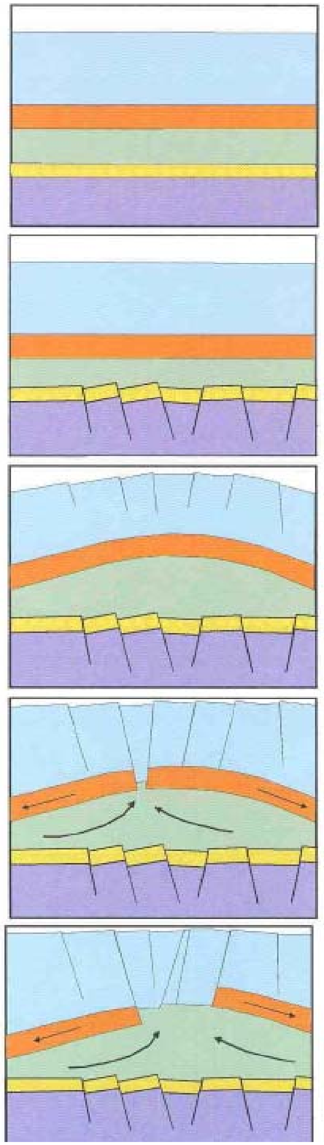


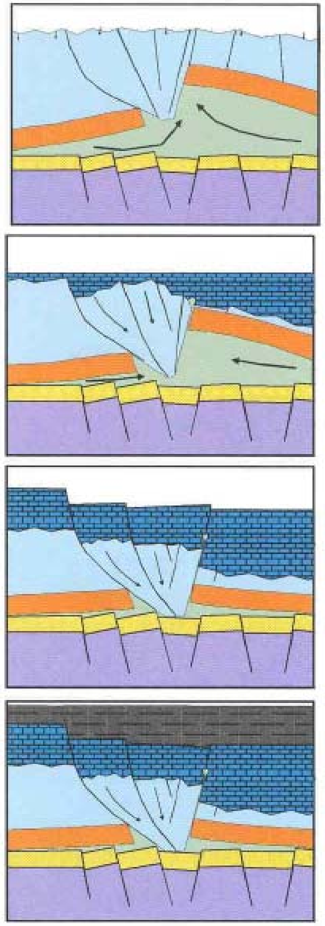
Southern Gas Basin (Quadrant 48)

Stack shows some preserved Normal ray paths which are migrated out of section

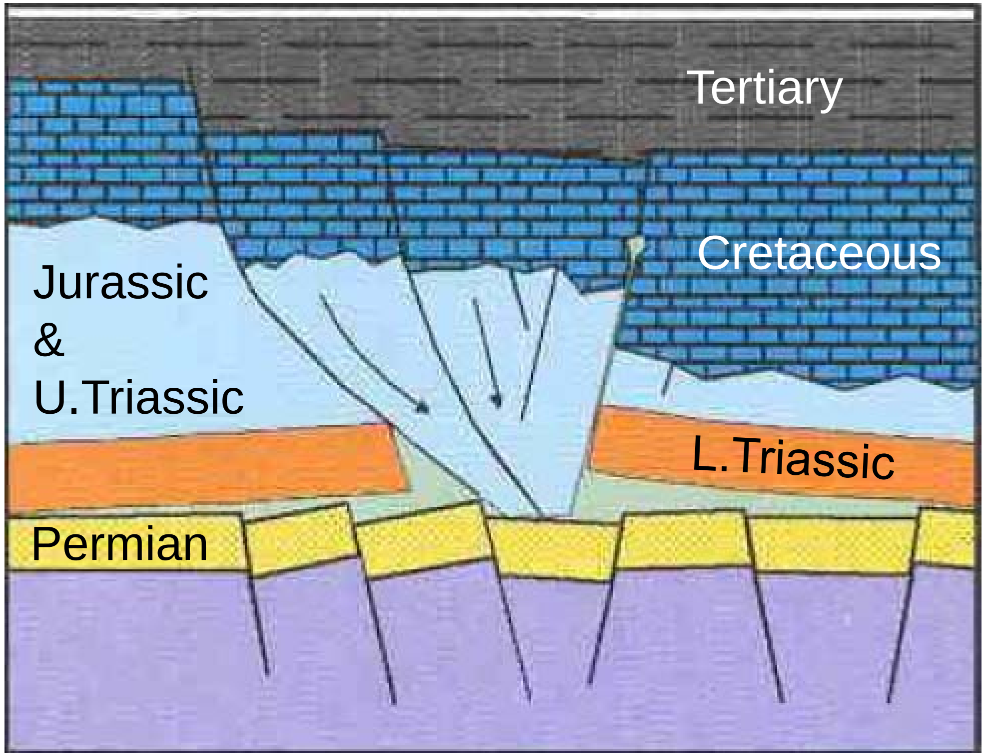
Failed Salt Wall Development

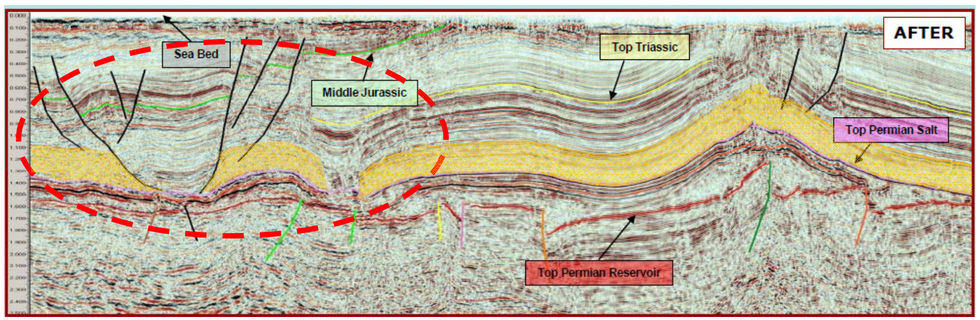
Southern Gas Basin (Quadrant 48)





C49/84-23
SALTWALL
DEVELOPMENT

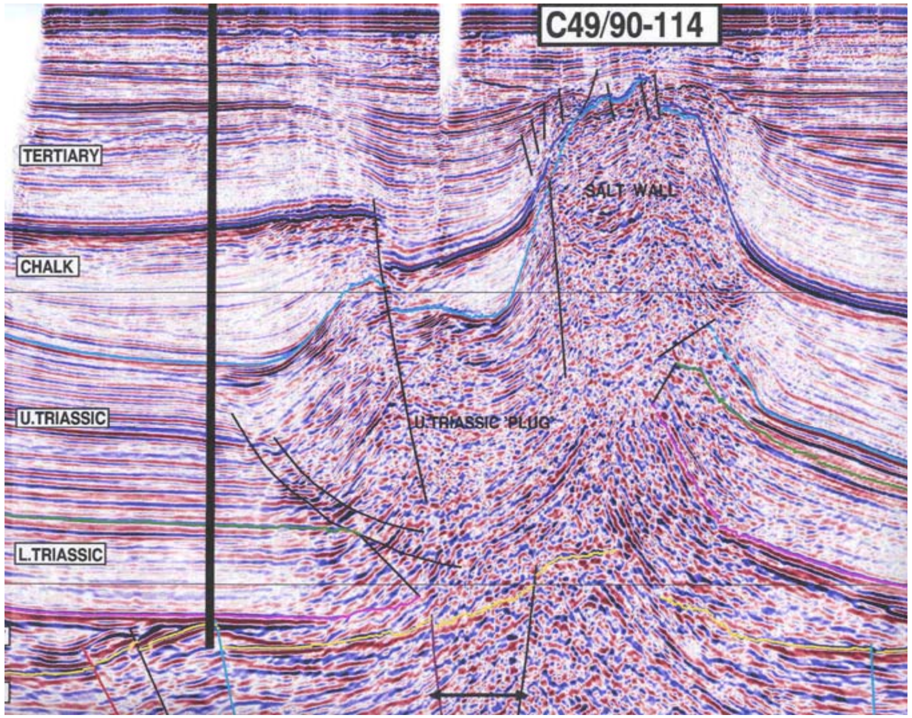


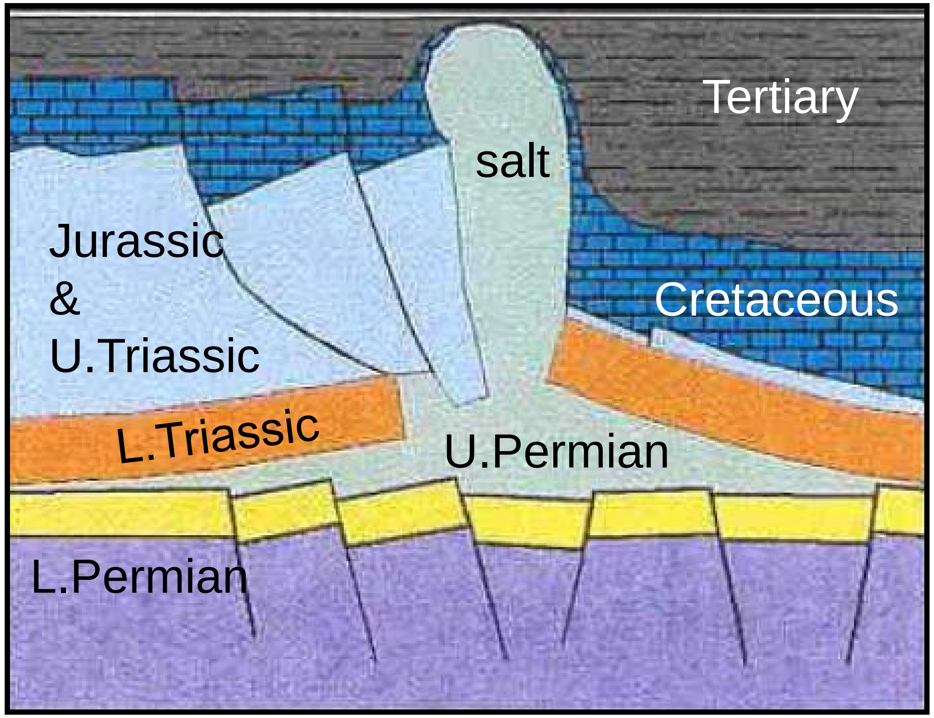


Successful Wall Development

MAKING THE NEXT GIANT LEAP IN GEOSCIENCES
AAPG 2011 Annual Convention & Exhibition
10-13 April 2011 • Houston

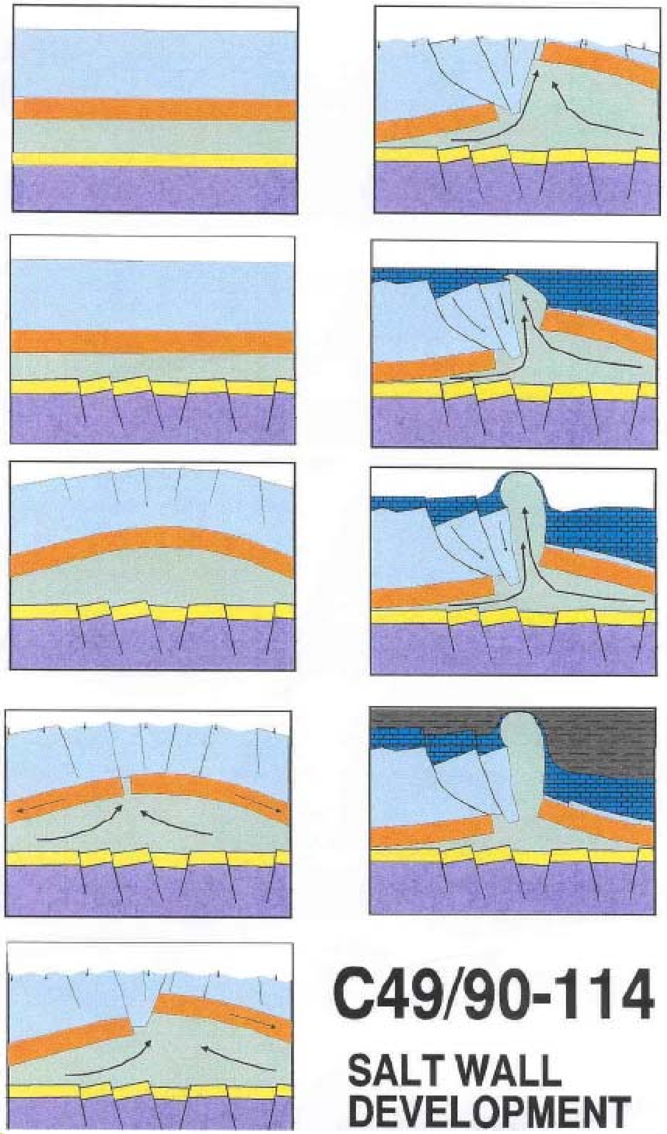
Southern Gas Basin (Quadrant 49)



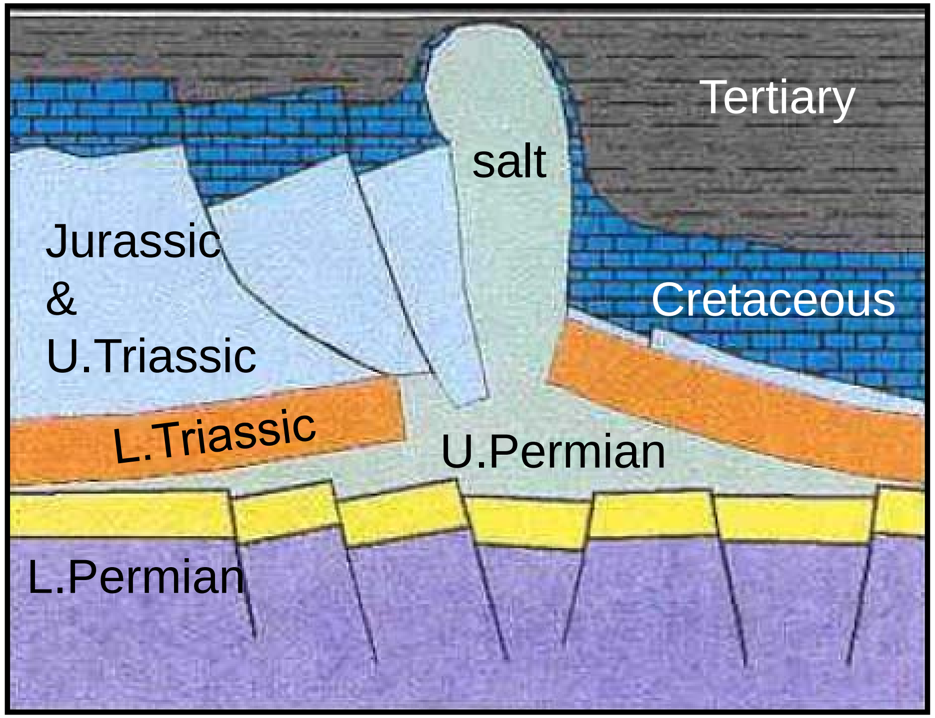


- Tertiary muds
- Cretaceous chalk
- Jurassic & U.Triassic mudstones & halite
- L.Triassic sandstones
- U.Permian halite
- L.Permian sandstones
- Carboniferous sandstones & mudstones

Successful Wall Development



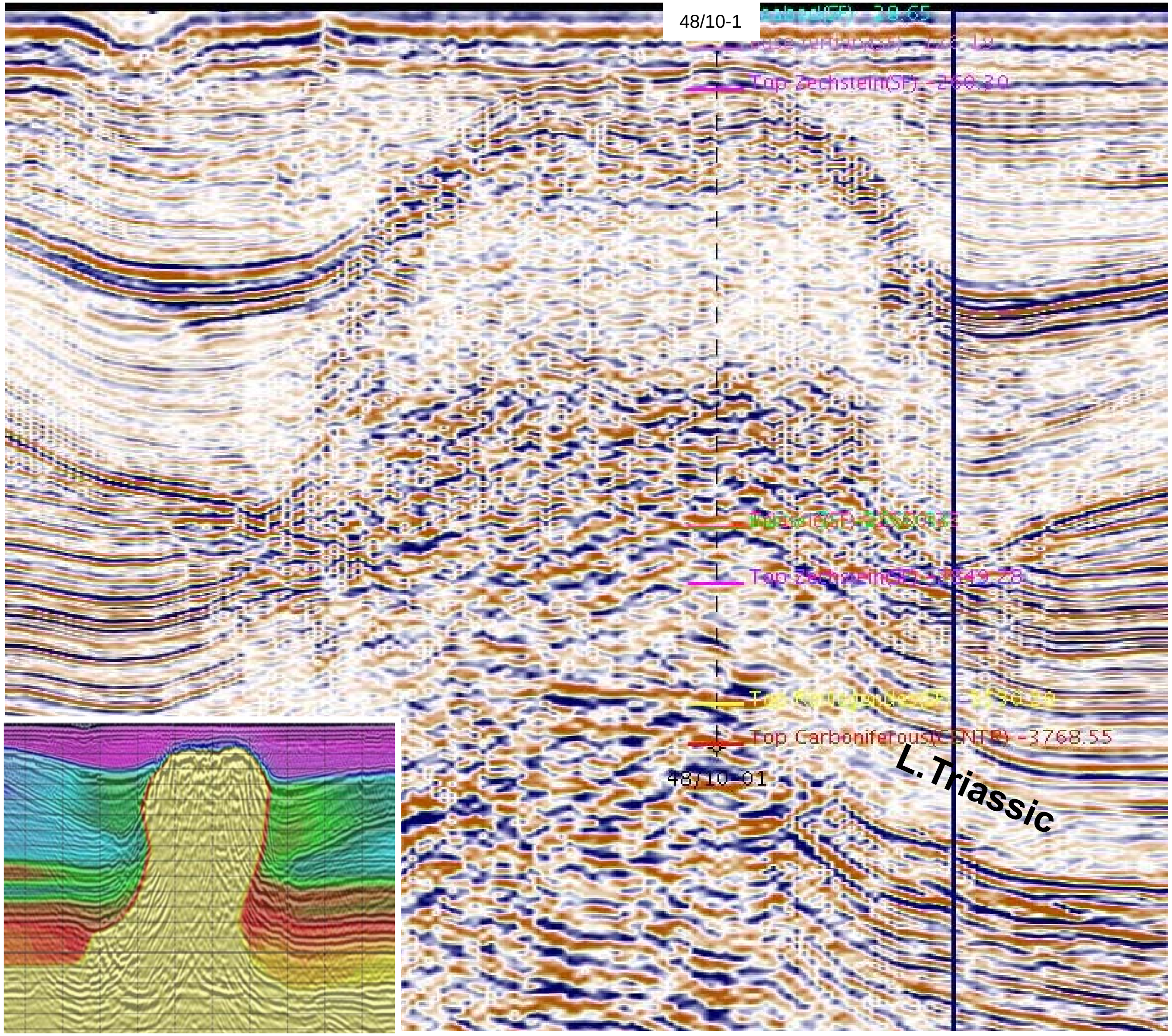
Southern Gas Basin (Quadrant 49)



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

Geology First

Southern Gas Basin (Quadrant 48)



1992 Acquisition (PPCo)

1993 Interpretation

1993 Vel model (PPCo)

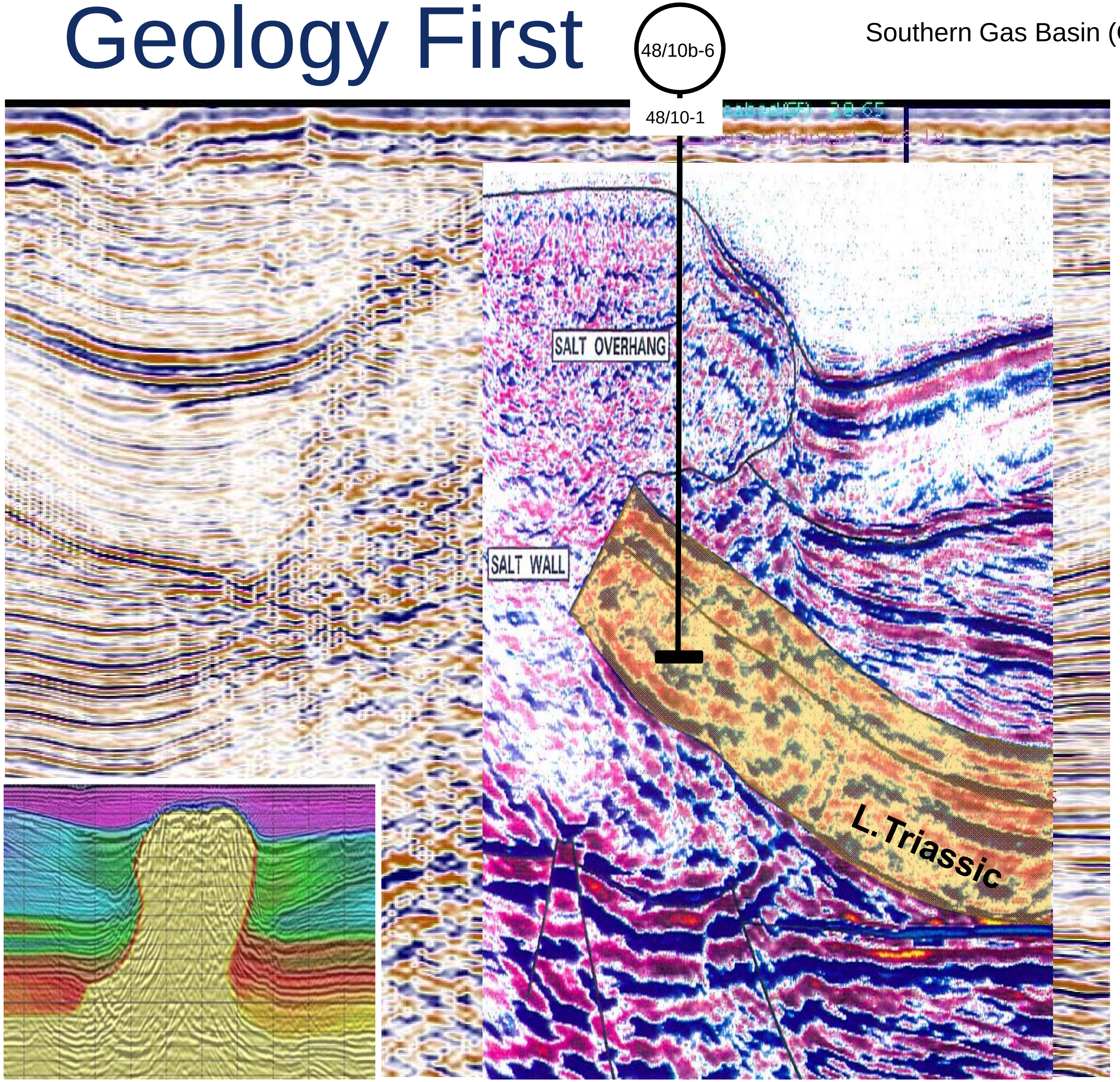
1994 PreSDM (PPCo)

1995 Re-Interpretation

Geology First

Southern Gas Basin (Quadrant 48)

centrica energy



1992 Acquisition (PPCo)

1993 Interpretation

1993 Vel model (PPCo)

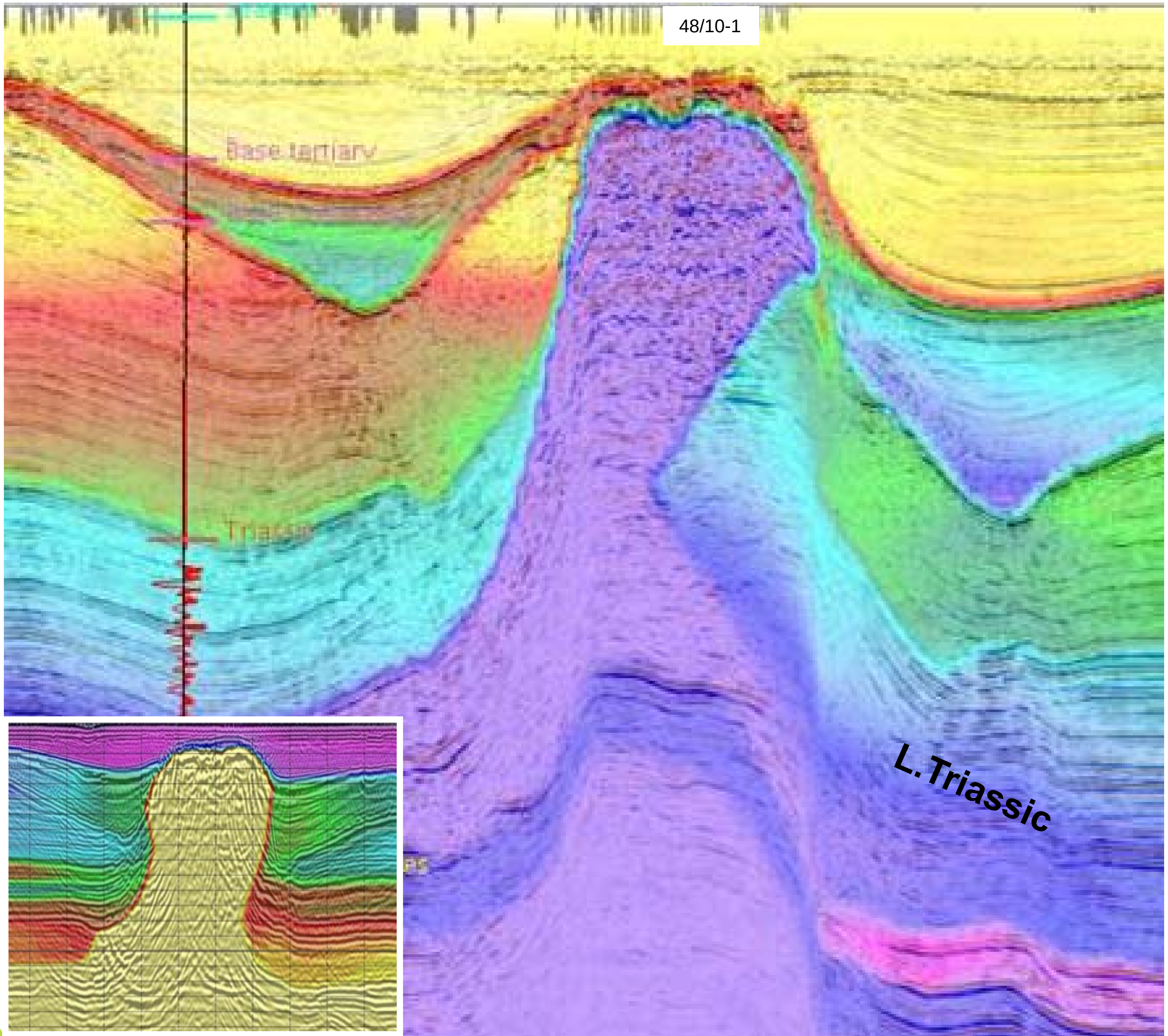
1994 PreSDM (PPCo)

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)

My thanks to the following people and organizations for their contributions and support:

Abby Elstob-Smith	Centrica Energy
Tim Evans	Centrica Energy
Kevin Purvis	Centrica Energy
Stuart Fletcher	Independent Contractor working with Centrica Energy
Ann Ramsook	Royal Holloway, University of London
Bill Kamps	Tsunami

Petroleum Exploration Society of Great Britain (PESGB)

Virtual Seismic Atlas