Mega-Scale Swells and Diapirs in the Deep Levant Basin, Eastern Mediterranean, and their Association with Recent World-Class Gas Discoveries*

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Abstract

The recent gas discoveries in Oligo-Miocene sand layers in the deep Levant Basin are trapped in Miocene age fold structures. Most of these structures are cored by swells and diapirs of unknown lithologies. None of these diapirs were penetrated so far in any of the wells. Three possible lithologies can be inferred comprising these intrusions: Magmatic (or volcanic) intrusions, salt upwelling, or mud diapirism, all must have been elevated from the deep-lying Early Mesozoic strata or below.

Magmatic intrusions can be rejected on the basis of the magnetic data; only one, the Jonah Structure, is associated with positive magnetic anomaly. Salt might have been deposited during the rifting stage (Triassic and Early Jurassic). Salt deposits of these ages are known from the distal Arabian Craton, though sulphate deposits are known onshore Israel. Mud diapirism is suggested to be the most likely cause. Fine-grained clastics dominate the Late Jurassic and Early Cretaceous sections penetrated in boreholes in the studied area.

The history of the Levant Margin and Basin can be summarized by the following four major phases: (1) Early Mesozoic rifting, (2) Middle Jurassic to Late Cretaceous passive margin, and (3) Late Cretaceous to Early Cenozoic contraction; this phase is associated with the Syrian Arc inverted structures, mapped onshore and throughout the shelf and slope of the basin, and (4) Tertiary to present sagging and filling of the Levant Basin with some 6,000 m of sediment. The Miocene structures in the deep basin differ from the Syrian arc structures not only by their age of folding but by several other parameters as well. Some of the deep-water structures are associated with severe disruption of the strata at their cores, sometimes piercing their way up through the Tertiary section. In most cases, they are not associated with older, Late Cretaceous or Early Cenozoic inverted structures; they are symmetrically folded unlike the Syrian Arc structures which are asymmetric. No reverse faults are observed at any level in the vicinity of these structures, they are dissected by normal faults of pre-Messinian age, and their amplitude is lower and their wave length is longer than the Syrian Arc structures.

It is thus suggested that the diapirism is caused by the gravitational instability of unconsolidated sediments during the fast subsidence of the basin since Early Tertiary. As the folding ceased prior to the Messinian, it is assumed that the intrusive material reached a state of equilibrium during the Late Miocene. Mud diapirs are known in other basins that experience plate collision and fast subsidence, such as the South Caspian Sea and the Caribbean forearc basin. The possible role of diapirism in the hydrocarbon charging of the sandstone reservoirs trapped in the Miocene structures is not yet clear.

Selected References

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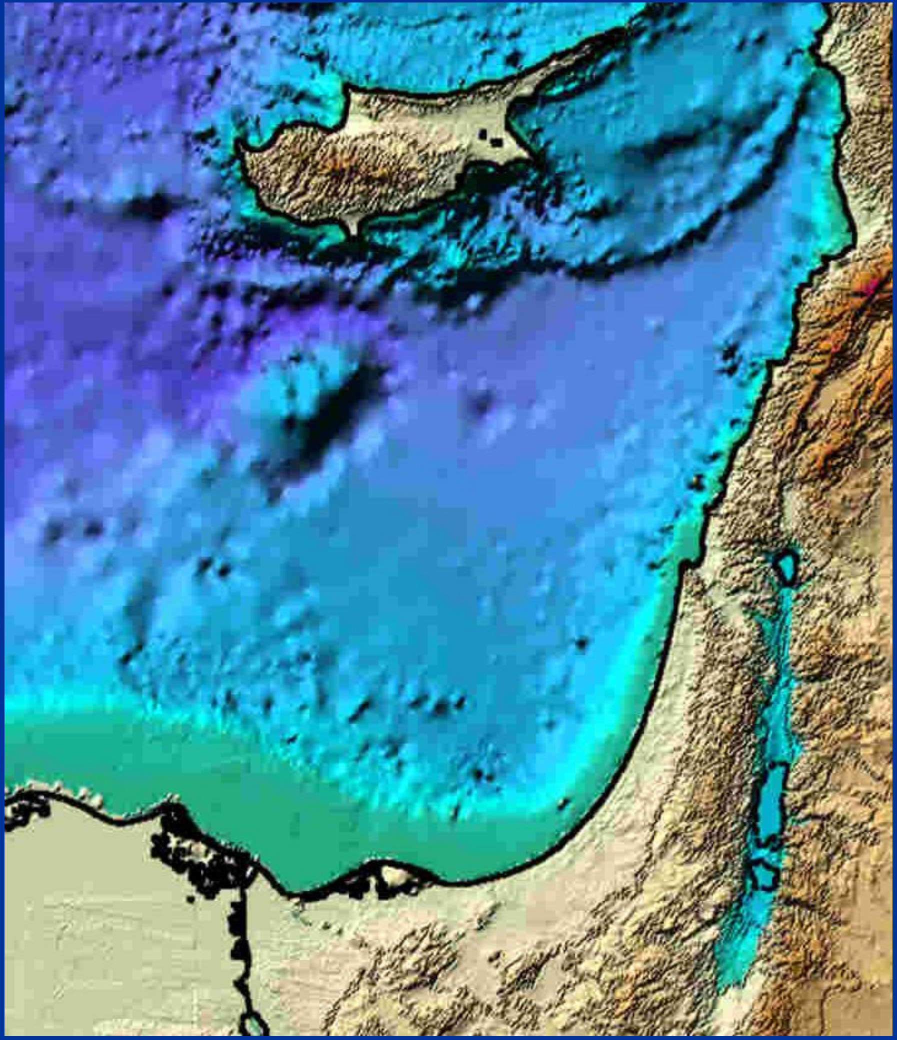

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ILDC Energy

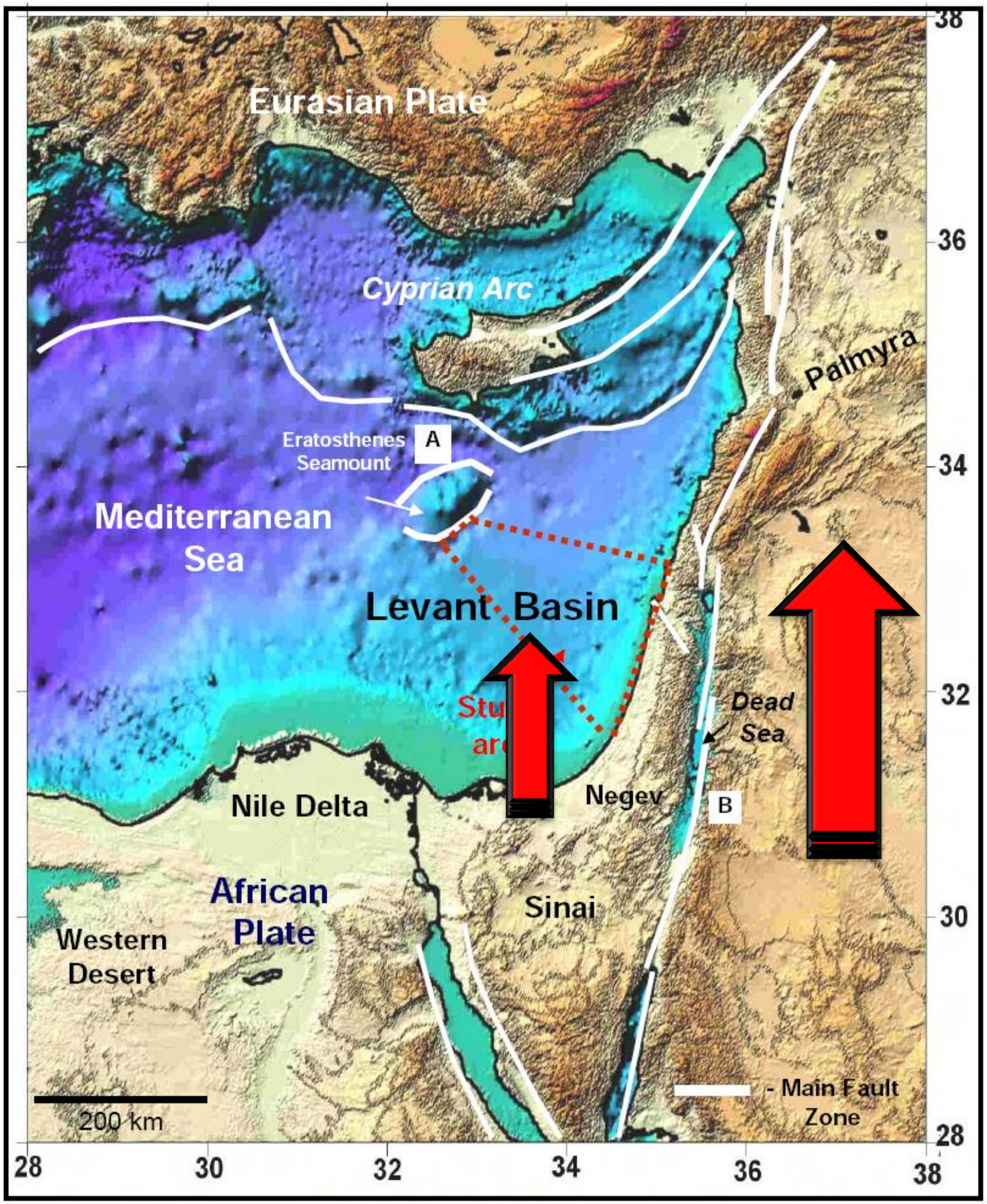
Yehezkel Druckman

Eden Energy Discoveries

April 2013

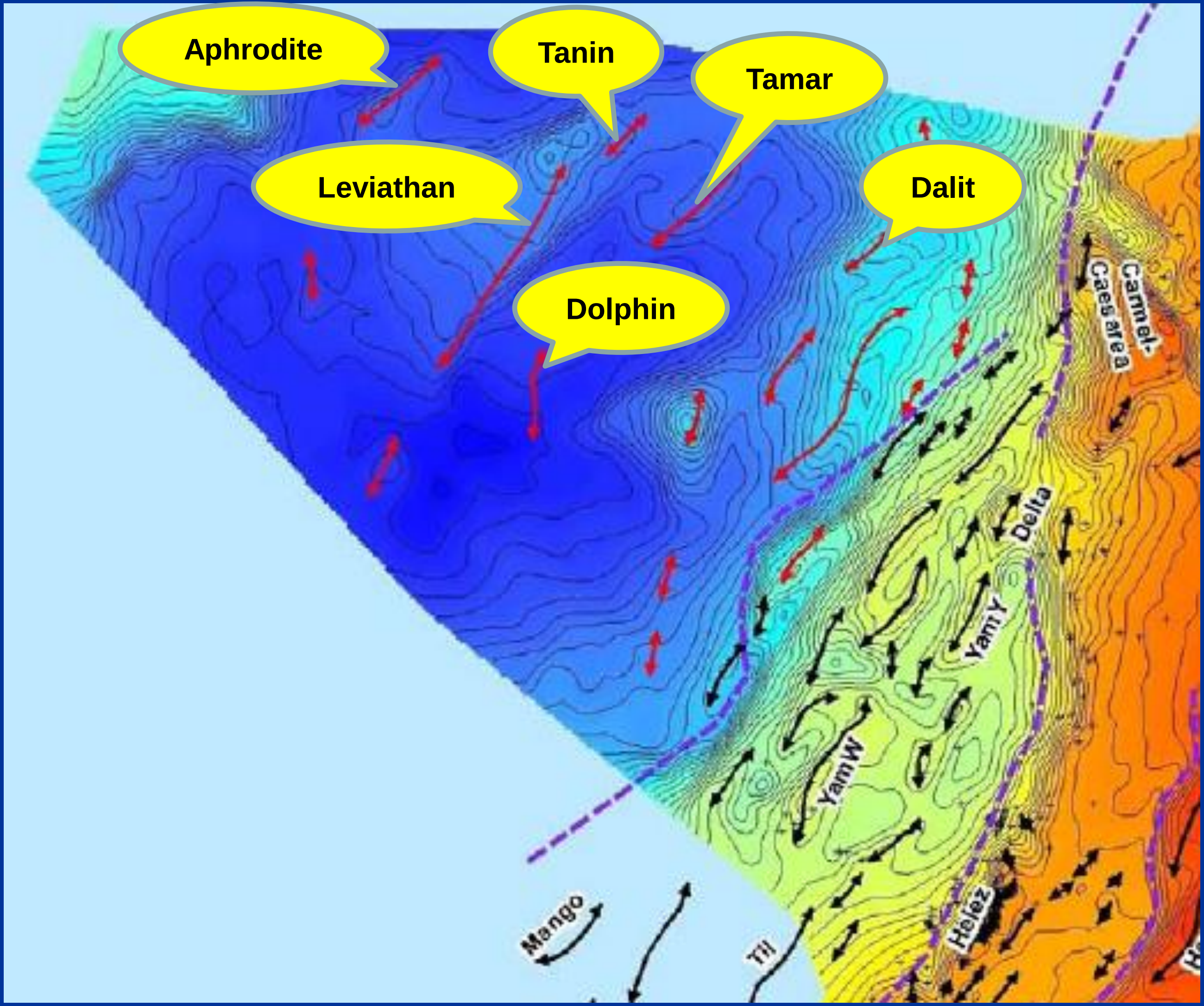
The setting of the Levant Basin

from Gardosh et al. 2008



Current Gas Discoveries in the Levant Basin

(total of ~ 30 Tcf)



Two phases of folding (=contraction) were observed in the Levant Basin:

- **Syrian Arc I** fold belt, of Senonian age confined to the onshore, shelf and slope.
- **Syrian Arc II** fold structures of Miocene age, confined to the deep basin only.

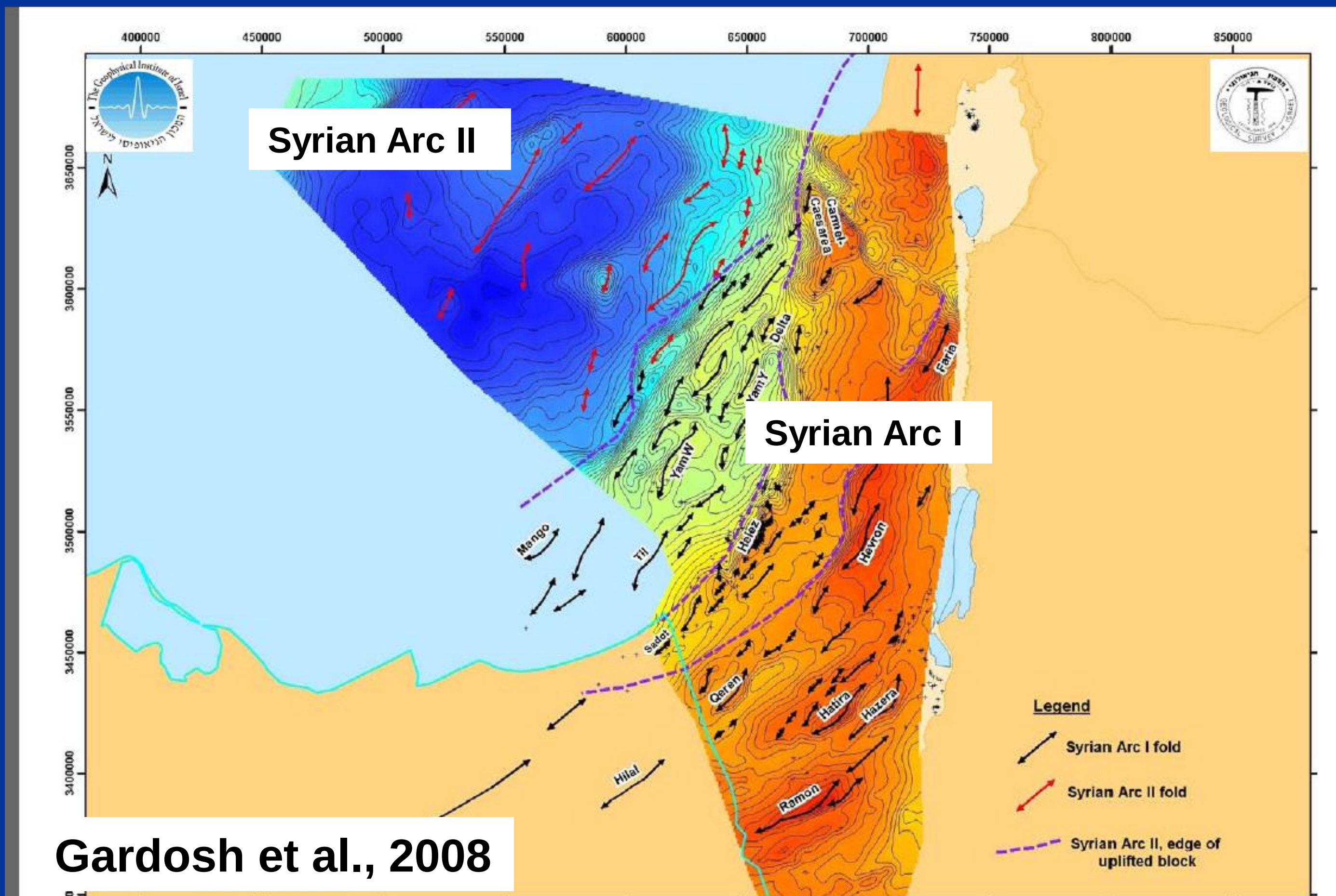
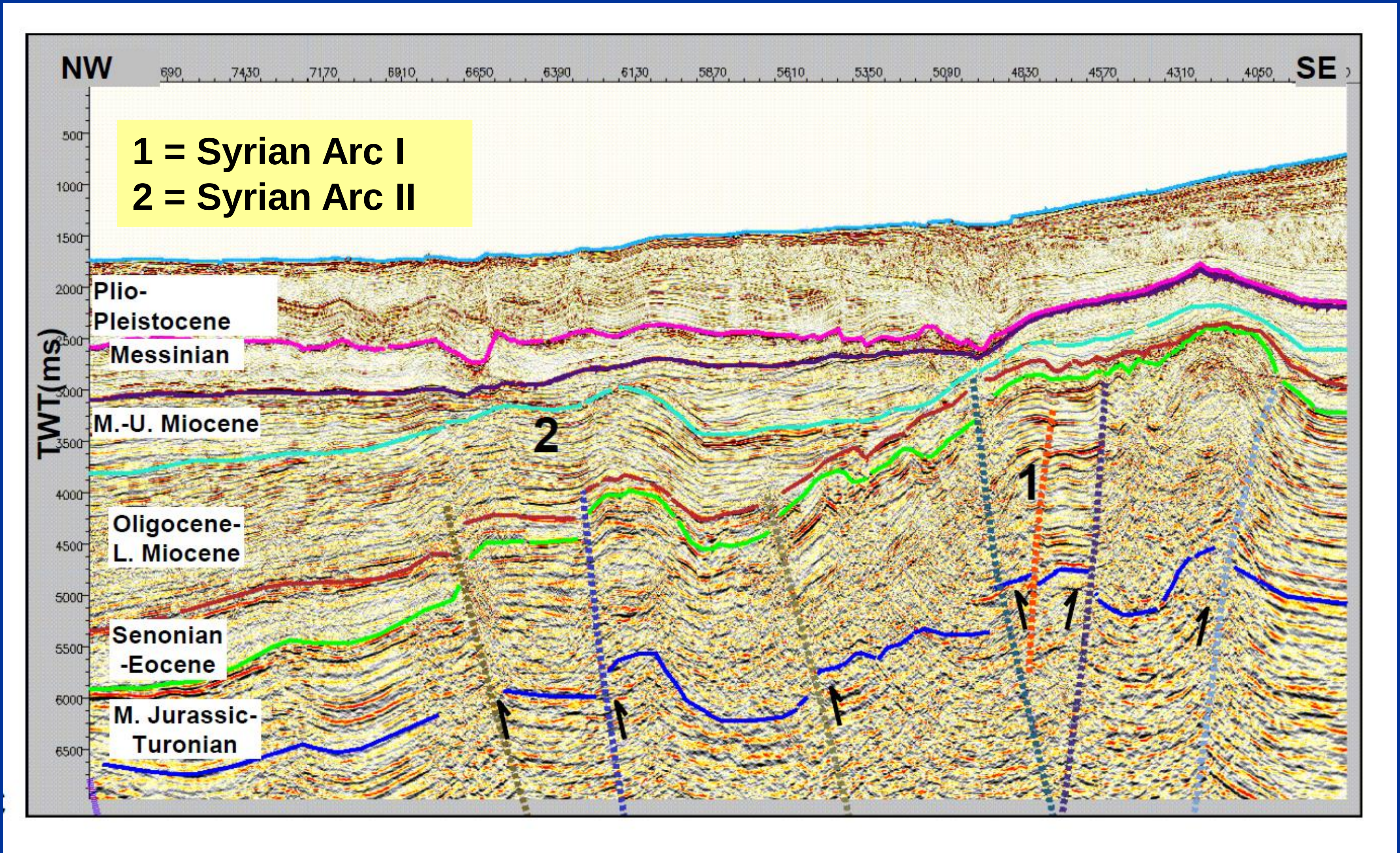


Fig 7.4 – Convergence stage, Syrian Arc fold structures of the Levant. A regional depth map of the Middle Cretaceous level, showing two types of Syrian Arc folds. The grid is constructed from the 'Top Judea' map of Fleischer and Gavso (2003)

The Hypothesis (Gardosh et al., 2008):

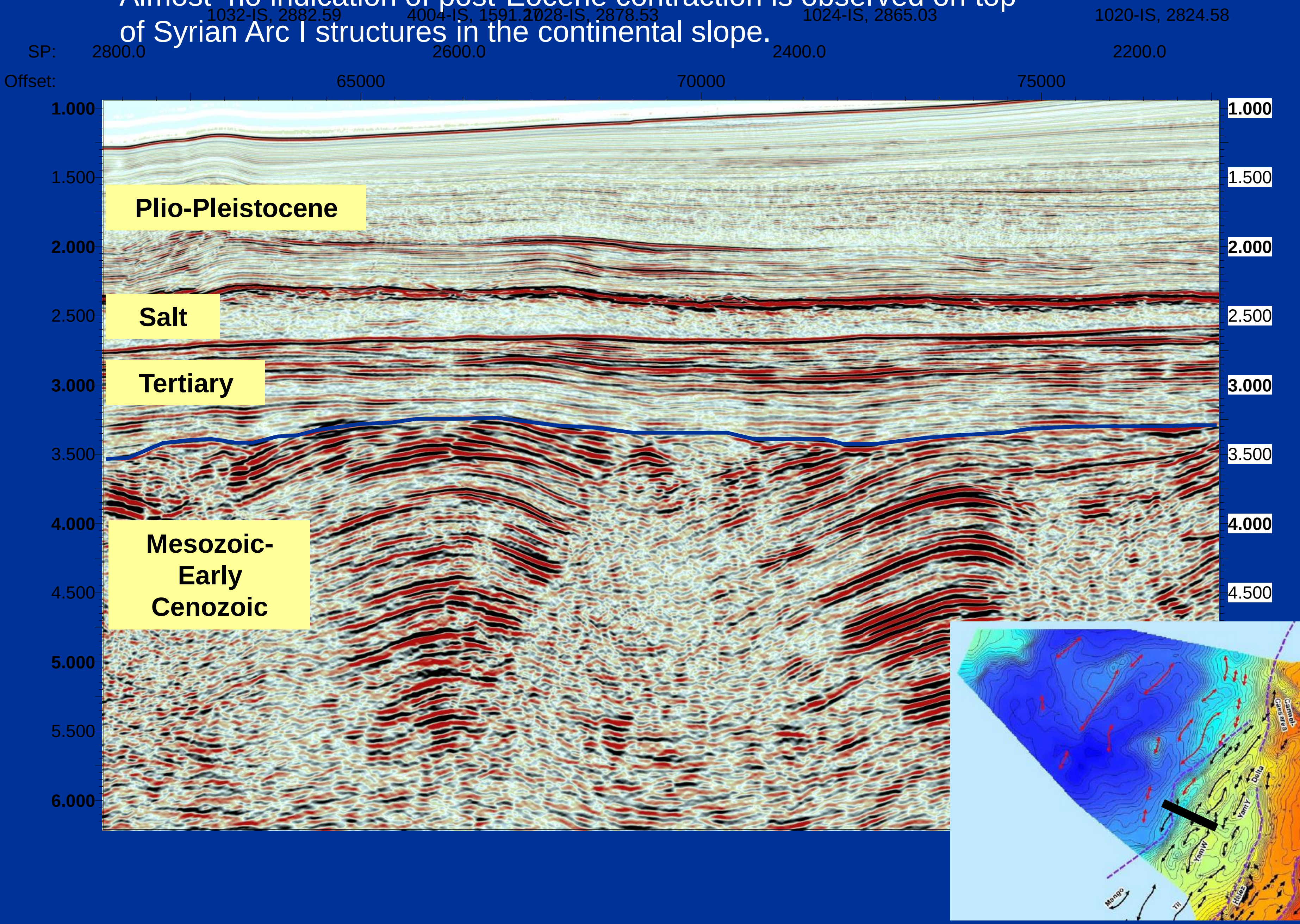
Syrian Arc II contractional deformation is superimposed on the older Syrian Arc I structures (rejuvenation).

The Observation:



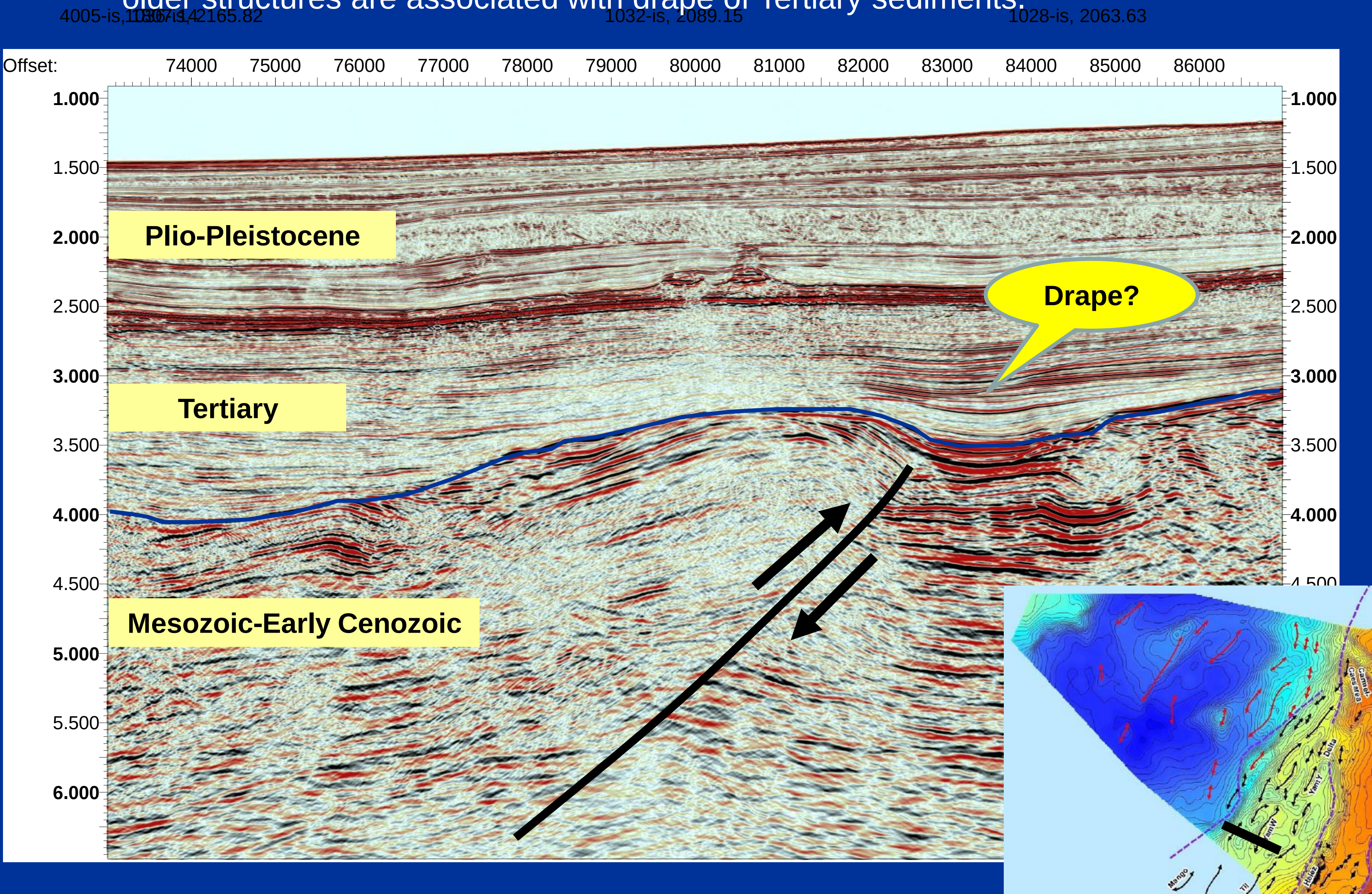
The Counter Observation:

Almost no indication of post-Eocene contraction is observed on top of Syrian Arc I structures in the continental slope.



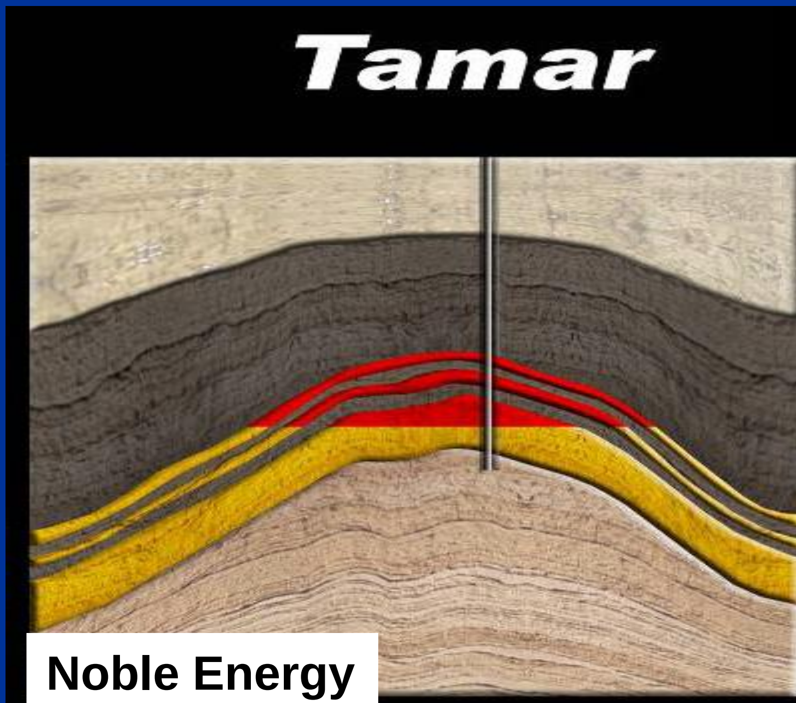
The Counter Observation:

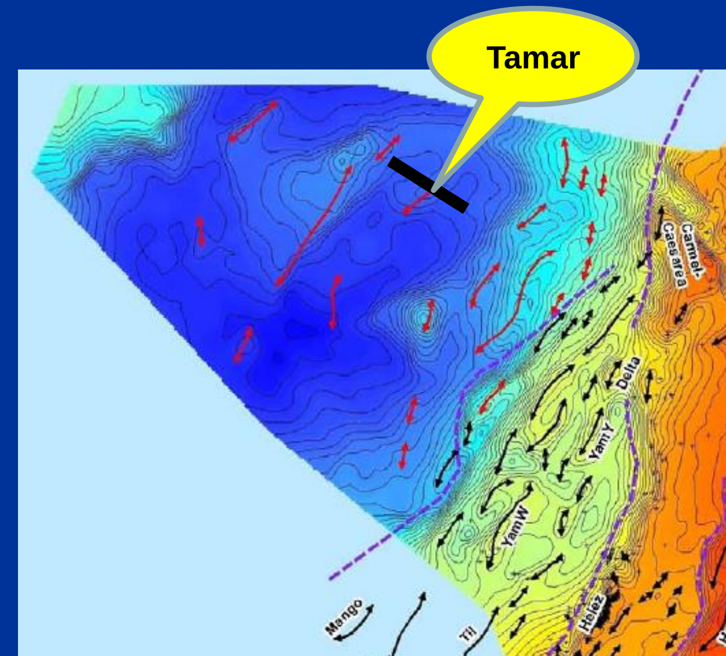
Almost no indication of post-Eocene contraction is observed on top of Syrian Arc I structures in the continental slope. In some cases the older structures are associated with drape of Tertiary sediments.



Miocene fold structures (Syrian Arc II):

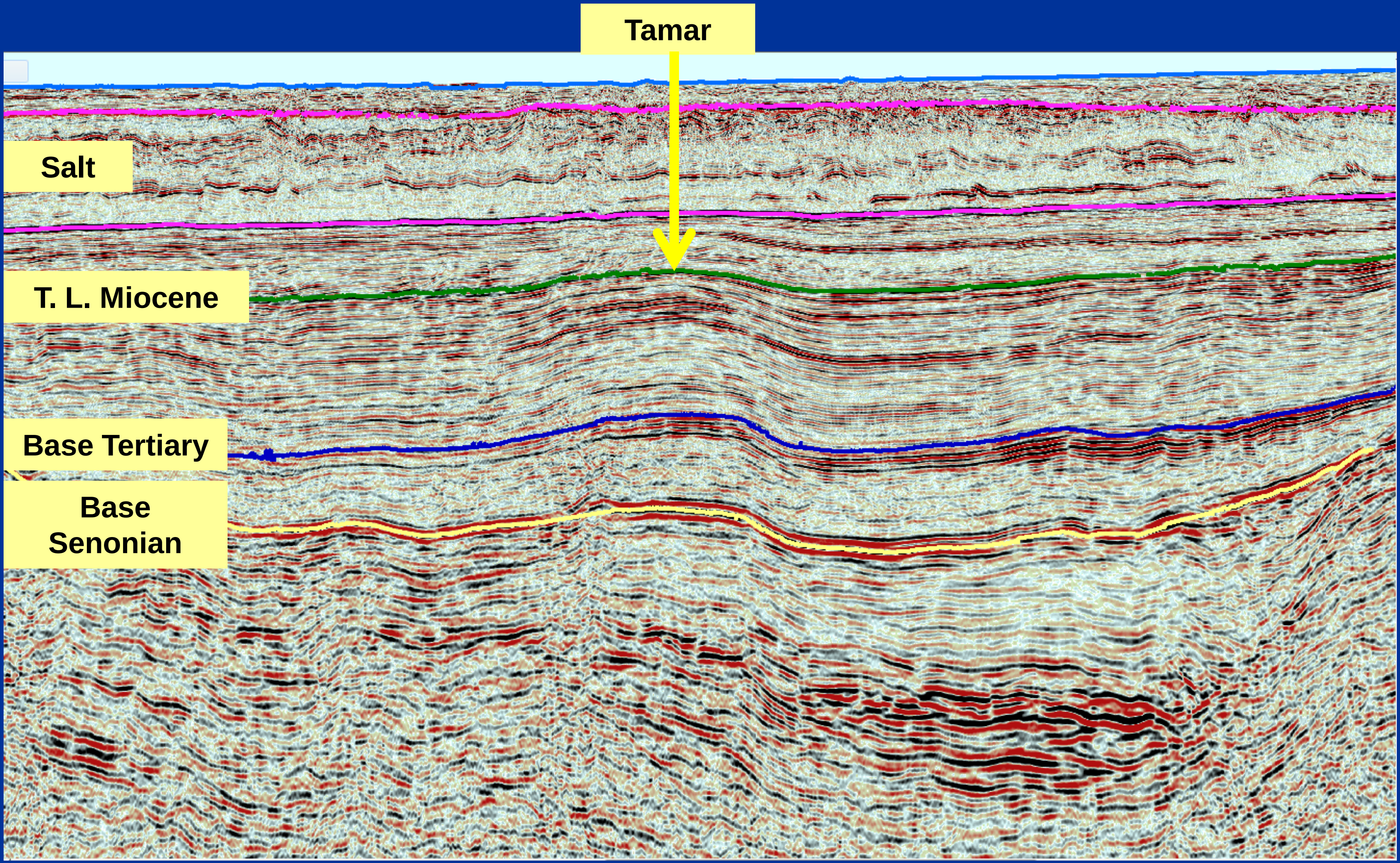
- Tamar is a **symmetrical** structure.
- **No reverse** fault observed.
- The structure is dissected by **normal** faults





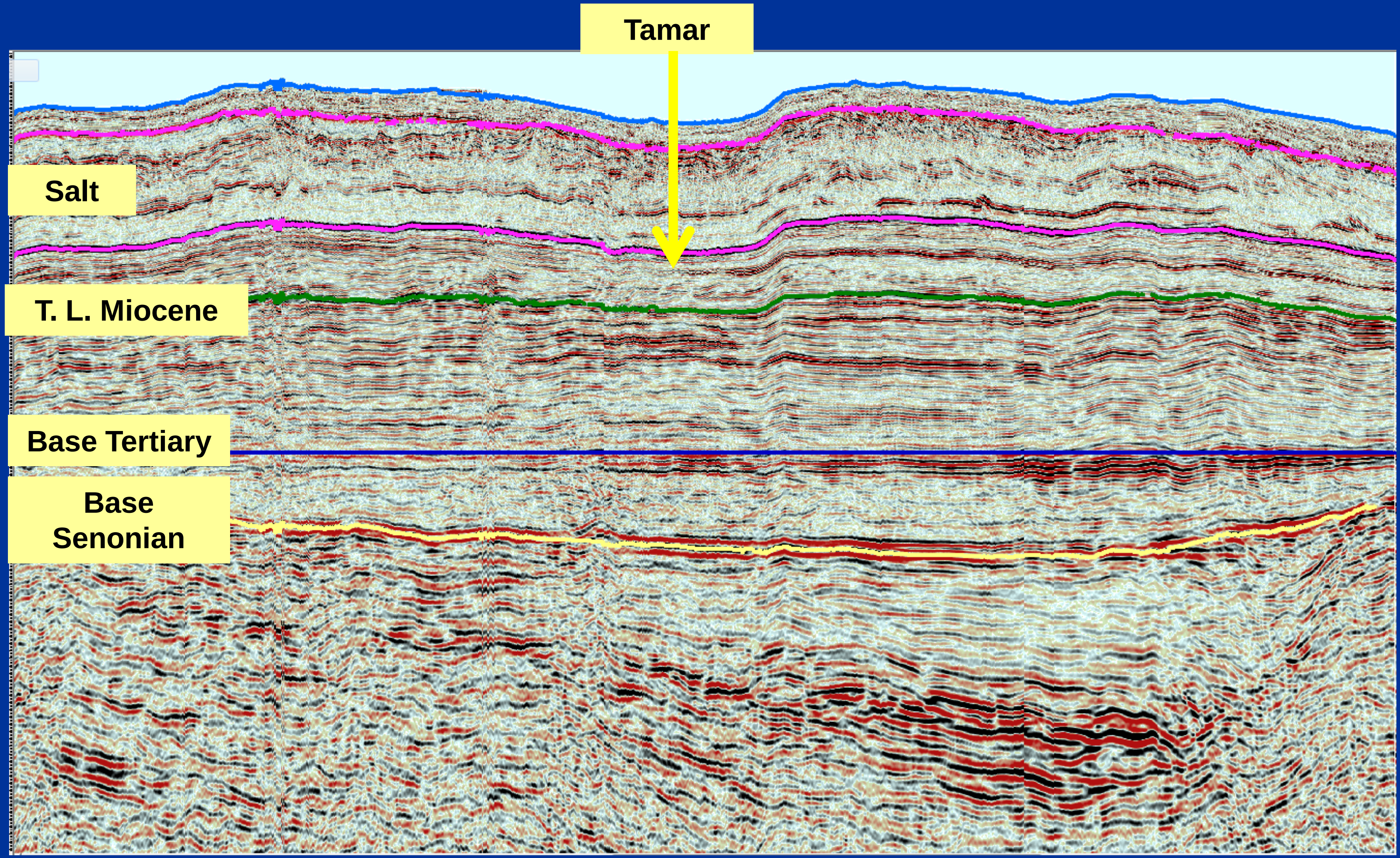
The Tamar Structure

Age is well determined by seismic and biostratigraphic control, assumed to be Middle Miocene.



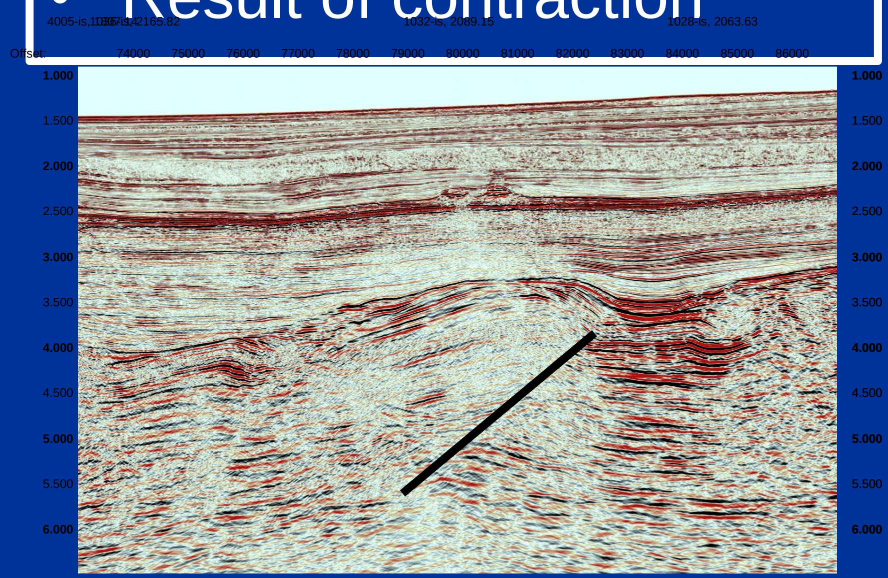
The Tamar Structure

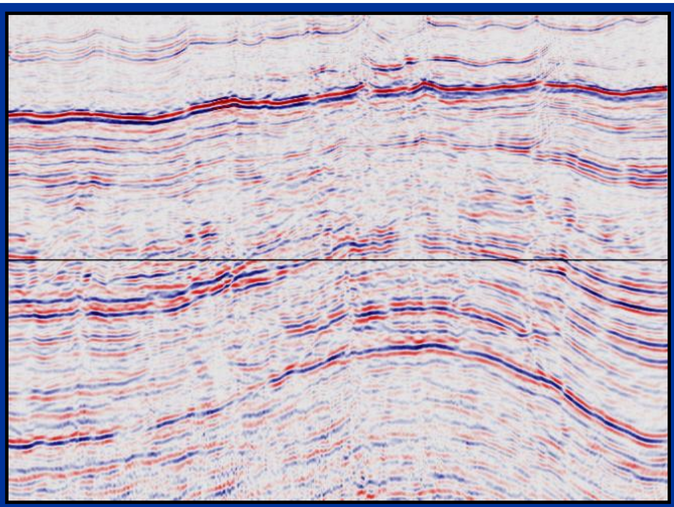
Flattening of Base Tertiary indicates that no structure exited below Tamar at the time of the Late Mesozoic – Early Cenozoic Syrian Arc.



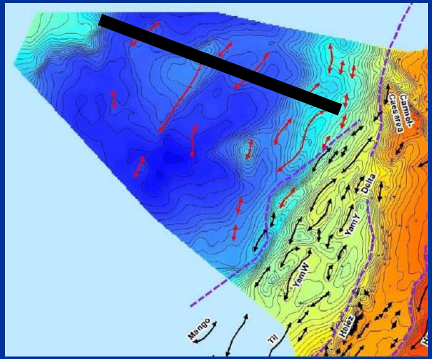
Syrian Arc Structures

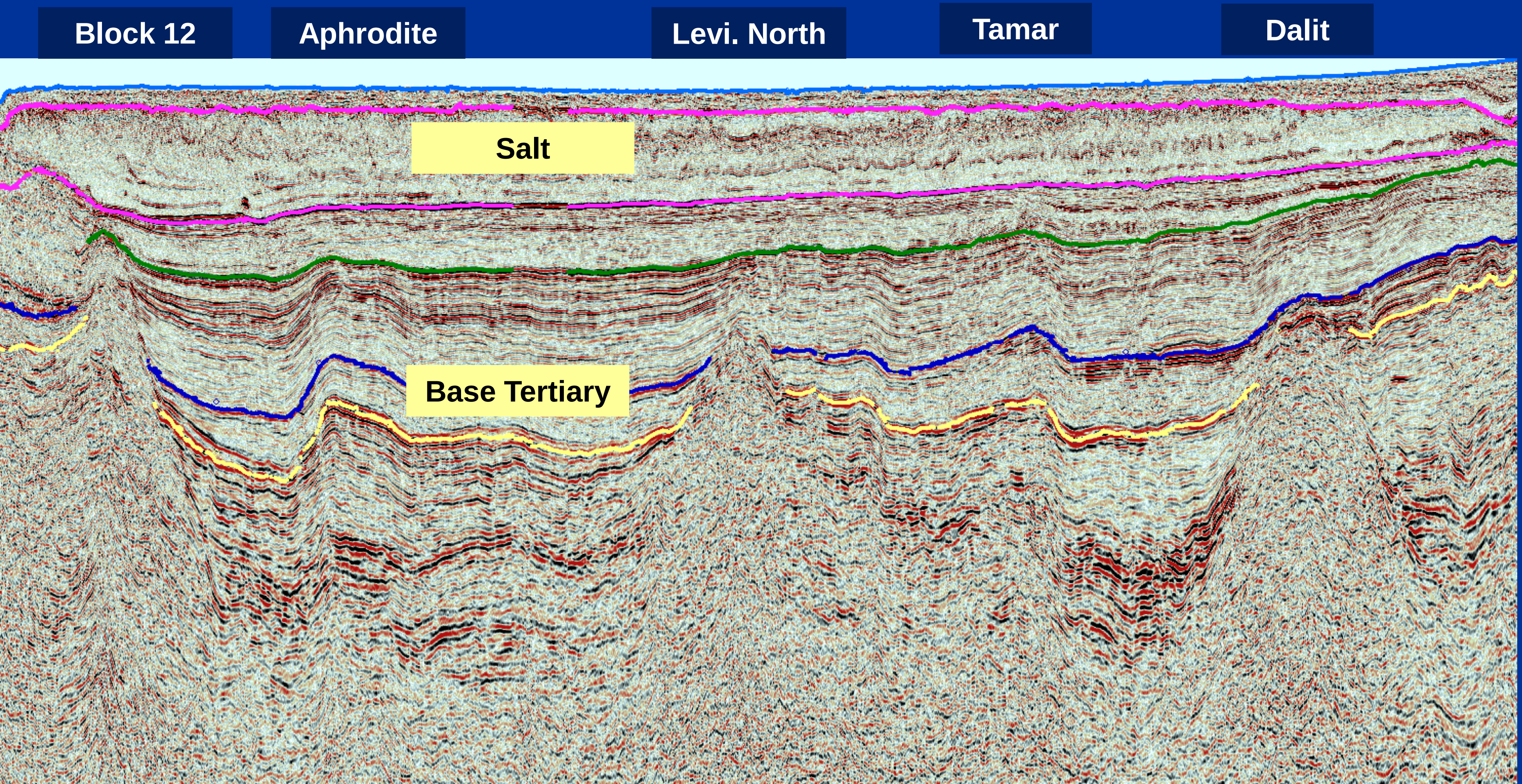
Syrian Arc I	Syrian Arc II
• NE-SW trending	• NE-SW trending
• Narrow and high	• Broad and low
• Asymmetric	• Symmetric
• High-angle reverse faults	• No reverse faults
• Onshore, shelf and slope	• Deep basin
• Result of contraction	• Result of contraction???





Some of the deep-water structures are associated with patchy incoherence seismic, severe disruption of the strata at their cores, sometimes piercing their way up through the Tertiary section; They are not associated with older, Late Cretaceous or Early Cenozoic inverted structures.





Three possible lithologies can be inferred comprising these intrusions:

1.**Magmatic** (or volcanic) intrusions

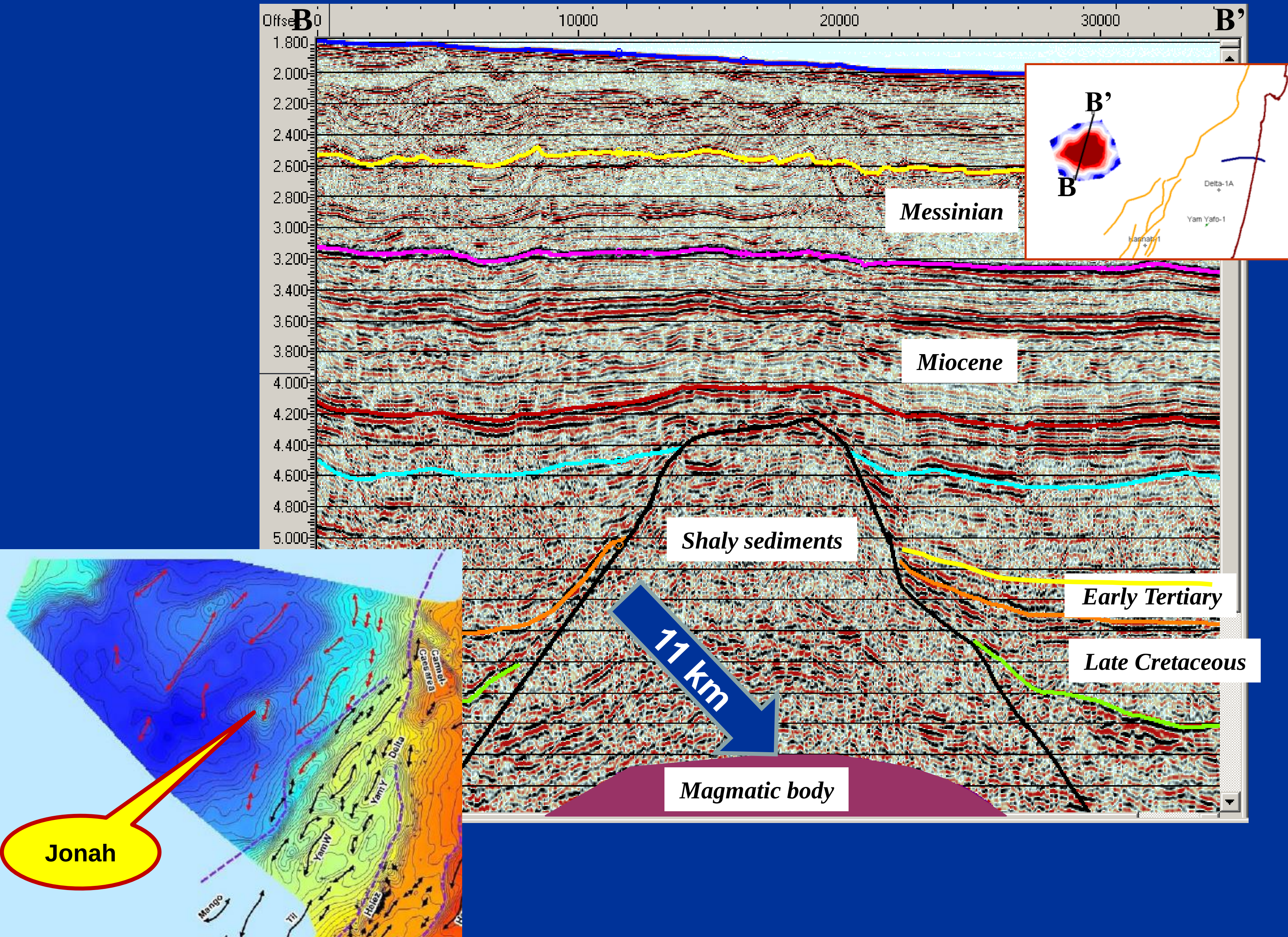
2. **salt** upwelling

3. **mud** diapirism,

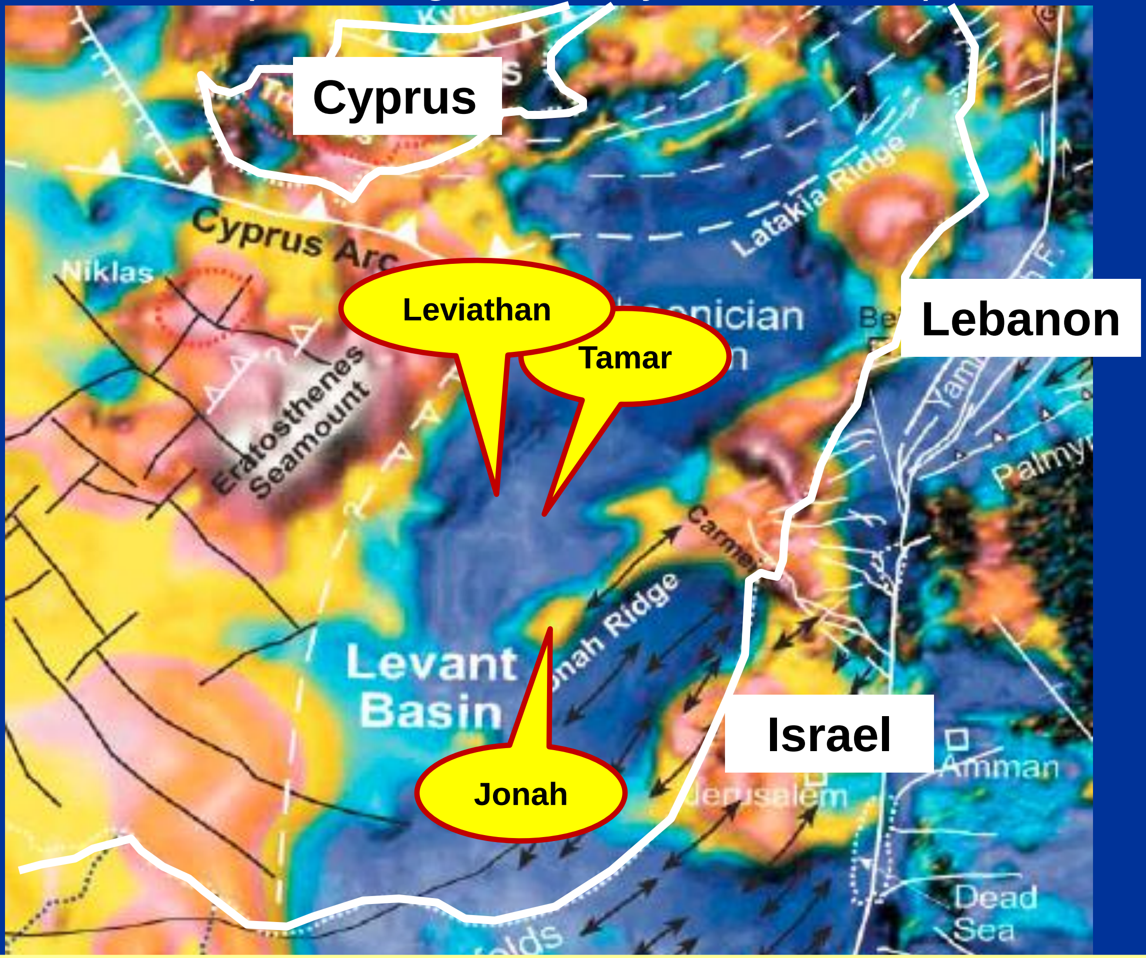
all must have been elevated from the deep-lying Early Cretaceous and Jurassic.

Jonah Buried seamount: magmatic intrusion?

Top of causative body is at 11 km (Folkman and Ben-Gai, 2004)



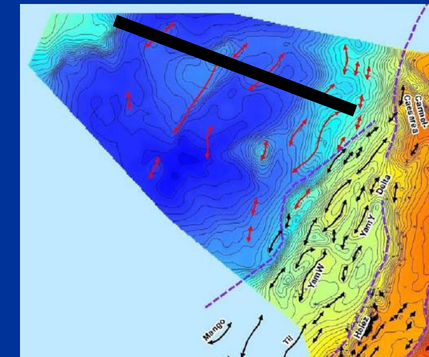
Structural elements on pole-reduced total intensity magnetic map
(from Segev and Rybakov, 2010)



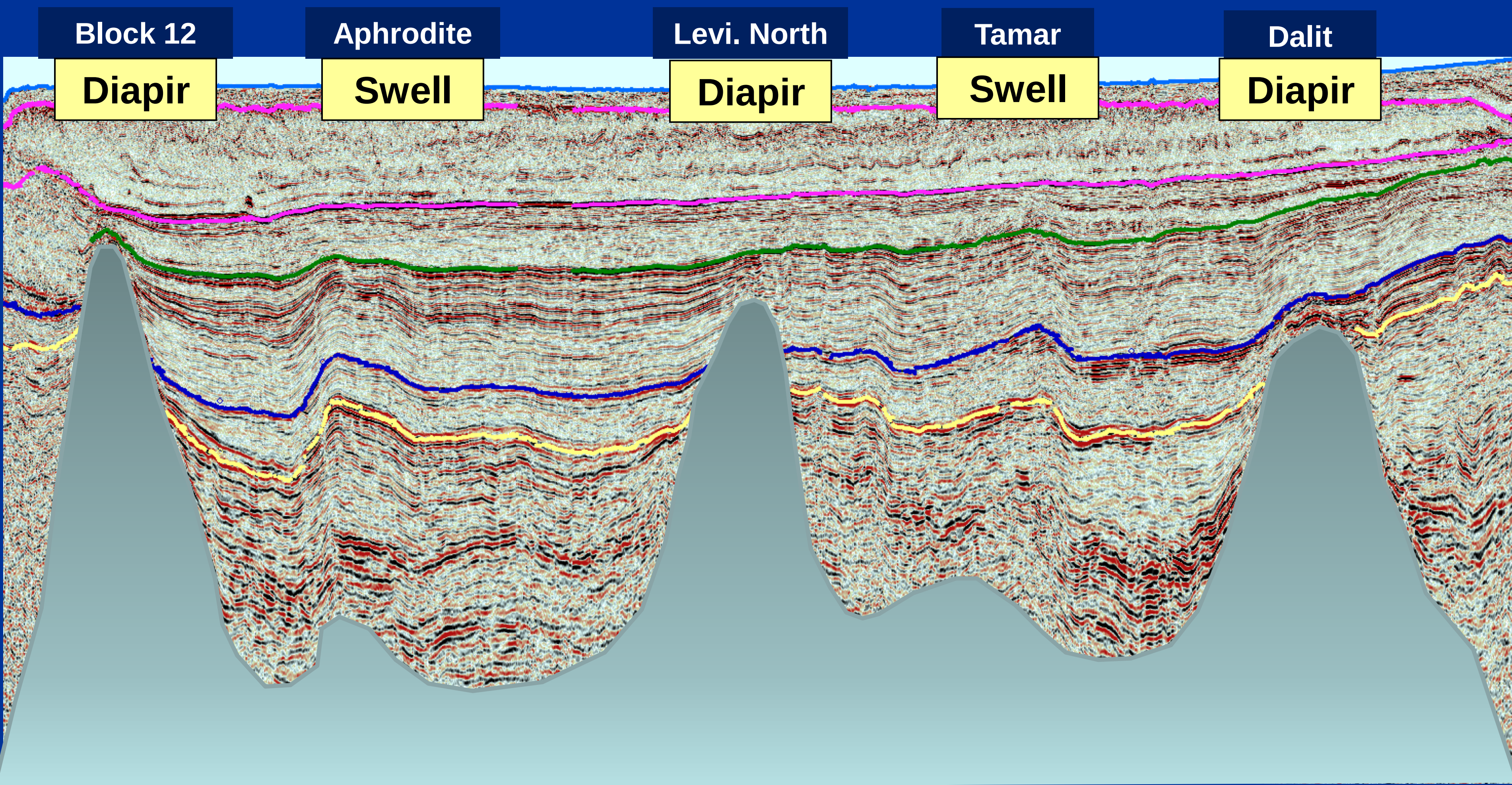
Magmatic intrusions can be rejected on the basis of the magnetic data; only one, the Jonah structure, is associated with positive magnetic anomaly

The Hypothesis:

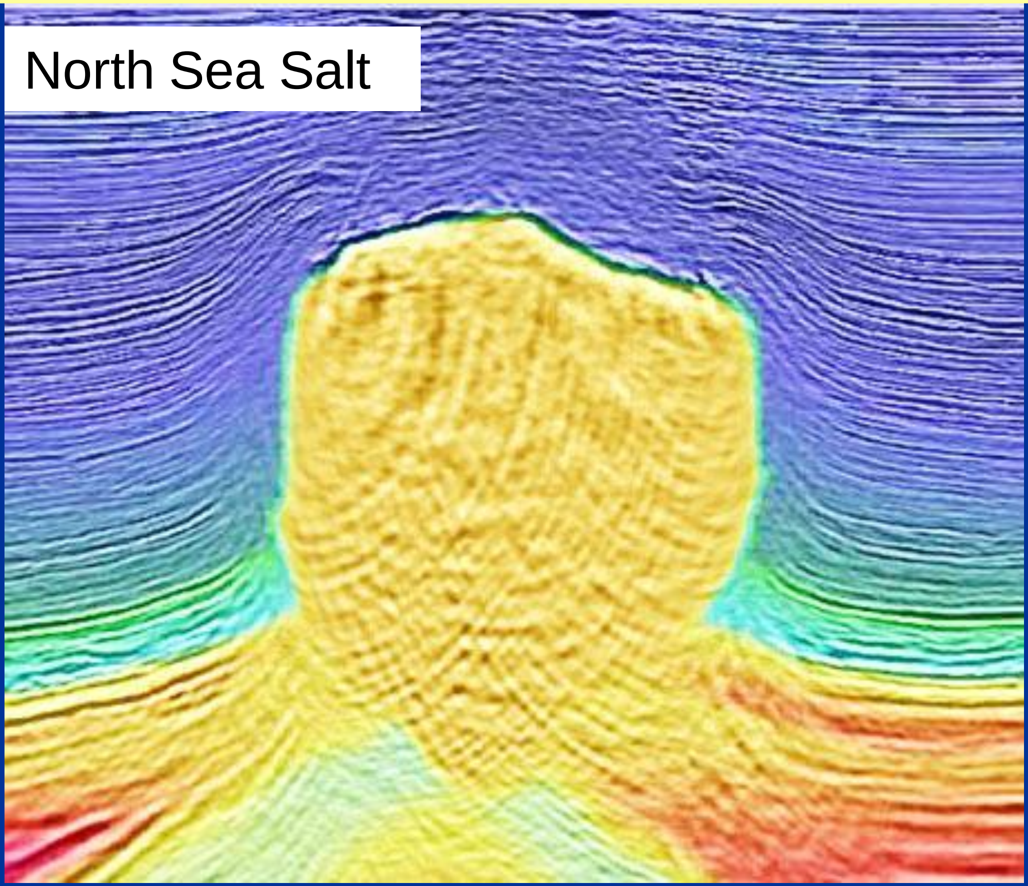
If magmatism is rejected, then the driving force underneath the Levant Tertiary structures are gravitationally unstable sediments. They upwelled in response to fast subsidence, load and on-going contraction due to plates movement and created the swells and diapirs.



The Observation:

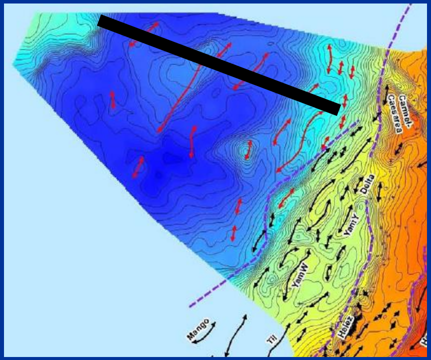


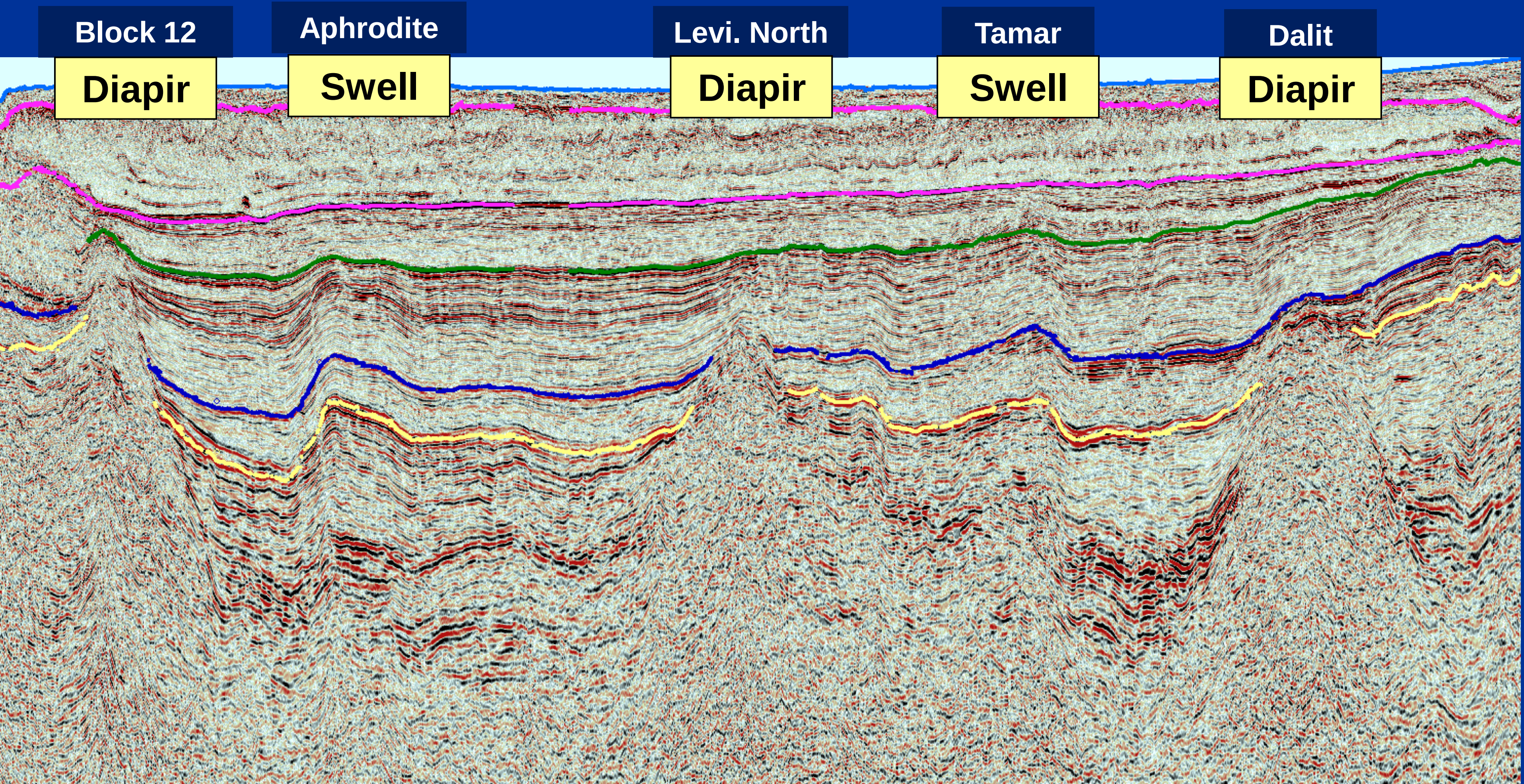
Salt might have been deposited during the rifting stage (Triassic and Early Jurassic). Salt deposits of these ages are known from the distal Arabian Craton, though only sulphates are known onshore Israel.



Vetle Vinje, CGGVerita http://www.geoexpro.com/article/Depth_Imaging_Seeing_the_Invisible/361f7888.aspxs

Mud diapirism is suggested to be the most likely cause.
Fine grained clastics dominate the Late Jurassic and Early Cretaceous sections penetrated in boreholes in the studied area.
However, the diffuse and low quality of reflections does not allow the definition of the detachment level.





Shale diapirs in the Alboran Sea. (from Soto et al., TLE, 2012)

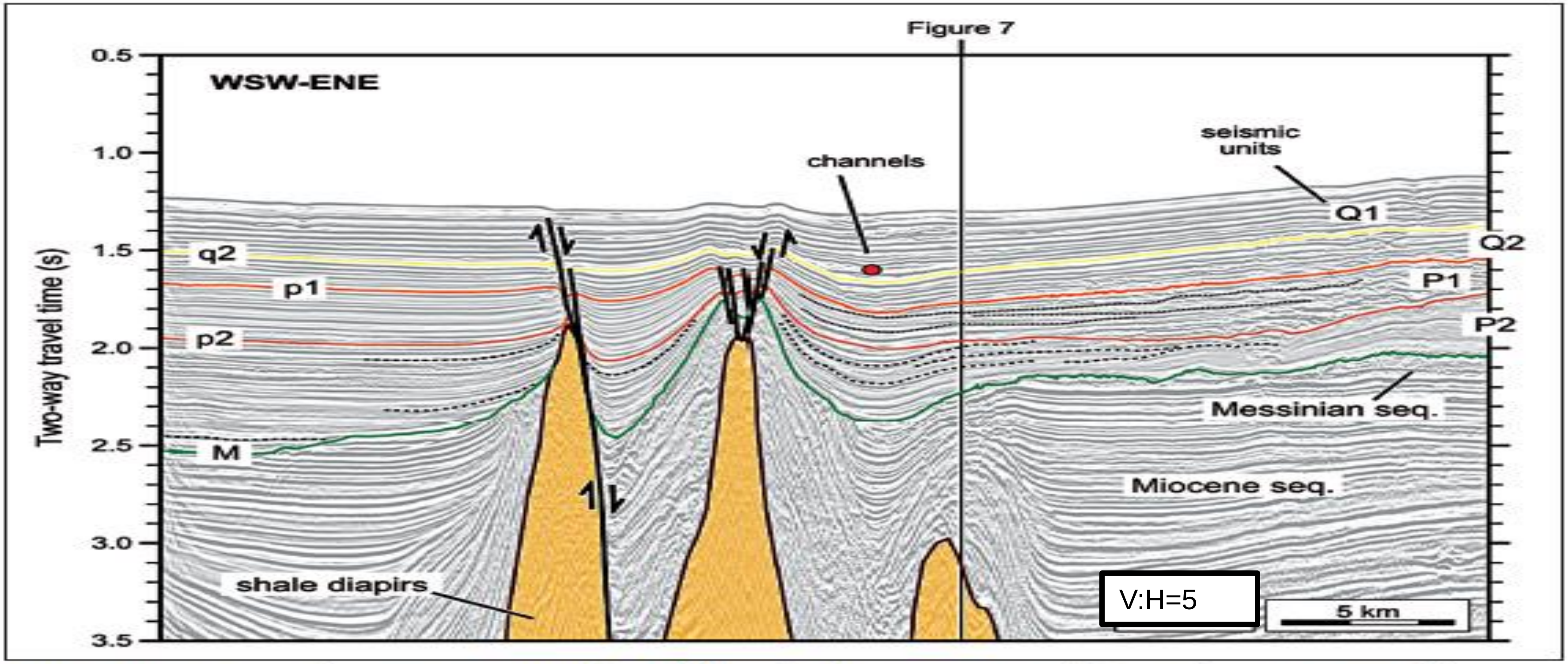
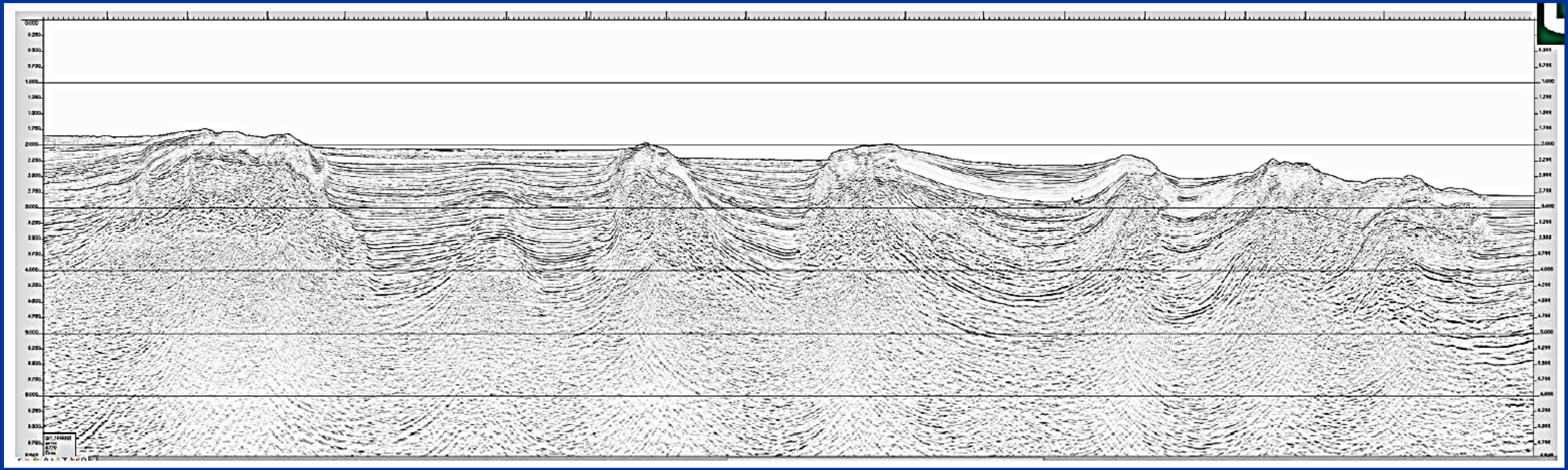


Figure 8. Interpreted seismic section subparallel to the depocenter axis of the northern margin of the WAB. It highlights some of the internal structure of seismic units P1 and P2 (Pliocene). Red circle marks one the channel systems identified in the P-Q series. Figures 4 and 10–12 show line location. Seismic data are courtesy of ConocoPhillips. V:H = ratio of vertical and horizontal scales.



Mud Diapiris offshore Trinidad (from: Graham and Pepper ,2009)

"Salt and mud move in response to contraction, extension or load. Mobility is the consequence of tectonics, not vice-versa.“

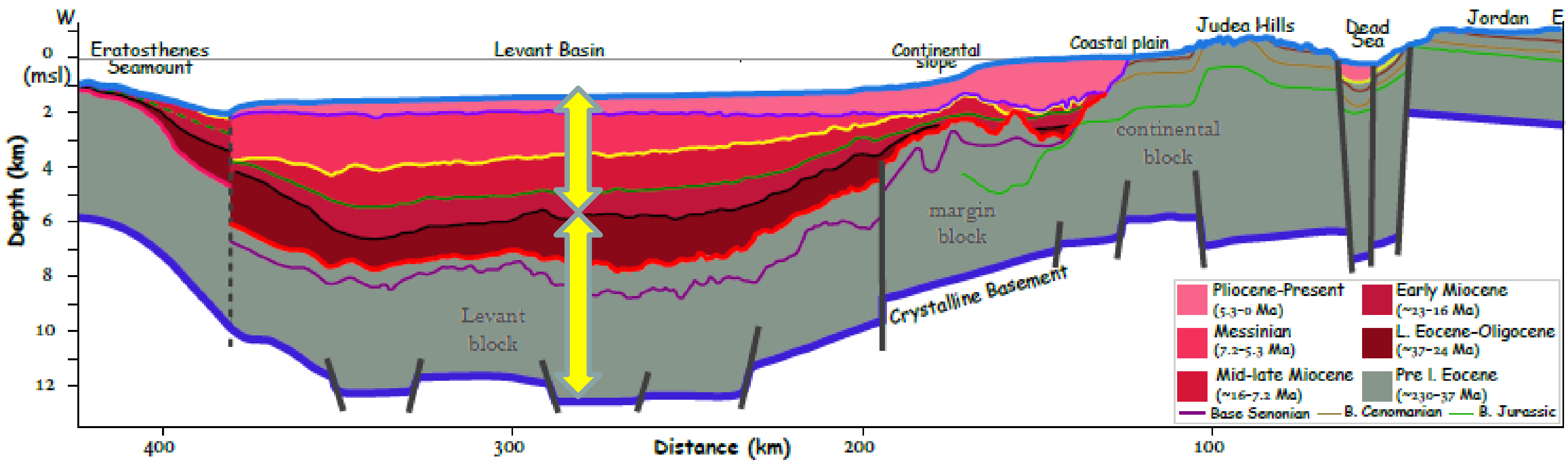
(Graham and Pepper, 2009).

The sedimentary fill of the Levant Basin is estimated to be **12km thick**.

Of these ca. **5 km** have been deposited within the last **37 My**.

The remainder ca. **7 km** were deposited over the entire Mesozoic, a time span of some **200My** since the rifting of the basin.

The sagging of **5km** during the Oligo-Miocene allowing accommodation space for the vast clastic sediment pile of this same age, which was derived from the emerging Arabian Craton.

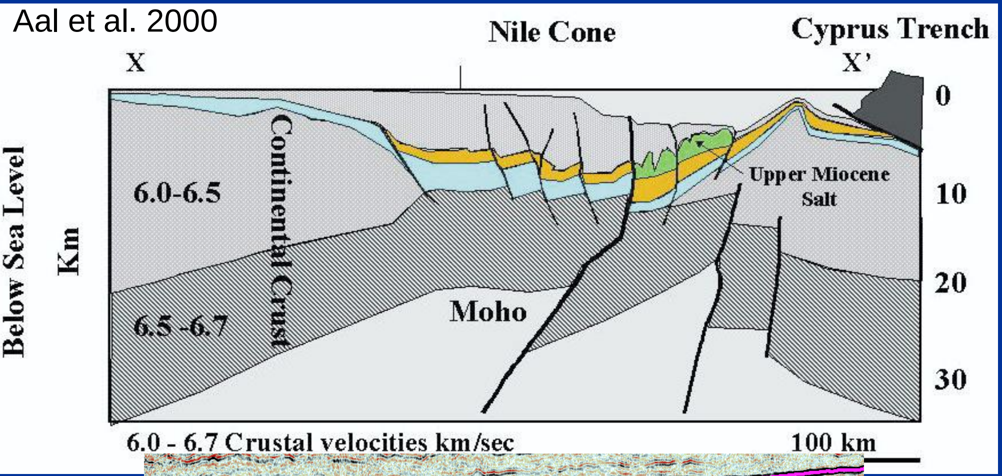


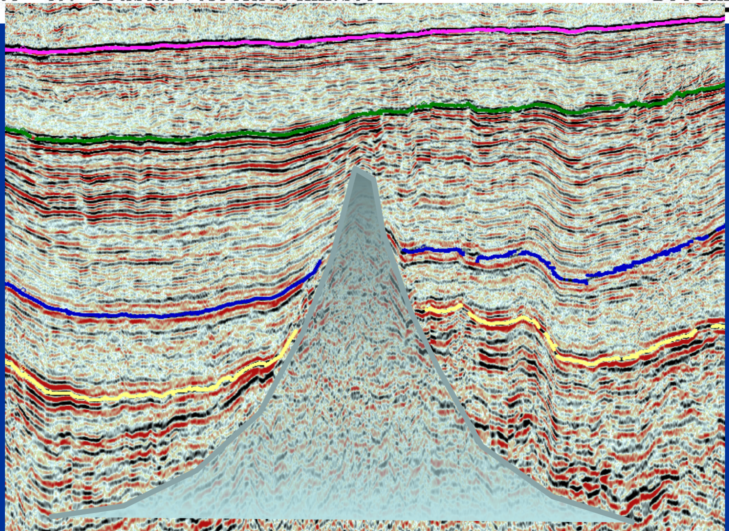
NW-SE Cross section through the Levant Basin. After Steinberg et al,2011

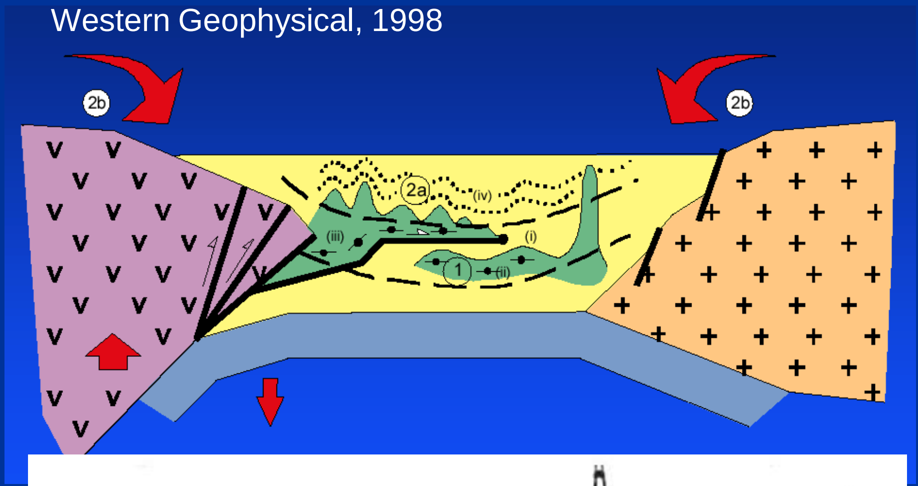
The sagging of the Levant Basin during the Oligo-Miocene is most likely the consequence of its loading.
This loading, in conjunction with the contractional Miocene folding, might be considered as prime cause for the over pressuring of fine clastic sediments of pre- Senonian age and their intrusion into the Tertiary section.

Levant Basin

South Caspian

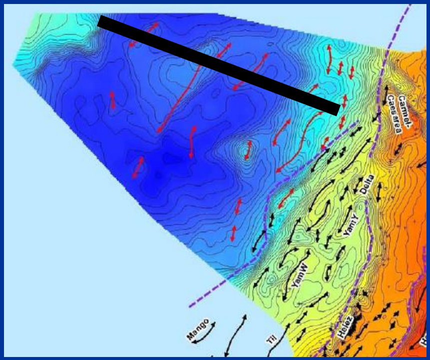


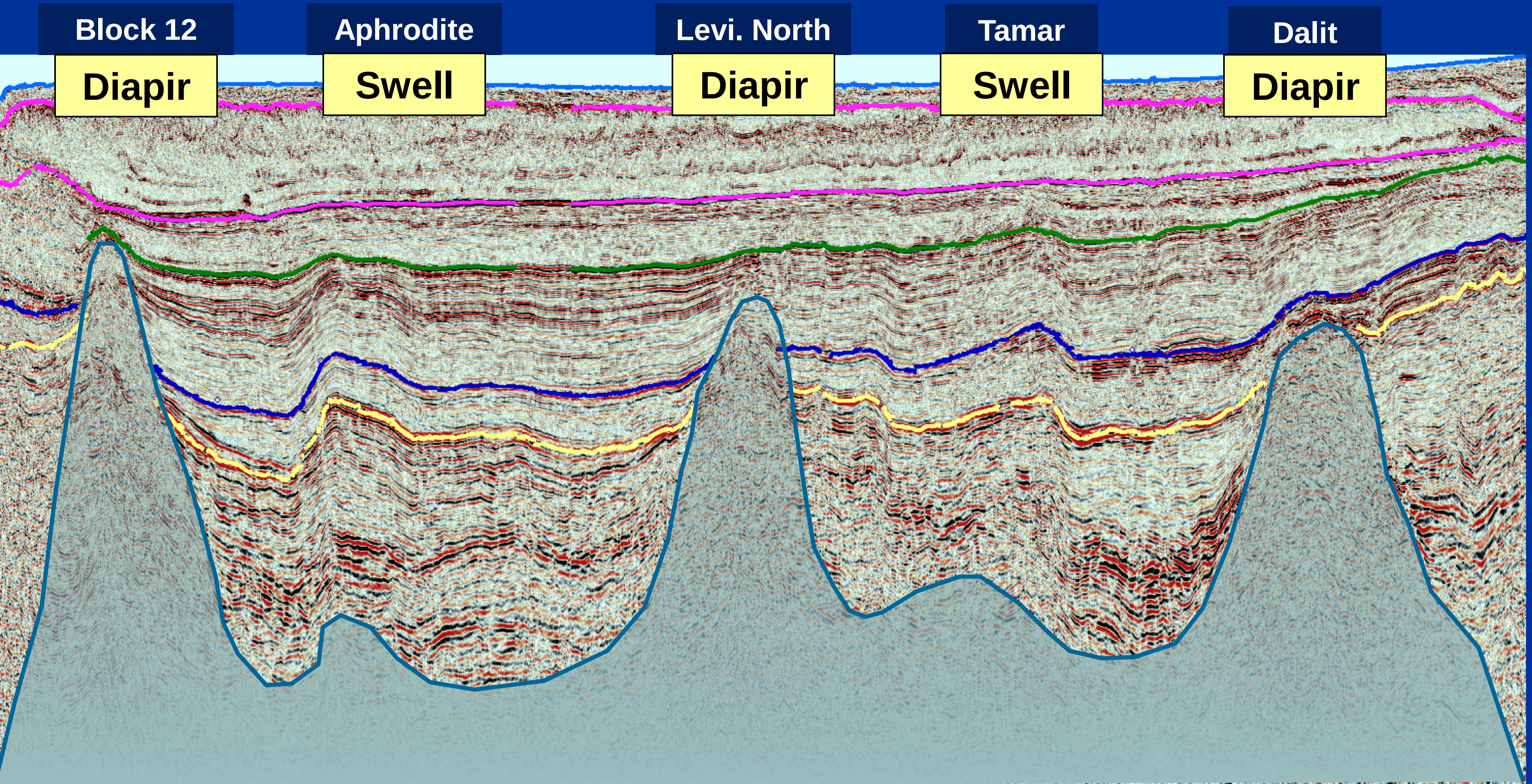




The Miocene folding and intrusive phase should **not** be named after the Syrian Arc, but deserves a separate name, hereby suggested to be the

“Tamar folding phase”





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TGS-NOPEC

Thank you!!!