# Tectonic Structure of the Karish Gas Field, Offshore Israel*

**Leonidas Gouliotis[1], Yannis Tsiantis[1], and Dennis Anestoudis[1]**

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## Abstract

The Karish Gas Field was discovered offshore Israel in 2013 through the exploration well Karish-1. The well encountered the prolific Tamar sands finding hydrocarbons in the A, B, C and D sandstone intervals. The Karish structure was interpreted on good quality 3D seismic data. The observed structural complexity of the field dictated the necessity to investigate in depth the structural evolution of the former, in order to understand: (1) the deformation of each Karish reservoir interval, and (2) fault evolution since faults may affect lateral and vertical fluid migration. Since both processes may have considerable influence on the final volumes of accumulated gas, comprehending the magnitude of their influence may unlock further upside potential in areas adjacent to the main Karish Field.

The seismic interpretation shows that the top 5 km of sediments are of Cenozoic age overlying the Mesozoic rift and syn-rift sediments. The investigation focuses on the time interval between Late Oligocene to Miocene. The examined interval is subdivided into three units: (1) a lower unit of Late Oligocene to Early Miocene age, (2) an intermediate unit of Middle-Late Miocene age, and (3) an upper unit of Latest Miocene age. The Karish Gas Field is a three way closure bounded to the north by the Karish Shear Zone (KSZ), an ENE-WSW zone of deformation exceeding 16 km length that extends to depths of more than 8 km into the Mesozoic sediments of the Levant Basin. The tectonic structure of the Karish Field is characterized by: (1) an NE-SW arcuate fold that progressively parallels the KSZ, (2) a series of NW-SE conjugate normal faults that propagate north and south of the KSZ, and (3) closely spaced ESE-WNW and ENE-WSW en echelon faults located along the KSZ.

The Late Vourdigalian-Serravallian strata show thickness variations and onlapping seismic reflections indicating deposition-related deformation, while the post-Serravallian strata are nearly horizontal with almost constant bed thicknesses. The NW-SE normal faults represent different generations of conjugate faults with horizontal fault intersections. The older normal faults are observed on both sides of the KSZ often truncating the Middle Miocene unit and are onlapped by undeformed Late Miocene strata, while the younger normal faults are restricted north of the KSZ cutting the base of the Messinian salt. Along the KSZ, an anastomosing network of ESE-WNW en echelon faults cuts also the base of the Messinian salt.

Our structural analysis implies that the tectonic structures observed within the Karish Field exhibit several changes in their development that are gradual but can be tentatively grouped into two periods of tectonic deformation: (1) an initial period of convergent deformation during Early Miocene, and (2) a second period of strike-slip faulting during Middle-Late Miocene. We propose that the ESE-WNW and ENE-WSW en echelon faults represent R- and P- shears respectively linking the NW conjugate normal faults with the KSZ. From the spatial distribution and the geometry of the faults, we suggest that the KSZ is a dextral transtensional zone.

The complex structural evolution calls for the necessity for quantifying the observed deformation using innovative structural modeling methods (e.g., sequential kinematic modeling and restoration). Forward and backward modeling of critical geological events and the determination of deformation rates will allow for extrapolating interpretations at areas of poor seismic quality (near the KSZ shadow zone) adding confidence to the reservoir volumes, and eventually enhance optimisation of gas production.

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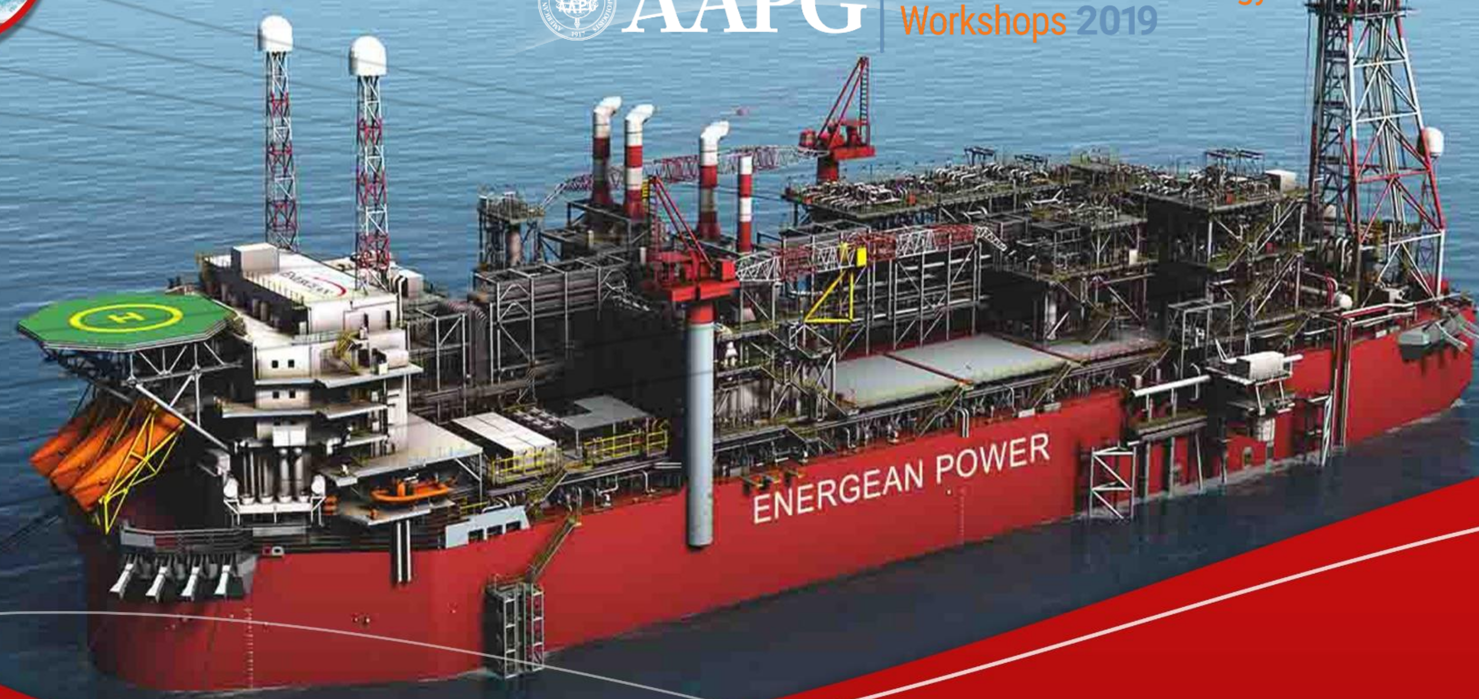


# Tectonic Structure of the Karish Gas Field, offshore Israel

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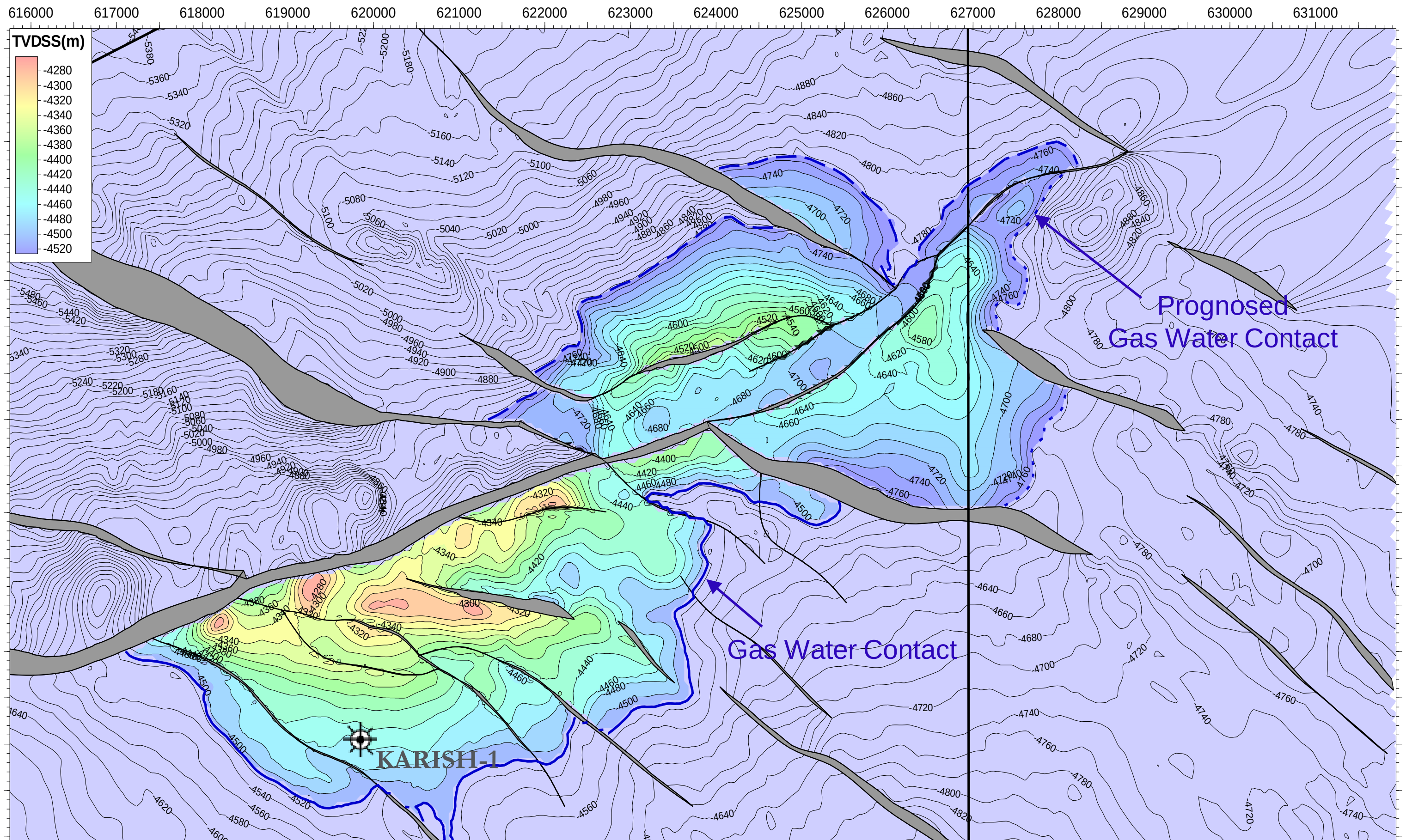
# The Karish Gas Field






- The Karish gas field was discovered in 2013 through the exploration well KARISH - 1
- The well encountered the prolific Early Miocene Tamar sands resulting in a significant gas discovery at the “KARISH MAIN” field
- The well is located along the crest of a structural closure lying approx. 76km from the Israeli coast
- Energean drilled the “KARISH NORTH” field and had a gas discovery.
- Future planning in the “Karish complex” includes drilling of the “KARISH EAST” prospect.

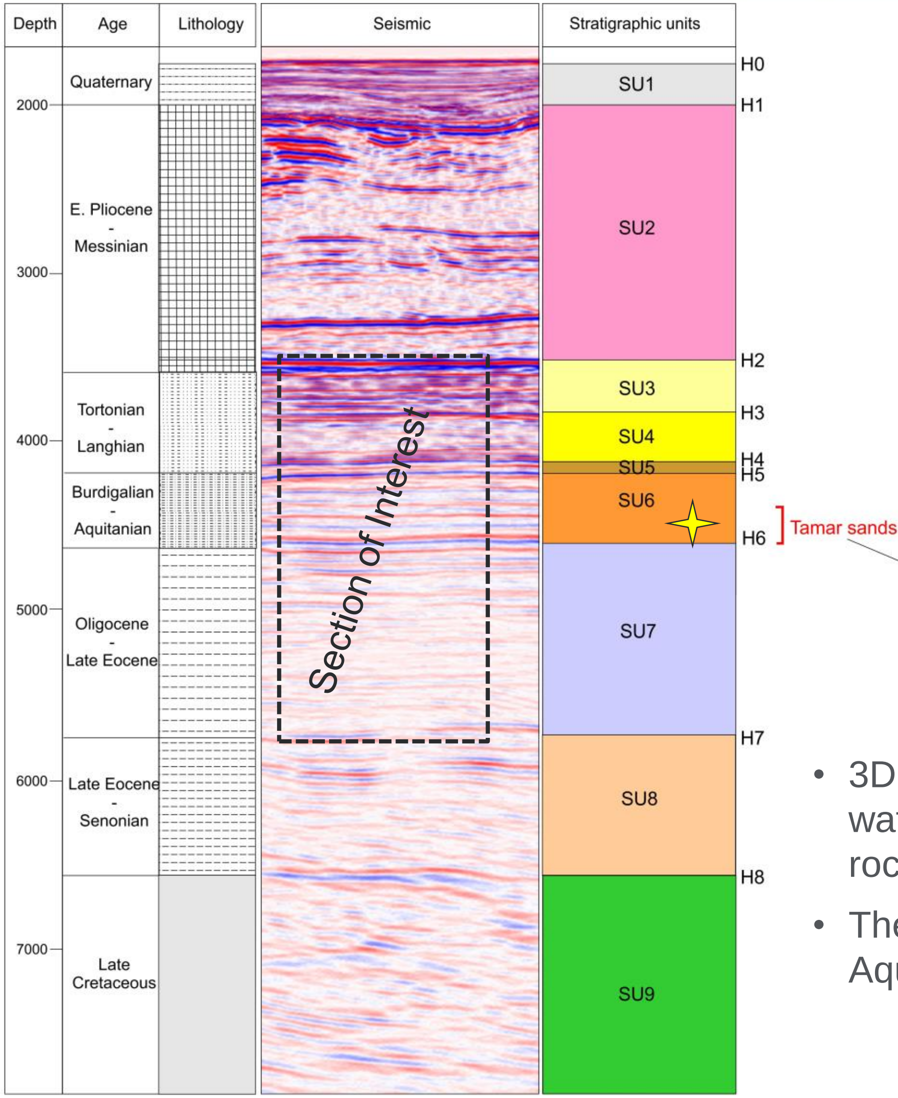
The structural complexity of Karish area dictates the necessity to investigate in depth the tectonic structure and evolution in order to understand:

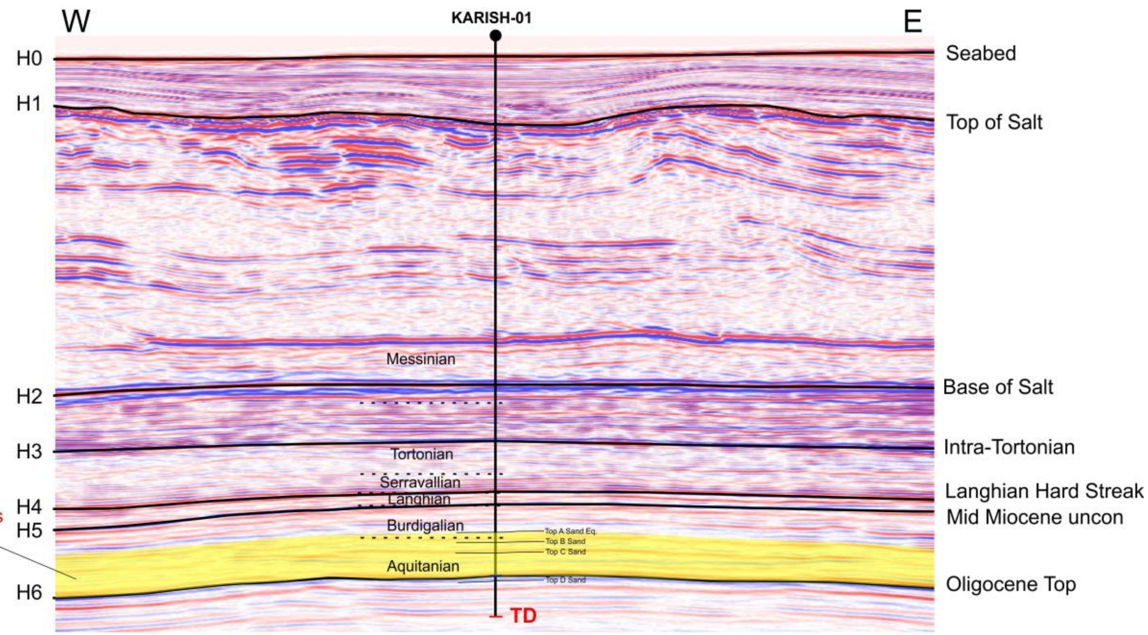
(i) the spatial and temporal distribution of the thickness variations of the Miocene units.

(ii) fault evolution since faults may affect lateral and vertical fluid/gas migration. Do faults affect?

**Both processes may have considerable influence on the final volumes of accumulated gas and comprehending the magnitude of their influence may unlock further upside potential in areas adjacent to the main Karish Field.**

# Seismic stratigraphy

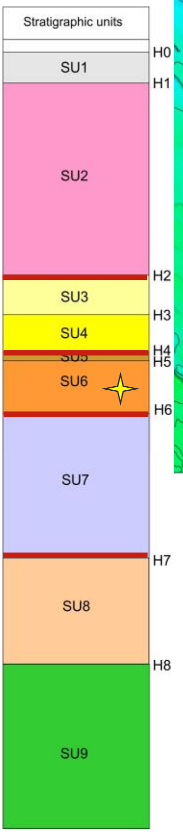


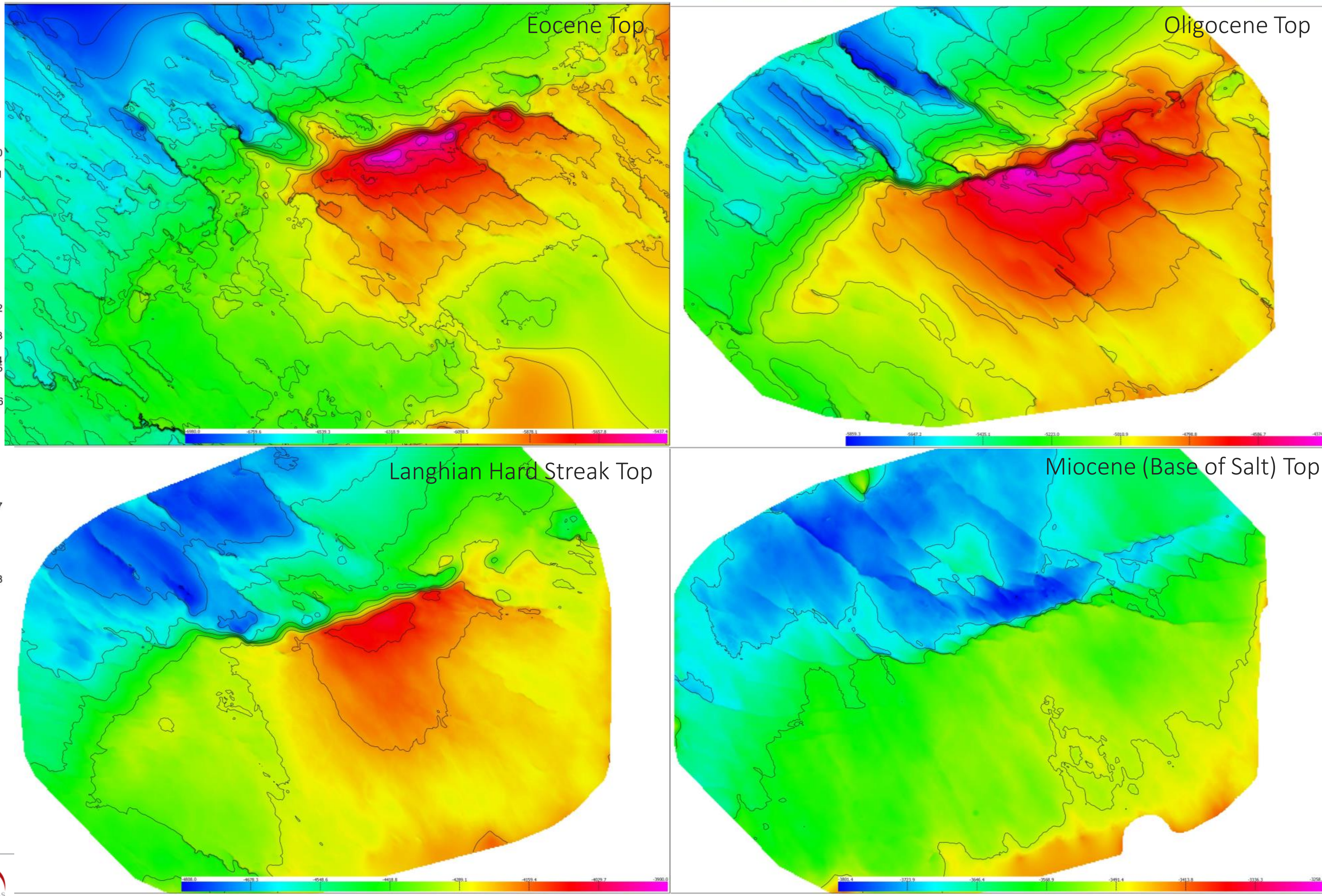




- 3D seismic surveys showed that the upper 5km of the brittle crust (below water depths 1750m) consists of Late Mesozoic - Cenozoic sedimentary rocks
- The Tamar sands of Karish Field are of Early Miocene age (mainly Aquitanian – Early Bourdigalian)

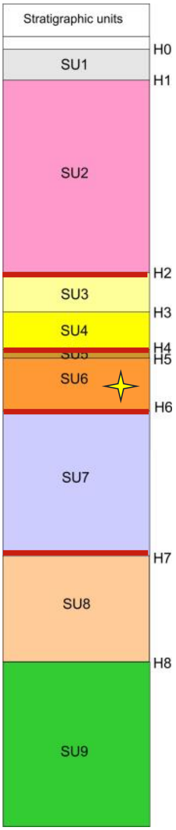
Alternations of claystones/siltstones/sands (Yafo Fm)
Evaporites with clayey and silty interbeds (Mavqiim Fm)
Alternations of claystones/sandstones/limestones (Ziqim & Beit Guvrin Fms)
Alternations of sandstones/limestones/claystones (Beit Guvrin Fm)
Alternations of marls/limestones (Beit Guvrin Fm)
Alternations of limestones/marls (Beit Guvrin Fm)

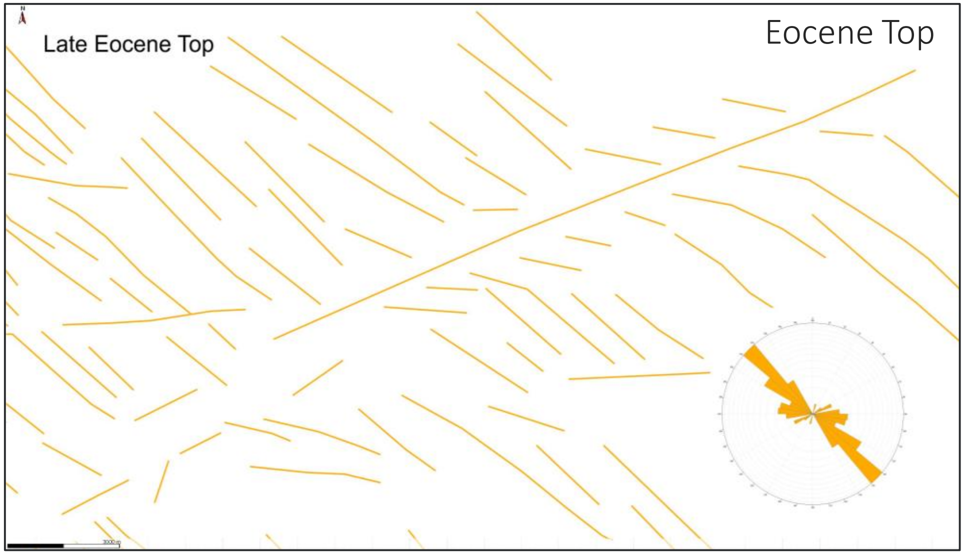
# Structural maps

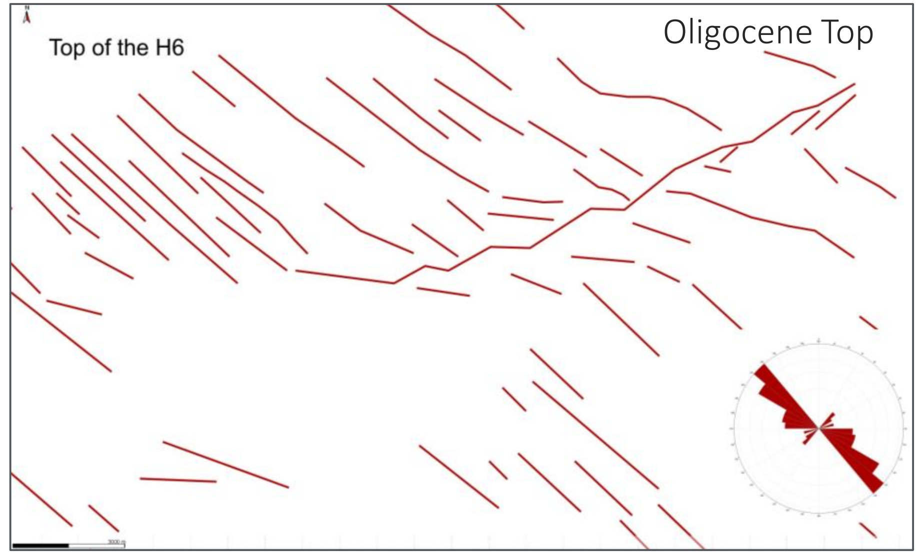


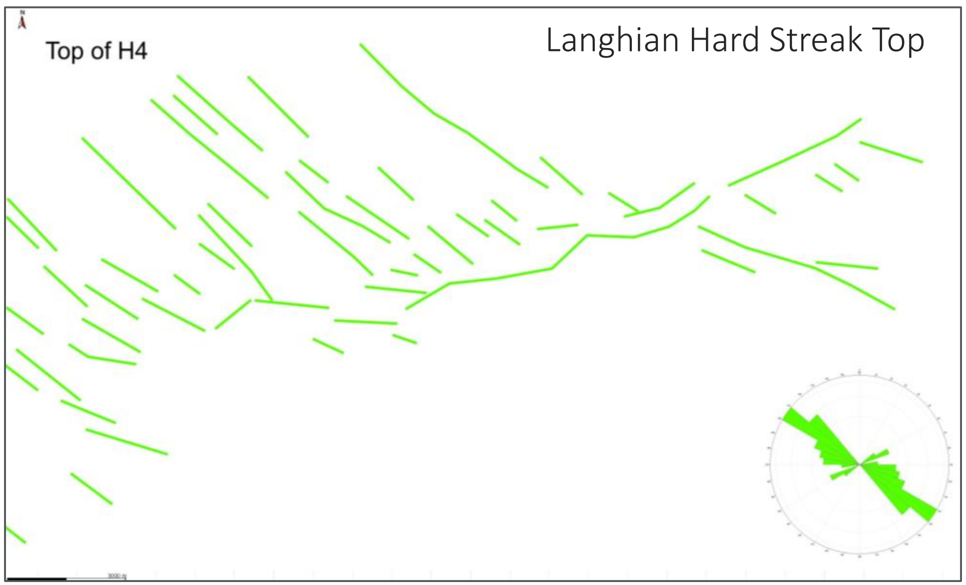



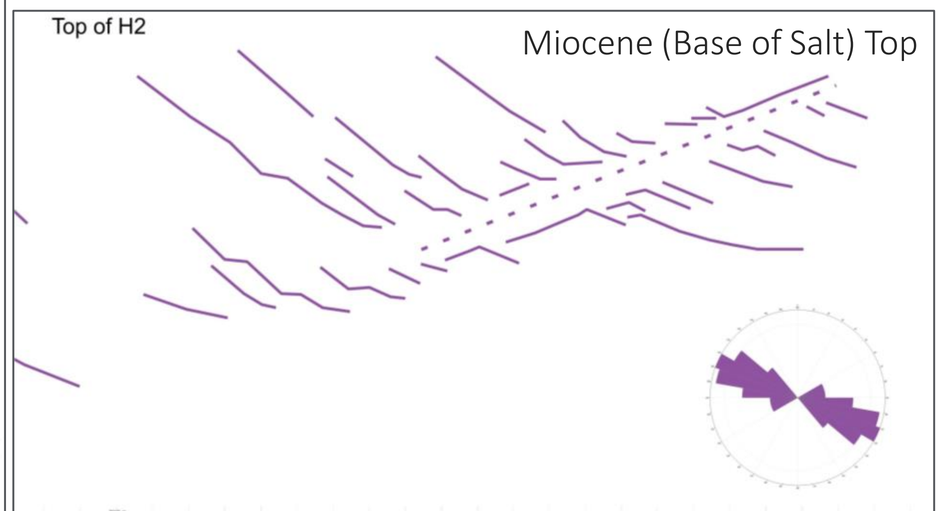
# Tectonic Maps



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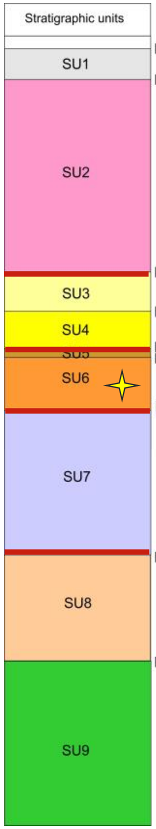
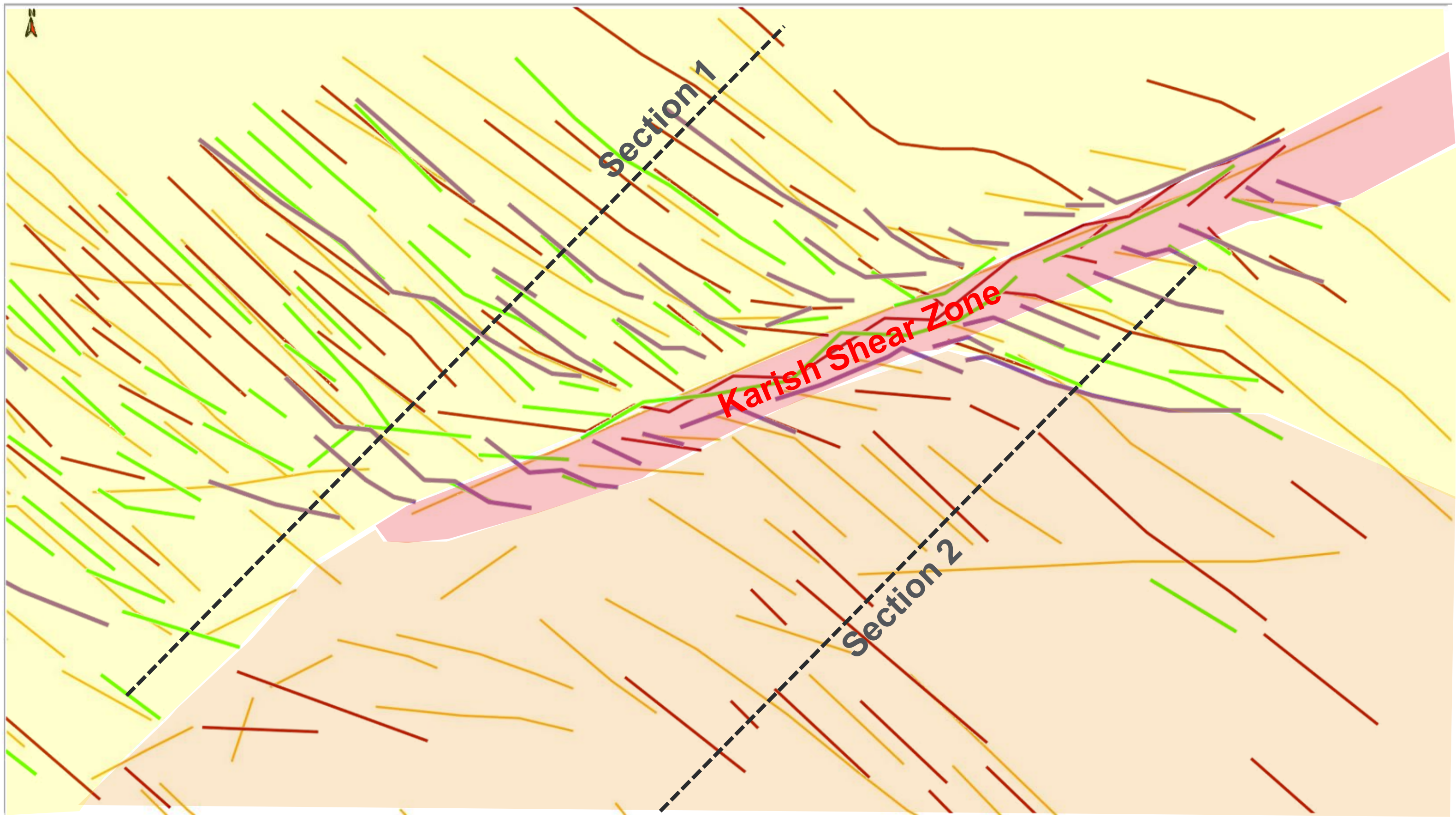


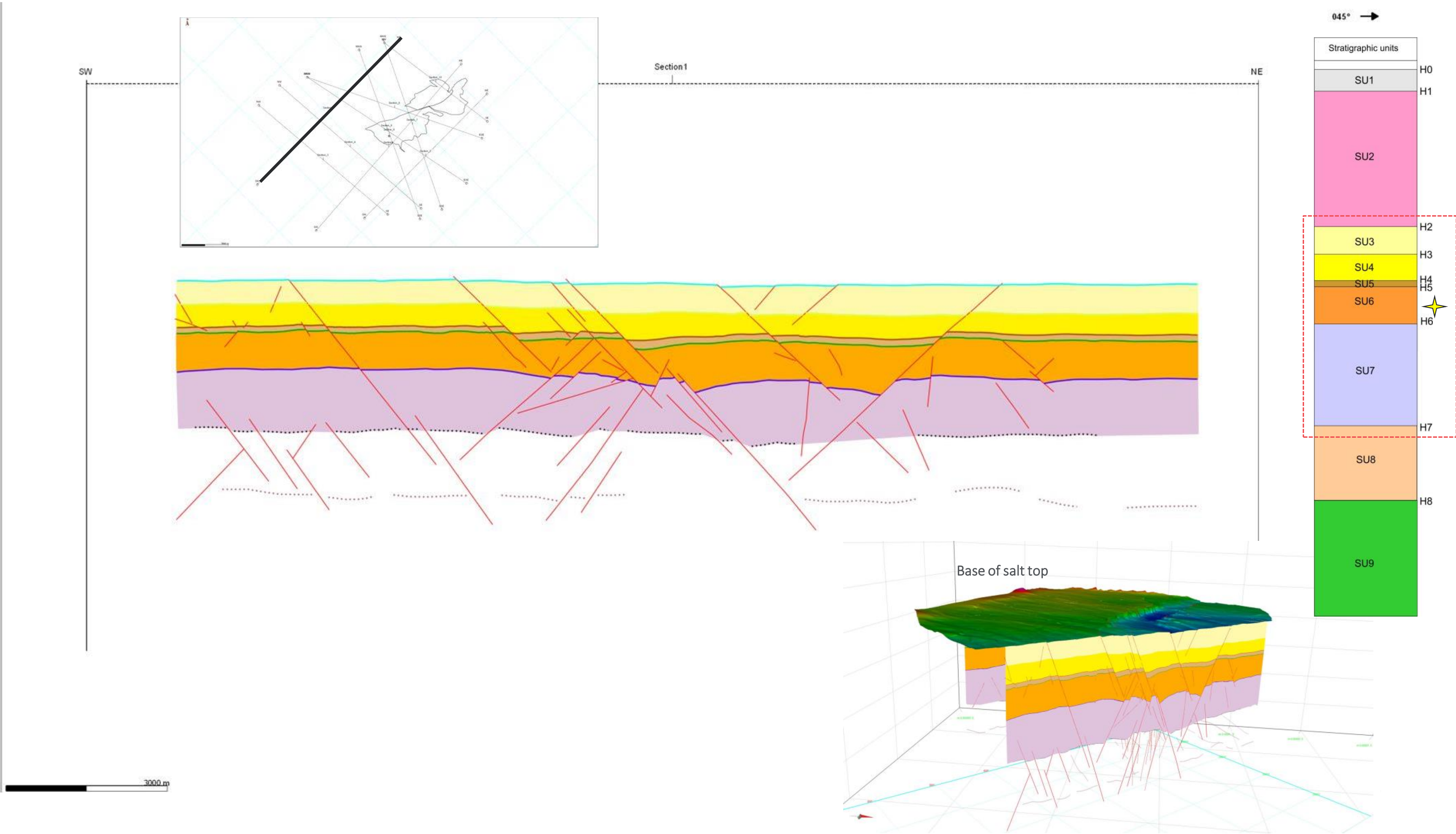




In the offshore Karish area the pattern of faulting suggests spatial and temporal variations

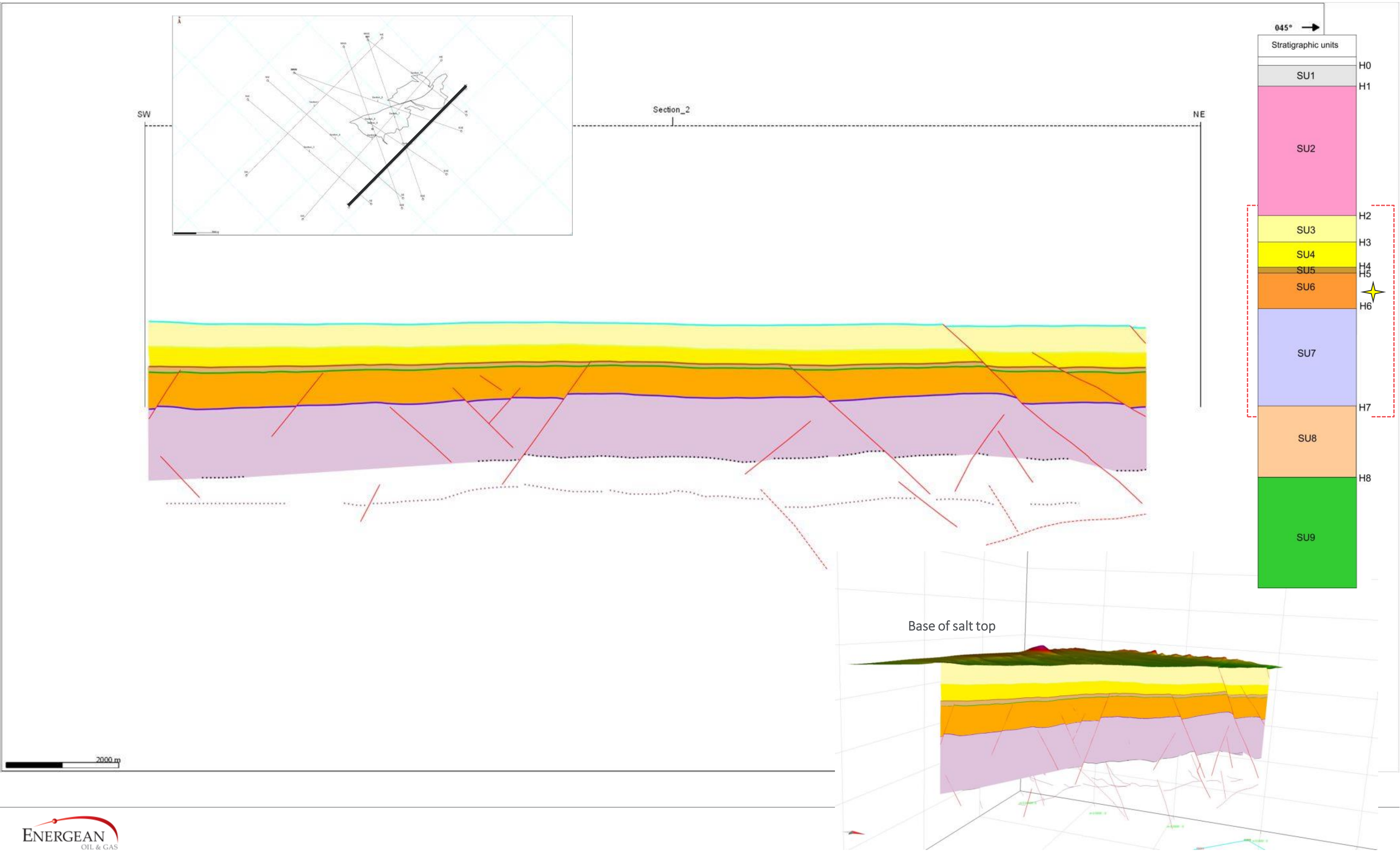
Three regions can be identified:

1. The northern and eastern region with NW-SE faults cutting through the Late Miocene strata (yellow)
2. The southern region with NW-SE and E-W faults that are sealed by Serravalian and Tortonian strata (brown)
3. The central with ENE-WSW & ESE – WNW faults that cut through the Late Miocene strata (red)

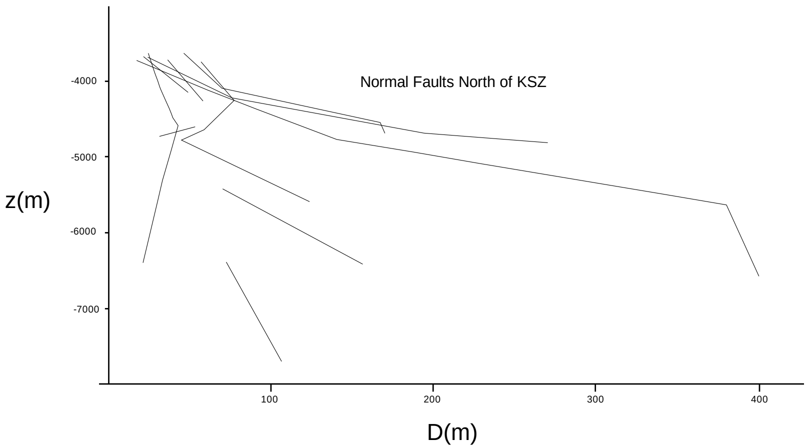
# NW-SE trending Normal Faults

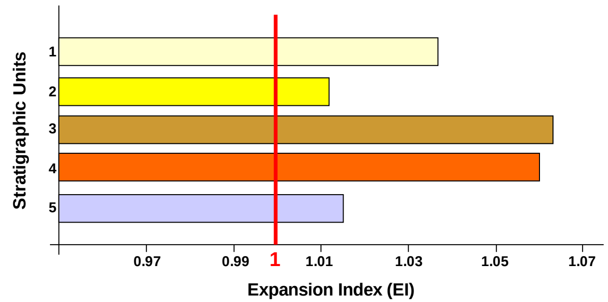


# NW-SE trending Normal Faults

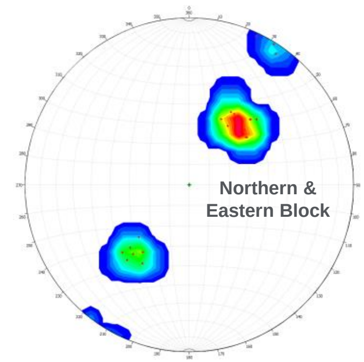


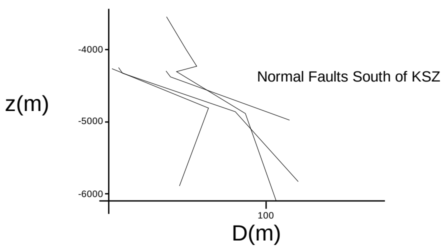
# NW-SE trending Normal Faults

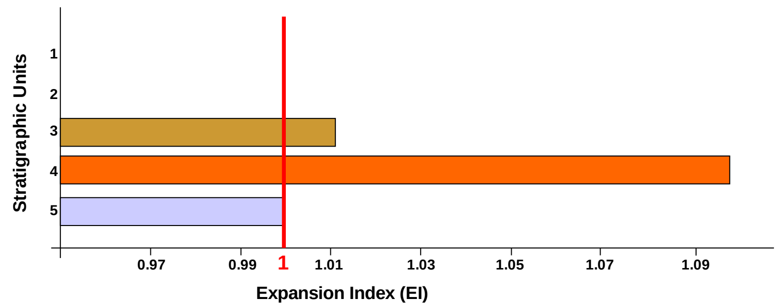


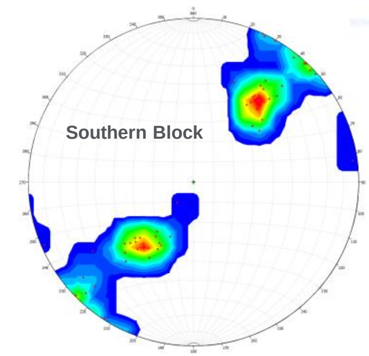

Northern Block



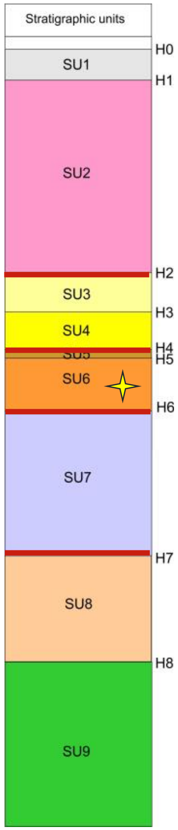



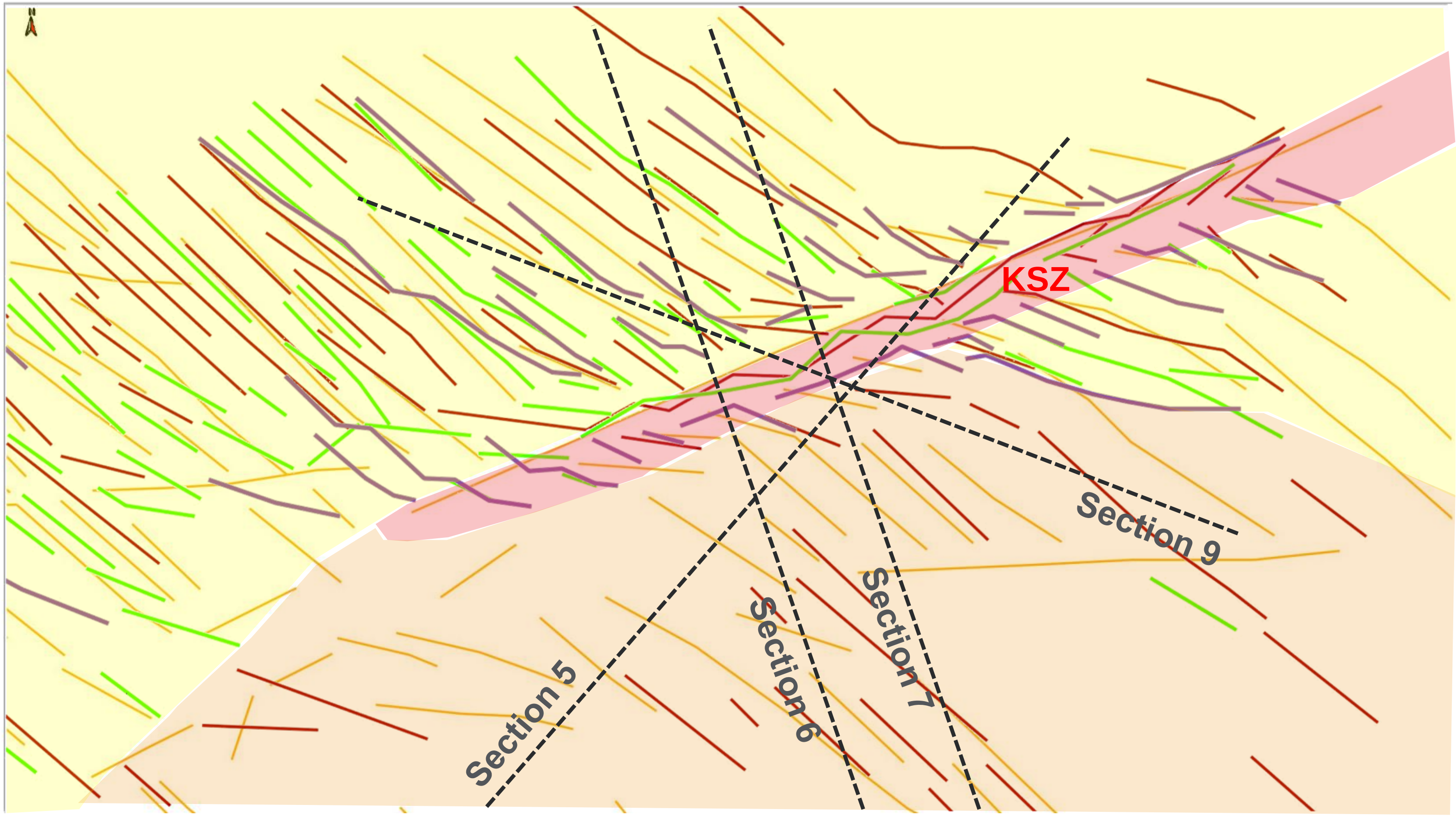

Southern Block

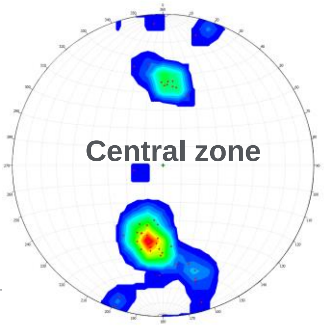



- The NW-trending **conjugate normal faults** are confined within the Eocene-Miocene sedimentary units (layer bounded faults?) dying out at depth at the ?Senonian strata
- The faults of the southern block are sealed by the Middle Miocene unconformity while the faults in the northern block cut shallower through the base of salt horizon
- All faults (to the northern and to the southern block) show increasing displacement with depth (we measured only the Miocene horizons)
- The faults are **syn-sedimentary with growth strata**. Expansion indices plots show increased growth during Early Miocene (mainly Late Vourdigalian)
- The faults **dip between 45° and 60°** and have horizontal intersections in both southern and northern blocks
- All faults have typically **4– 6 km length**
- Conjugate and en echelon faults are usually segmented forming soft and hard relay bends

# Tectonic Map

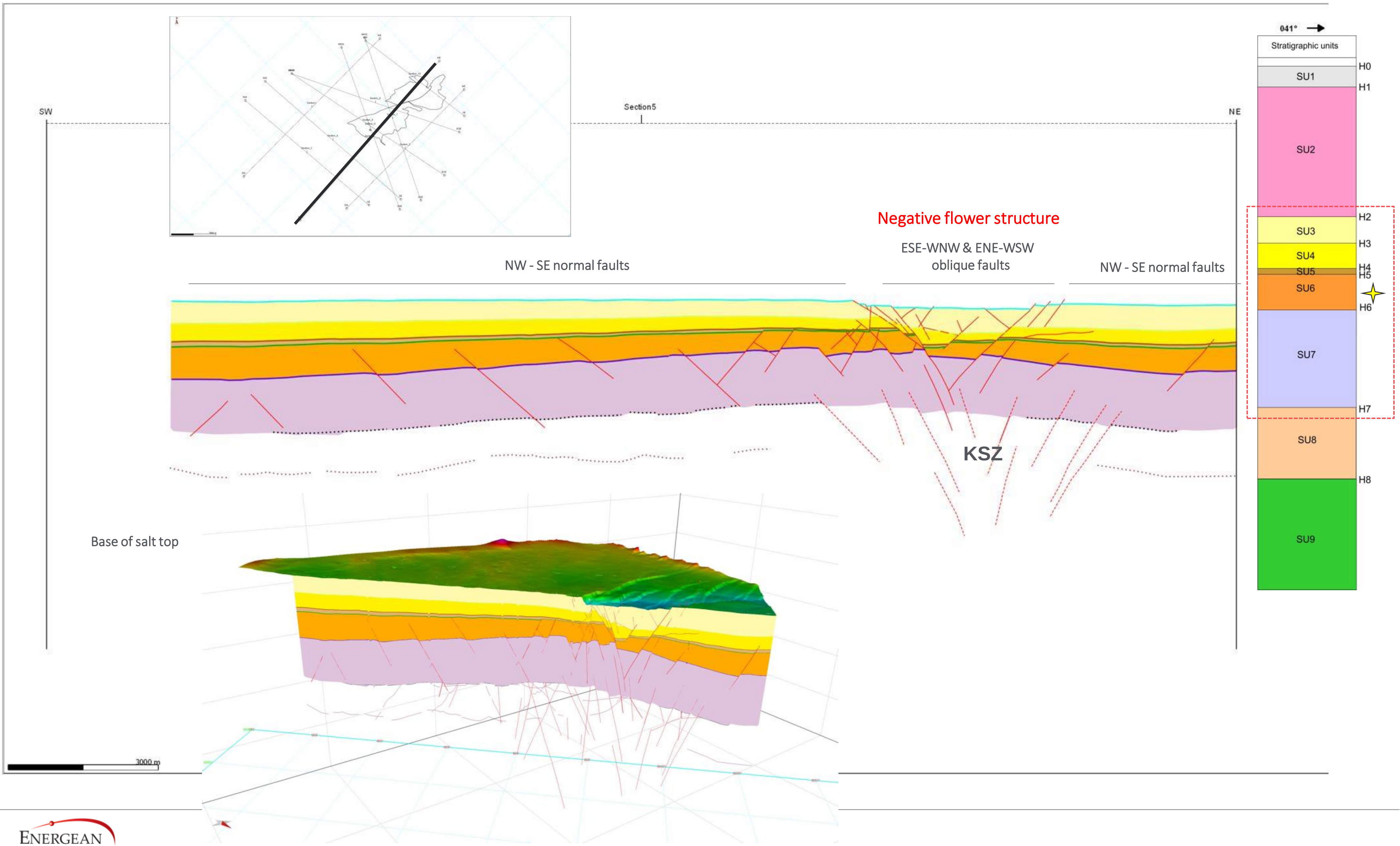



- The KSZ contains a series of en echelon conjugate ESE – WNW and ENE-WSW faults
- The faults dip at intermediate to high angle
- They represent R- & P- shears (of oblique-slip?) linking the NW-SE trending normal faults of the northern and southern part

# The Karish Shear Zone



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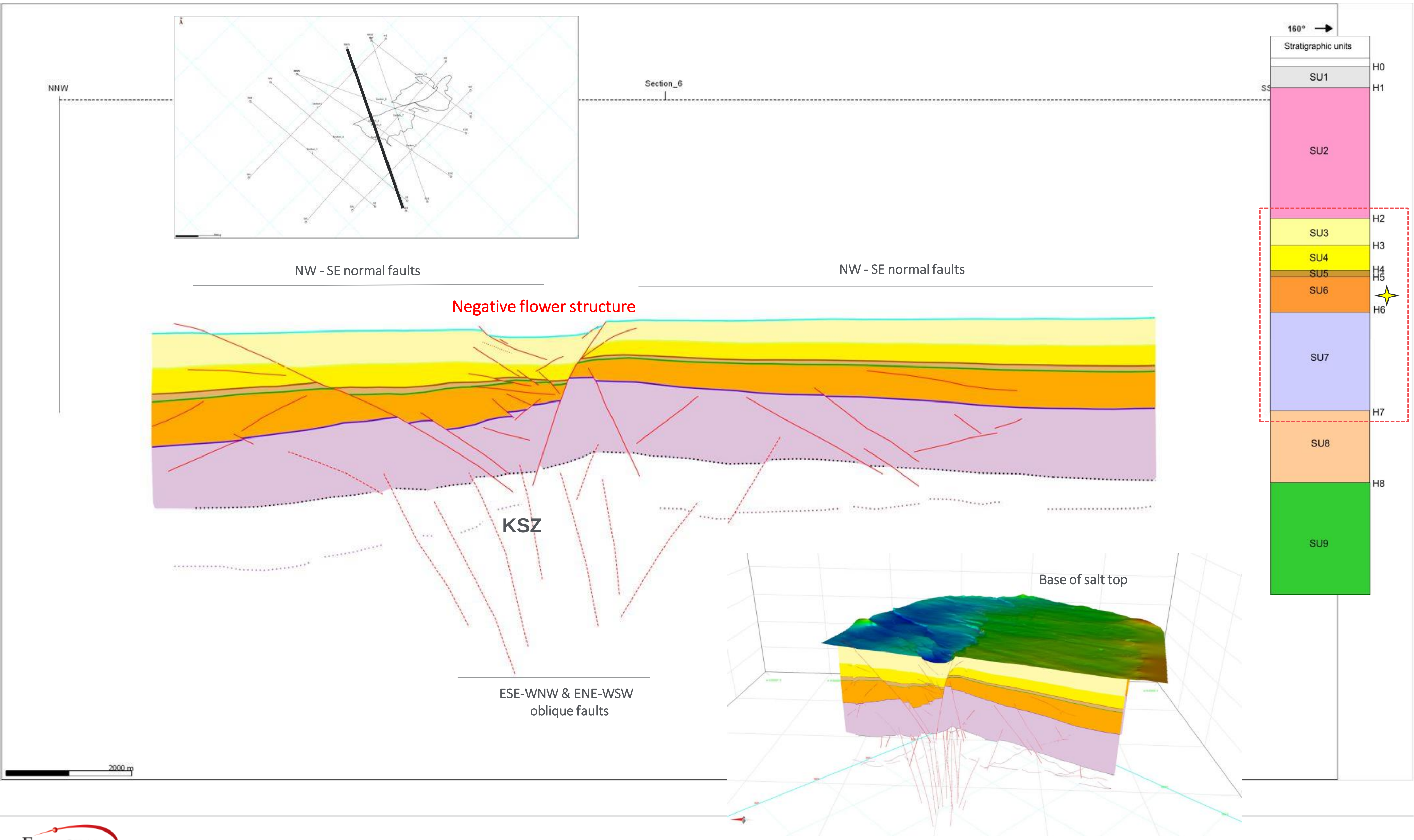


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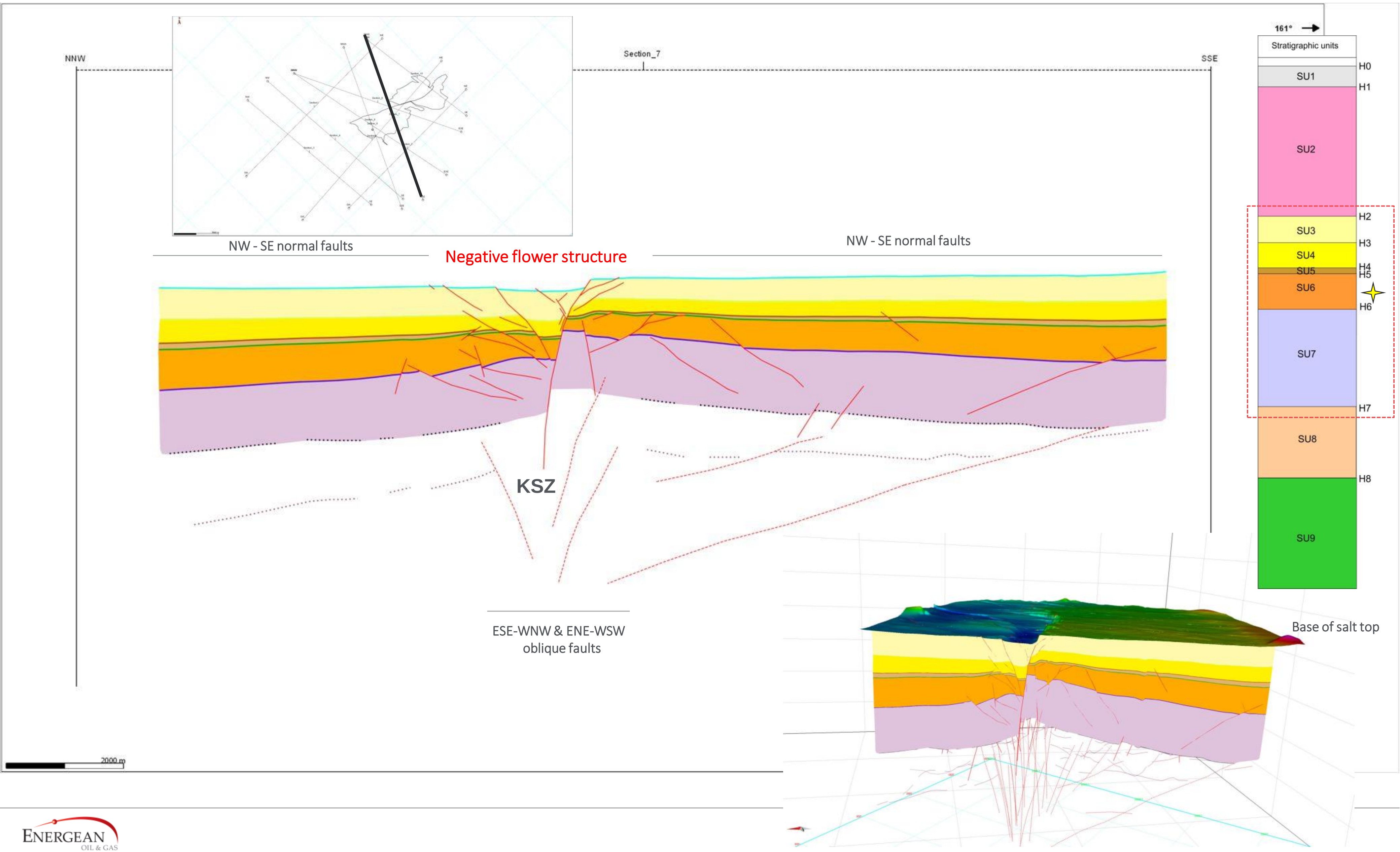
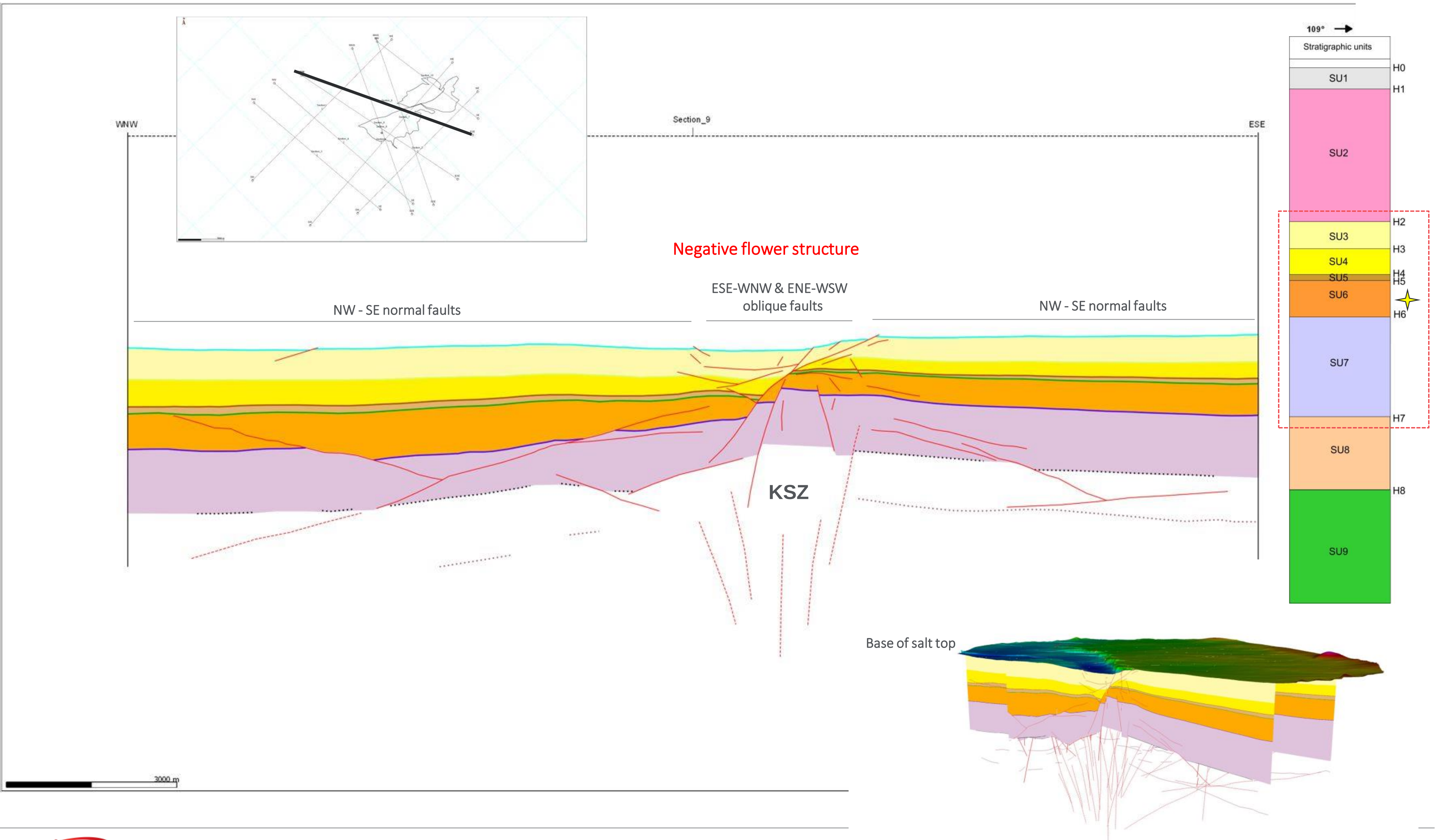
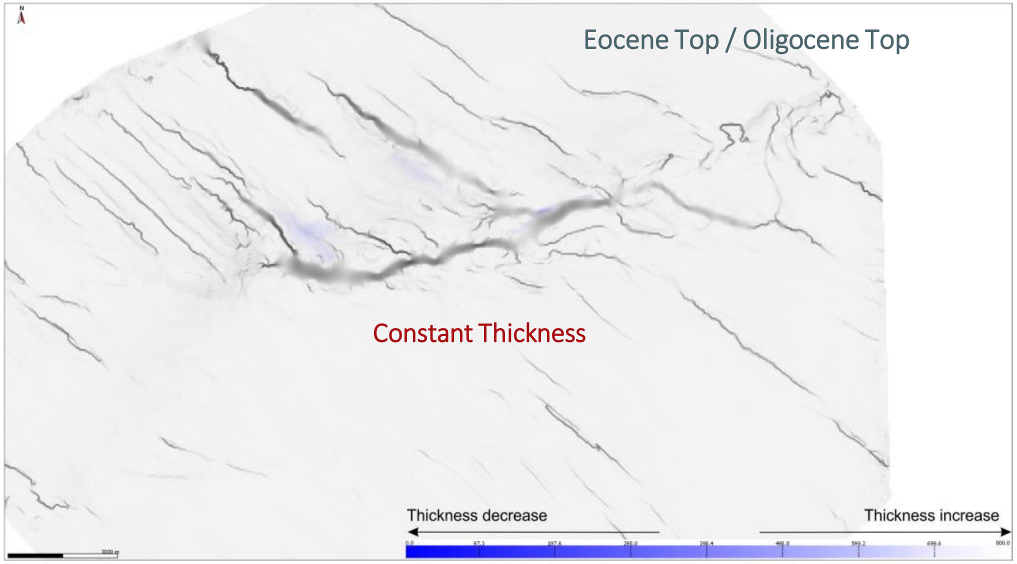
# The Karish Shear Zone

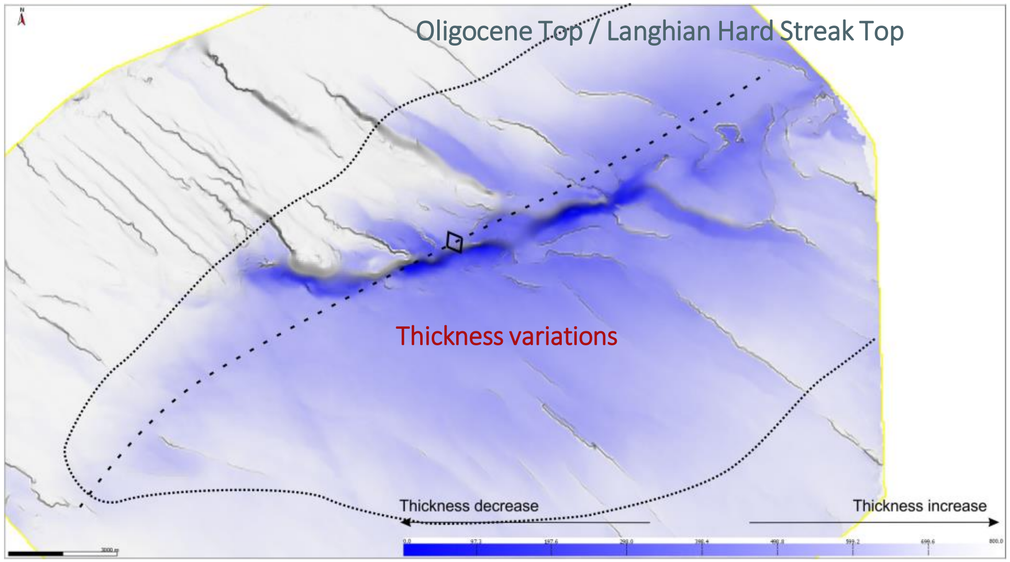


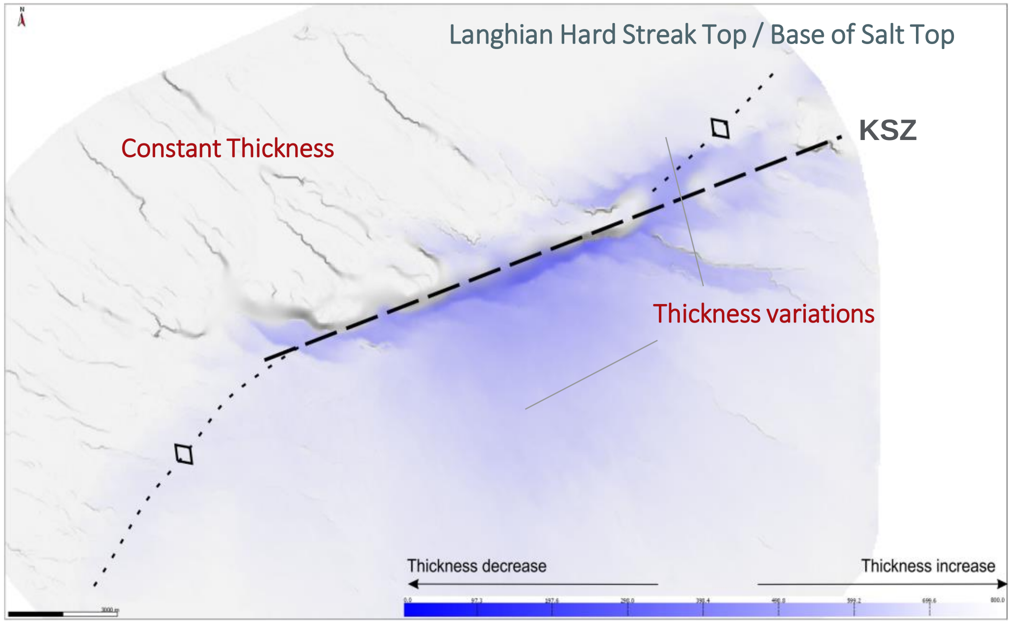
# The Karish Shear Zone



# Isopach maps



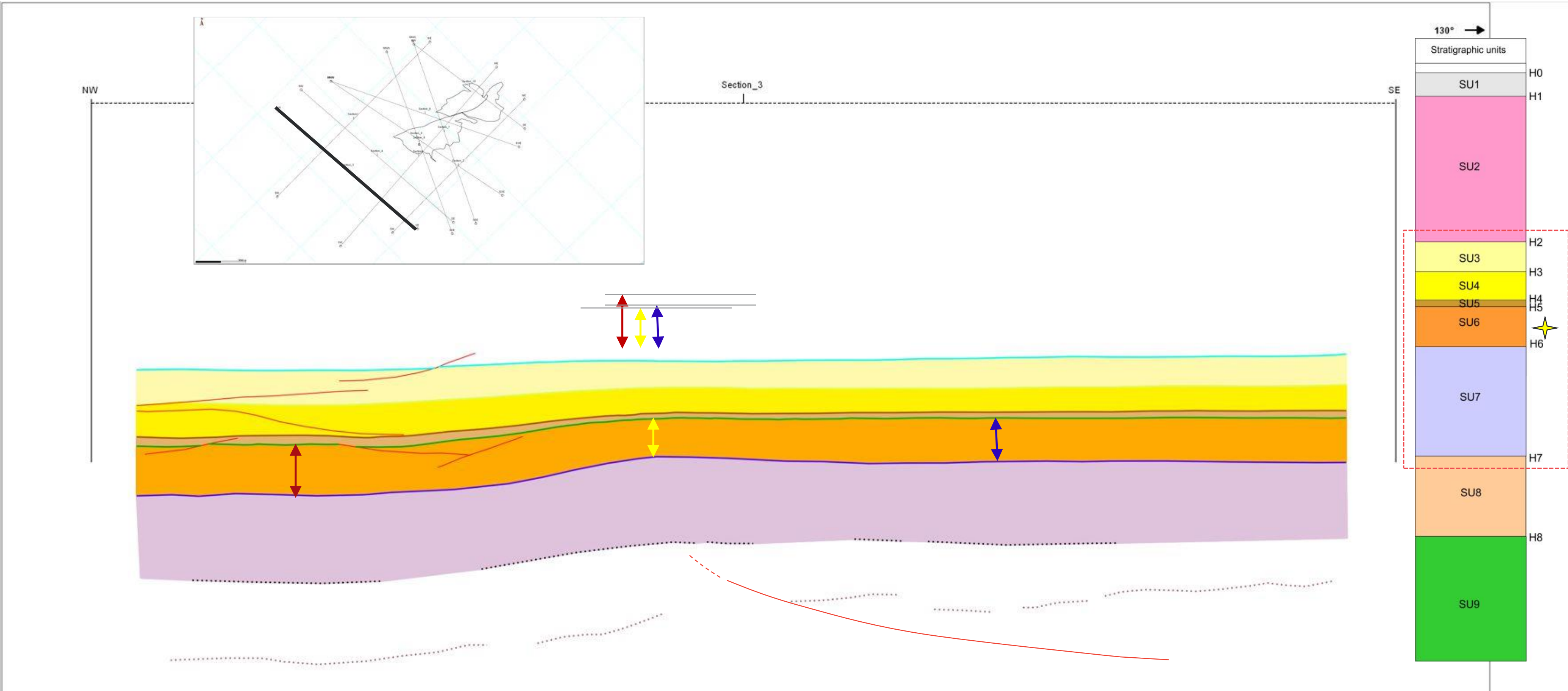

**Early Miocene (mainly Late Vourdigalian)**

- The observed syn-depositional thickness variations of the Early Miocene strata points out to the presence of an asymmetric NE-SW trending monoclinal fold.
- The thickness of the Tamar sands decreases along the fold's crest and increases towards the NW

**Late Miocene**

- The observed syn-depositional thickness are restricted to the south and are absent or very limited north of KSZ

# NE-SW trending Fold

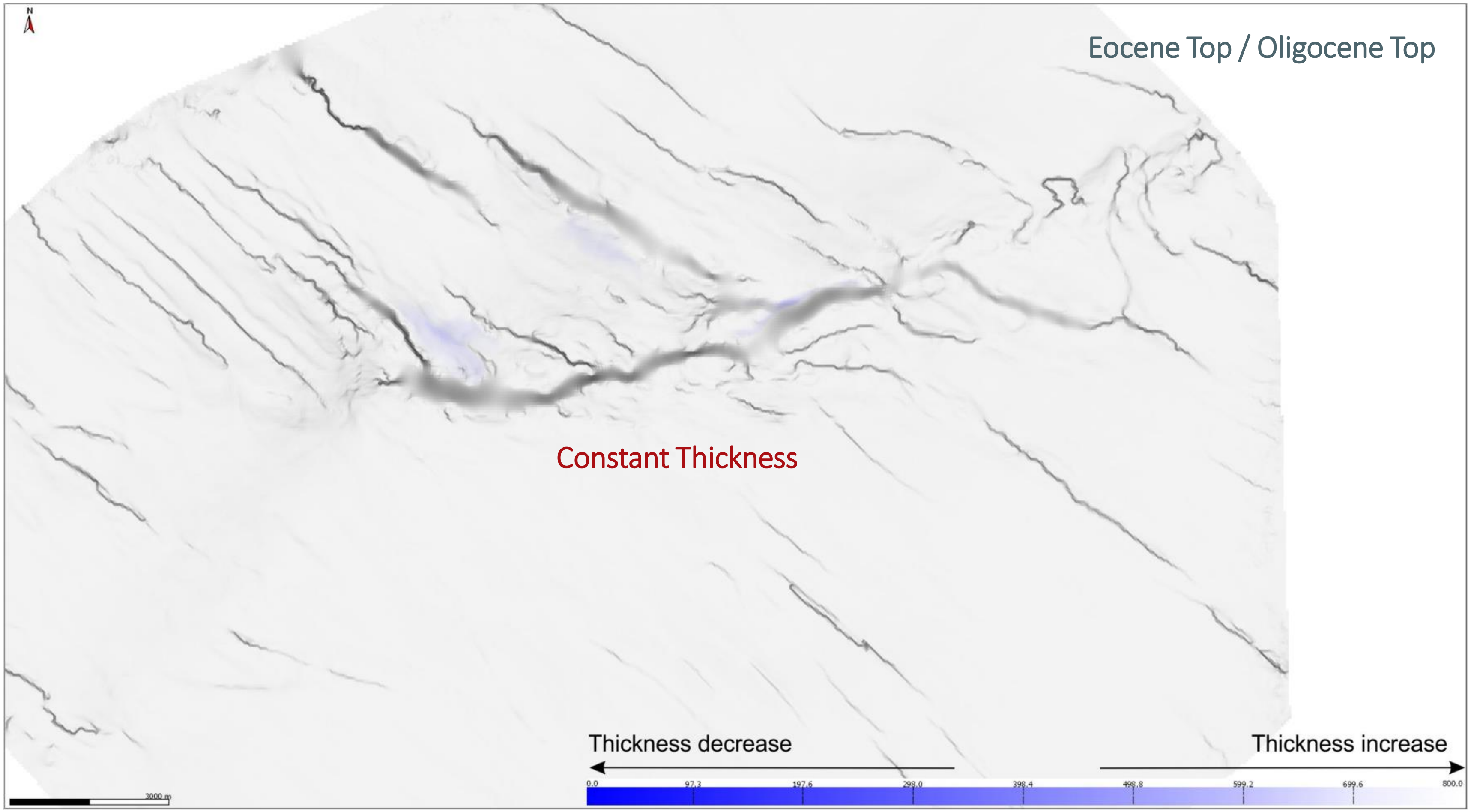



- Thickness variations along the NE-SW trending monoclinal fold.
- Structural style from seismic lines suggests thin-skinned detachment folding.

2000 m

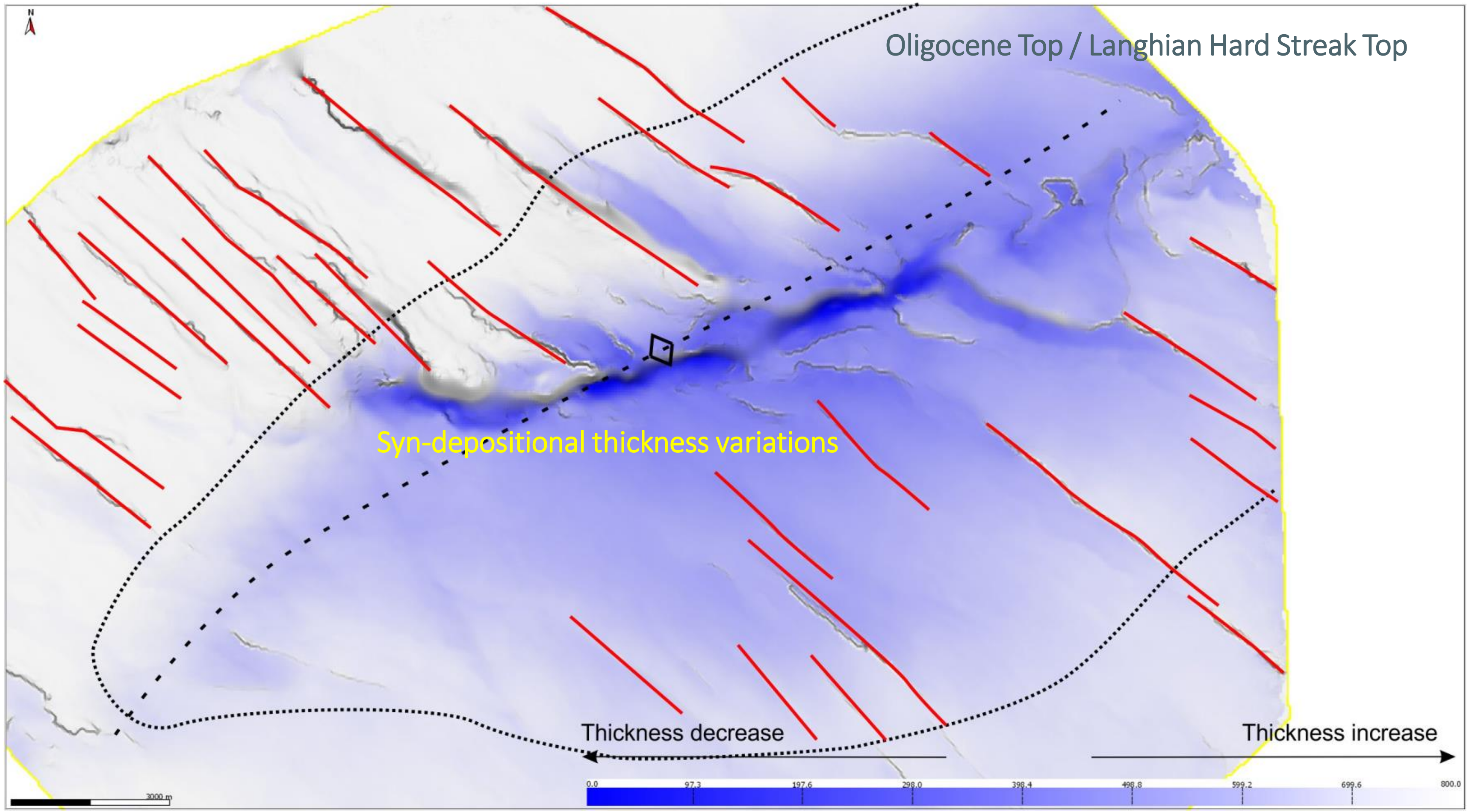
# Synthesis

**Oligocene:** Tectonic quiescence



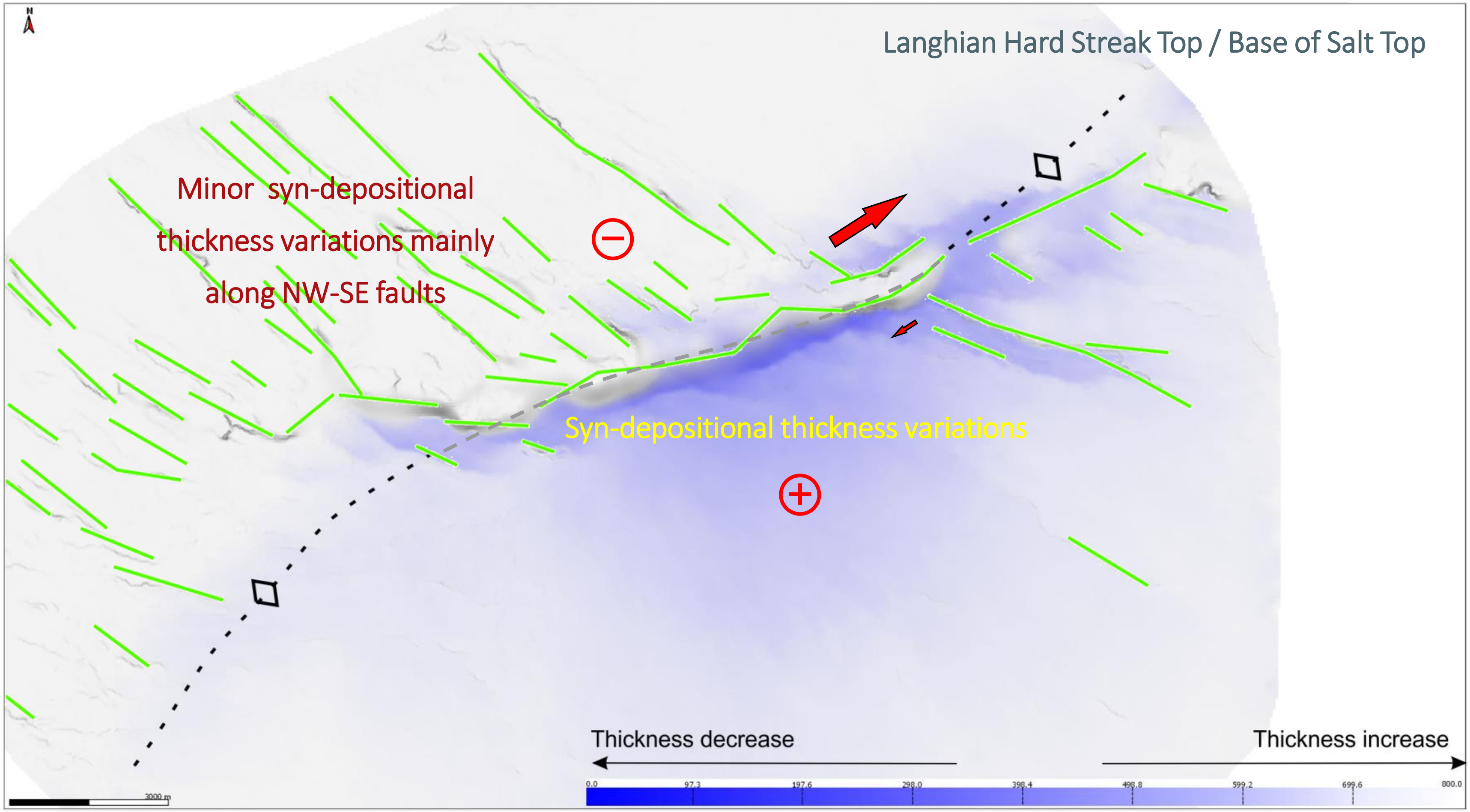
# Synthesis

**Early Miocene (mainly Late Vourdigalian):** Convergent tectonic setting (detachment folding and formation of the NE-SW monoclinal fold, coeval formation of NW-SE layer-bounded conjugate normal faults)



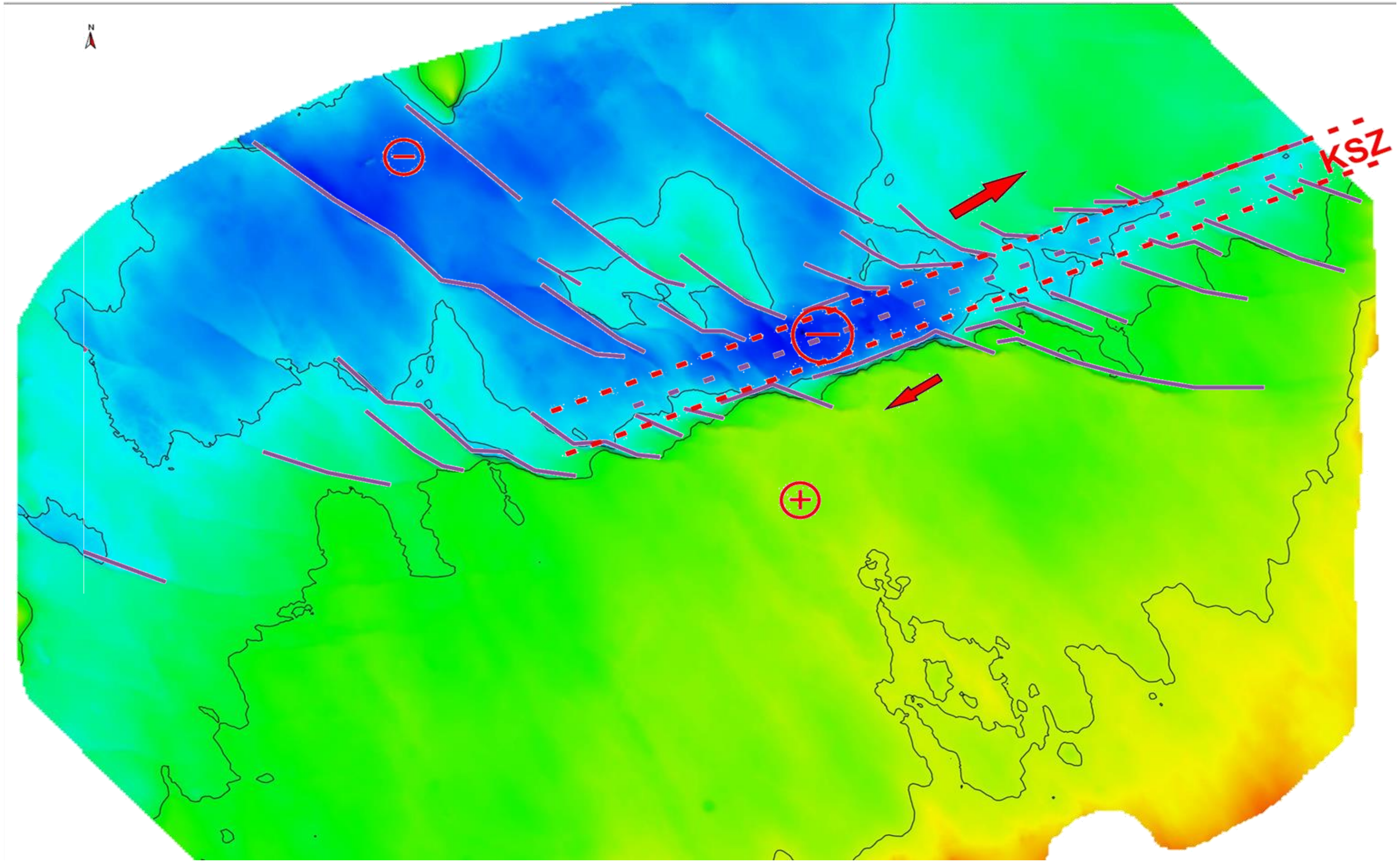
# Synthesis

**Middle Miocene:** Strike slip tectonic setting (initiation of the KSZ along the NE-SW fold, disconnection of faulting north and south of the KSZ)



# Synthesis

**Late Miocene:** Strike slip tectonic setting (Maturation of the KSZ and development of a dextral transtensional zone)




Base of Salt Top

# Conclusions



- The Karish Shear Zone disconnected the southern from the northern region during Middle – Late Miocene and resulted in the prevention of lateral and vertical gas migration.
- Faults along and close to the “Karish complex” show a polyphase tectonic evolution throughout the Miocene. The geometries and lateral extent of the fault blocks assisted in the optimization of the well design.
- Subsequent fault seal analysis show that the intra-reservoir faults are likely to be in communication.

**Future work**

- Necessity for quantifying the deformation using innovative structural modelling methods (e.g. sequential kinematic modelling and structural restorations).
- Necessity for forward and inverse modelling for extrapolating interpretations at areas of poor seismic quality (near the KSZ shadow zone), enhancing optimisation of gas production.

**References**

https://www.energean.com/media/2078/energean-karish-and-tanin-field-development-plan-web-version.pdf

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Thank you!