Salt Induced Stress Anomalies affecting rock properties

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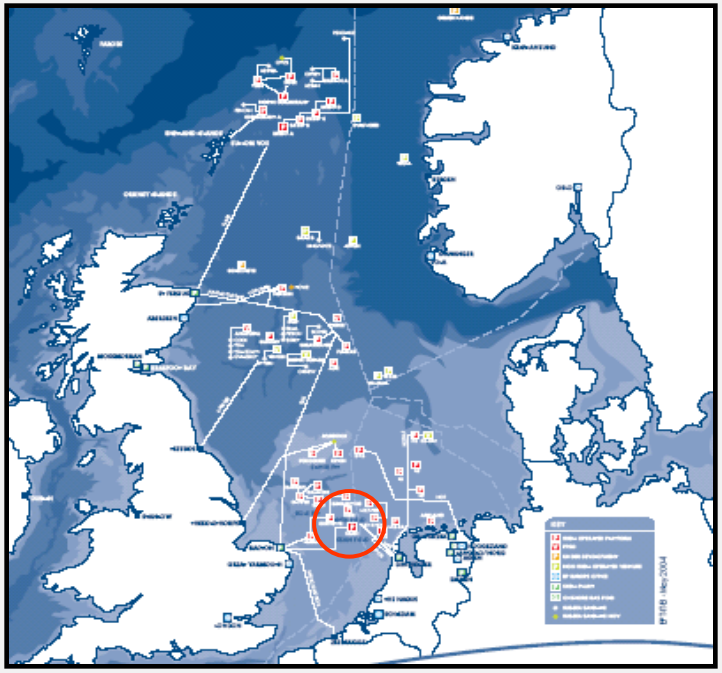
SISA
acknowledgements

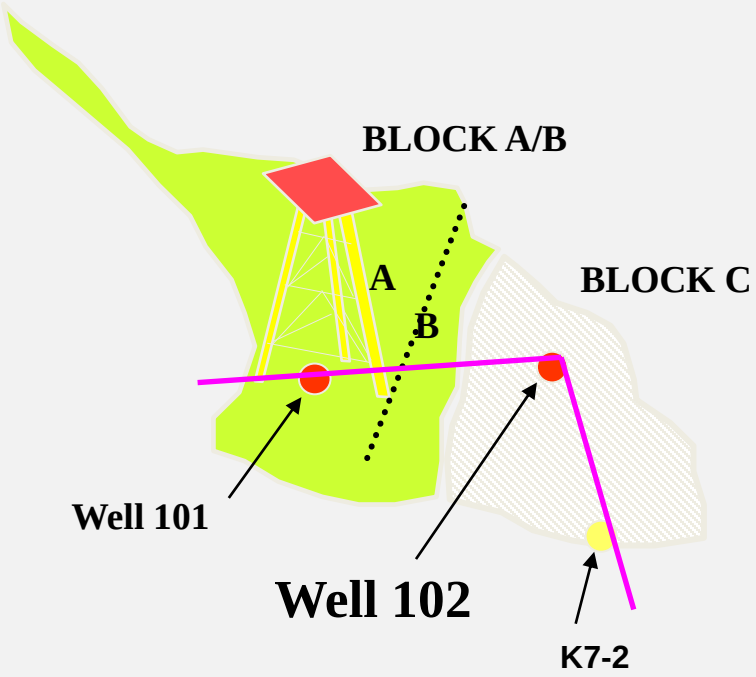
Michiel Harings	EBN
Stefan Luthi	TU Delft
Niek Bekkers	,,
Annemieke Vogelaar	,,
Joris Steenbrink	NAM
Juan Pi Alperin	,,
John Verbeek	,,
Alice Post	,,

SISA content

- **Background**
- **Triassic study**
- **The *common factor***
- **Stress Anomaly**
- **Implications**
- **Conclusions**

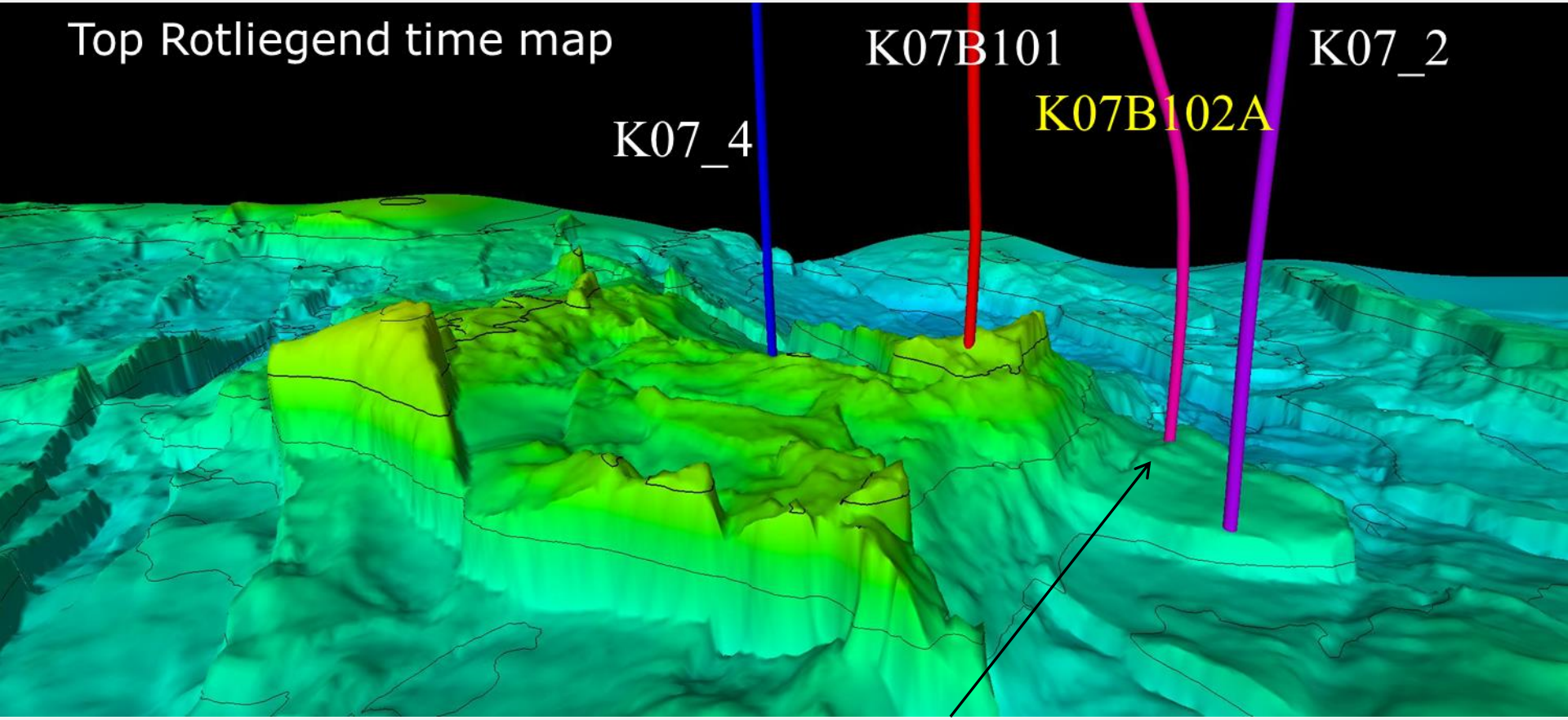
K7FB-102 depth error





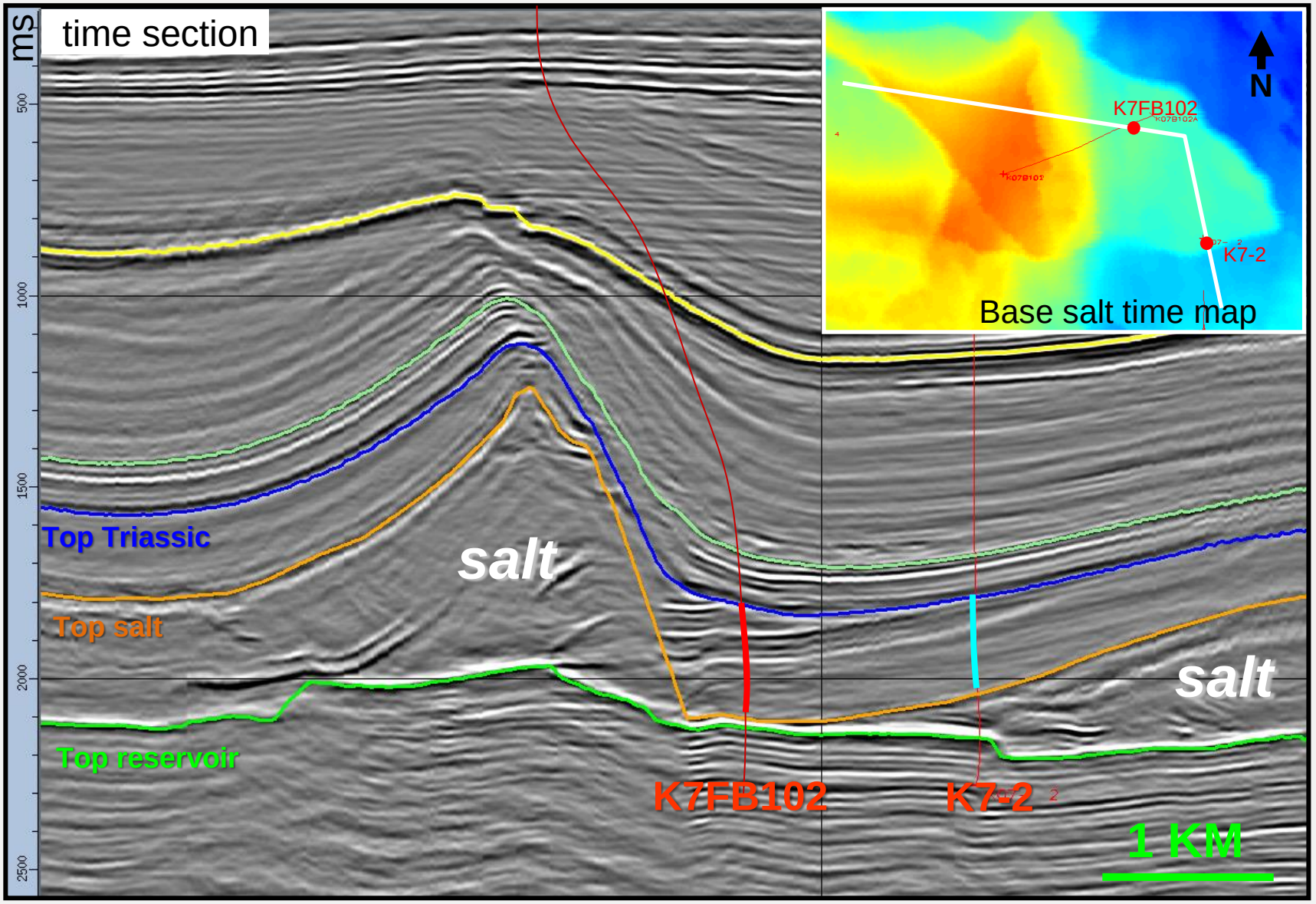
- Rotliegend development target
- well cost: 12 mil €
- objective 103 m deep to prognosis
- gas column too small to complete
- GIIP reduced

background

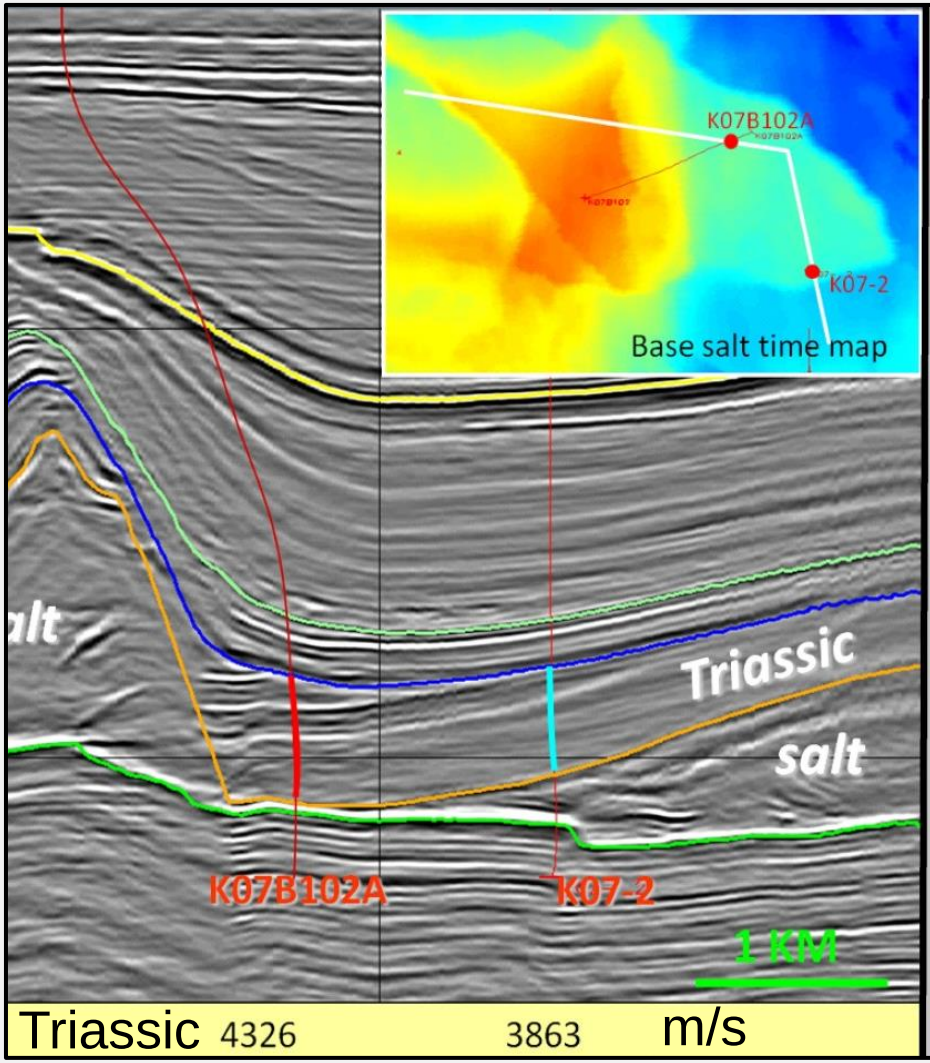


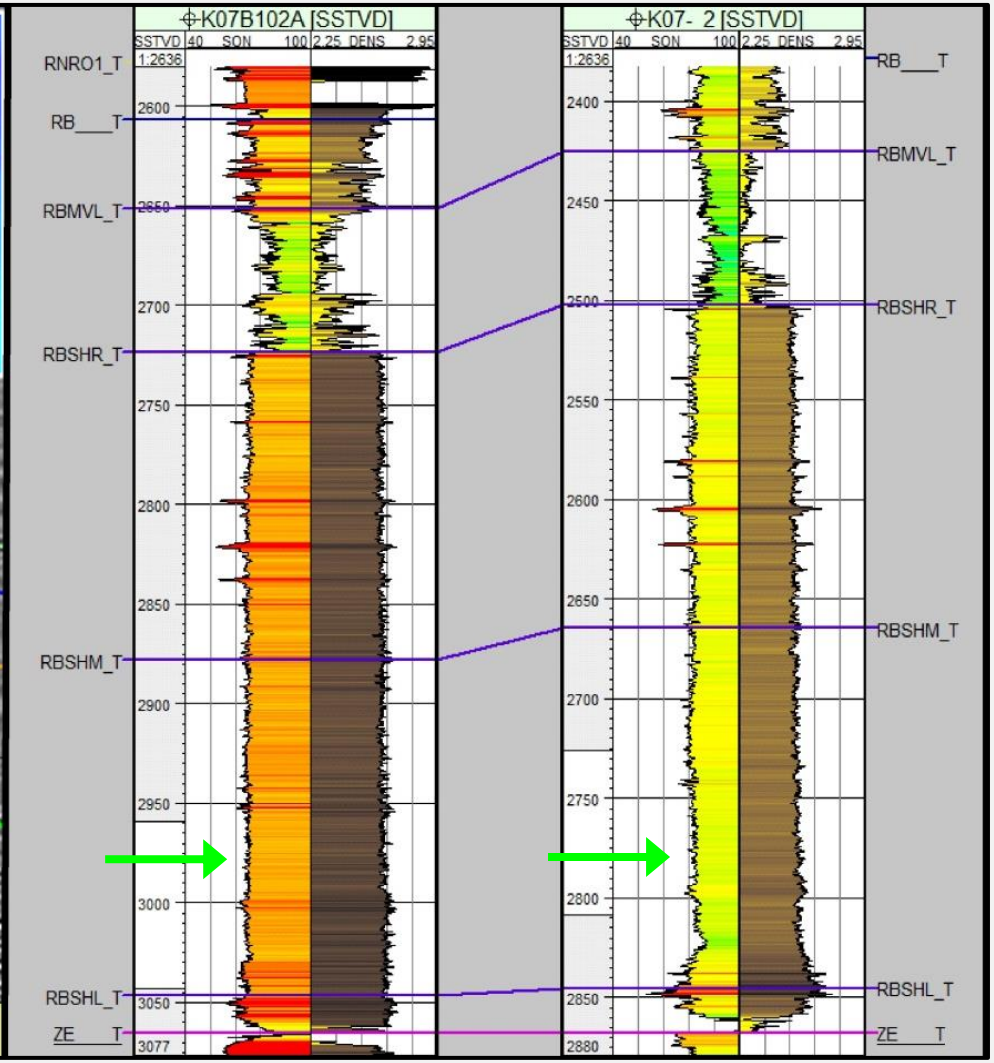
K7FB102: deep to prognosis

Seismic line: K7FB102



background





Sonic log: ~10% velocity difference at ~1.5 km distance

K7FB-102 Depth error Investigation

Summary

Depth error (103m) mainly caused by failing to model an unusually strong lateral velocity gradient in the Triassic.

(Note: the velocity anomaly was not picked up by the seismic velocities)

Question:

Could this have been predicted?

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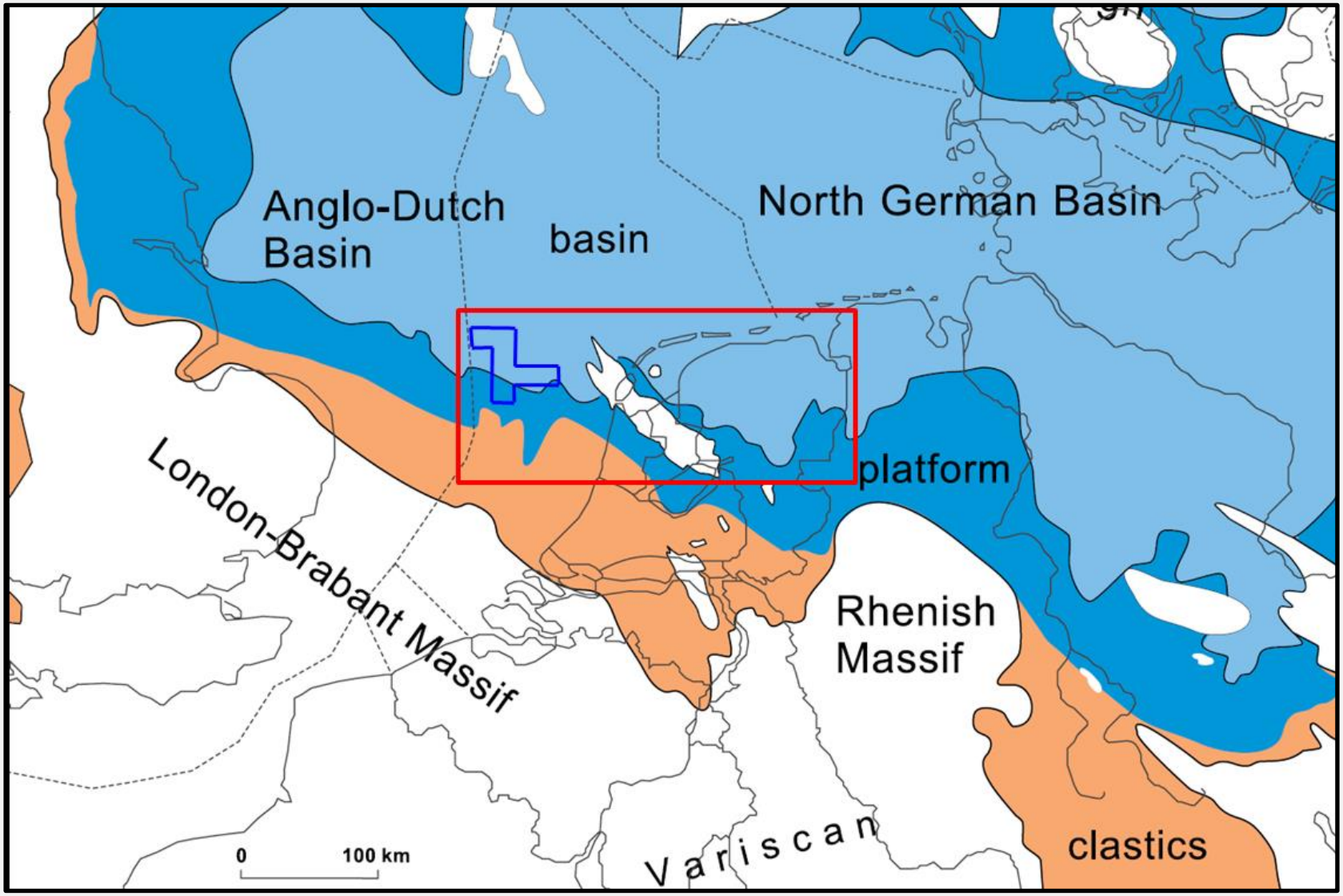
Geological study Triassic velocity
workflow

- Compile & QC all sonic data of Triassic in JDA area (~80 wells)
- Validate intra-Triassic stratigraphy
- Find practical Triassic sub-division (7 layers)
- Find controlling factors for velocity variation:

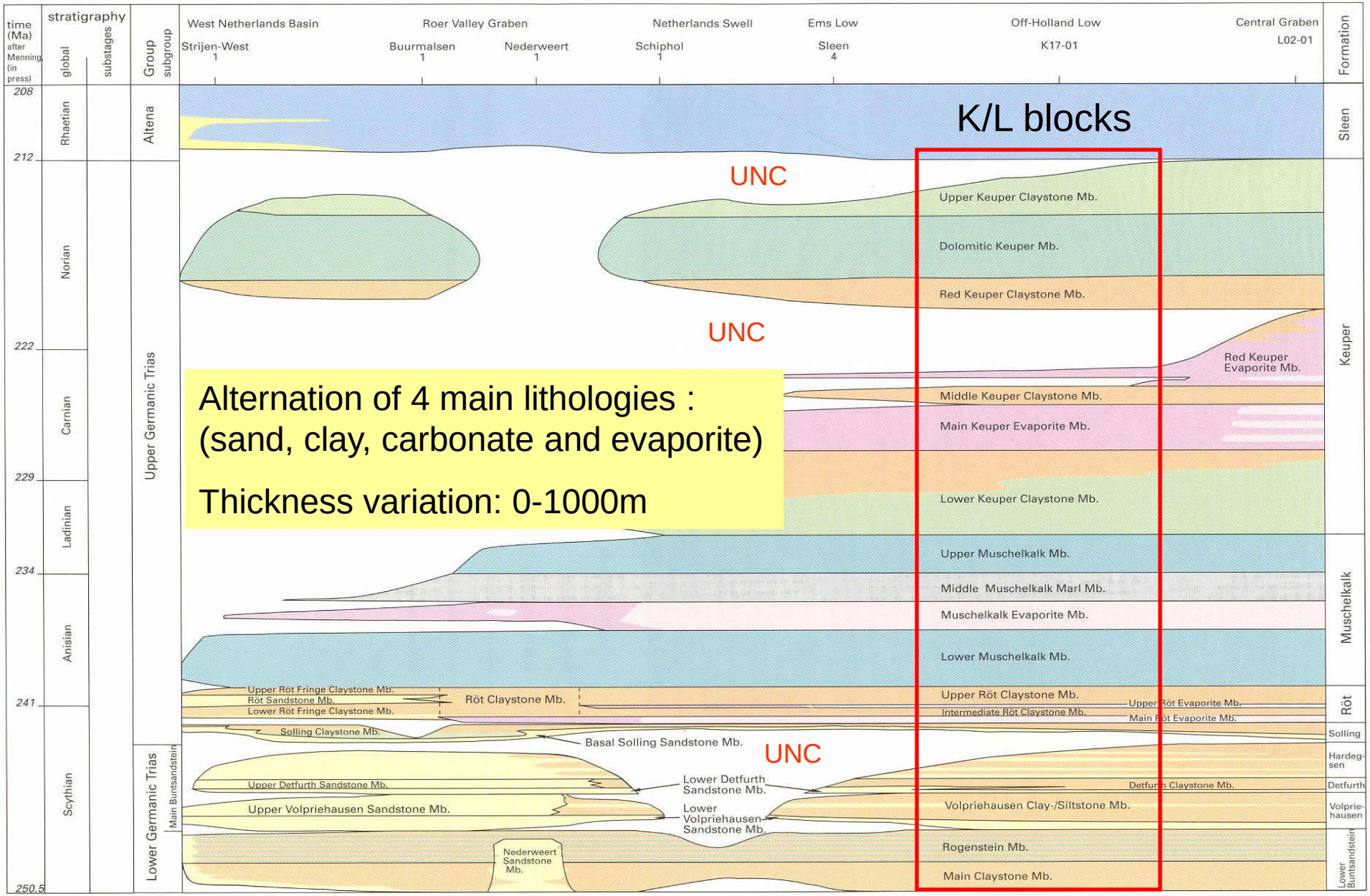
1) Stratigraphic composition
2) Depth of burial (present day burial)
3) Inversion (paleo-burial)
4) Other?

Study area: K/L blocks

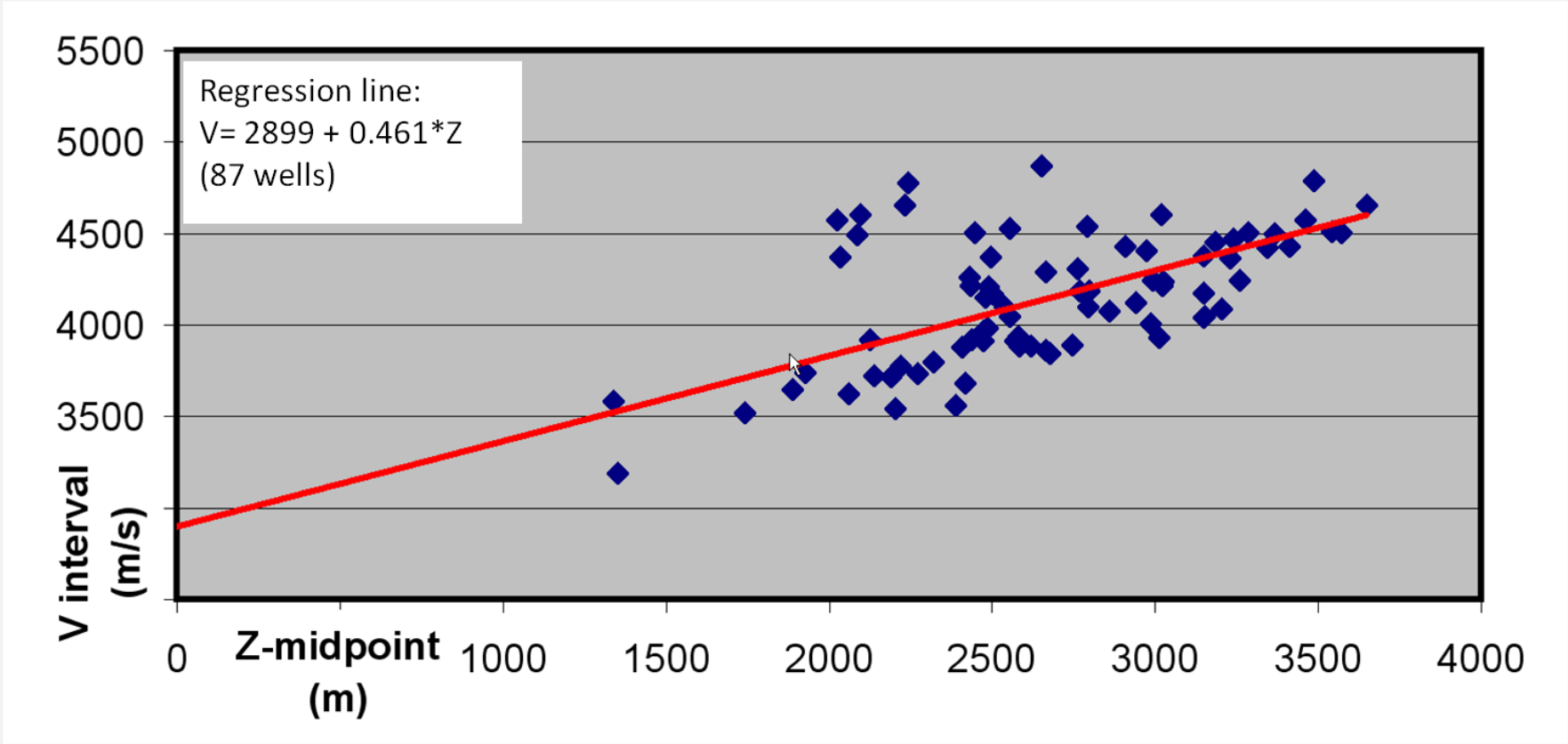


Study area 1 Study area 2

Triassic stratigraphy



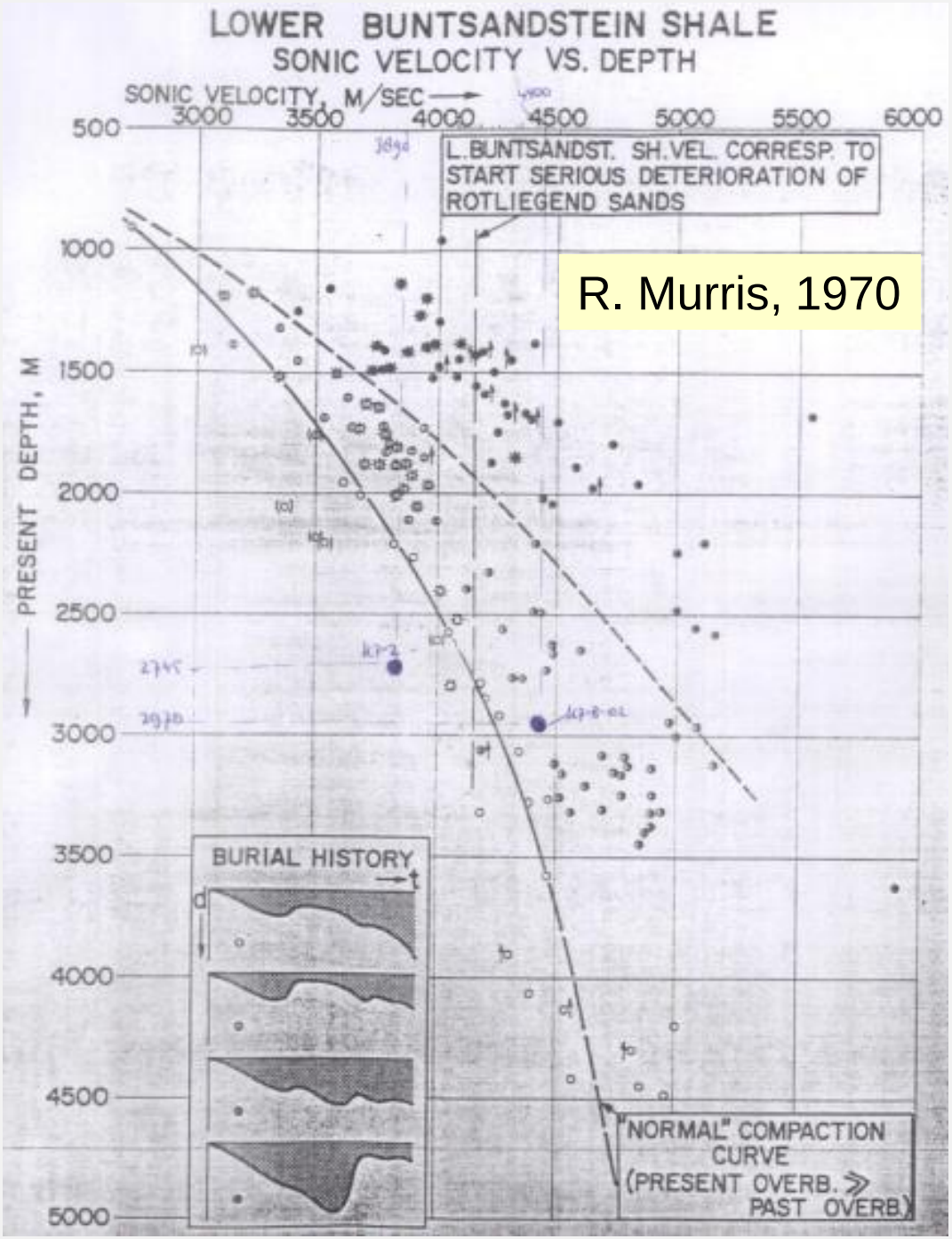
Velocity & burial compaction



Interval velocity vs midpoint depth plot (Lower Bunter)

Velocity *vs.* present day depth:

deviations from *normal compaction curve* indicate *inversion*



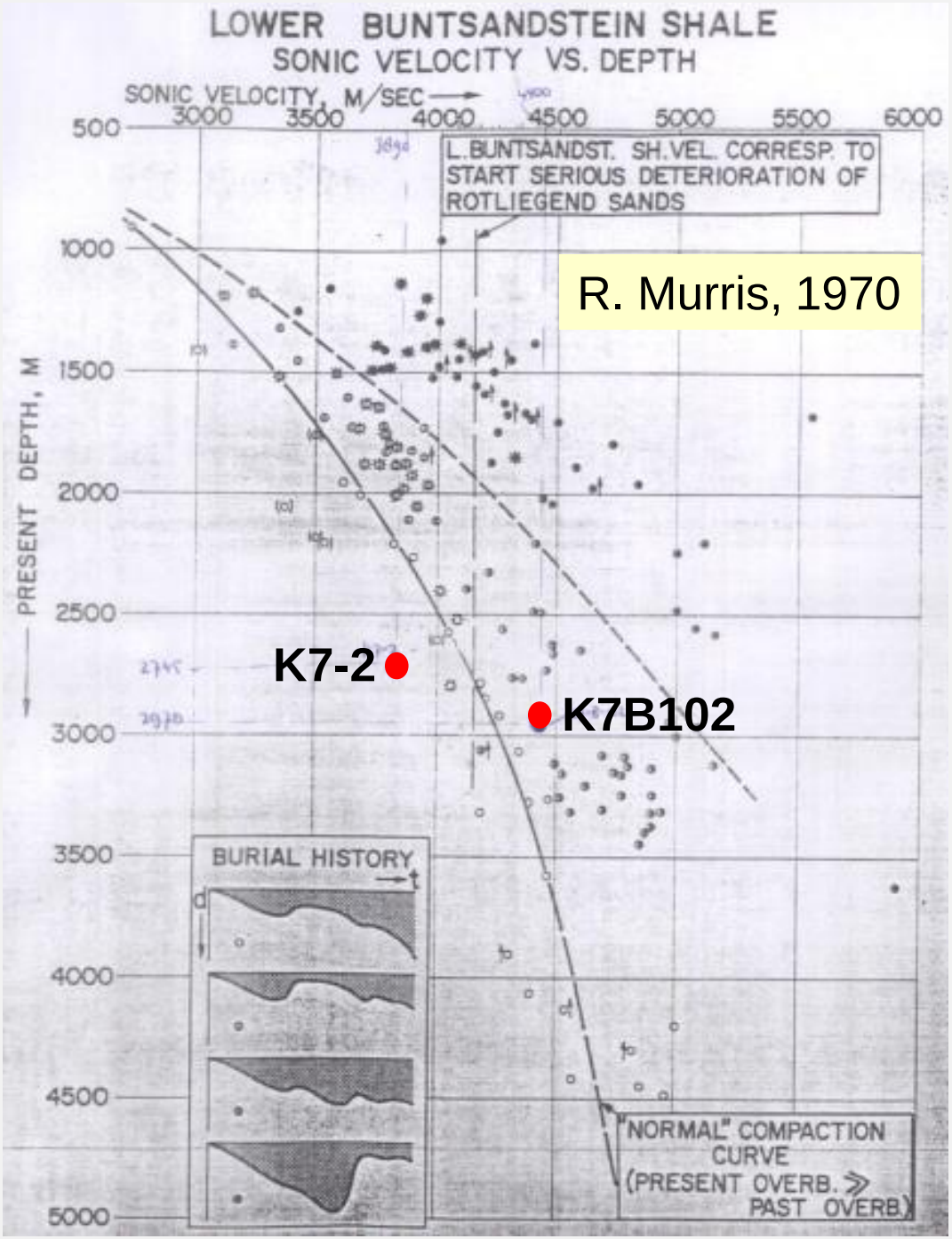
Velocity *vs.* present day depth:

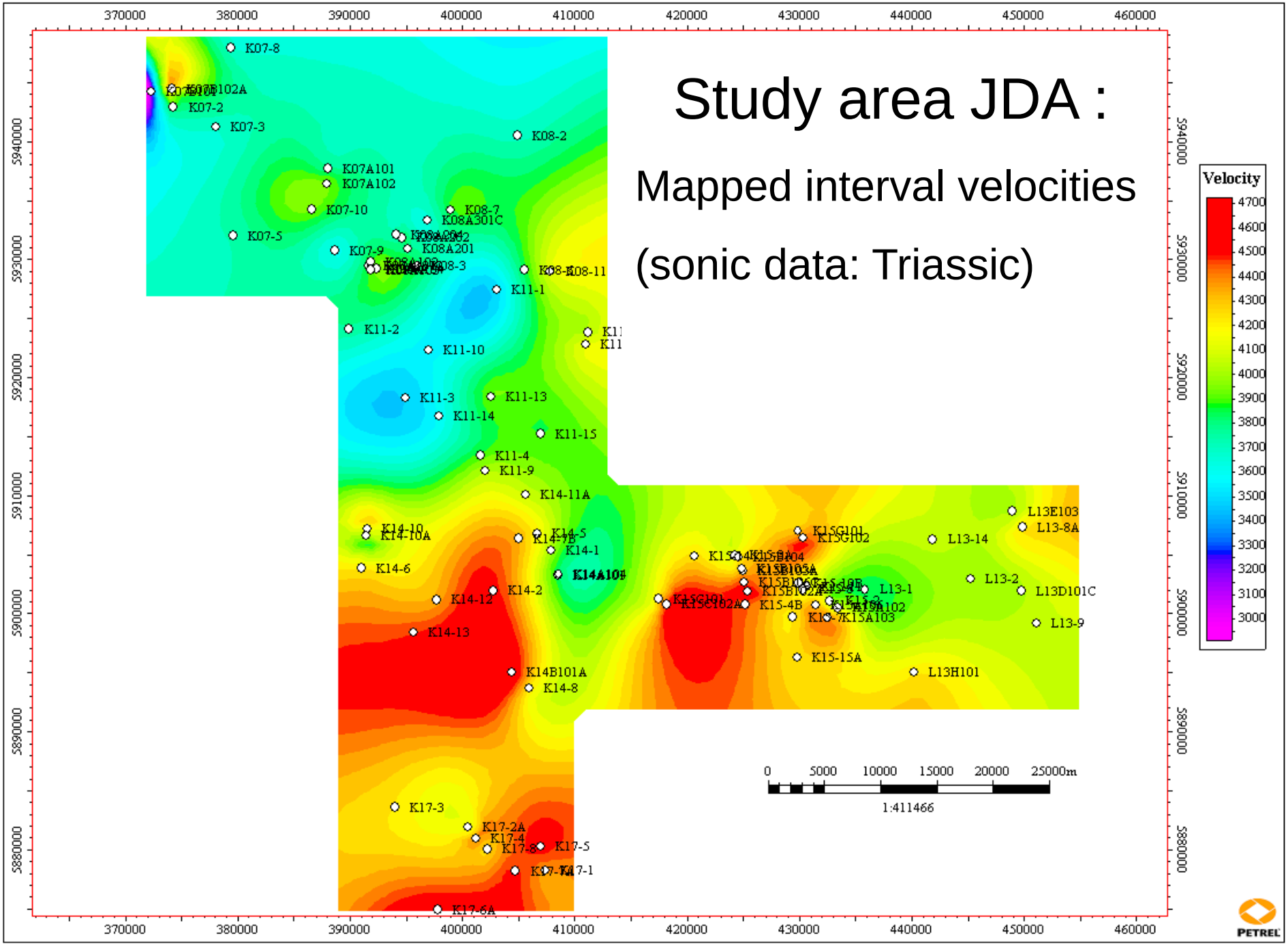
deviations from *normal compaction curve* indicate *inversion*

K7-2 and K7B102 at opposite sides of normal compaction curve

Short distance:

Inversion effect unlikely

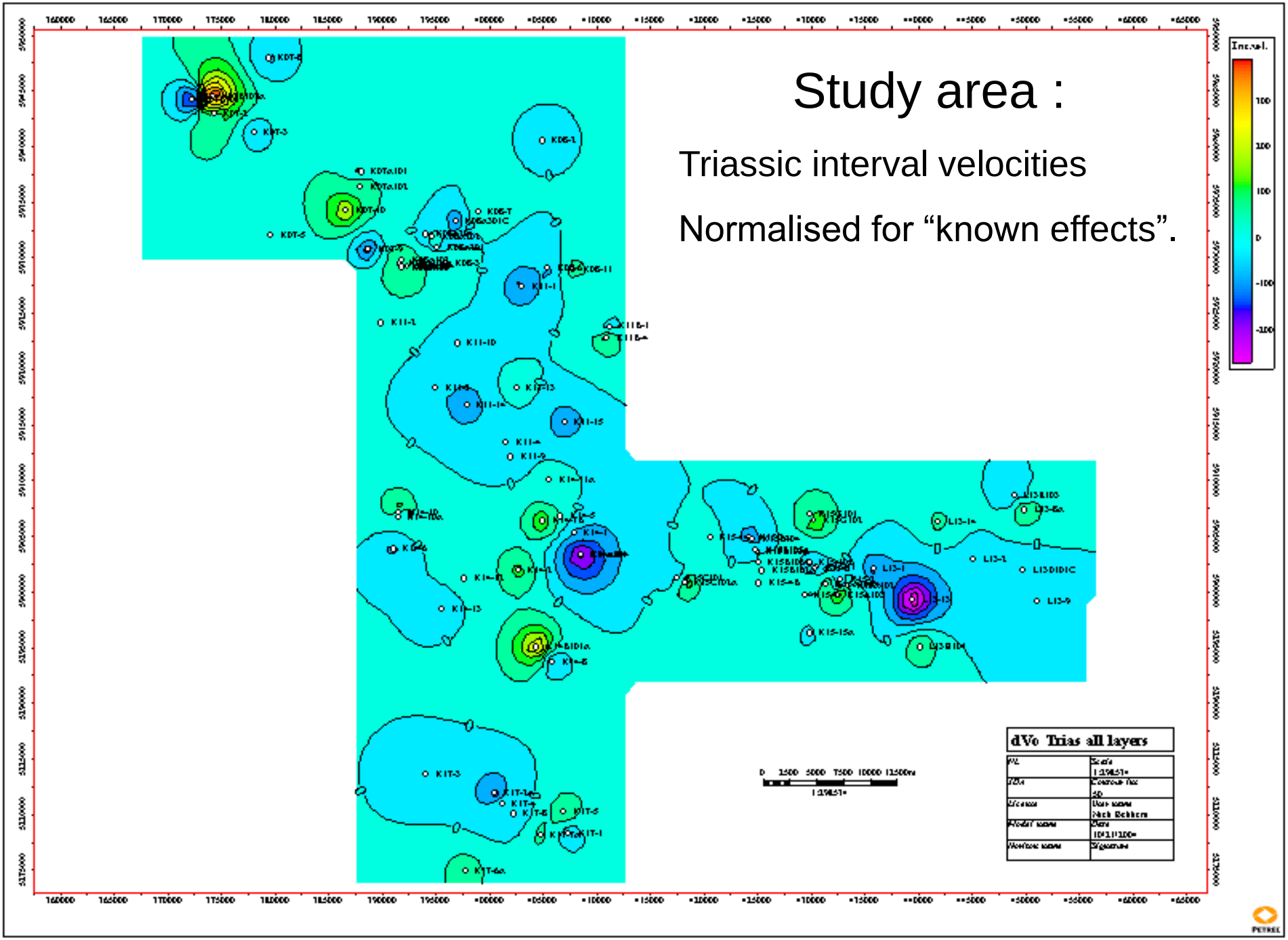



Study area JDA :
Mapped interval velocities
(sonic data: Triassic)
Velocity
4700
4600
4500
4400
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
370000
380000
390000
400000
410000
420000
430000
440000
450000
460000
5940000
5930000
5920000
5910000
5900000
5890000
5880000
0
5000
10000
15000
20000
25000m
1:411466
K07-8
K07-2
K07-3
K08-2
K07A101
K07A102
K07-10
K08-7
K08A301C
K07-5
K08A201
K07-9
K11-1
K11-2
K11-10
K11-3
K11-13
K11-14
K11-15
K11-4
K11-9
K14-11A
K14-10
K14-10A
K14-5
K14-1
K14-6
K14-2
K14-12
K14-13
K14B101A
K14-8
K15-4B
K15-15A
L13-14
L13E103
L13-8A
L13-2
L13D101C
L13-1
L13-9
L13H101
K17-3
K17-2A
K17-4
K17-8
K17-5
K17-1
K17-6A

Study area :

Triassic interval velocities

Normalised for “known effects”.

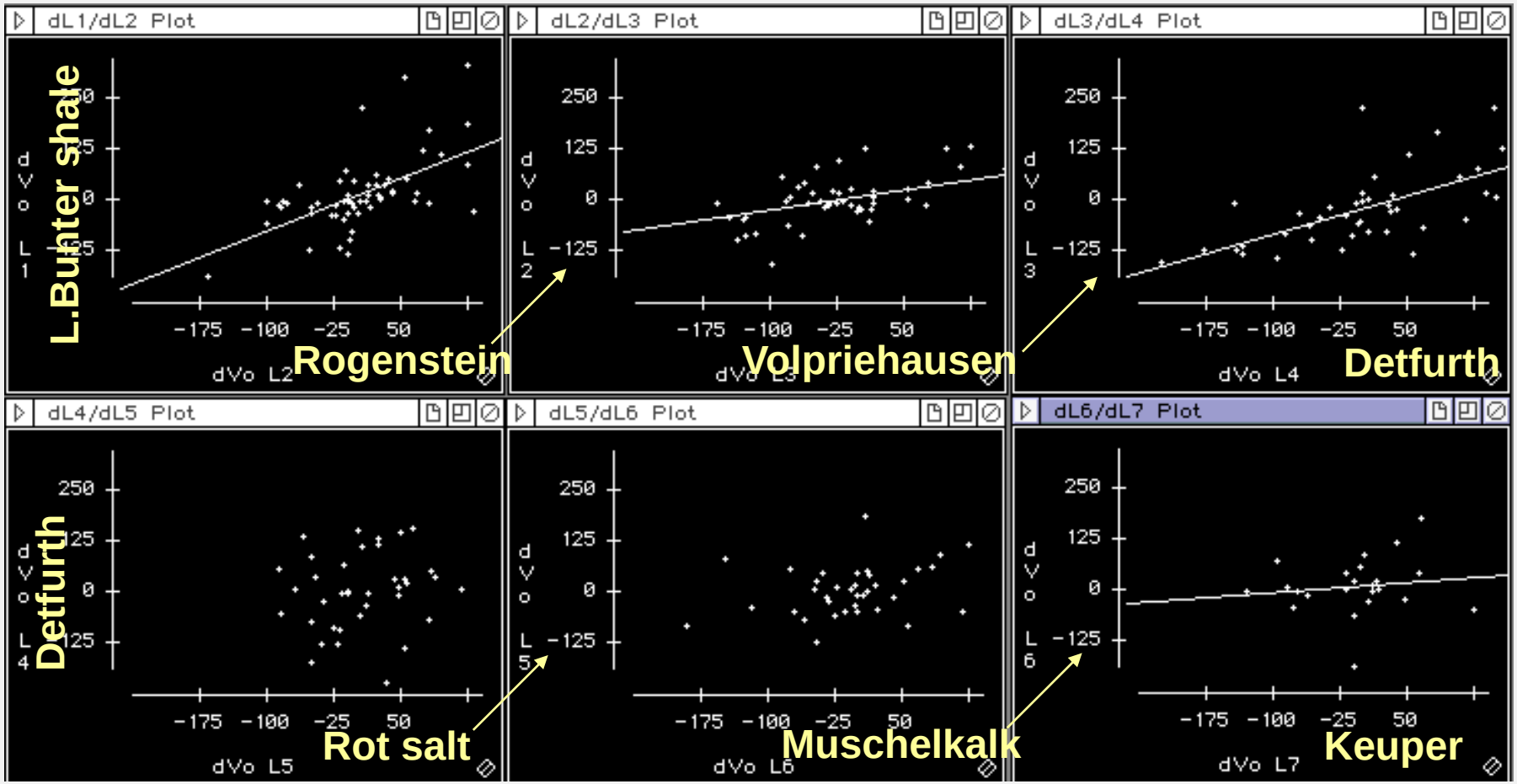


Geological study Triassic

Velocity cross-plots

80 wells, 7 layers: - velocities of layers are correlated

- velocity anomalies are not layer but area specific!



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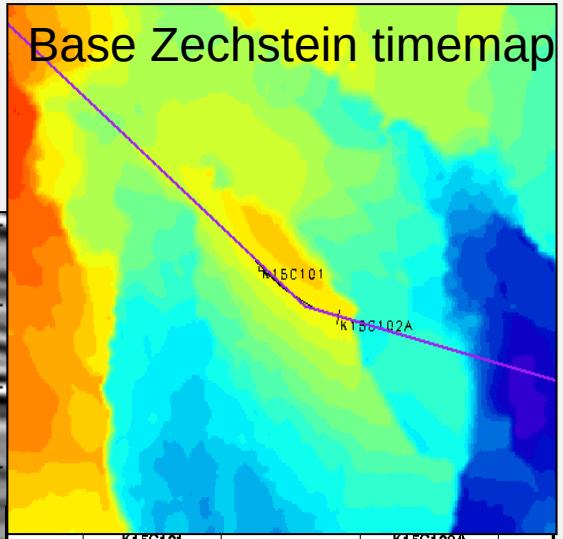
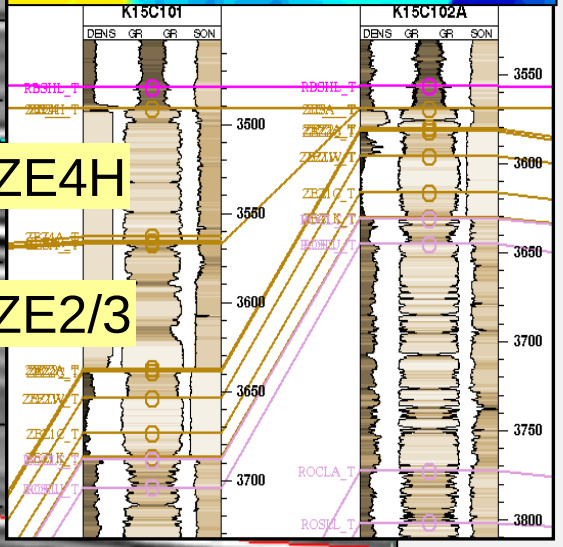
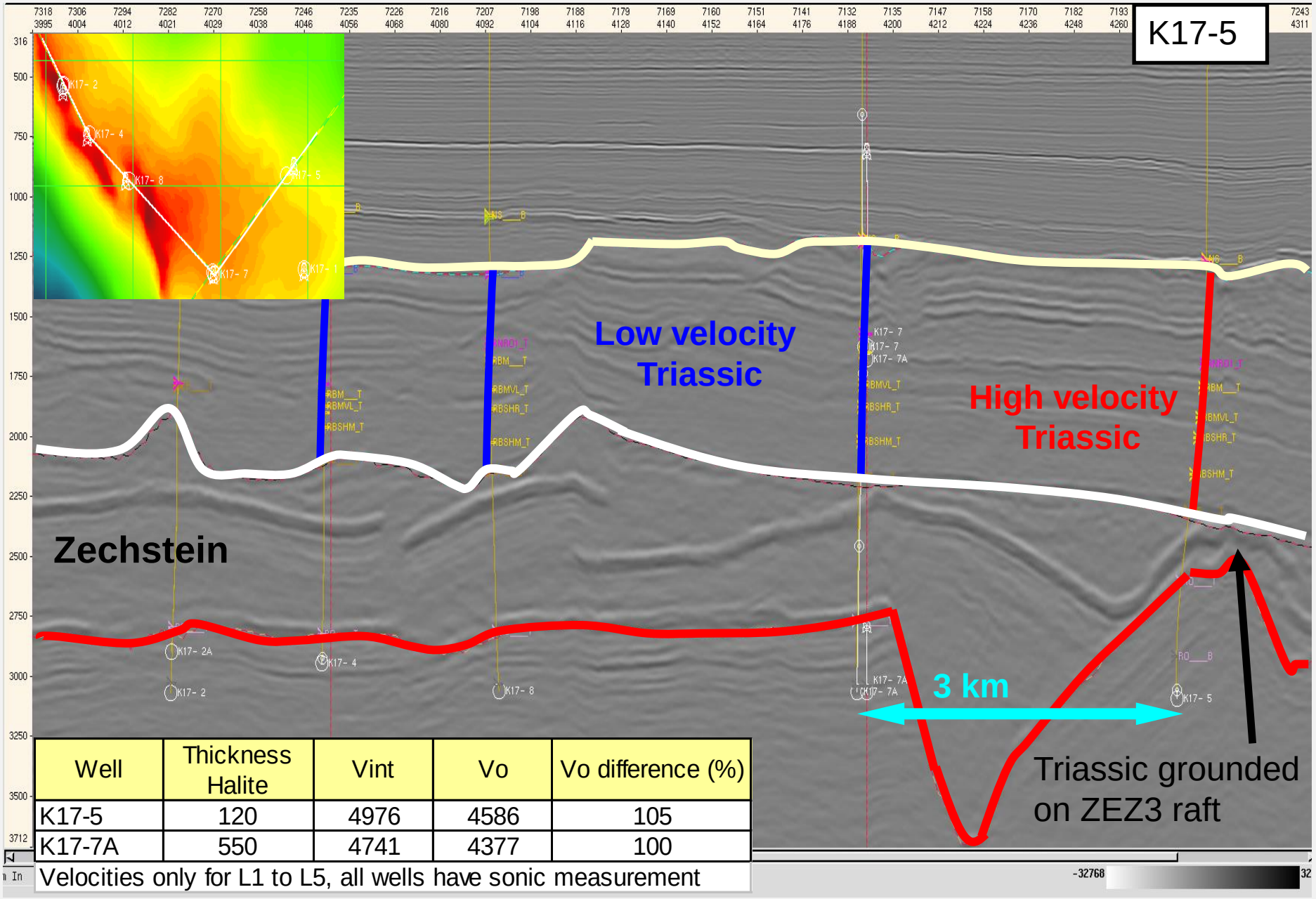
Triassic example #2





Well	Thickness Halite	Vint	Vo	Vo difference (%)
K15C101	150	4240	3600	100
K15C102A	10	4535	3876	108

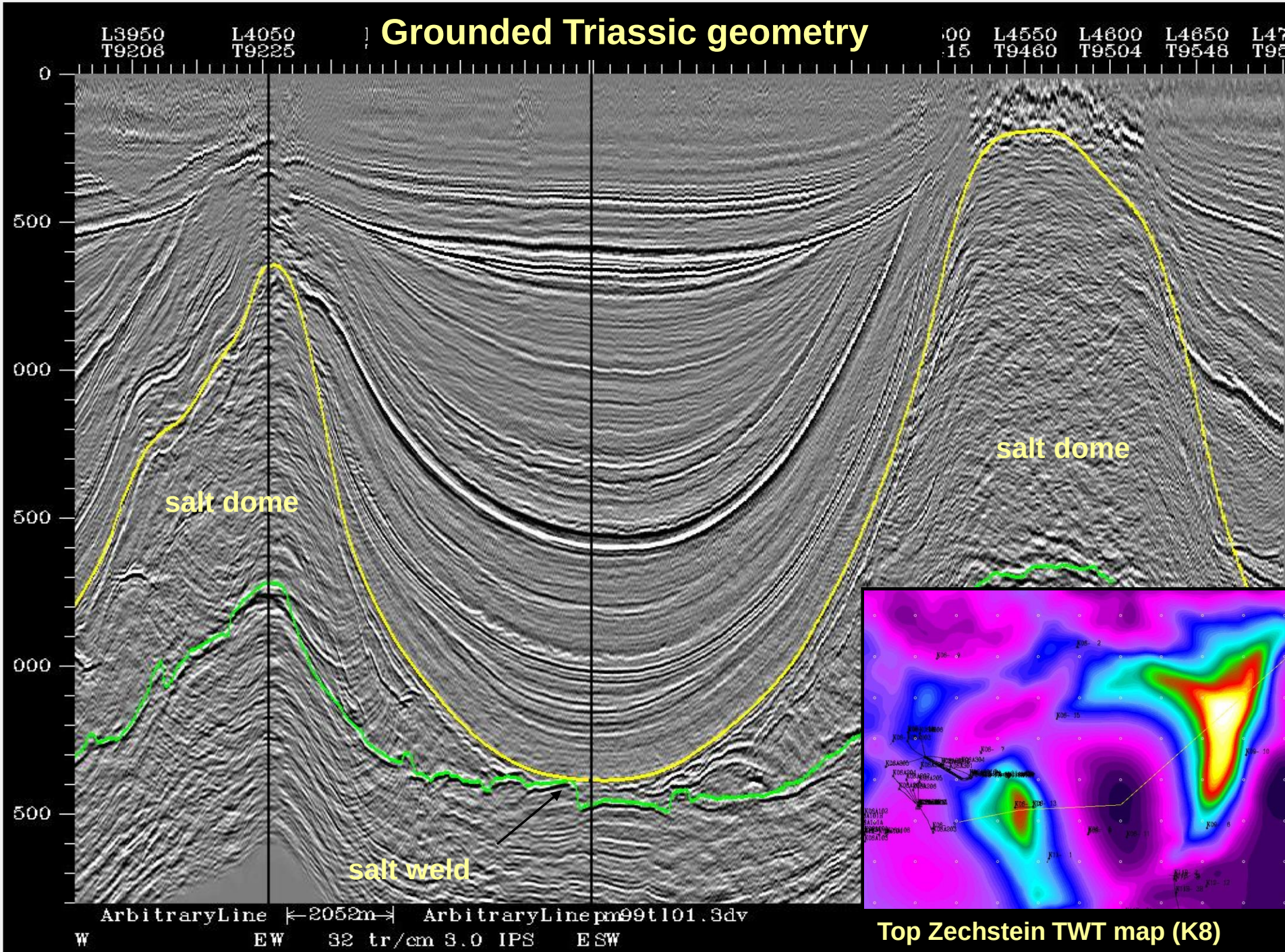
Triassic example #3



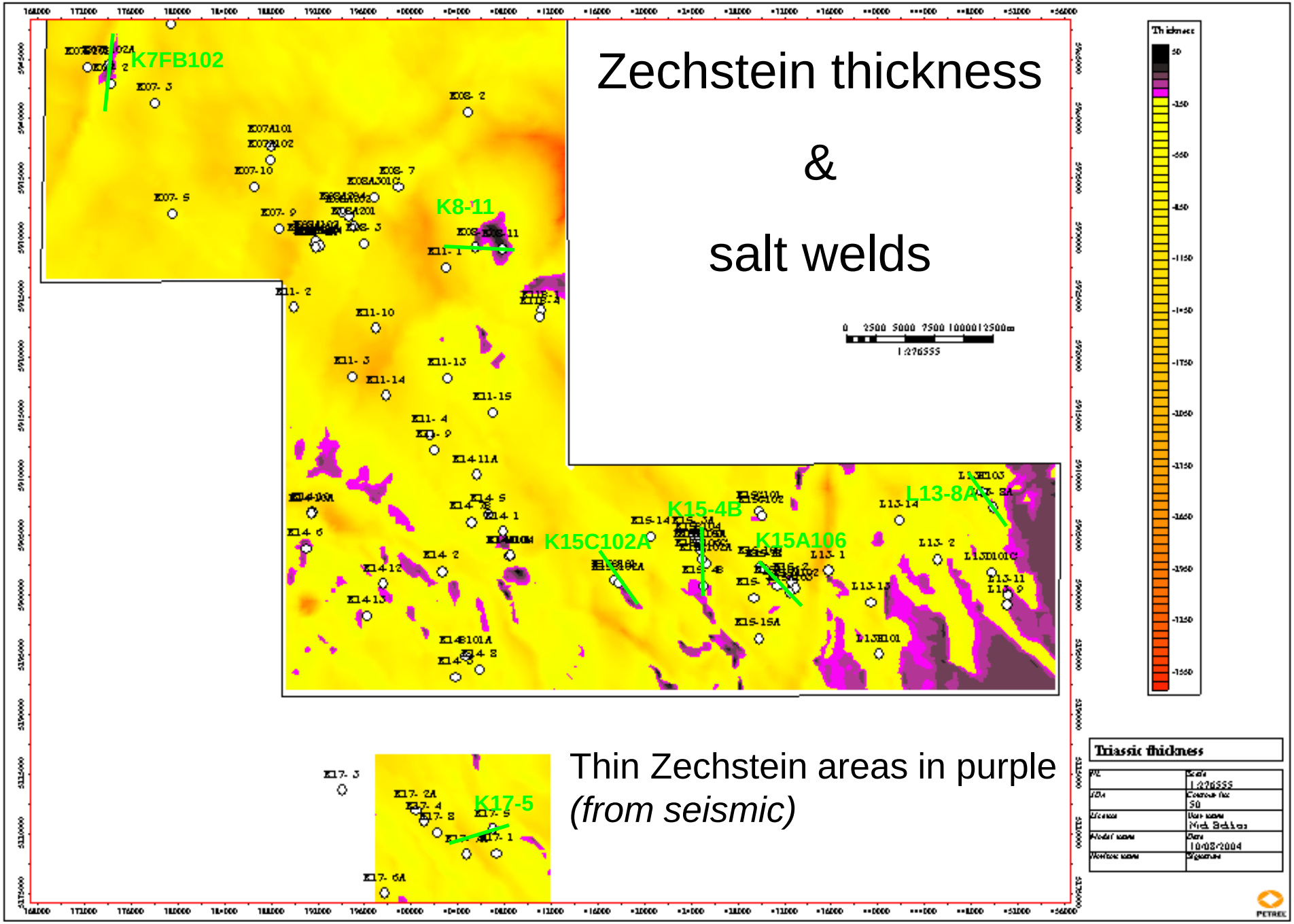
Well	Thickness Halite	Vint	Vo	Vo difference (%)
K17-5	120	4976	4586	105
K17-7A	550	4741	4377	100

Velocities only for L1 to L5, all wells have sonic measurement

Grounded Triassic geometry



Top Zechstein TWT map (K8)


Zechstein thickness
&
salt welds
K7FB102
K8-11
K15-4B
K15C102A
K15A106
L13-8A
K17-5
Thin Zechstein areas in purple
(from seismic)
Triassic thickness

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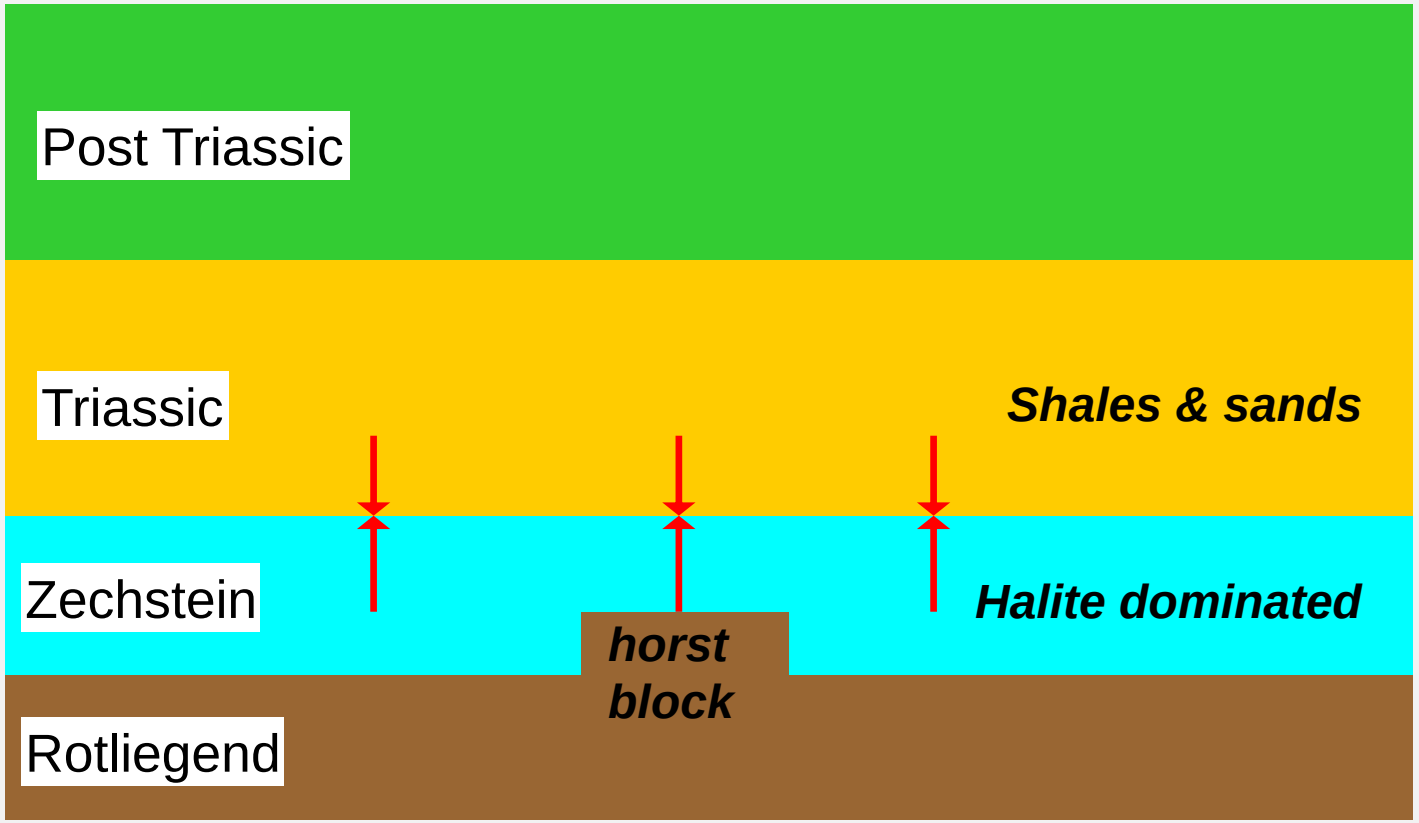
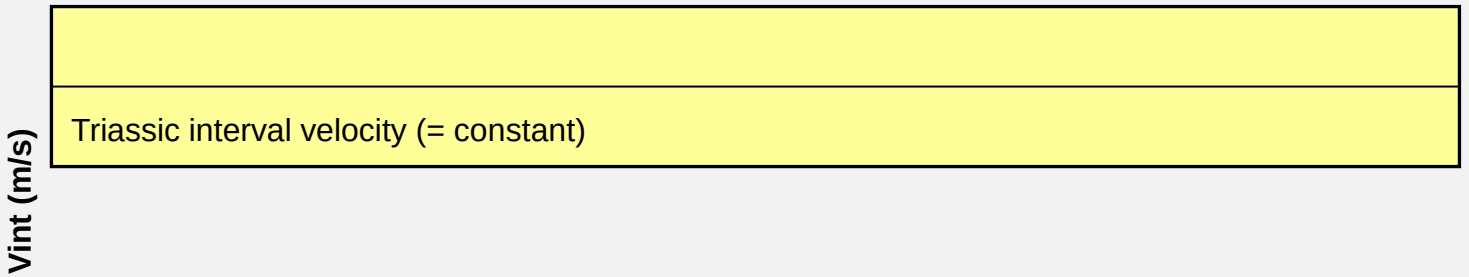
Salt Induced Stress Anomaly (1)

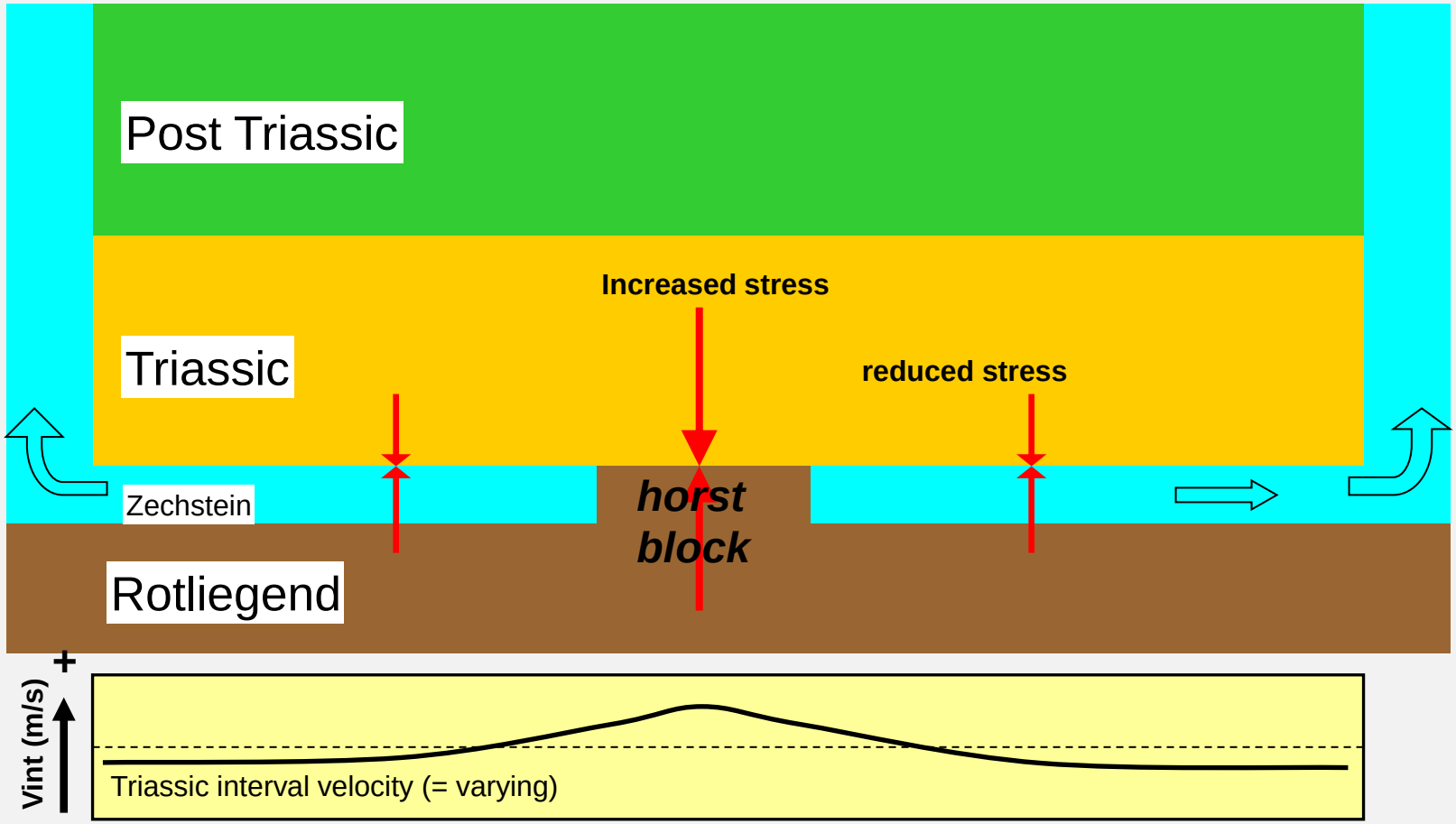
Initial condition





Salt Induced Stress Anomaly (2)

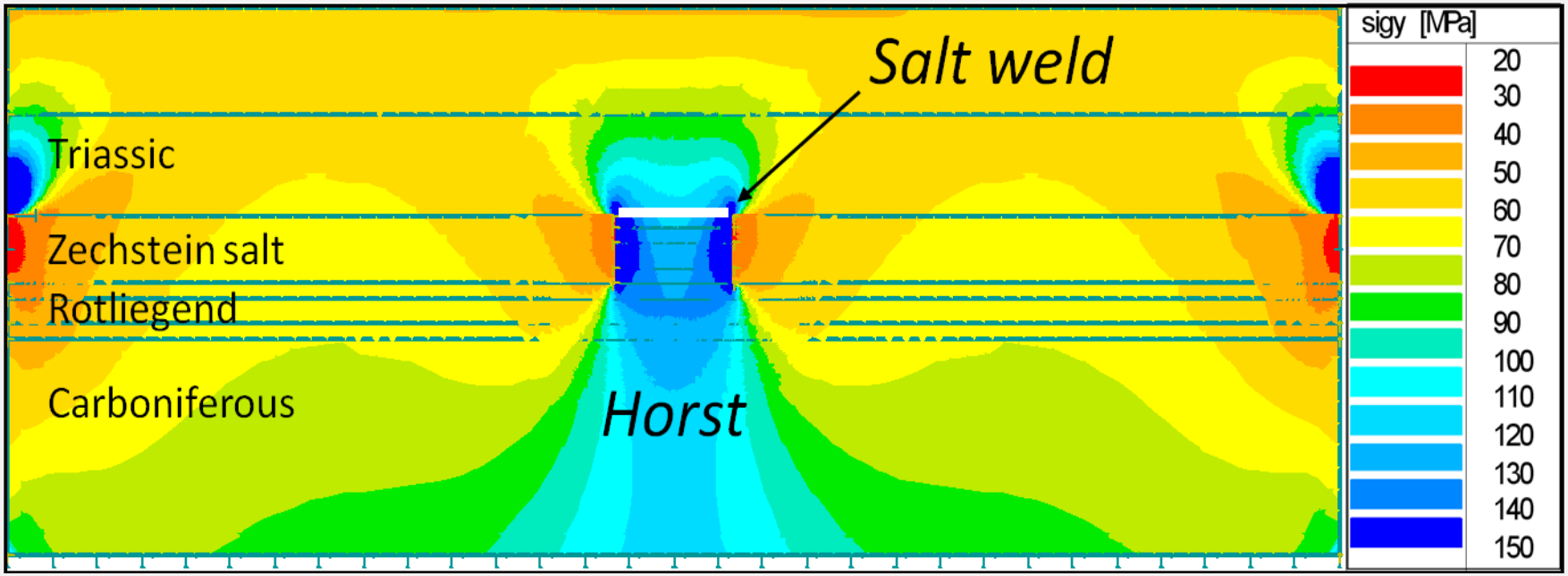
adjusted condition



"brick in the bathtub" model

GEOMECHANICAL FE modelling

"brick in the bathtub" model



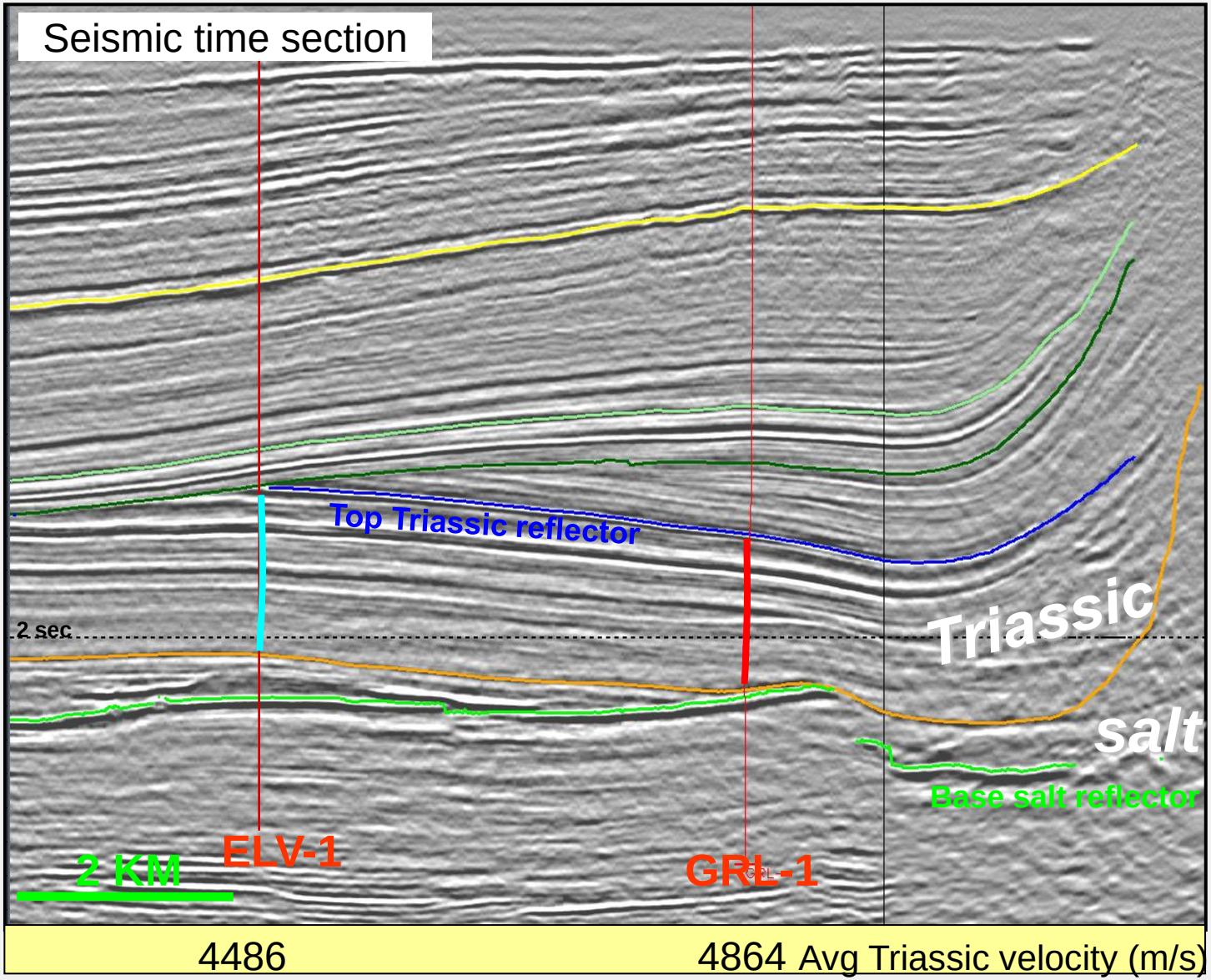
Vertical Stresses

from Finite Element Modelling

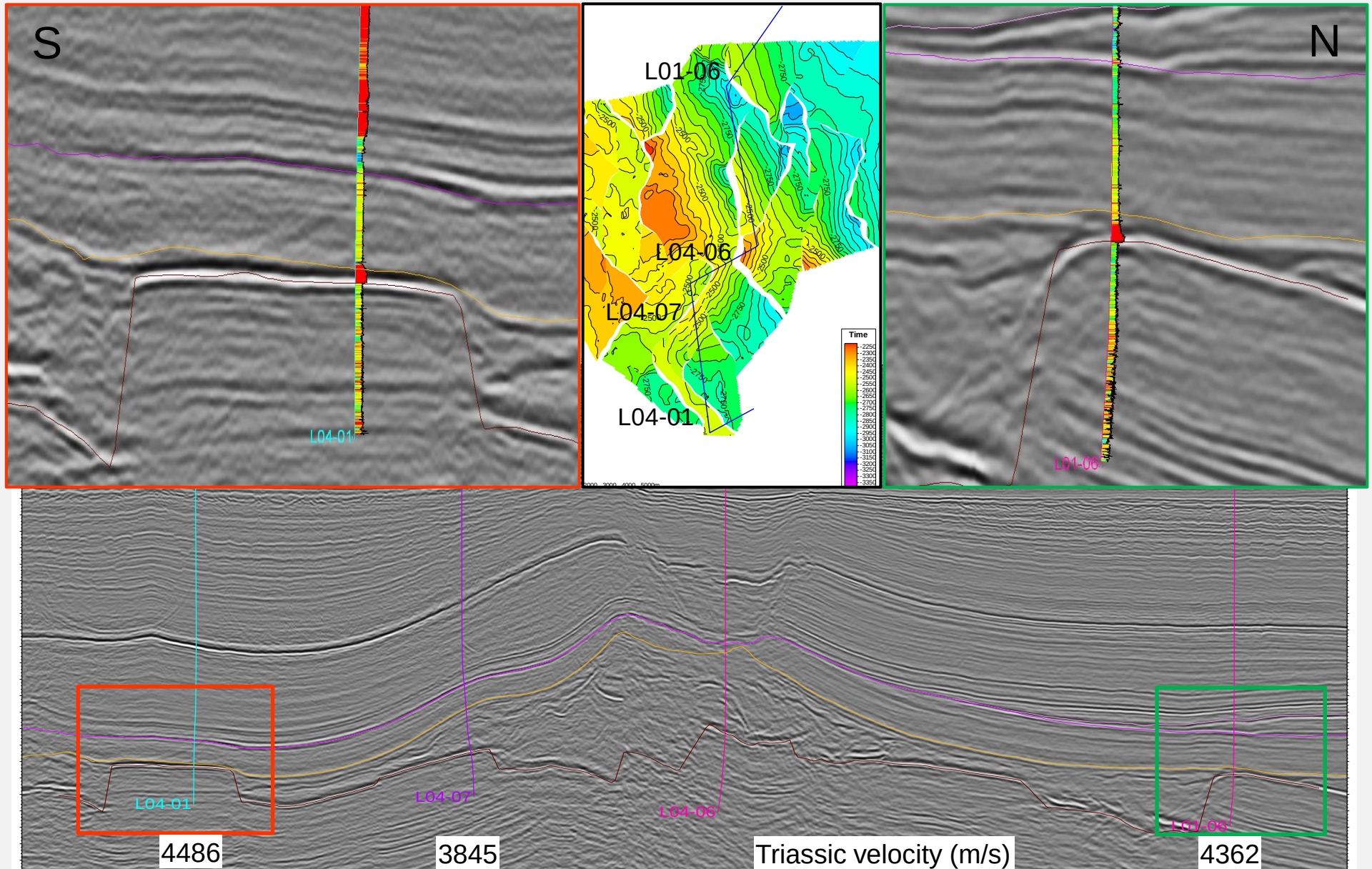
Largest magnitude = dark blue

Smallest magnitude = red

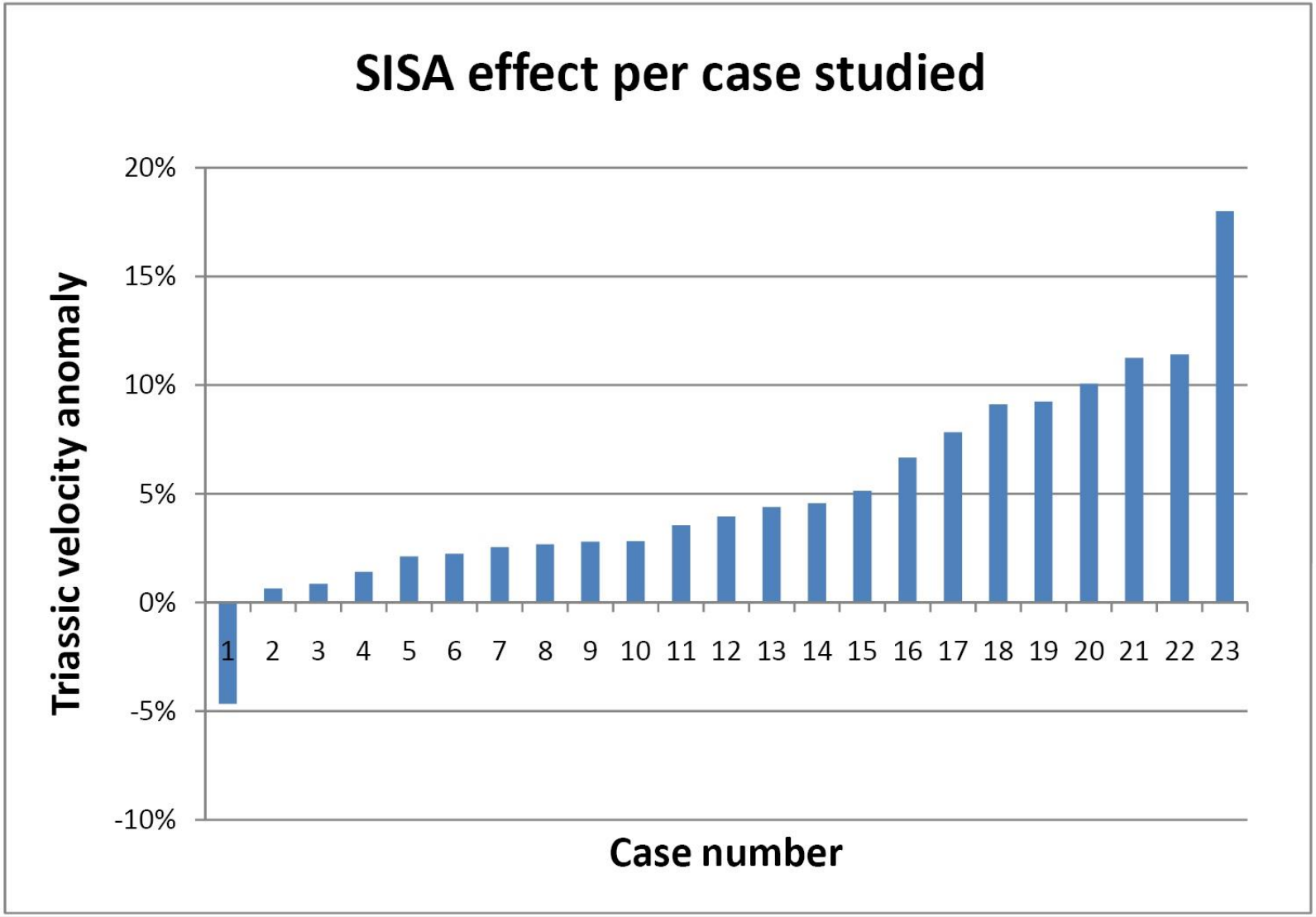
Example #5 (Drenthe)



Example #6 & #7 (L4)



Results study area 1&2 (2010)

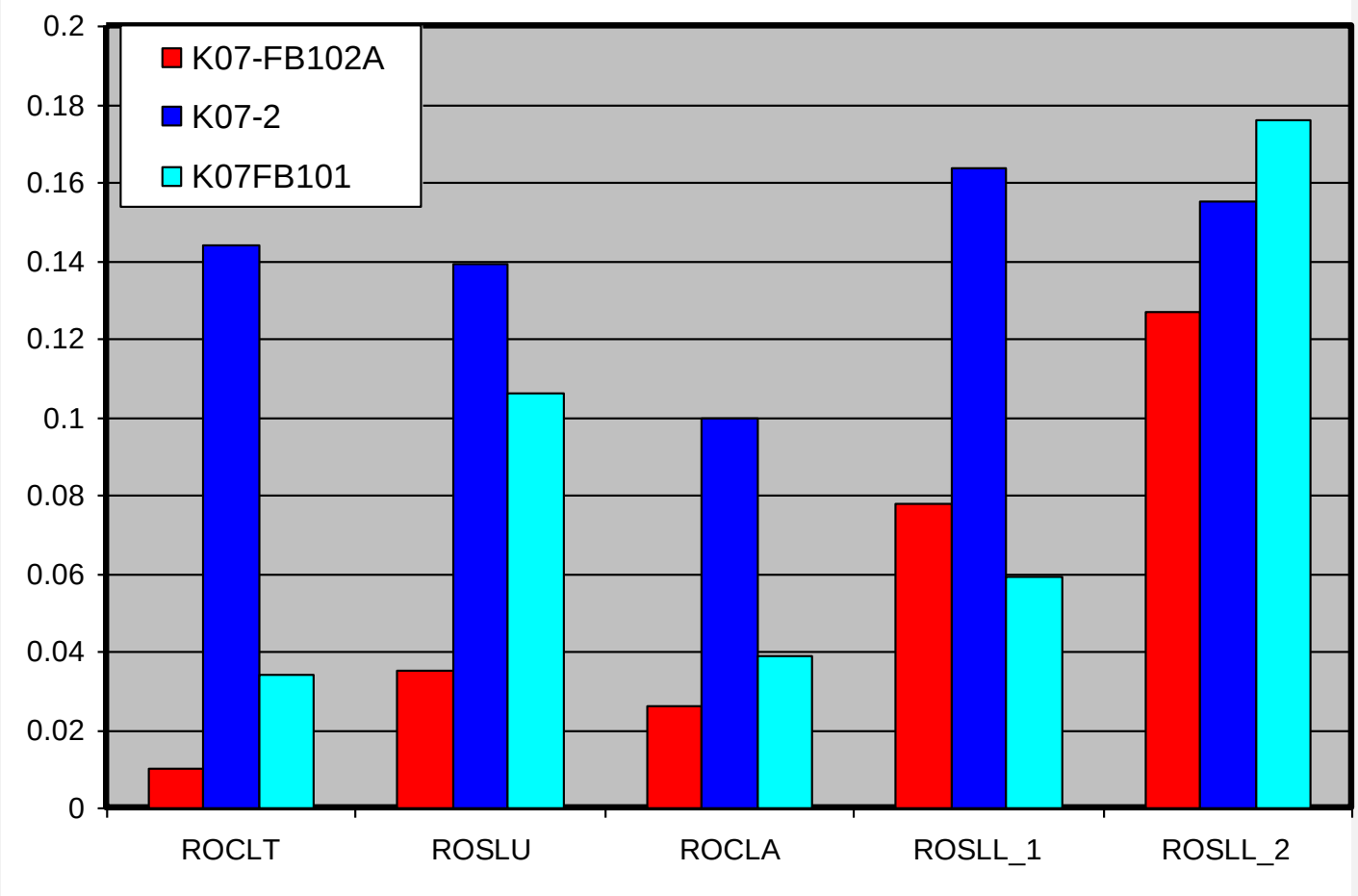


Implications

If salt welds cause increased stress ("point loading") in the Triassic above the weld, what about the rocks below the weld?

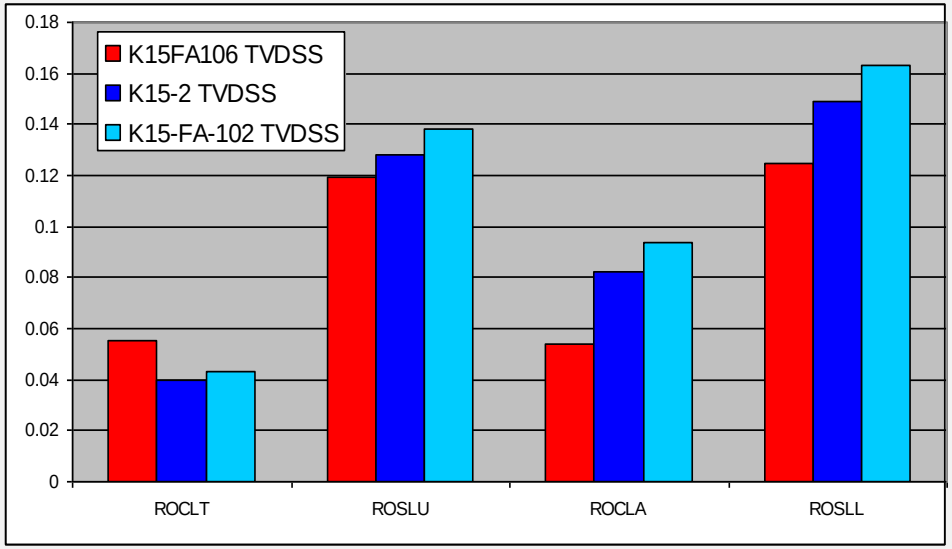
Assumption:
Rotliegend reservoir properties should be adversely affected by the "stress concentration" resulting from the salt weld.

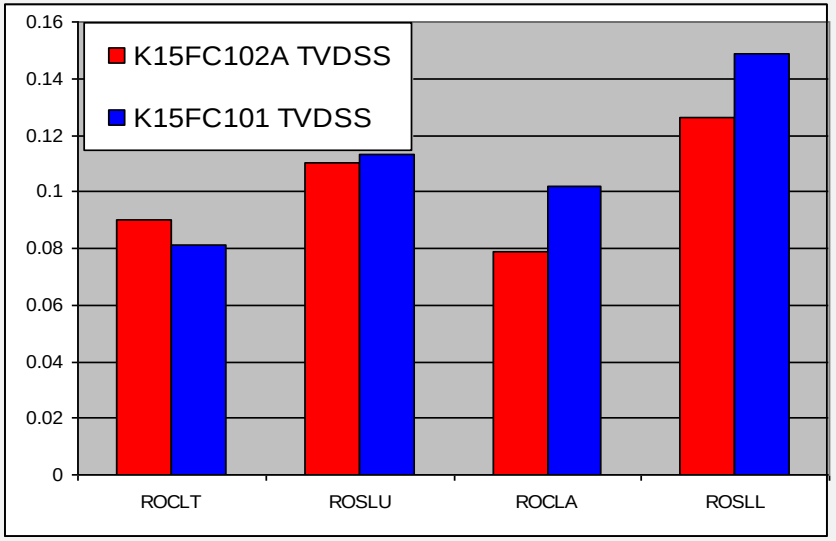
Rotliegend properties (1)



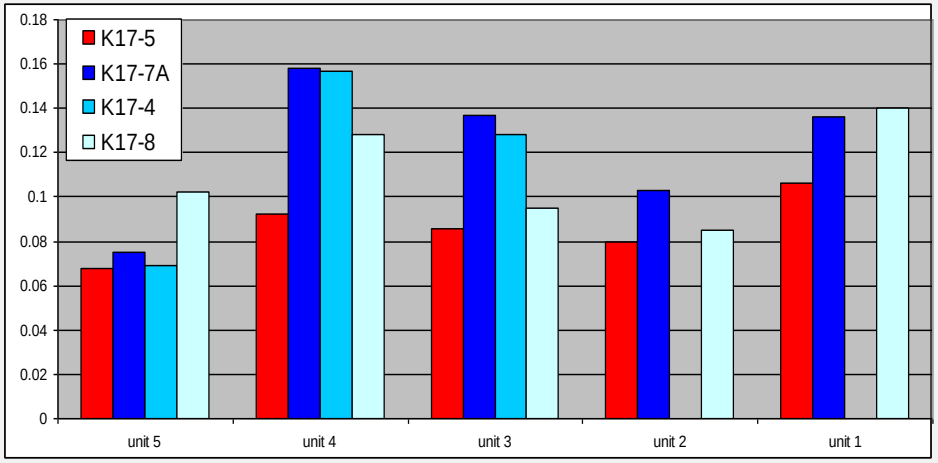
Reservoir below salt weld: lower porosity

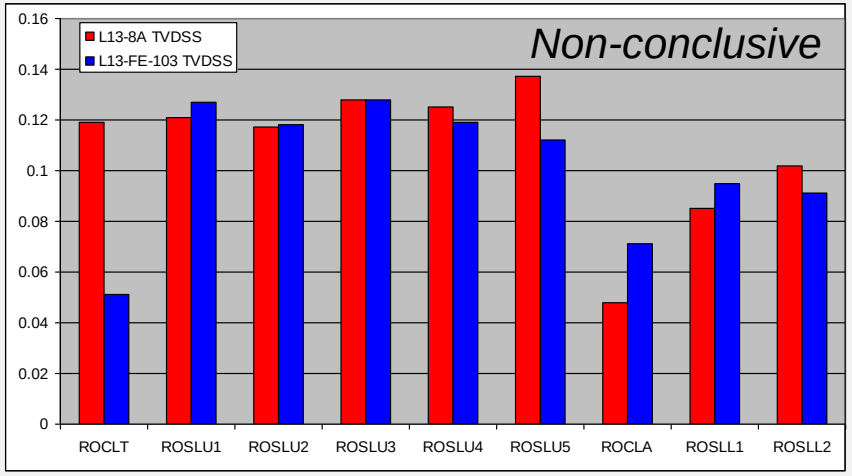
Rotliegend porosities (2)





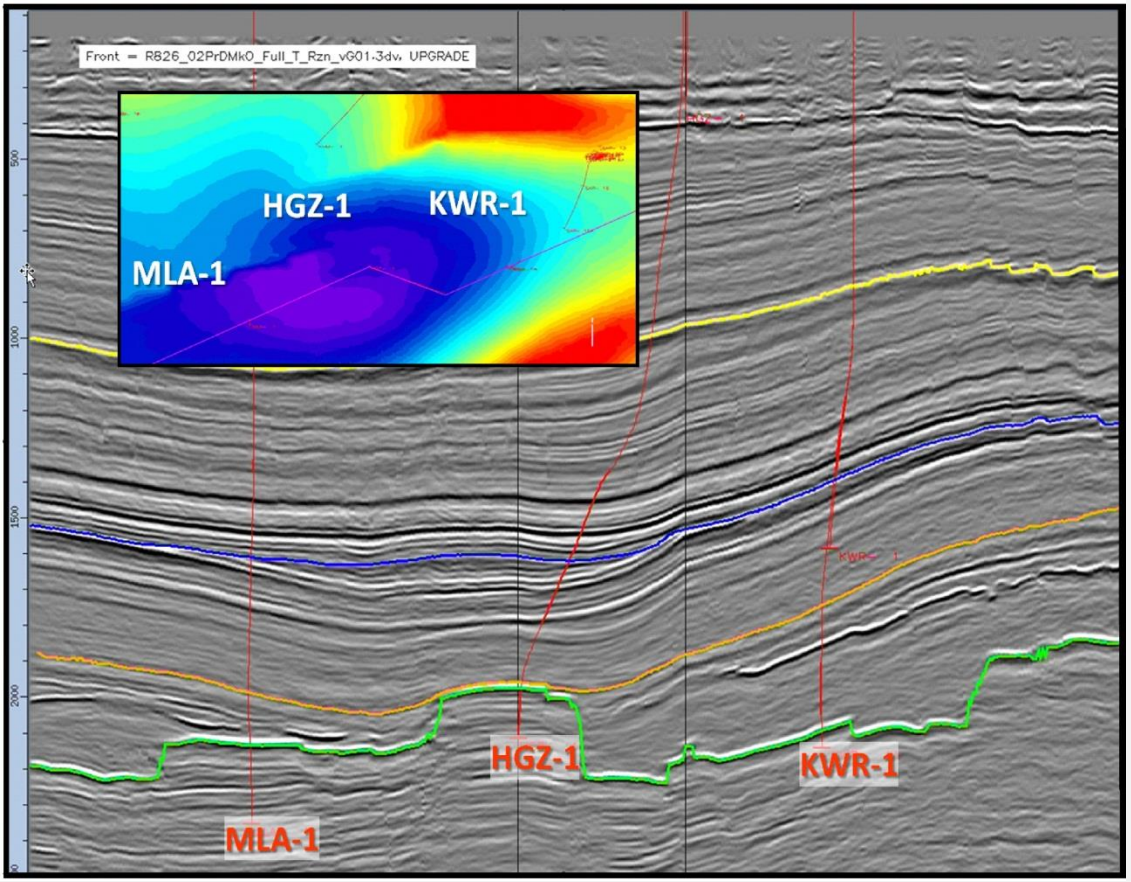
Well in red: at (near) salt weld





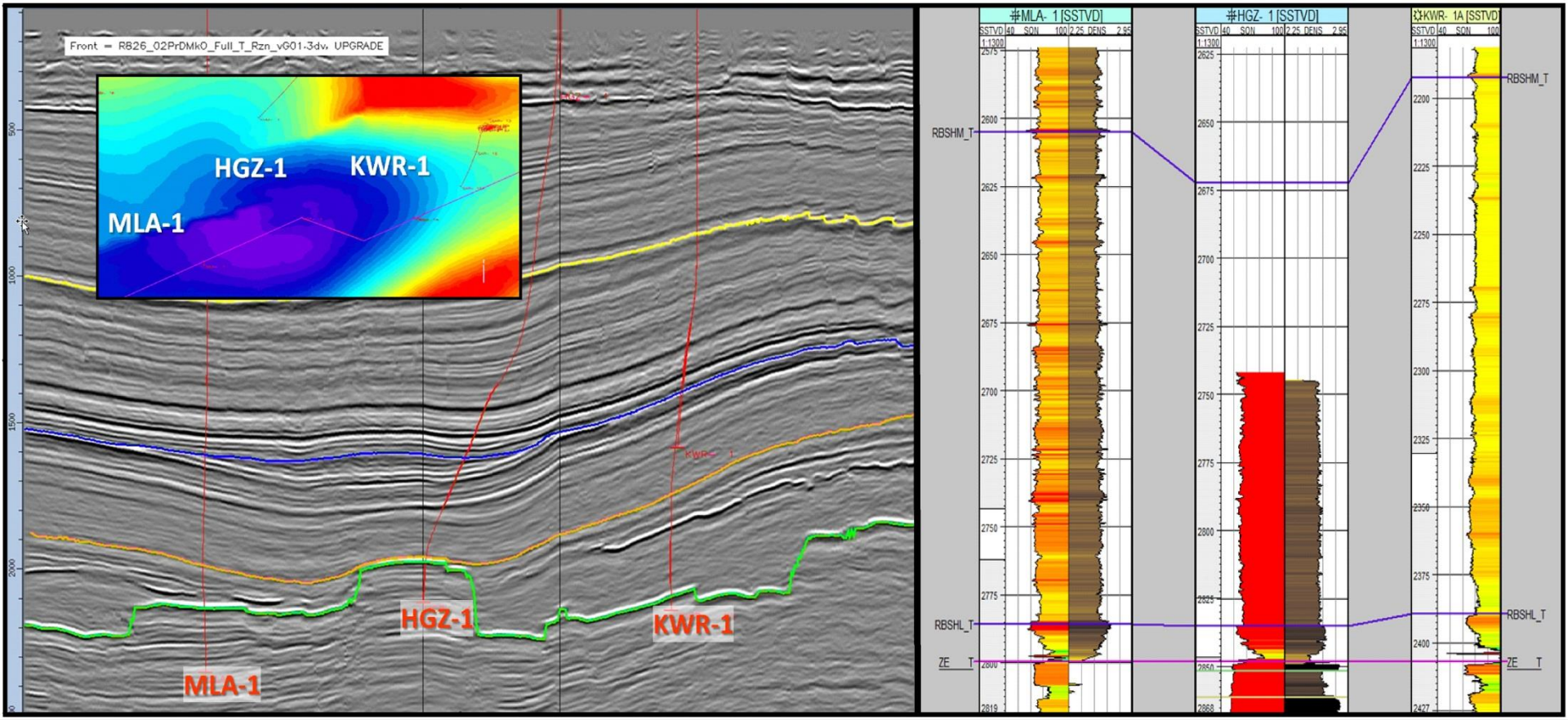
From 8 examples: 5 confirm model, 3 are non-conclusive

2009: SISA predicted and ….



Hoogezand-1 appraisal well

2009: SISA predicted and confirmed

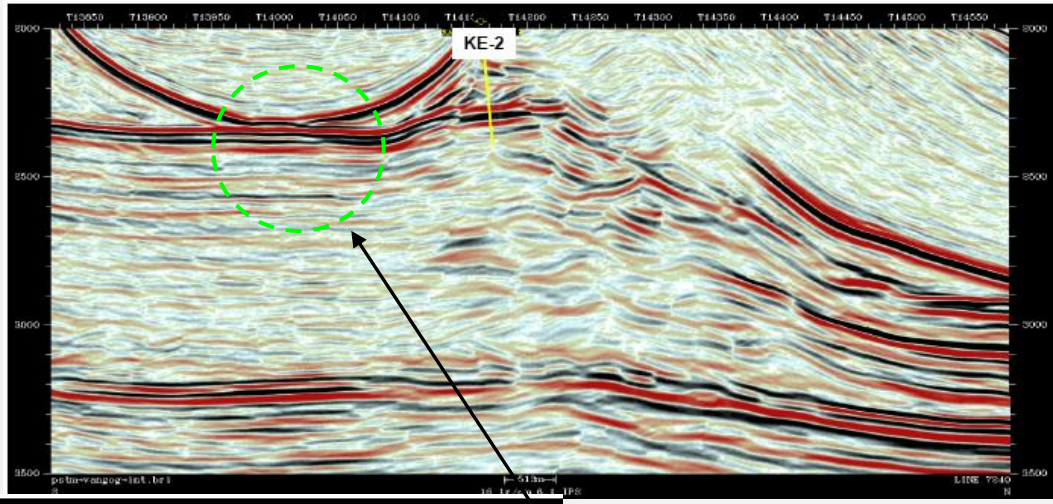


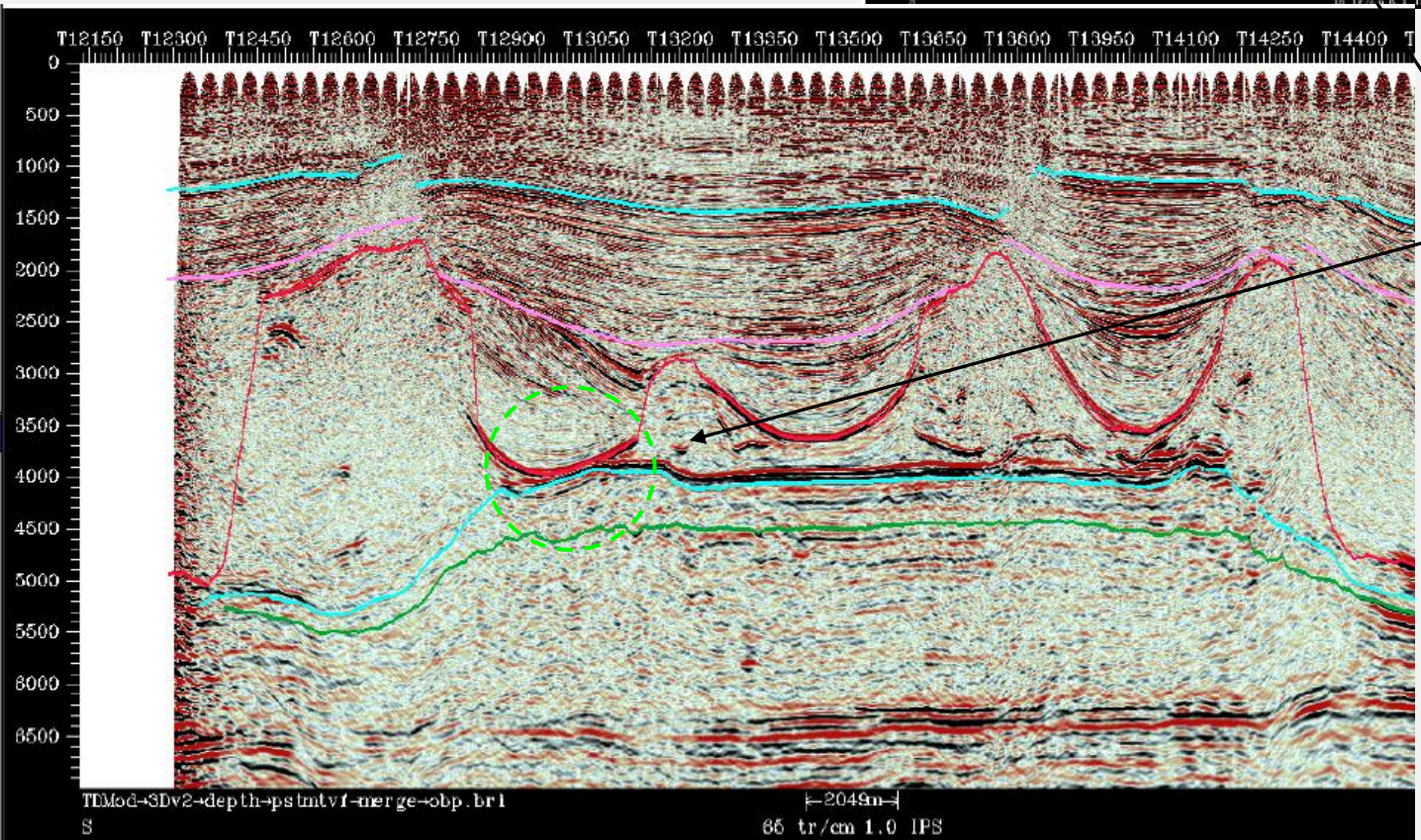
Hoogezand-1 appraisal well

Triassic velocity: +18%
Rotl. Porosity: -2.5% point

More SISA?

Kazakhstan,
Kashagan field





Salt welds

Summary

1) Depth error caused by enigmatic velocity anomaly can be explained by geomechanical model

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2) SISA is based on pointloading and impacts near saltweld area.

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2) SISA is based on pointloading and impacts near saltweld area.

3) SISA affects velocity (up to 18%) and reservoir porosity (up to 3% *points*)

Summary

1) Depth error caused by enigmatic velocity anomaly can be explained by geomechanical model

2) SISA is based on pointloading and impacts near saltweld area.

3) SISA affects velocity (up to 18%) and reservoir porosity (up to 3% *points*)

4) Never waste a good *trainwreck!*

SISA

More reading

Petroleum Geoscience November 2011 Volume 17

Salt-Induced Stress Anomalies: an Explanation for Variations in Seismic Velocity and Reservoir Quality

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