

# **Seismic Tectono-Stratigraphy Modeling of Deep Marine Oligo-Miocene Siliciclastic Reservoirs in Levant-Cyprus Basin Frontier Zone\***

**Mourad Bédir<sup>1</sup> and Mohamed Nacer Aissaoui<sup>2</sup>**

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## **Abstract**

After the recent commercial gas fields discoveries in Miocene sandstones in the southern part of the frontier zone of Levant-Cyprus Basin, greatest interests have concerned this area. The Neogene plays are essentially represented by Miocene sandstones turbidites as it was discovered firstly in Aphrodite 1 well, with gross mean reserve of 16 TCF of biogenic gas, succeeded by Leviathan 1, Dalit 1 and Tamar 1 well discoveries. The source rocks are assured by Jurassic, Cretaceous and Tertiary hemipelagic rich organic marls. The basin tectonic structuring and new seismic sequence stratigraphy study of Oligo-Miocene siliciclastic deposits horizons based on the analysis and interpretations of new regional selected E-W and N-S 2D seismic grid acquired in 2008 using new PGS geostreamer technique and calibrated to wells data and outcrops had highlighted the basin configuration and sequence deposits infill nature and distribution of Oligocene and Miocene siliciclastic reservoirs. Geotectonic setting of the basin is marked by NE-SW and N-S deep-seated sub vertical strike slip normal and reverse inherited faults around the shelf borders and by NW-SE faults in the centre. These basin dynamics allow classifying the Levant basin as a deep-water mobile substrate basin characterized by the existence of Deep-water fold belts fed by large rivers. Oligo-Miocene horizons are organized in three second order sequences composed by five Oligocene, four Lower Miocene, and 5 to 7 Middle-Upper Miocene third order seismic sequences. Oligocene and Miocene early lowstand horizons of deposits present downlap prograding sigmoid, oblique and mounded slope fans system tracts and basin floor mounds and large turbidites sheets and lobes, overlain and cut by late lowstand incised channels, canyons and levees. The size of channels and canyons of Oligocene ranges from 3 to 5, 10 and 15 kilometers width with an average thickness between 100 and 350 meters, sometimes reaching 1500 meters whereas size of

channels and canyons of Miocene ranges from 3 to 10 kilometers width and 100 to 300 meters infill thickness. Locally, canyons are bigger and stacked as multistory extending from Oligocene to Lower Miocene. Reconstructed paleogeographic reservoir fair maps highlight three new exploration domains around the Levant basin of sandstone/shale system tracts deposits related to the upper slope, lower slope and basin floor.

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# Seismic Tectono-Stratigraphy Modeling of Deep Marine Oligo-Miocene Siliciclastic Reservoirs in Levant-Cyprus Basin Frontier Zone

**Mourad Bédir <sup>1</sup> & Mohamed Nacer Aissaoui <sup>2</sup>**

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2. Mohamed Naceur Aissaoui-Repsol, Madrid, [nasser.aissaoui@yahoo.fr](mailto:nasser.aissaoui@yahoo.fr)

## **SITUATION**

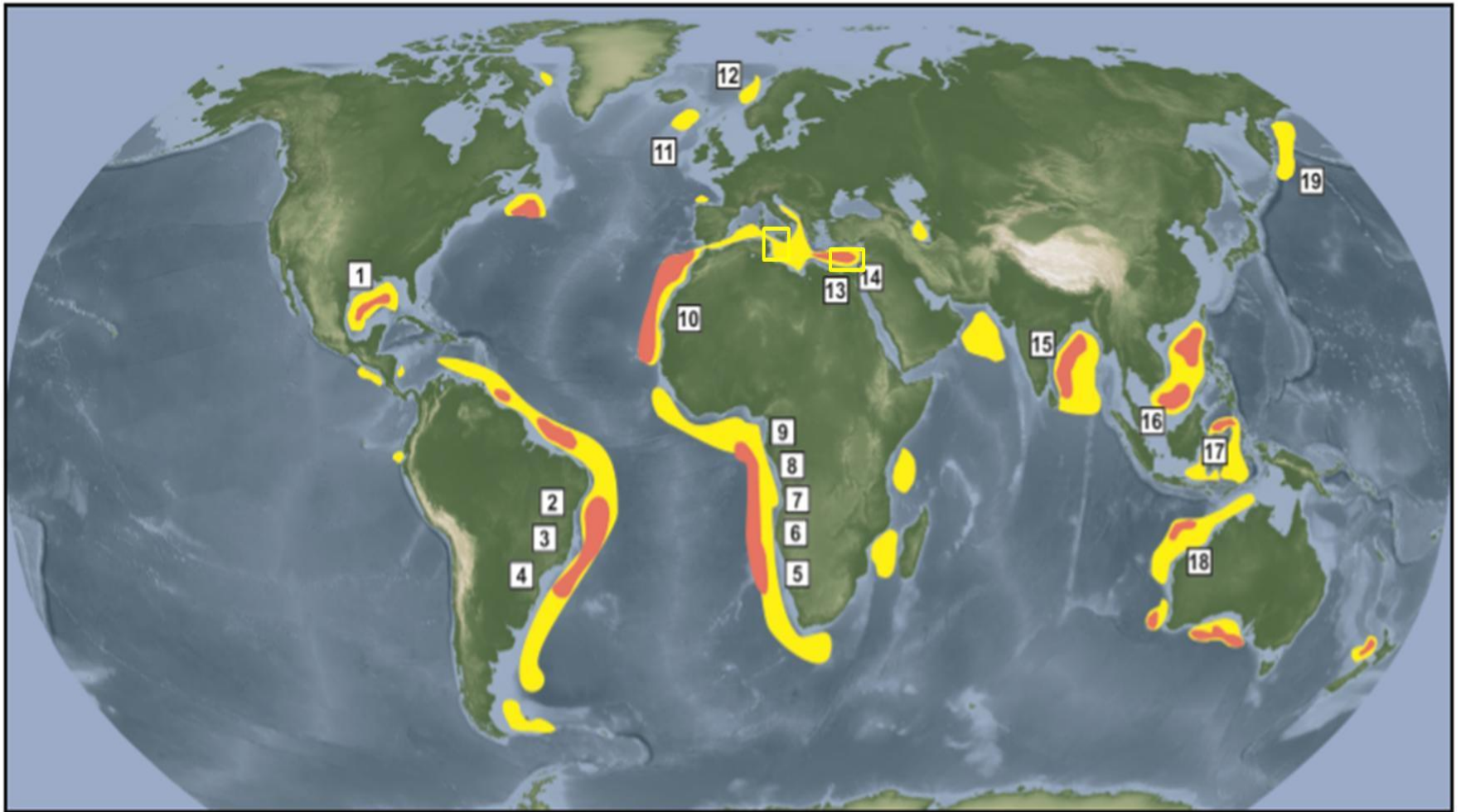
- UNDER EXPLORED FRONTIER BASIN
- PROMISING HYDROCARBON AREA
- OLIGO-MIOCENE DEEP WATER CLASTIC RESERVOIRS INFILL

## **CHALLENGE**

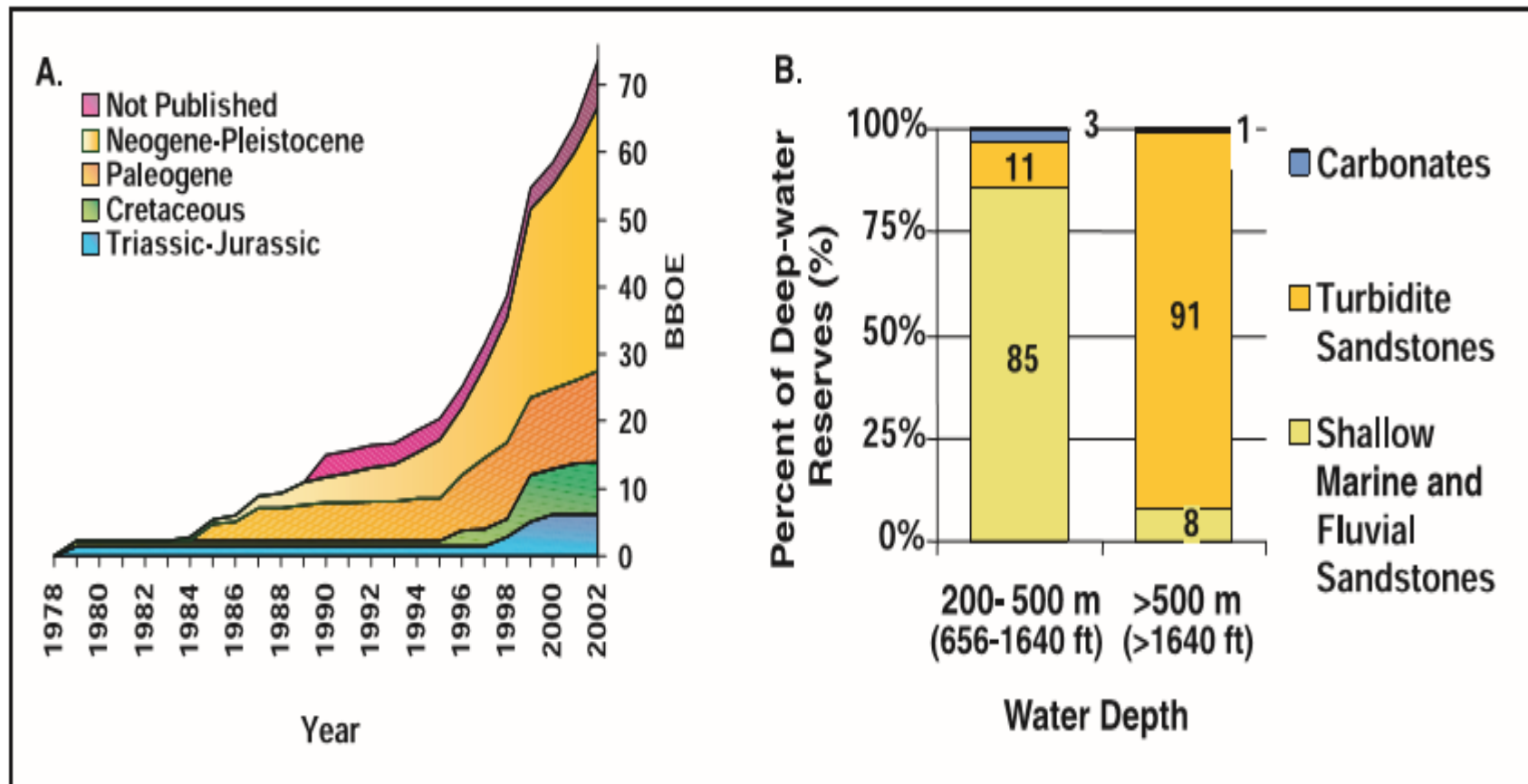
- HIGHLIGHTS OF SEQUENCE DEPOSITS INFILLING ORGANISATION
- LOWSTAND CLASTIC RESERVOIRS AND DEPOSITIONAL ENVIRONMENTS DISTRIBUTION
- RESERVOIR DISTRIBUTION FAIRWAY MAPS

## **APPROACH**

- SEISMIC TECTONIC CONFIGURATION
- SEISMIC SEQUENCE STRATIGRAPHY CONCEPTS AND ANALYSIS
- E-W AND N-S 2D SEISMIC STRATIGRAPHY REGIONAL SECTIONS



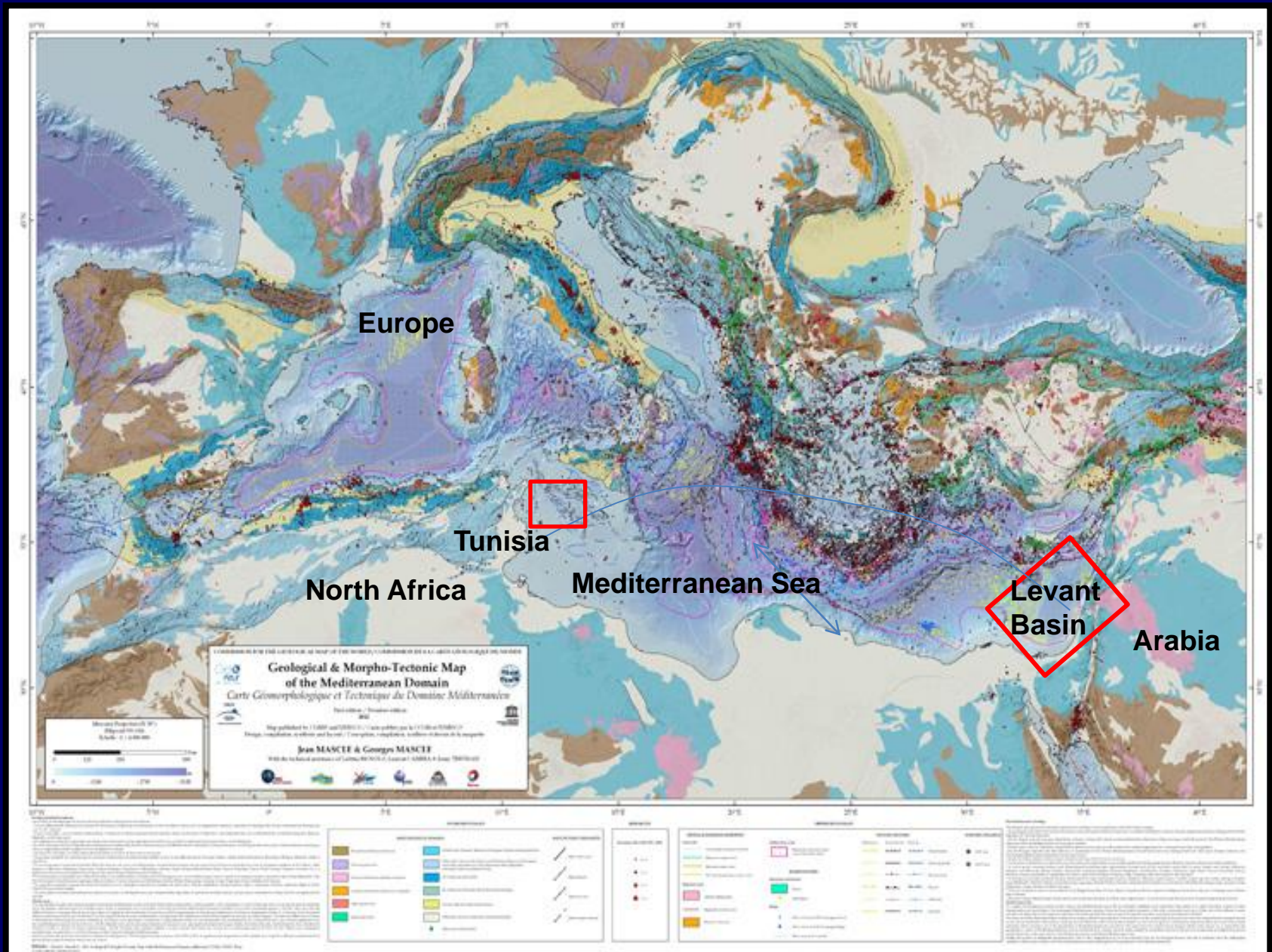
Map showing the distribution of deep-water basins with production or announced discoveries: (1) northern Gulf of Mexico, (2) Sergipe-Alagoas (3) Campos (4) Santos, (5) Angola, (6) Gabon, (7) Congo, (8) Equatorial Guinea, (9) Niger Delta, (10) Mauritania, (11) offshore Shetlands Islands, UK, (12) mid-Norway, (13) Nile, (14) Israel, (15) Krishna-Godivari, (16) northwest Borneo (offshore Sabah), (17) eastern Borneo (offshore Mahakam delta), (18) northwest Australia, and (19) Sakhalin Island. Known source rocks for each basin are listed in Table 3. Yellow = deep-water basin. Red = ultra-deep-water basin.



(a) Graphs of deep-water resources discovered from 1978 to 2000 versus reservoir age and (b) deep-water reserves versus lithology. Lithology data for 200–500 m (656–1640 ft) are from Cook (1999, used with permission); data for >500 m (>1640 ft) are from Pettingill and Weimer (2001). Note the differences in reservoir types with the water depths. Updated from Weimer and Pettingill (2000).

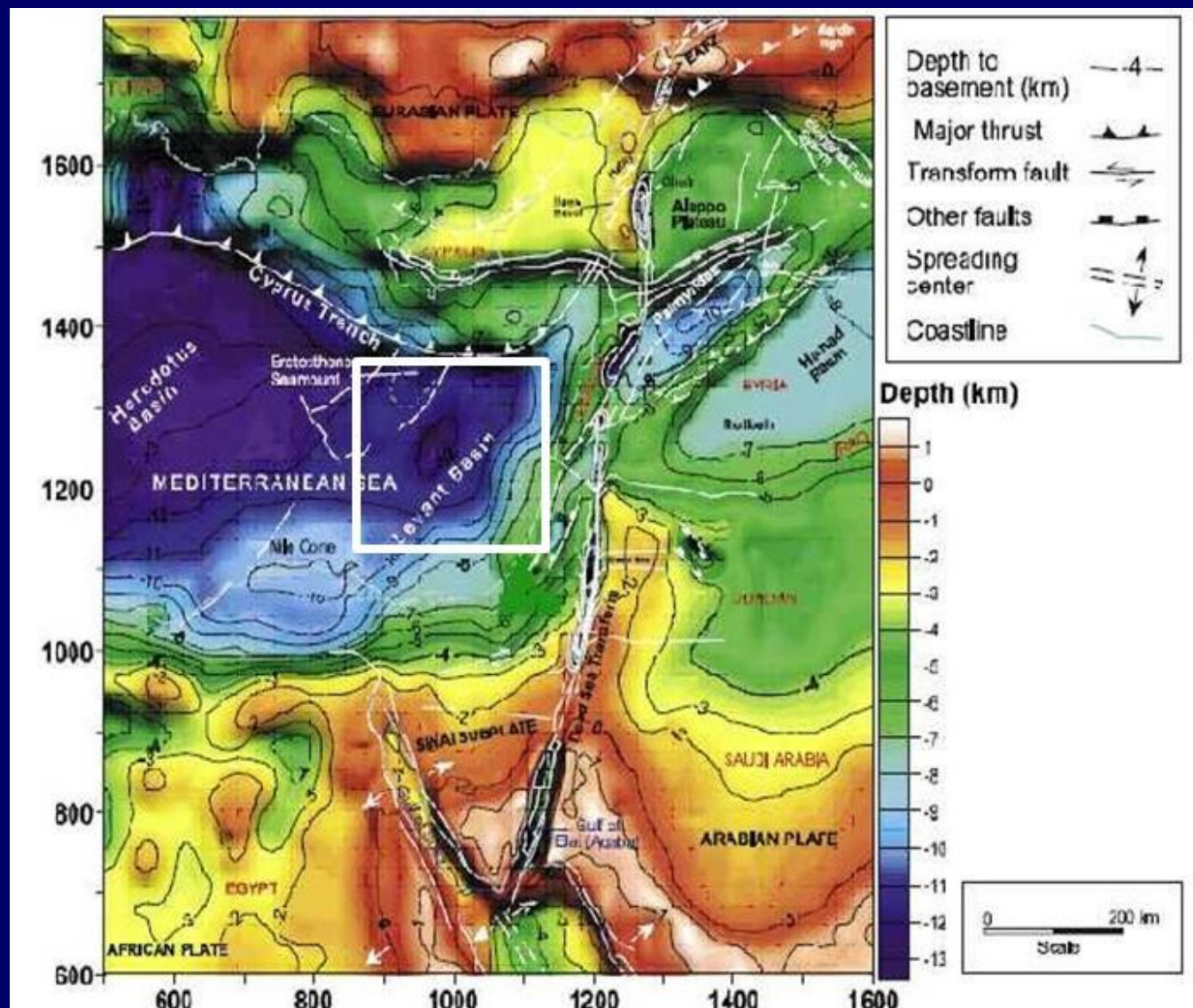
# **Study Area and Hydrocarbon Interest**



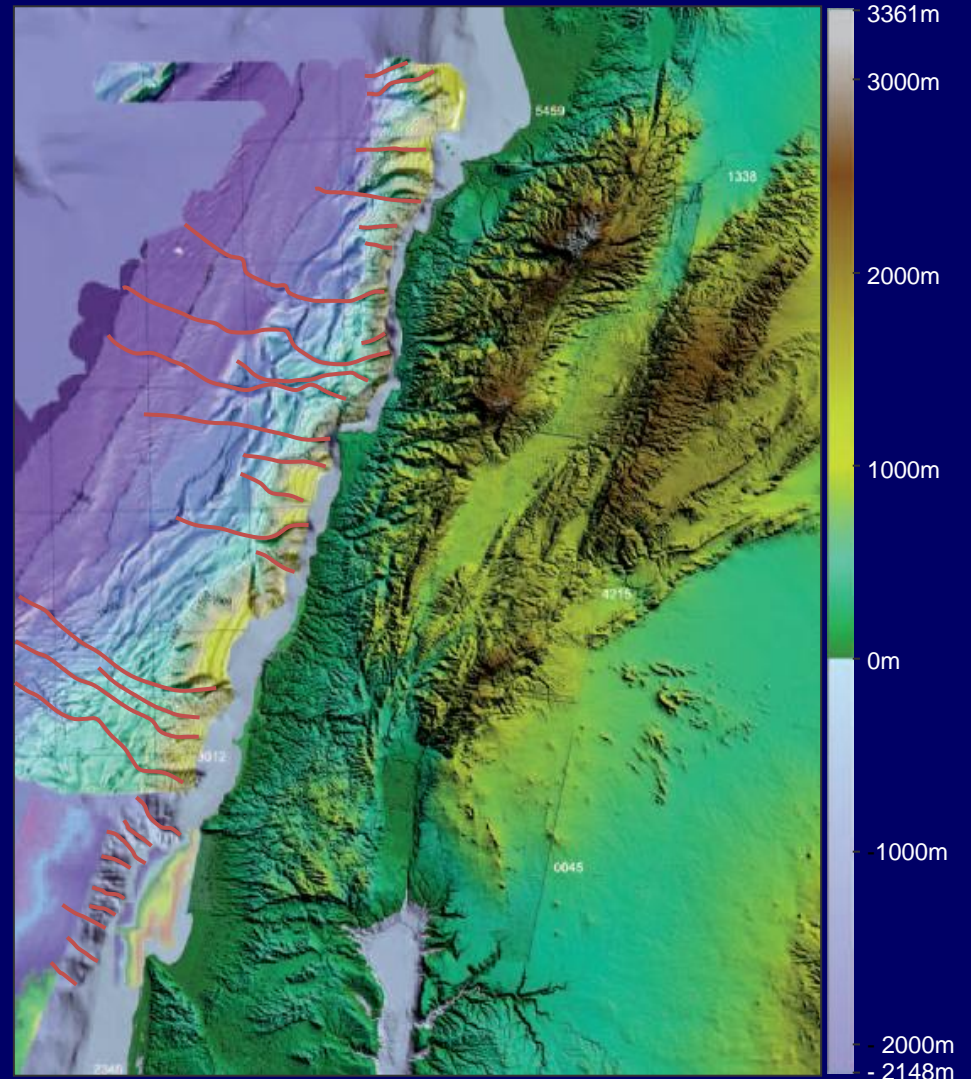
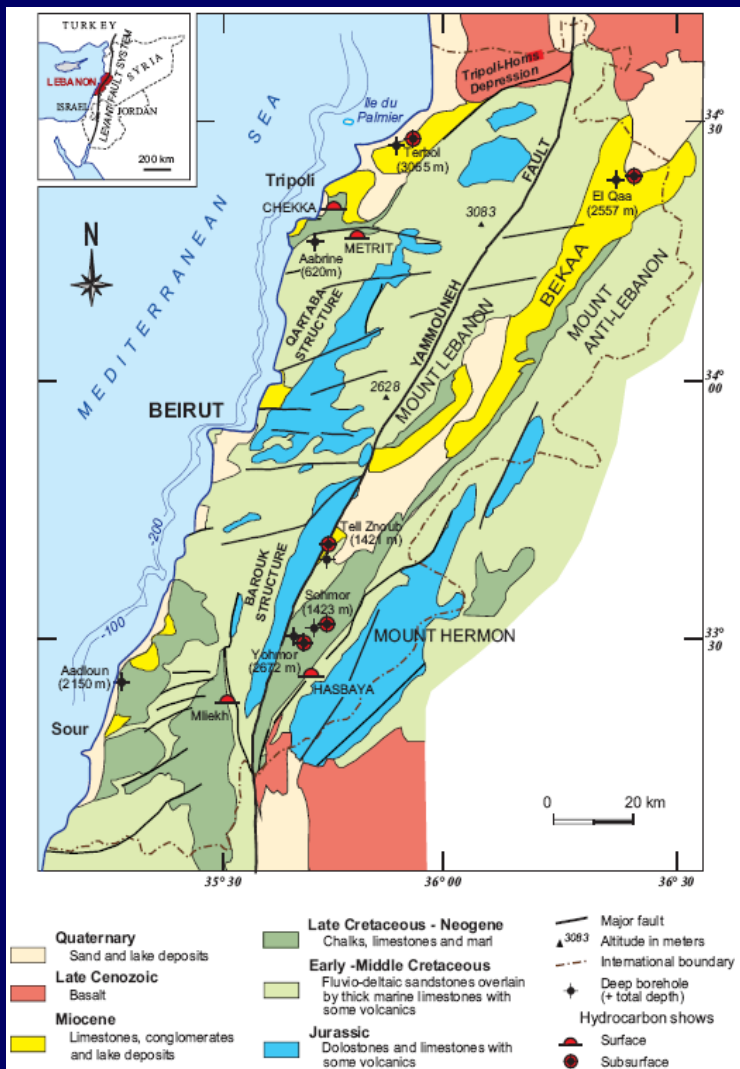


**The first Geological and Morpho-Tectonic Map of the Mediterranean  
 (Mascle and Mascle, 2012)**





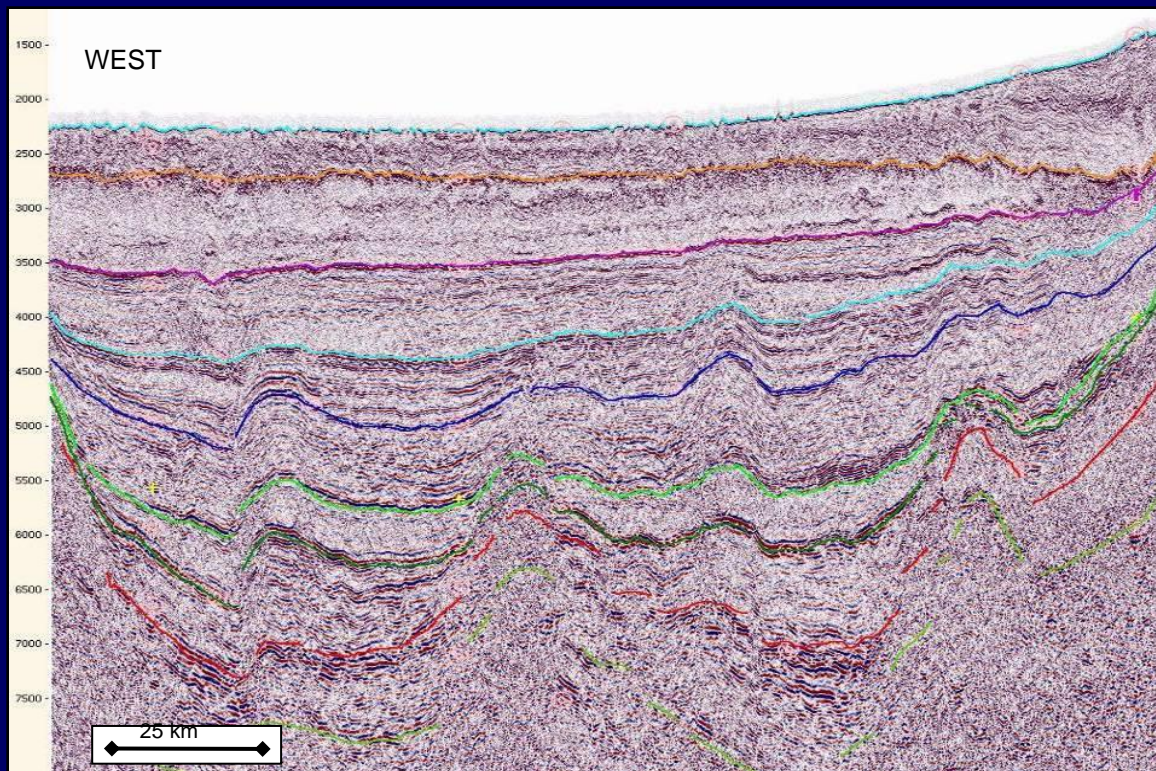
Tectonic Structural Framework  
of the Levant Basin (Rybakov et al., 2004)



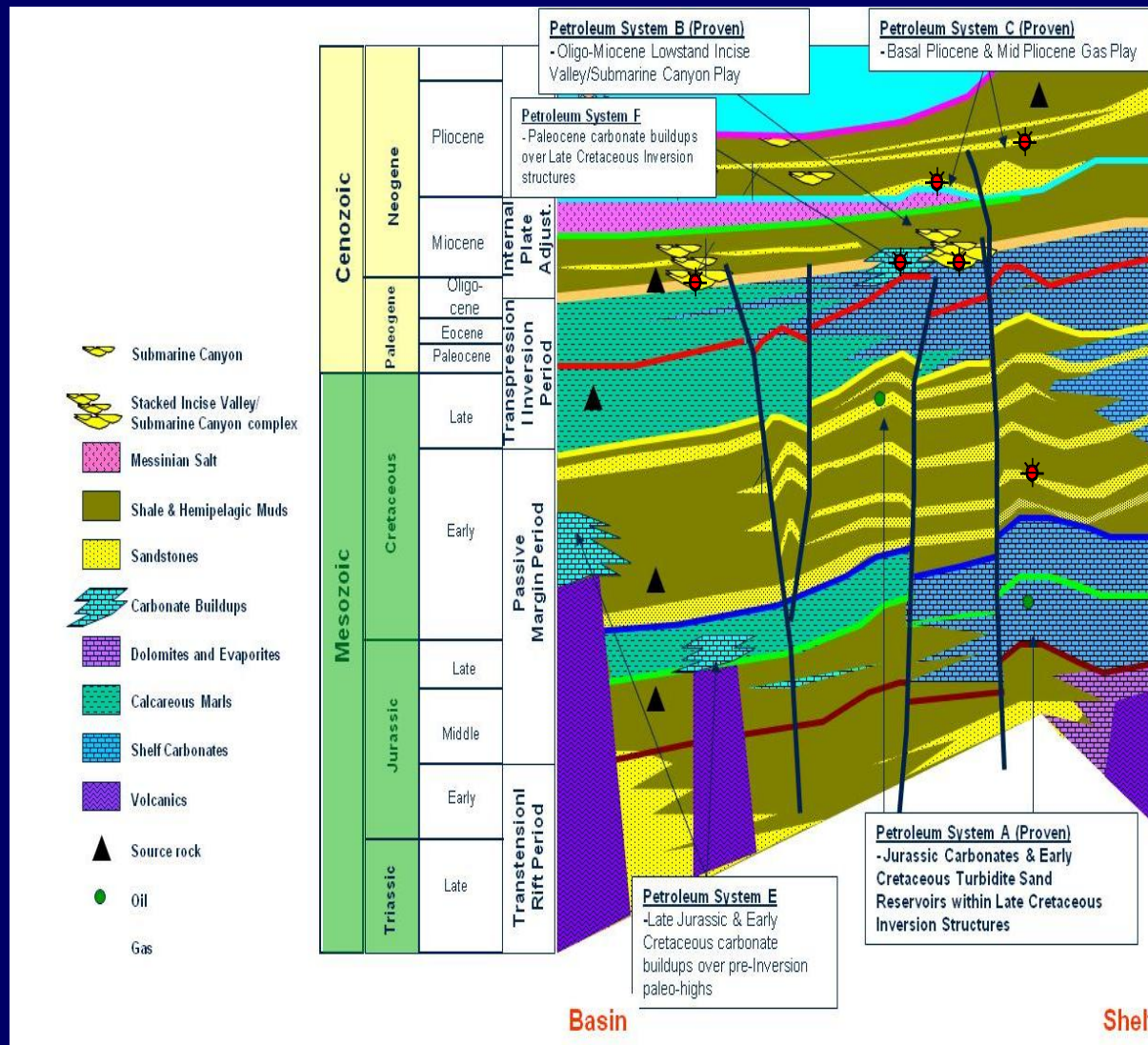
**Lebanon On/Offshore Geological maps & Satellite composite Image showing Paleo-fault Trends & Drainage system**



- East Mediterranean has about 98 TCF gas reserve and have been proved in Egypt Nile Delta (70 TCF) and South Levant basin (28 TCF); discovered in post salt Pliocene & pre salt Oligo / Miocene plays
- Levant basin is Frontier area under-explored
- Seismic data shows:
  - Many DHI's (Gas chimney, pockmarks & flat spot)
  - Turbidites channel systems & sand sheets
  - Large structures & variety of play types
  - Combined structural & stratigraphic traps



# Hydrocarbon Plays



E. Mediterranean General Stratigraphic Column & Play Concept

Bardawil Trend

- 10.3 TCF Plio.
- turbidite channels
- 8.9 TCF M. Miocene turbidites

Leviathan (Noble10)

- 16 TCF

Tamar (Noble 09)

- 8.4 TCF gas & 0.84 MMB Cond.
- L. Miocene

Dalit ( Noble 09)

- 500 BCF

Cherrife (SPC 84)

- 195 BCF gas & 2

Yam – 2 & Yafo 1 (Isramco 90 – 94)

- 3.5

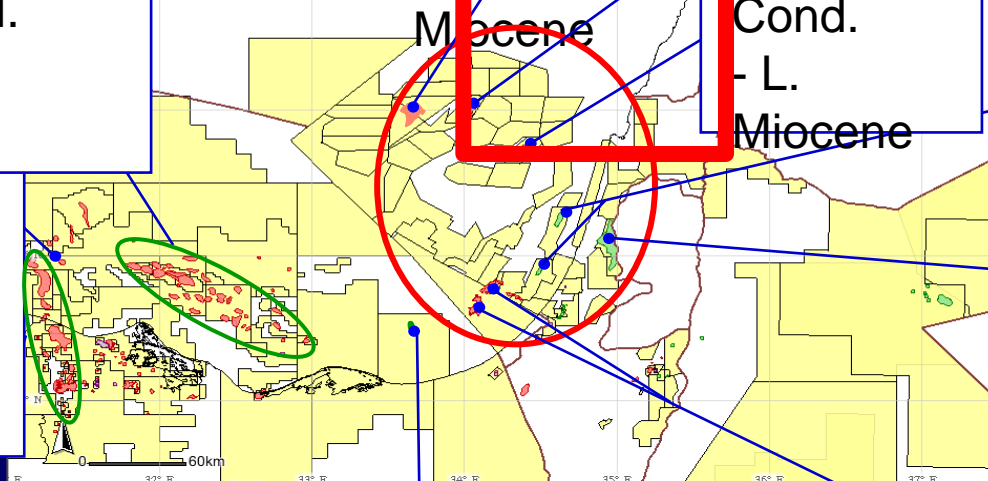
Meged - 2 (Givot 98)

- 0.5 MMB oil
- M. Triassic
- DOL

Satis (BP 07)

- 1.3 TCF gas & 2.5 MMB Cond.
- Oligocene

- Egypt Nile Delta:- ~ 70 TCF  
- South Levant Basin : ~ 28 TCF



Abu Madi / Baltimore Trend

- 5.9 TCF Mess.
- fluvial canyon infill

Mango (Total 85)

- 13.6 MMB Oil, 10 BCF gas & 0.5 MMB Cond.
- E.Cretaceous

Gaza & M (Bg 01)

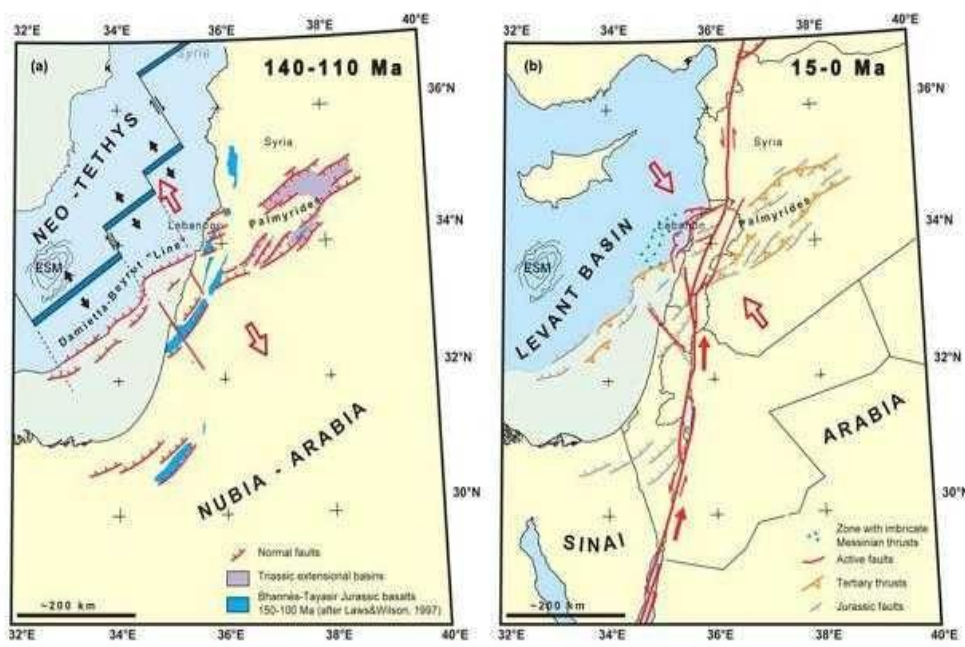
- 3.2 TCF gas
- Basal Pliocene

East Mediterranean gas reserve Repartition discovered in post salt Pliocene & pre salt Oligo / Miocene plays

GEOHISTORY

GEOTECTONIC SETTING

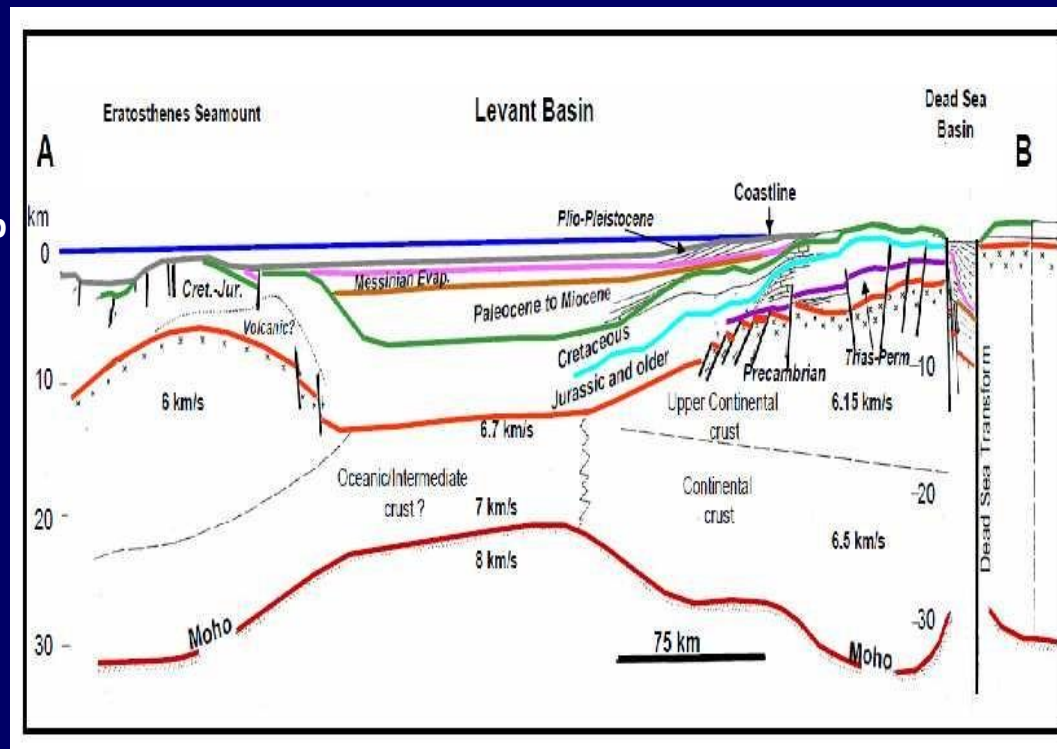




## Triassic-Jurassic-Cretaceous Tectonic Rifting, Tertiary Compressional Stages and Associated Structuring of Levant Basin (Tapponnier et al., 2004)

- NE-SW, NW-SE and N-S Faults
- Associated Pull Apart & Foreland Basins & Strike Slip
- Fold Belts

**East-West Regional Geoseismic Cross Section of Levant Basin**  
**showing Continental and Seamount borders**  
**Continental and Oceanic Crust and Phanerozoic Infill**  
**(Gardosh et al., 2008)**

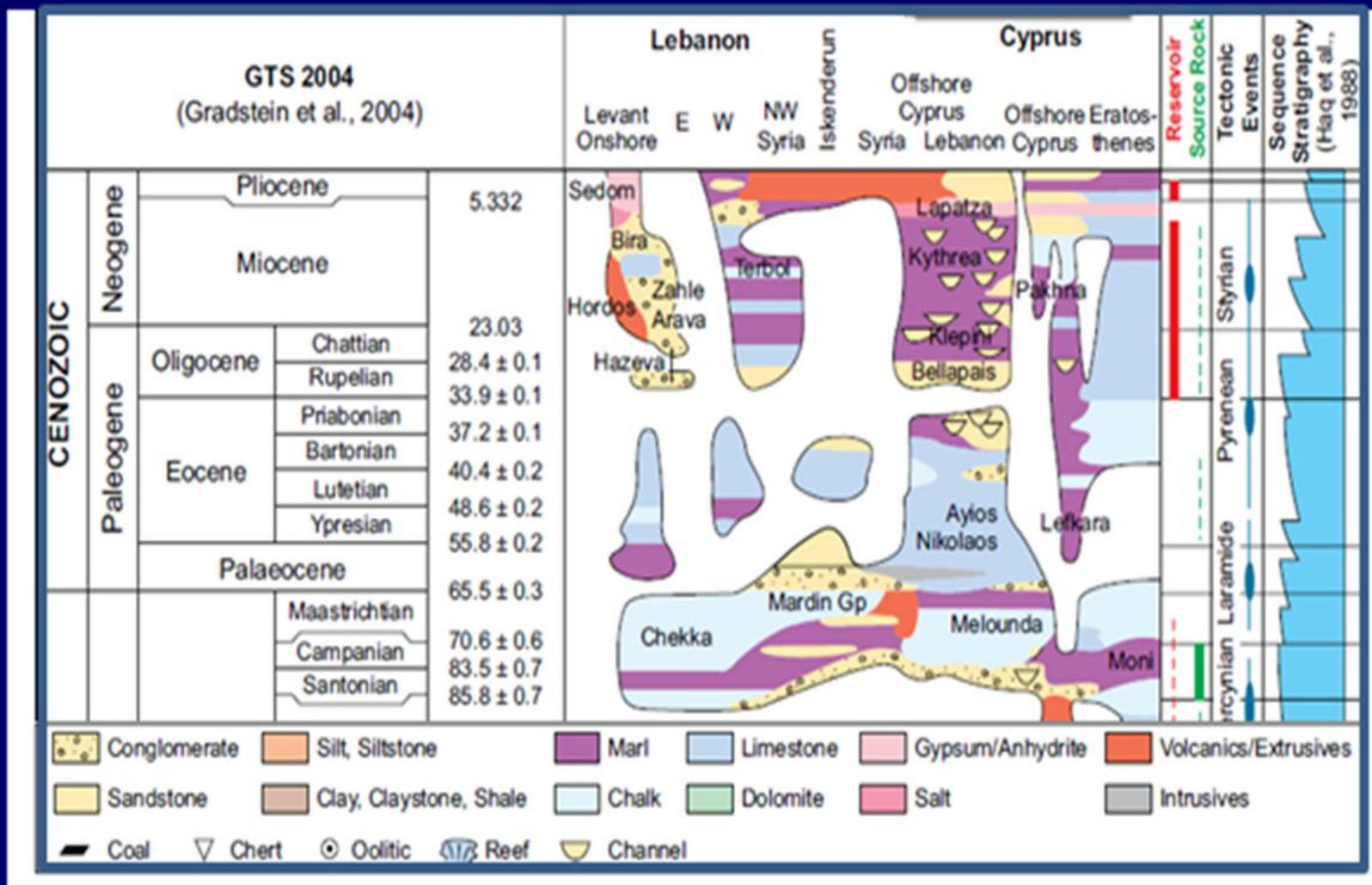


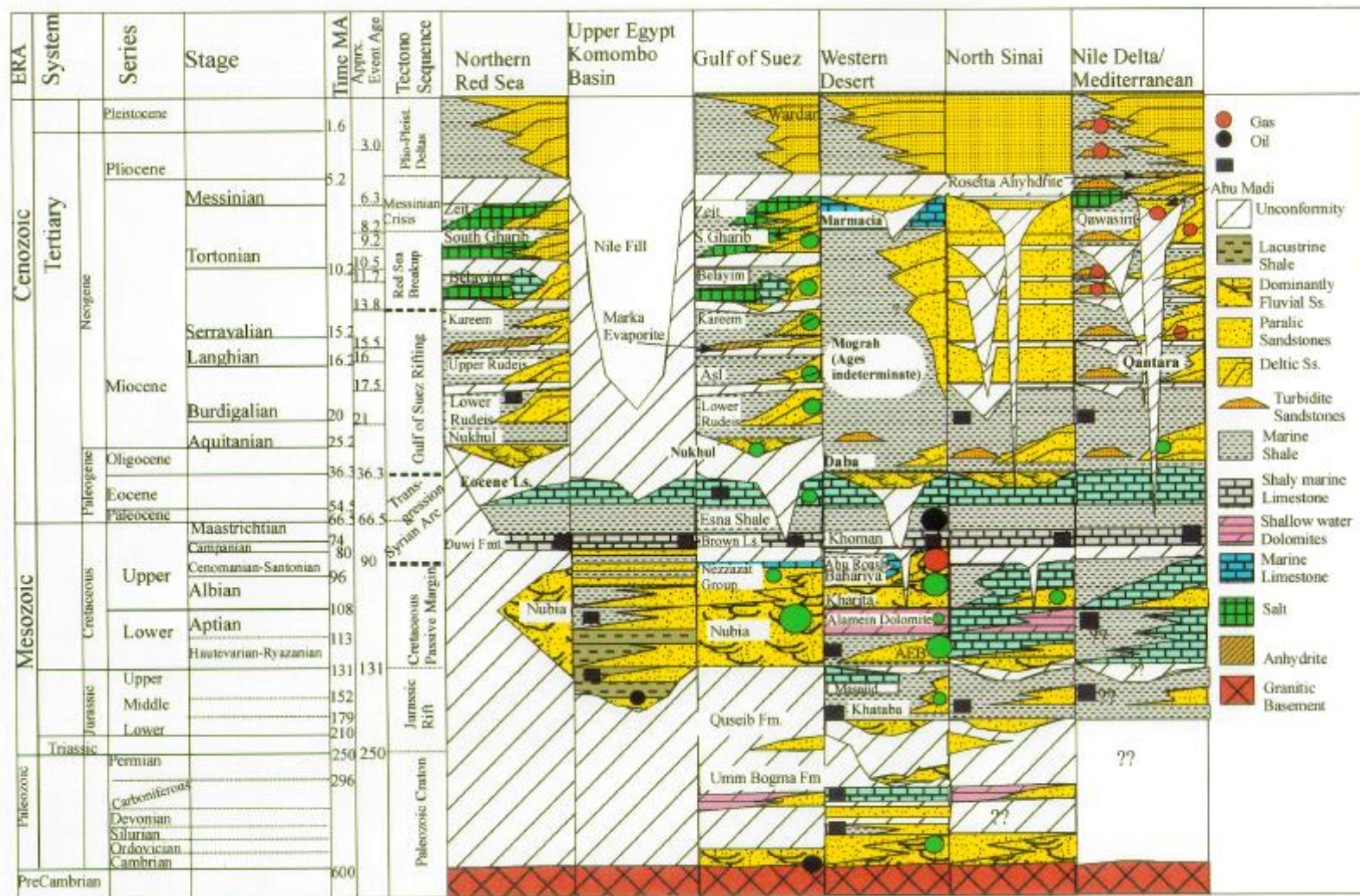


STRATIGRAPHY

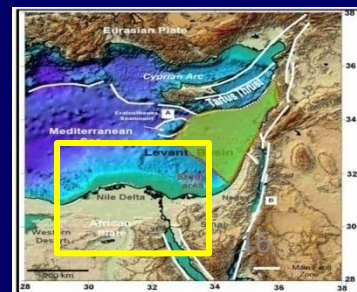
&

DEPOSITIONAL ENVIRONMENTS



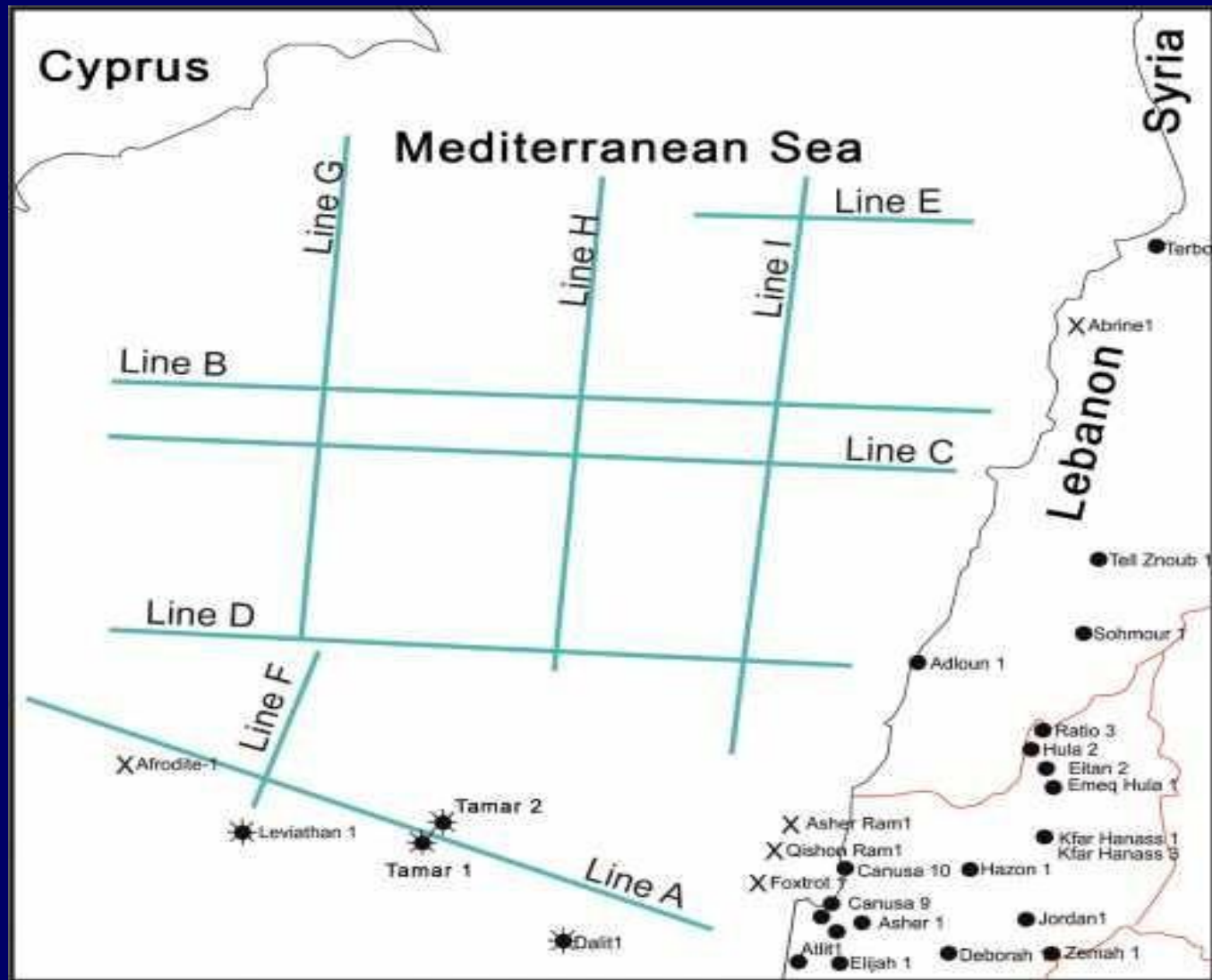


**Stratigraphic Correlation Chart from Continental to Off shore Nile in Egypt showing Major Tectono-Stratigraphic Breaks and Hydrocarbon Occurrences ( J. C. DOLSON et al., 2000)**



# SUBSURFACE BASIN CONFIGURATION



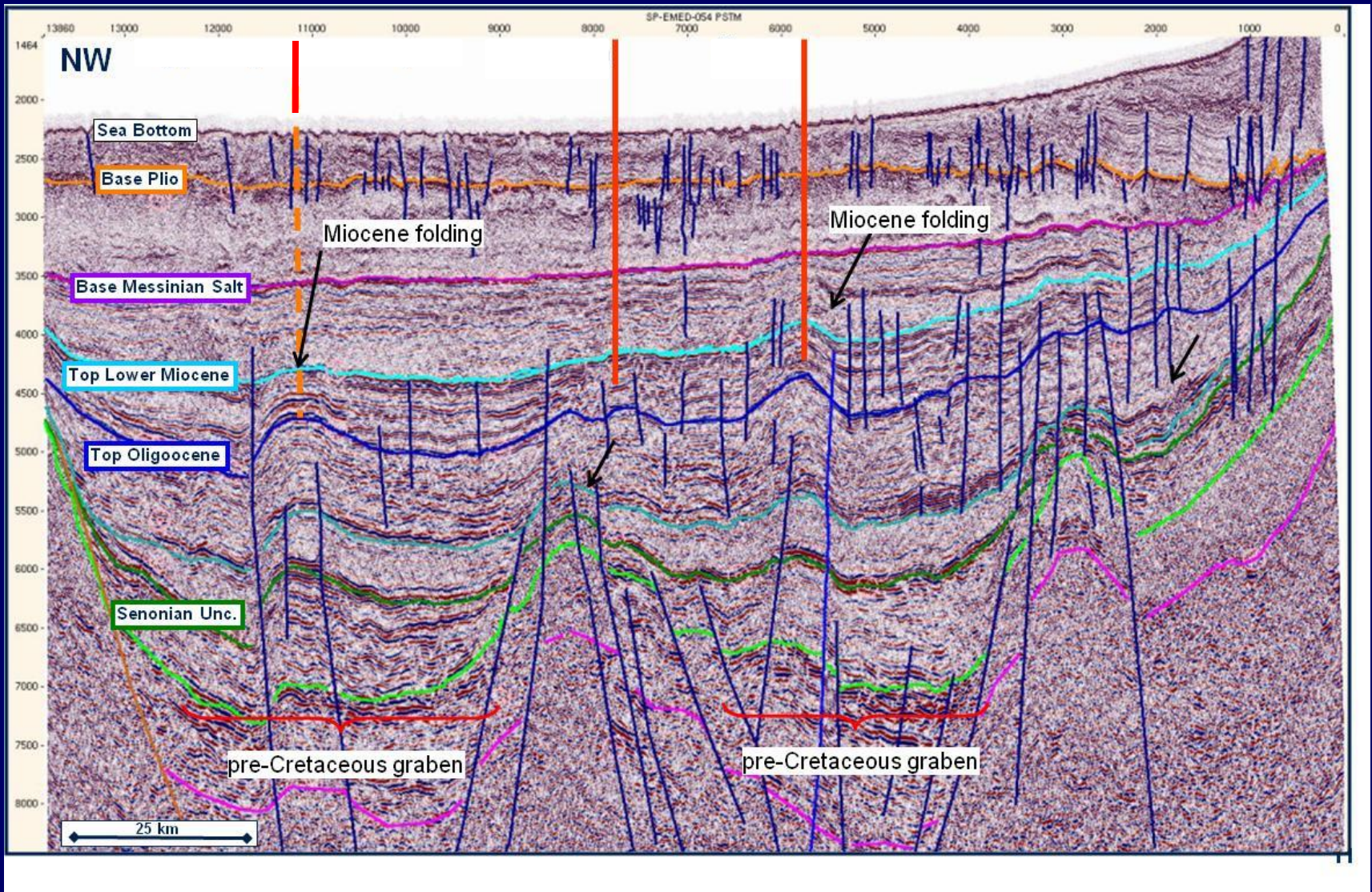


**2 D Seismic Selected Lines and Wells Location Map  
of Levant Basin**

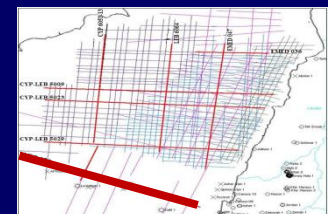
## Seismic Characteristics

- 2008 PGS Geostreamer Techniques reaching 8-10 s two way travel time waves
- Normal polarity, Zero phase Amplitude
- 60-70 meters seismic vertical reflector resolution for Oligocene horizons
- 50 meters seismic vertical reflector resolution for Miocene horizons

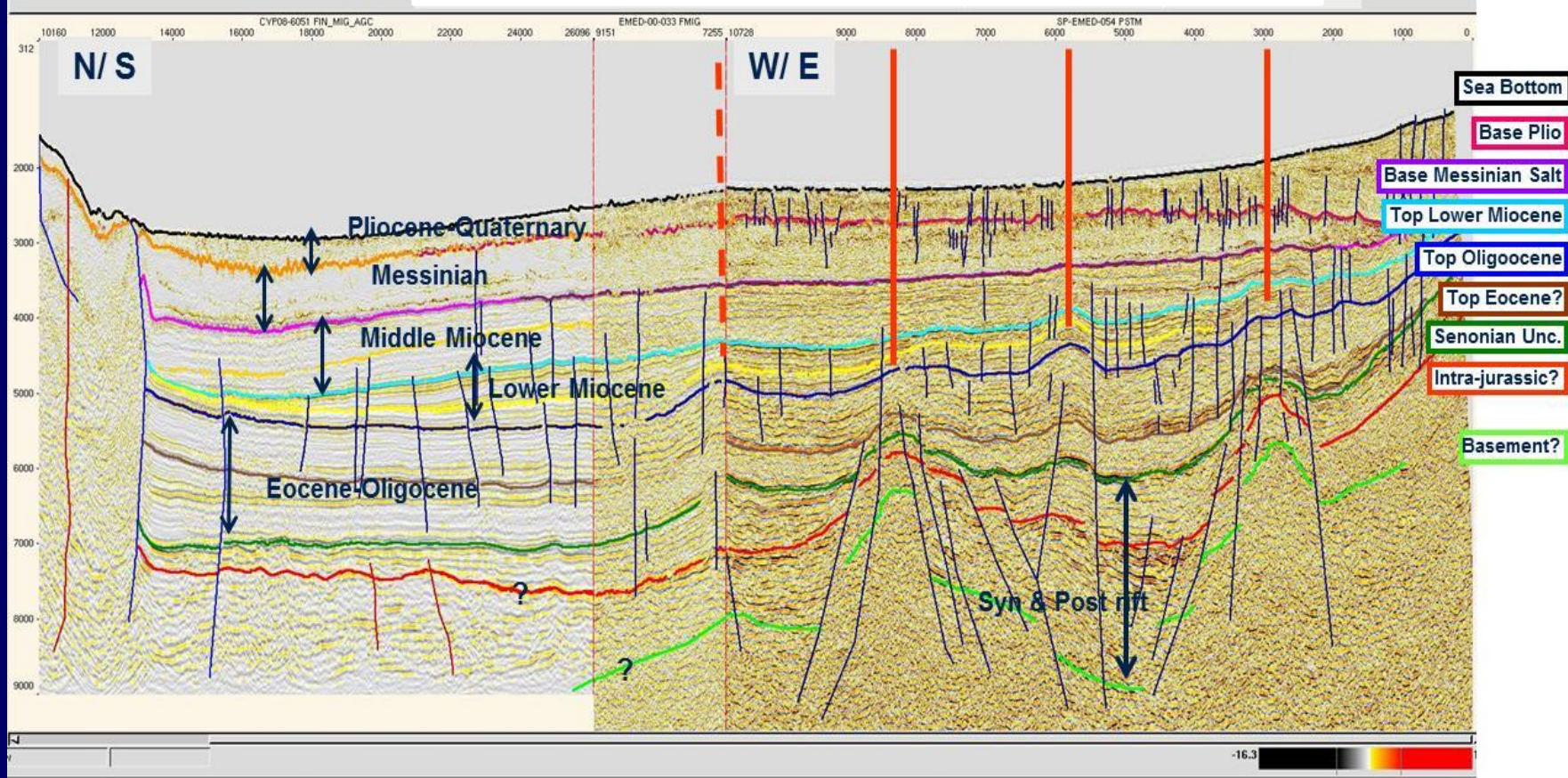




WNW-ESE Seismic Calibration Line A



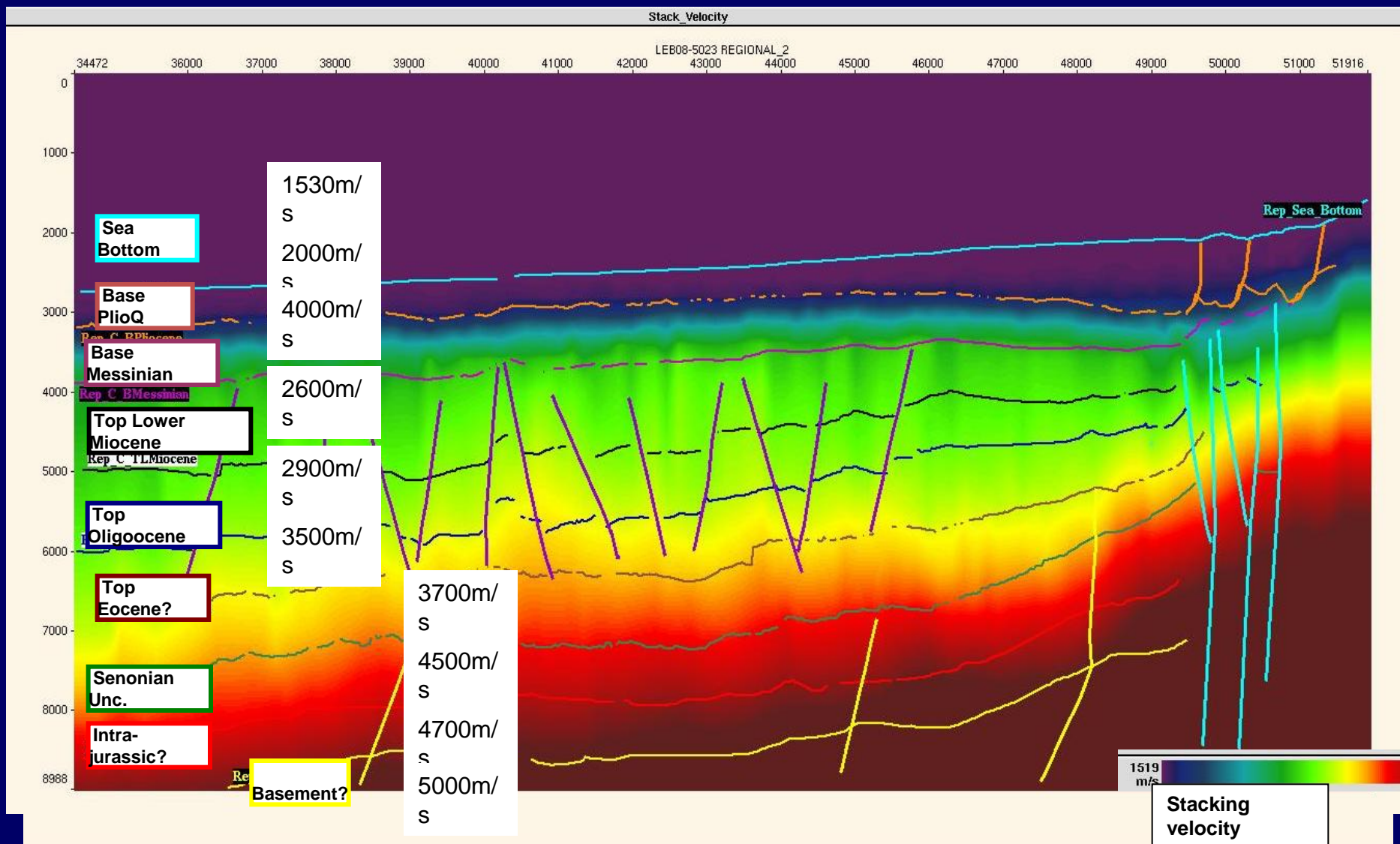




WNW-ESE N-S Seismic Regional Calibration Link Lines



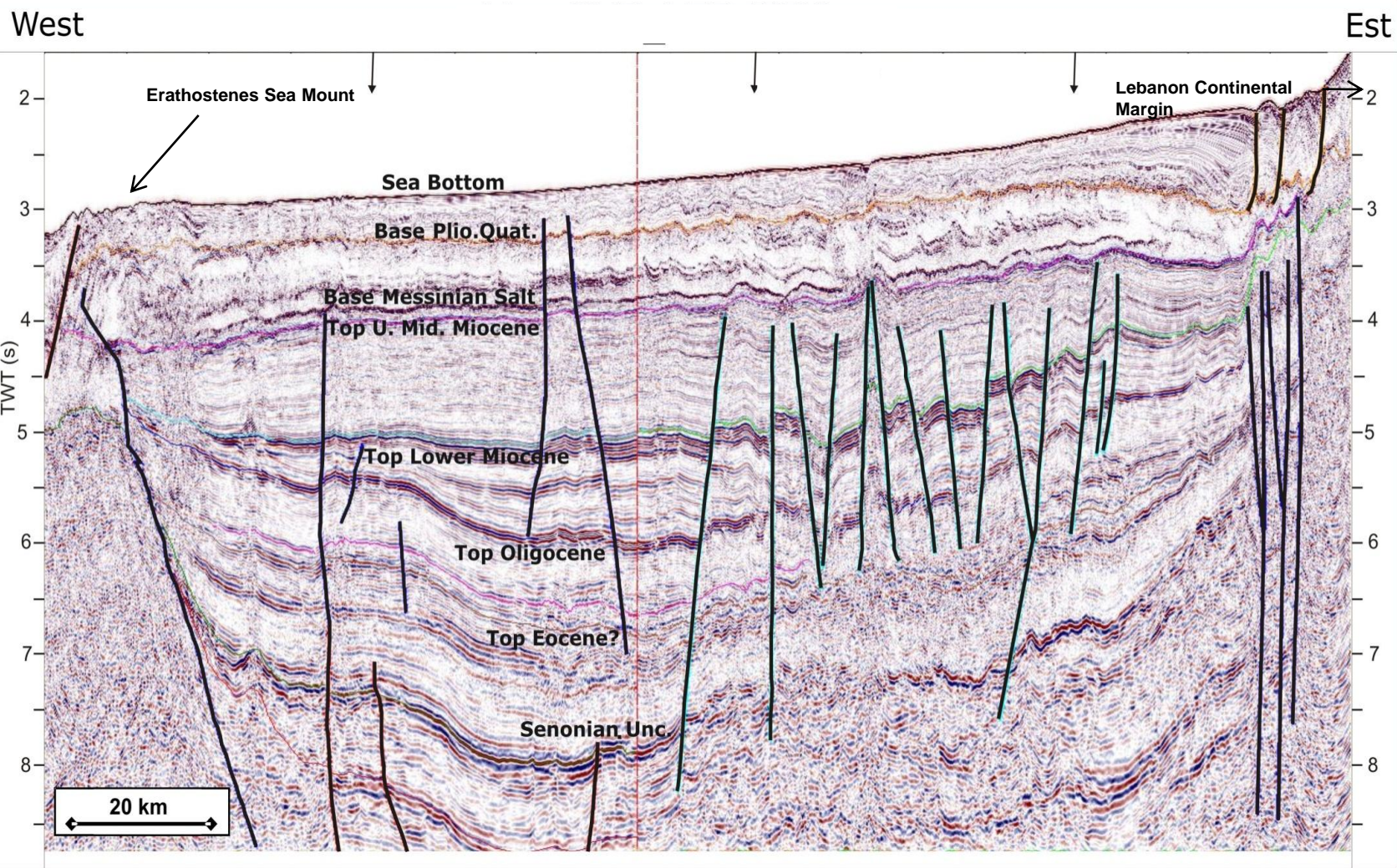




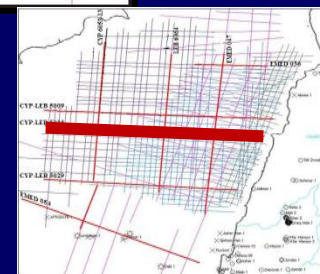
REPSOL / D.G. UPSTREAM / D. GEOLOGY / SPECIAL PROJECTS / G&G SERVICES

Extracted Constant interval velocity from layer computed interval velocity from stacking

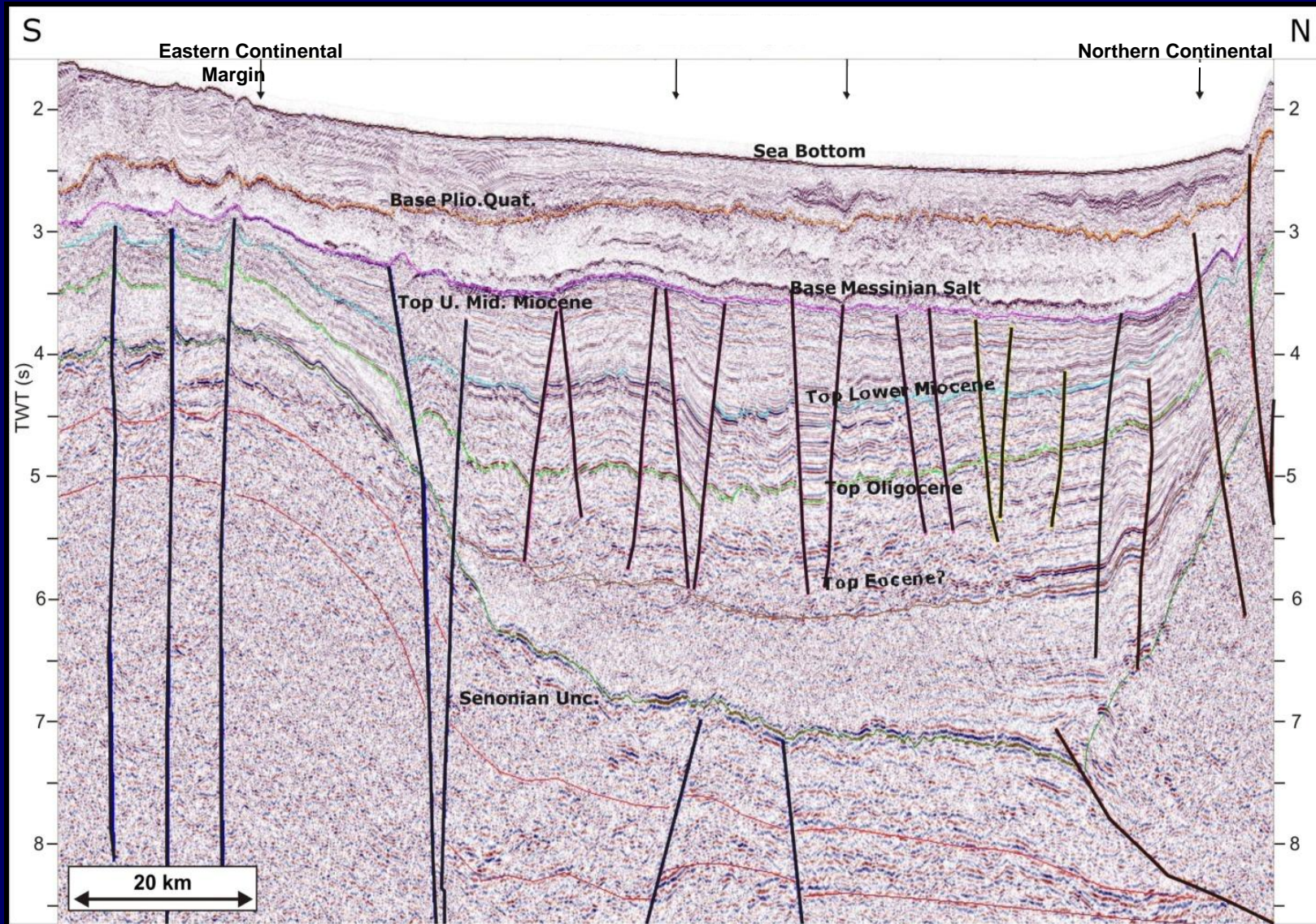




E-W Seismic Line C



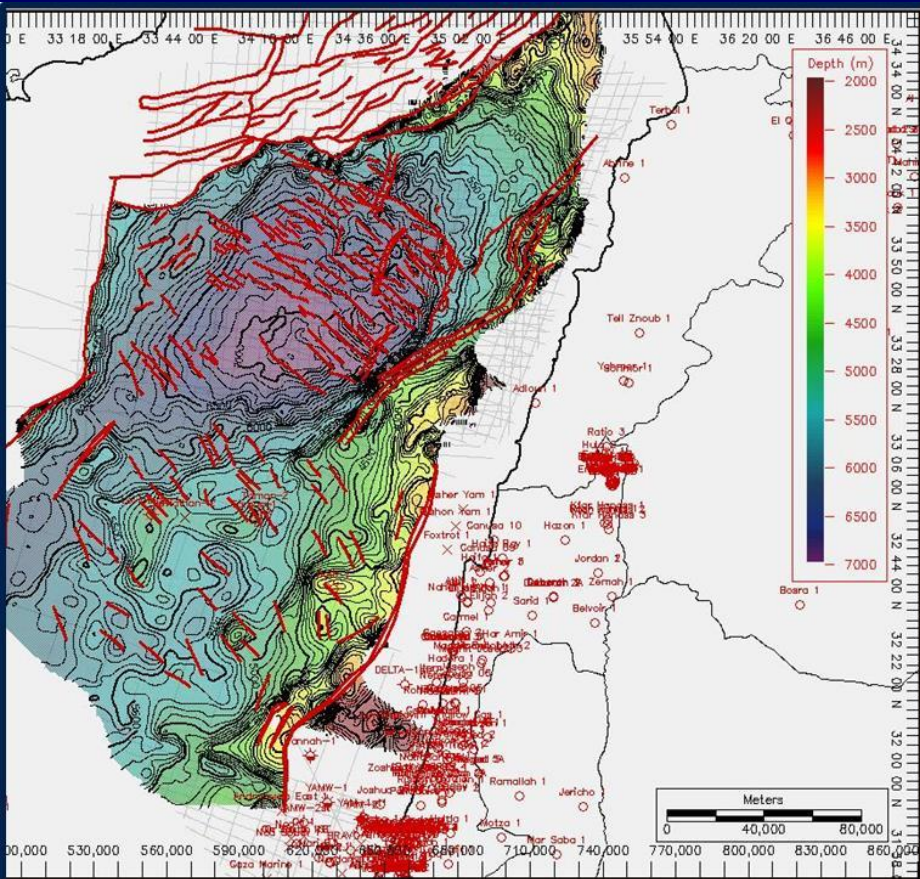




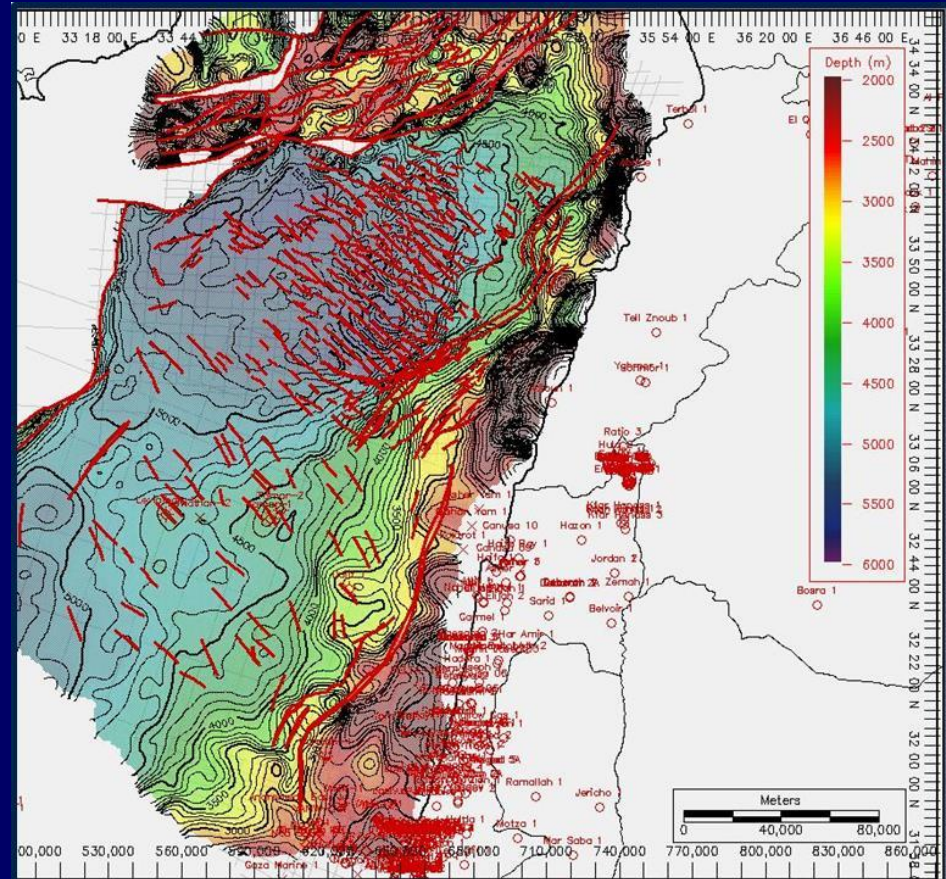
**N-S Seismic Line 1**





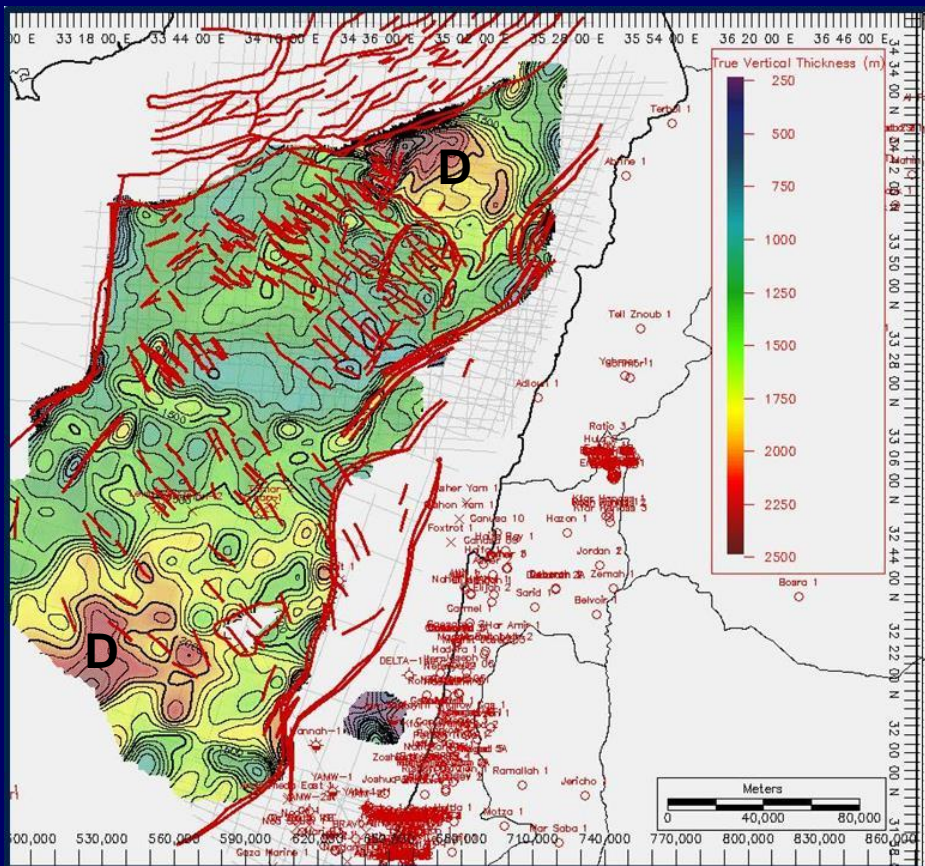


## Top Depth Oligocene Structural Map of the Levant Basin Study Area (CI 100 m) (Repsol, 2011)

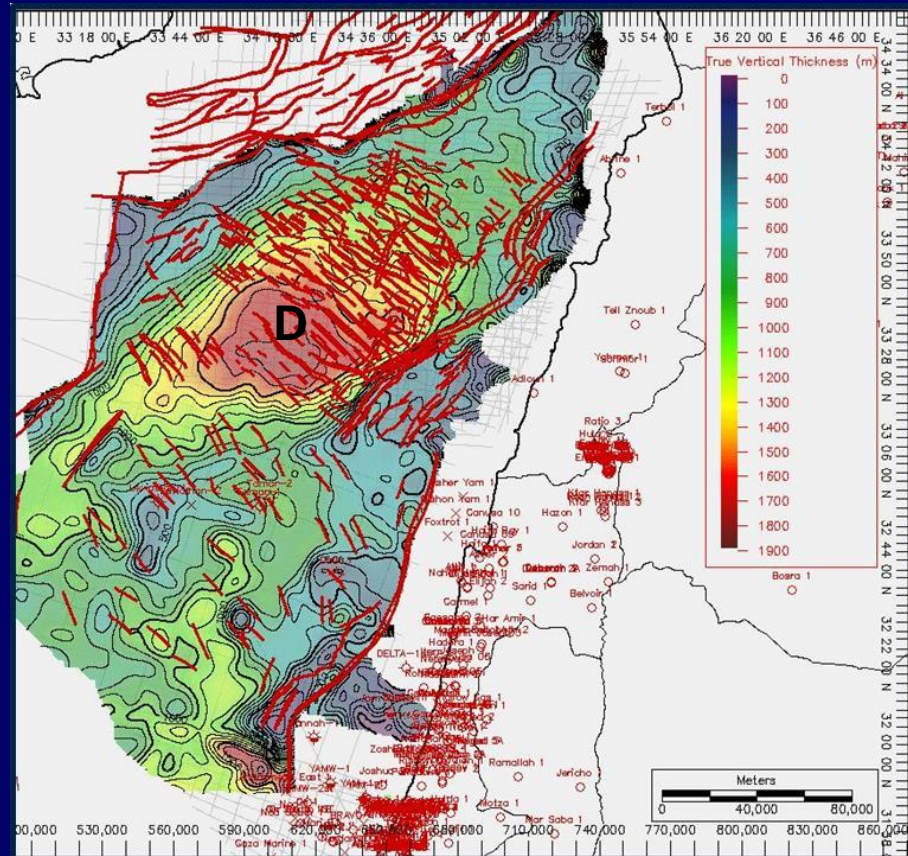


**Top Depth Lower Miocene Structural Map of the Levant Basin Study Area (CI 100 m) (Repsol, 2011)**





**Top Eocene-Top Oligocene Isopach  
Map of the Levant Basin Study Area  
(CI 100 m)**

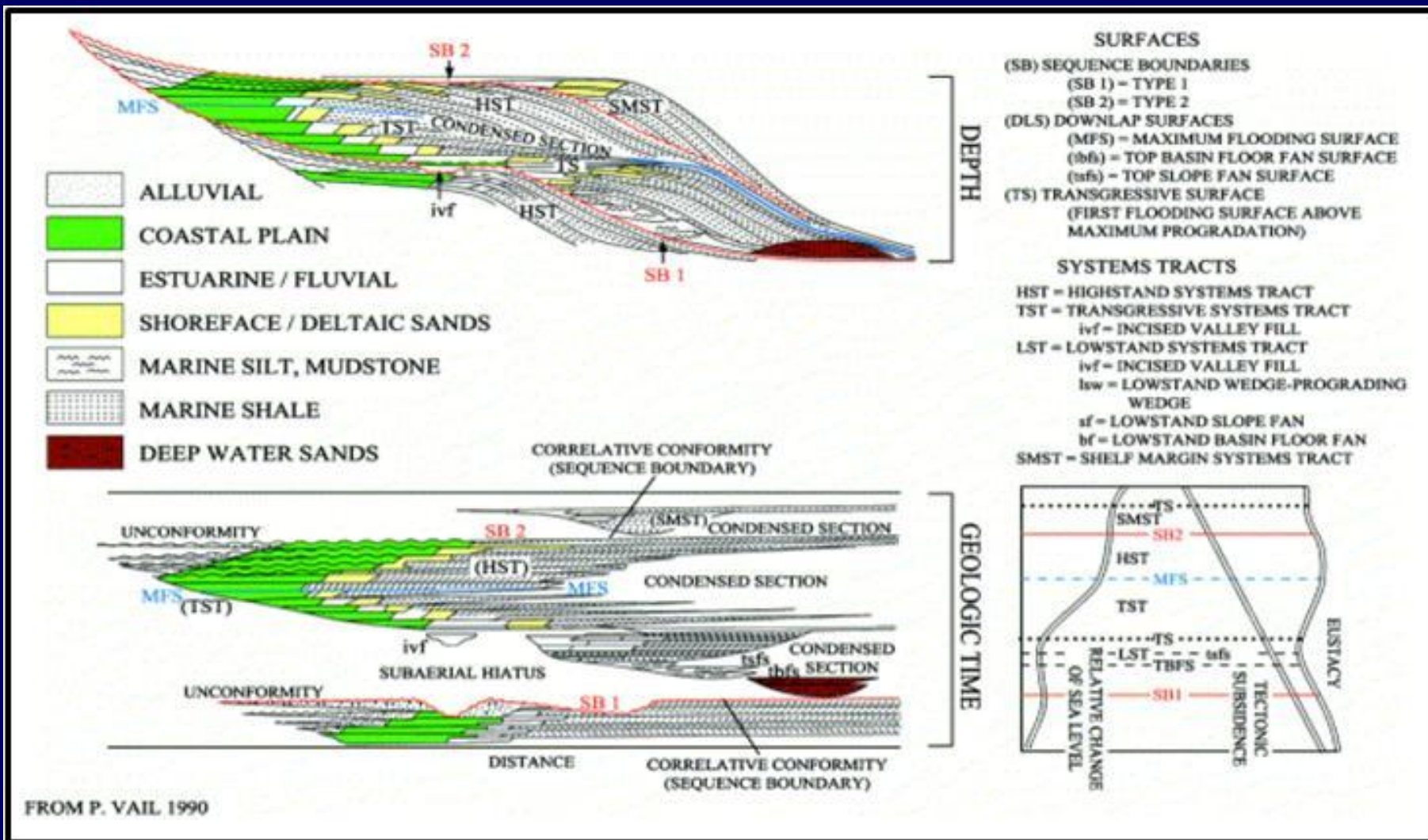


**Top Oligocene – Top L Miocene Isopach  
Map of the Levant Basin Study Area  
(CI 100 m)**

# SEISMIC SEQUENCE STRATIGRAPHY

**SYSTEM TRACTS AND DEPOSITIONAL  
MODELS OF SILICICLASTIC  
ENVIRONMENTS FROM  
CONTINENTAL SHELF TO BASIN FLOOR**

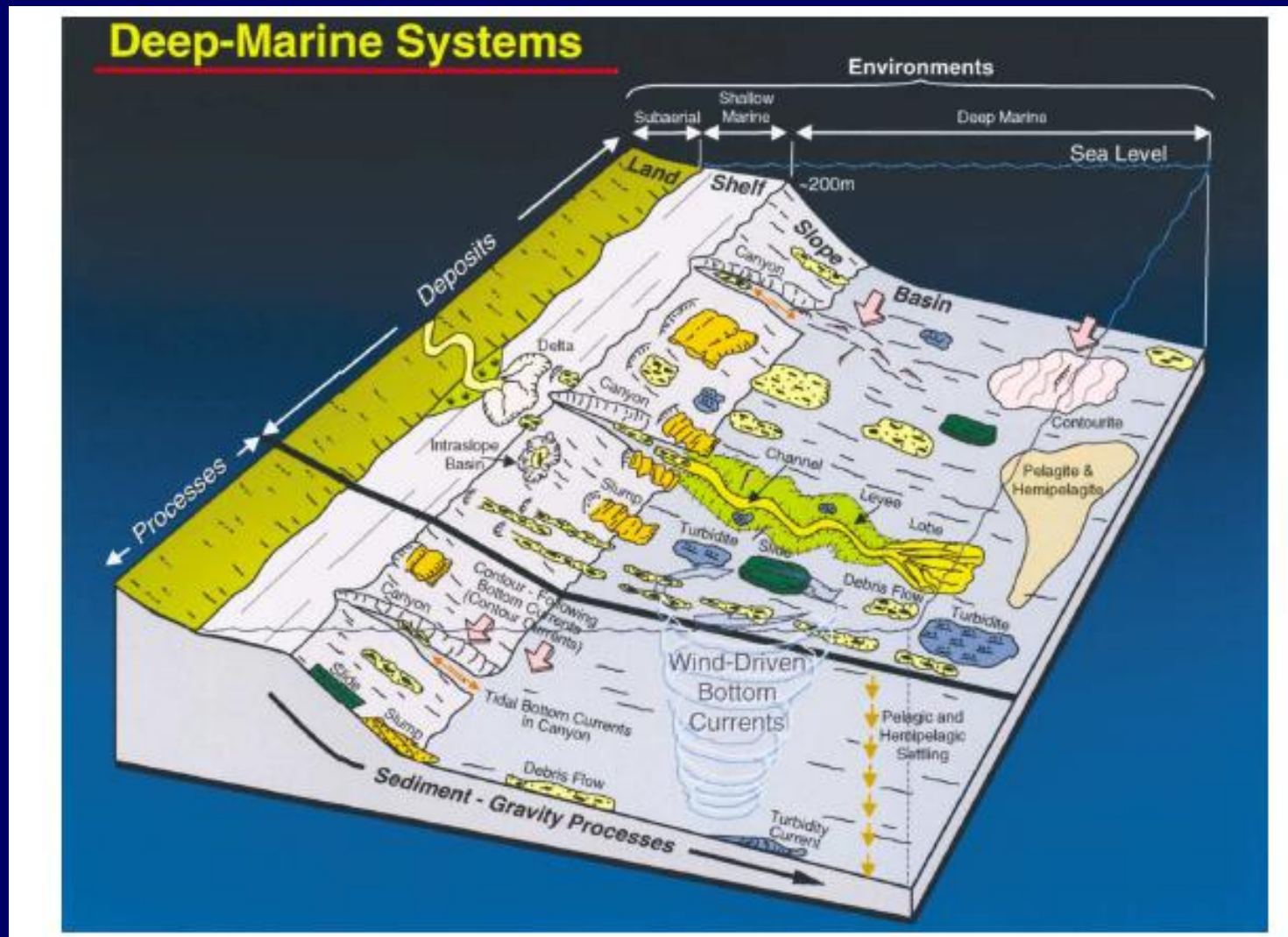




Theoric Sequence Deposit Representation in Siliciclastic Environment along a Continental Margin, showing Remarkable Surfaces and Unconformities, Sequence Boundaries and Systems tracts lithofacies (Vail et al., 1987 ; Van Wagoner et al., 1988)



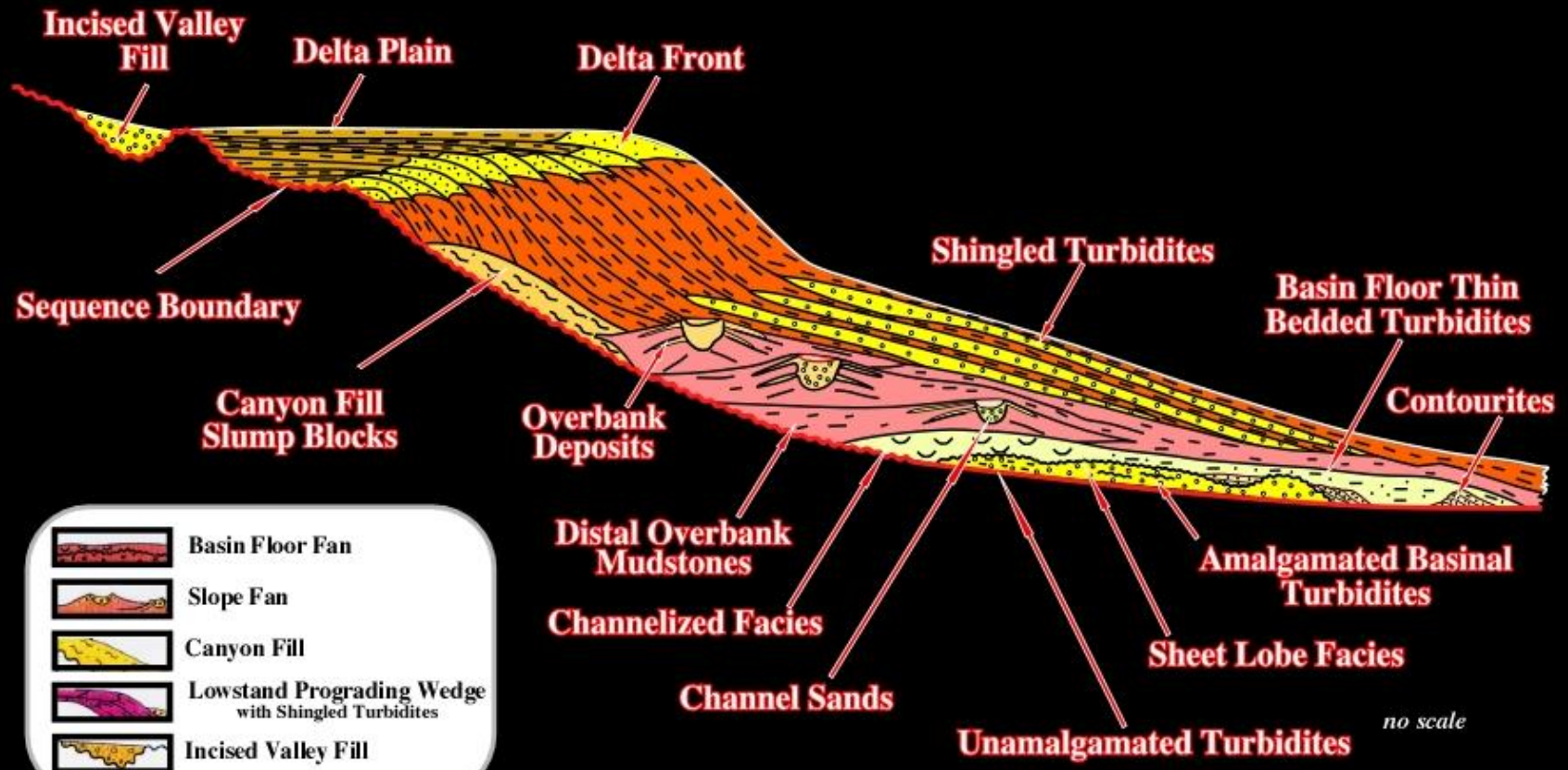
# DEEP-MARINE ENVIRONMENT SYSTEMS



Schematic Diagram showing Shelf, Slope and Basinal Deep-Marine Sedimentary Environments Occurring at Water Depths Deeper than 200 m (shelf-slope break). (Shanmugam G. 2003)

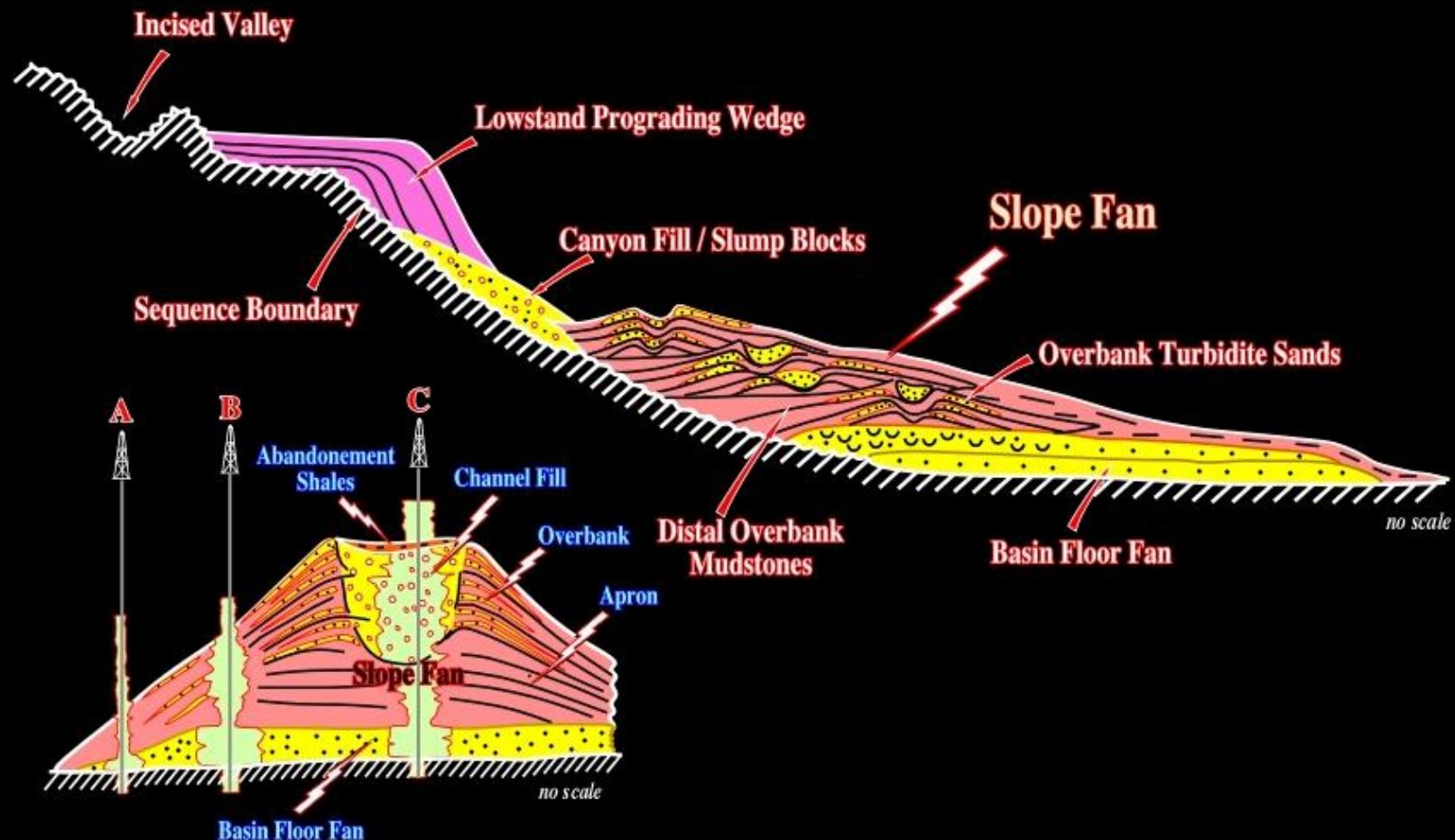
# Lowstand Systems Tract

based on P. Vail, 1993



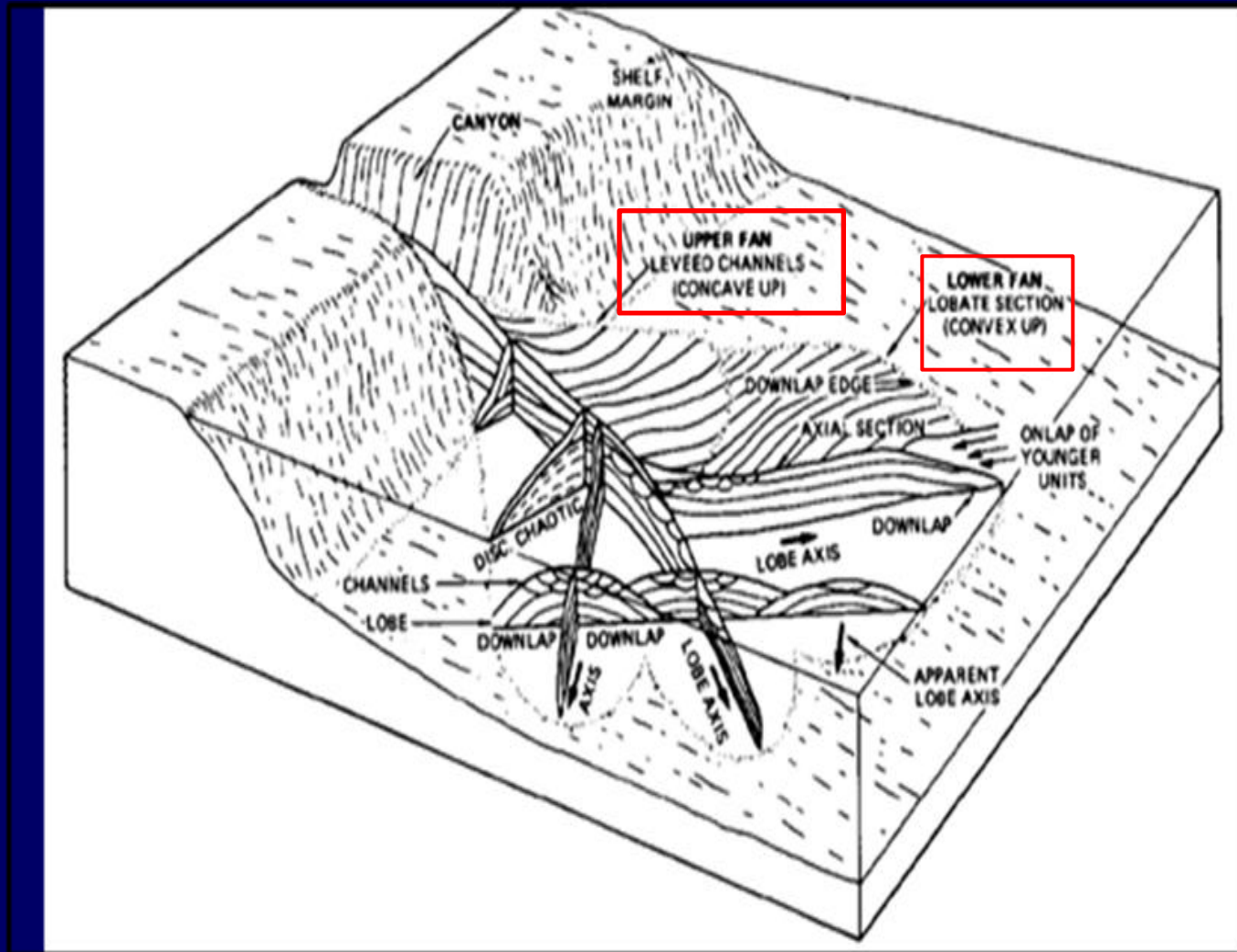
(from Vail, 1989)

# Slope Fan (SF)



Geological model of Lowstand Slope Fan Deposits (from Vail, 1989)

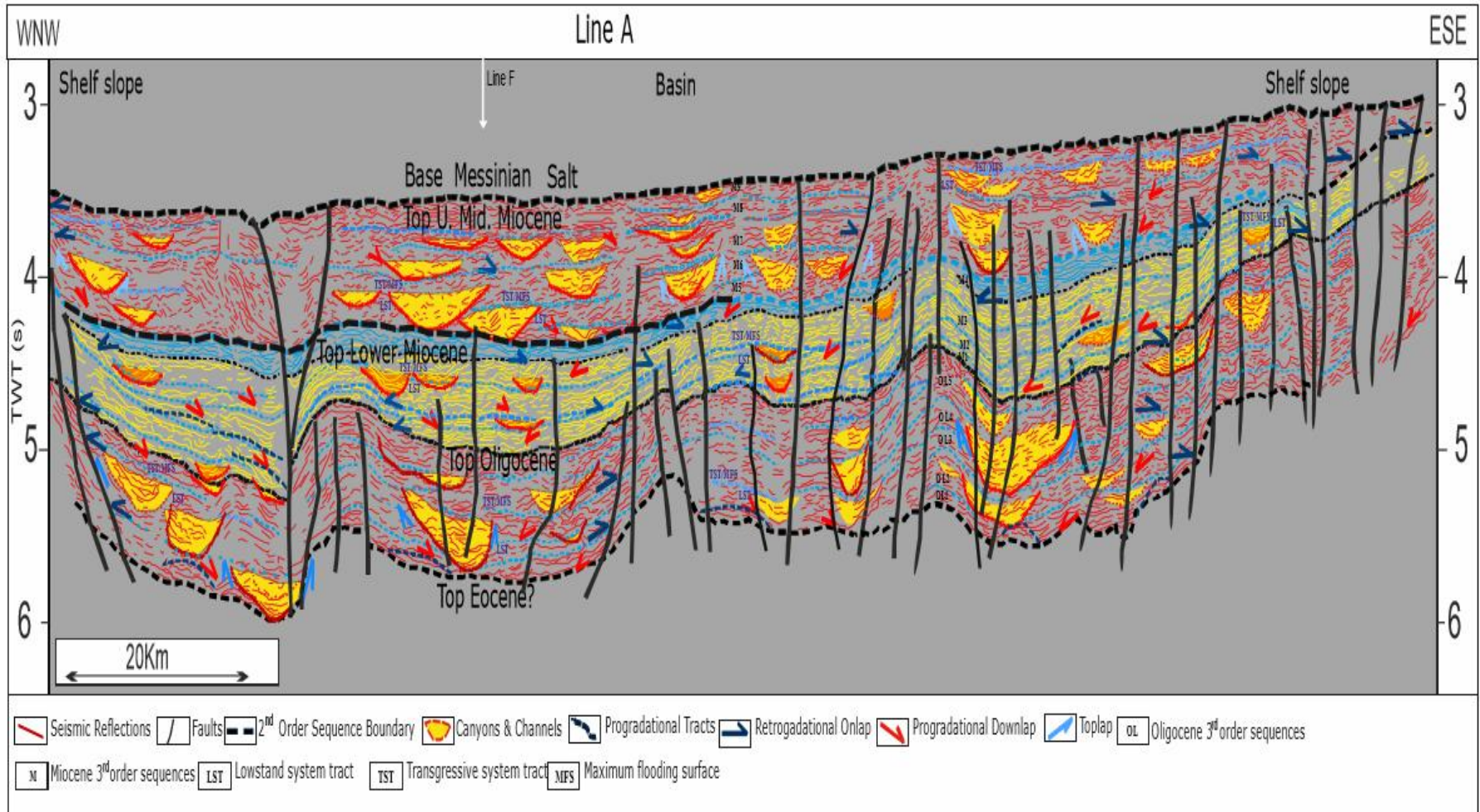




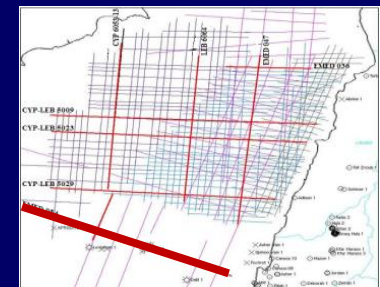
Seismic Facies Diagram of Idealized Canyon-Fan System, Concave up and Convex up Geometries (Mitchum, 1985)

SEISMIC SEQUENCE STRATIGRAPHY

LINES



E-W Seismic Stratigraphic Section of Line A

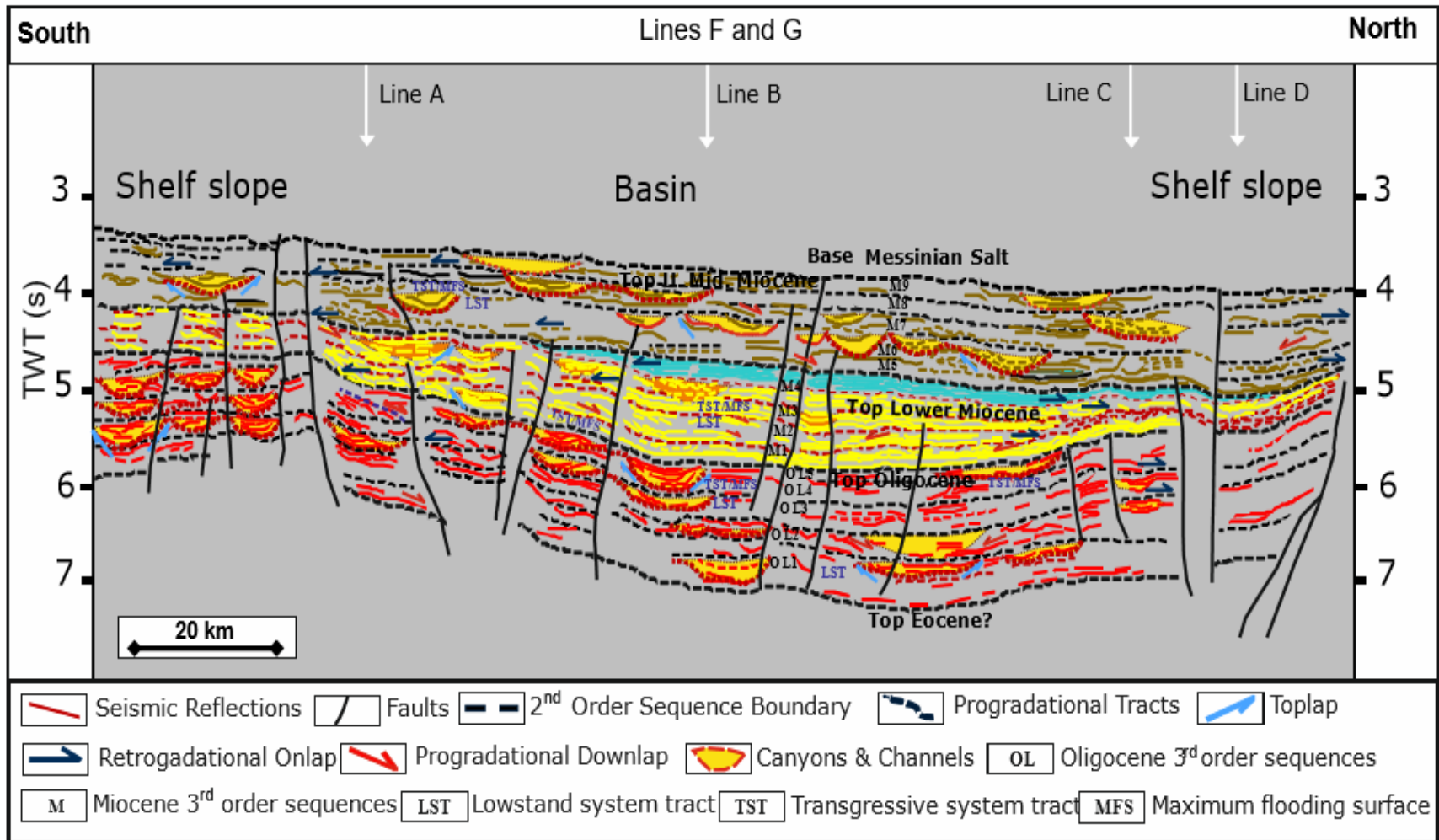












E-W Seismic Stratigraphic Section of Line F and G

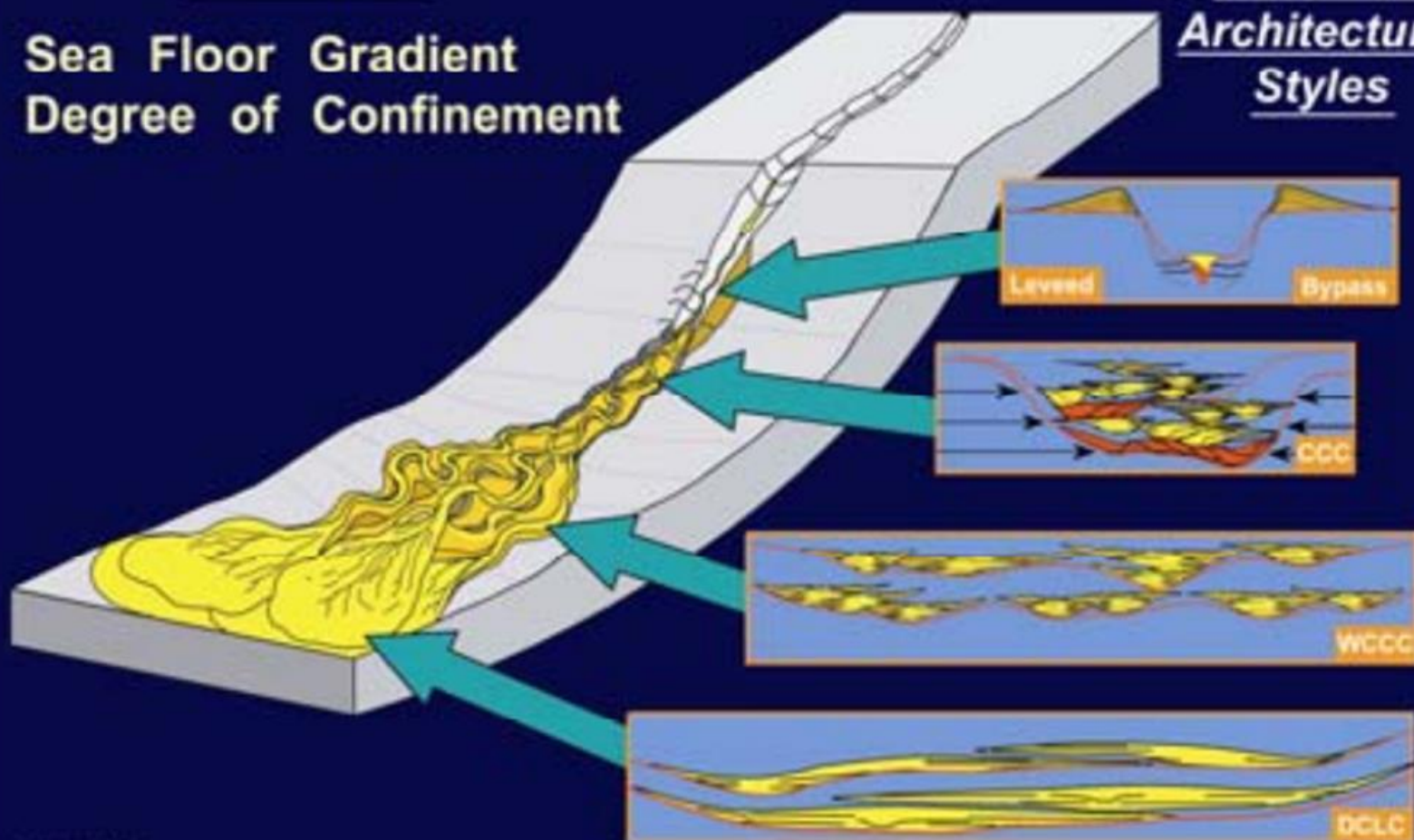


# Slope to Basin Floor Depositional Model

## Controls

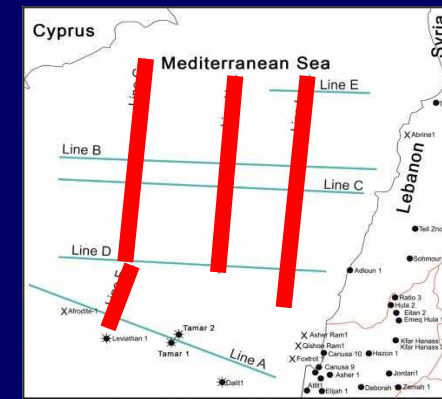
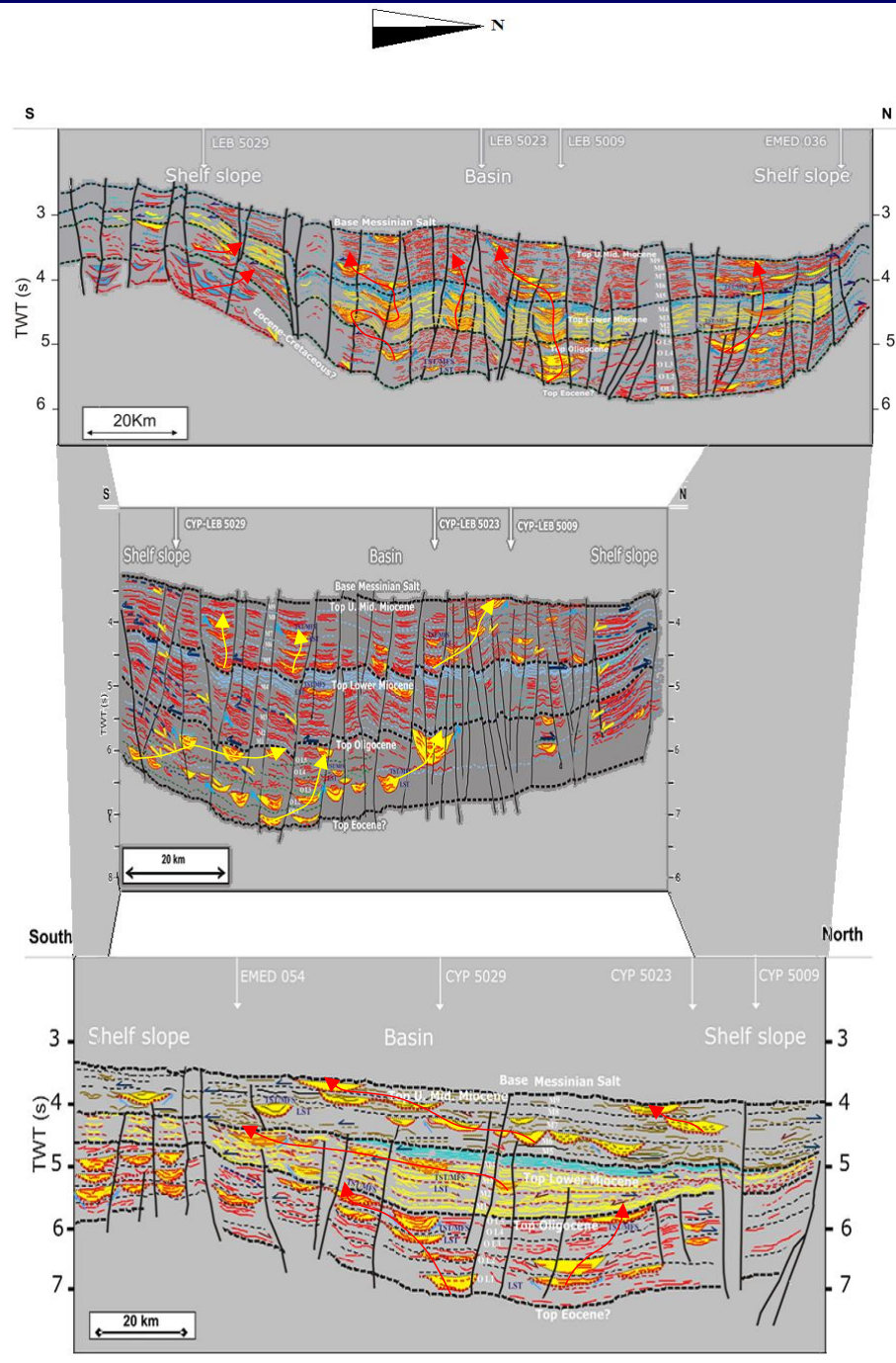
Sea Floor Gradient  
Degree of Confinement

## Reservoir Architectural Styles

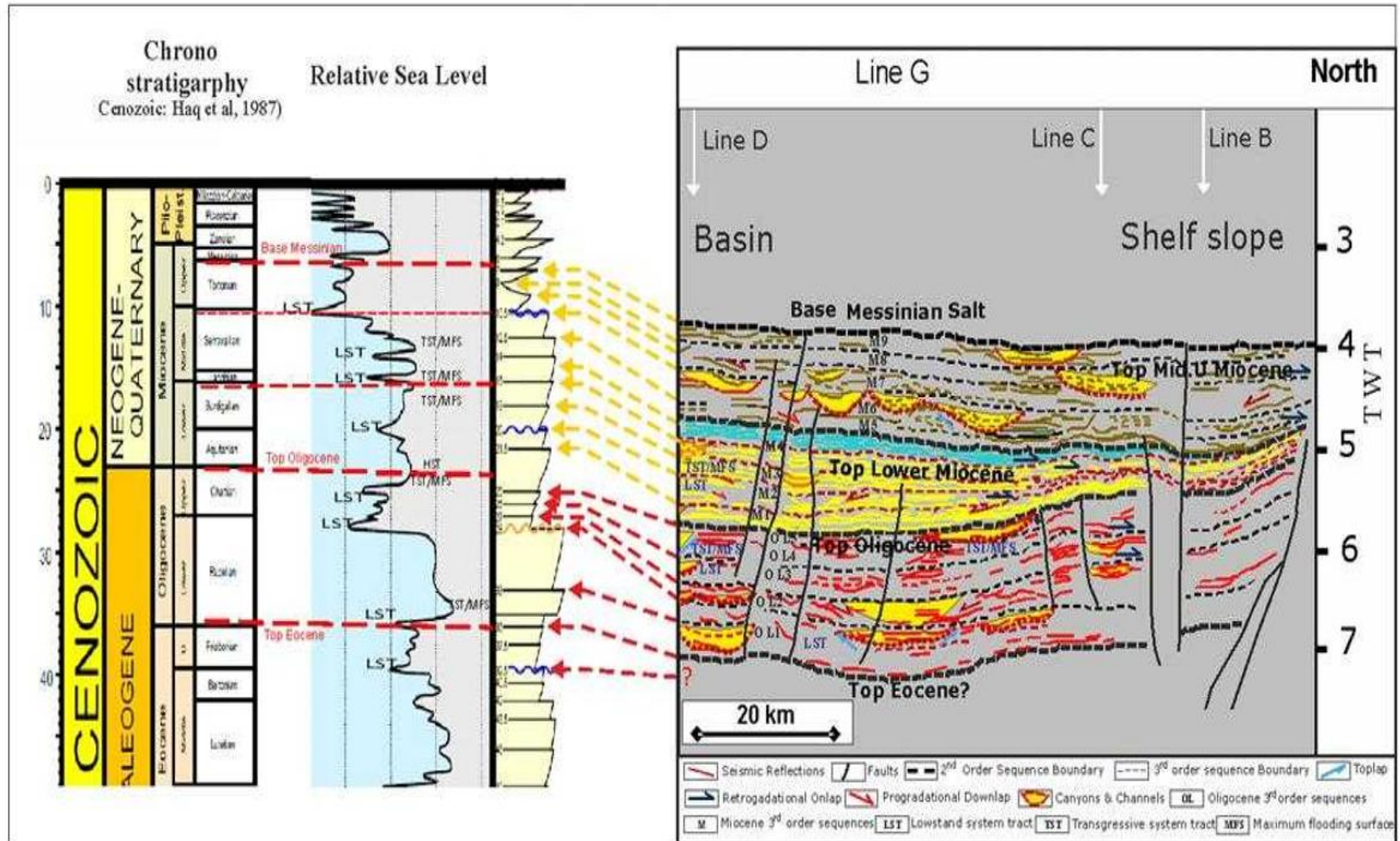








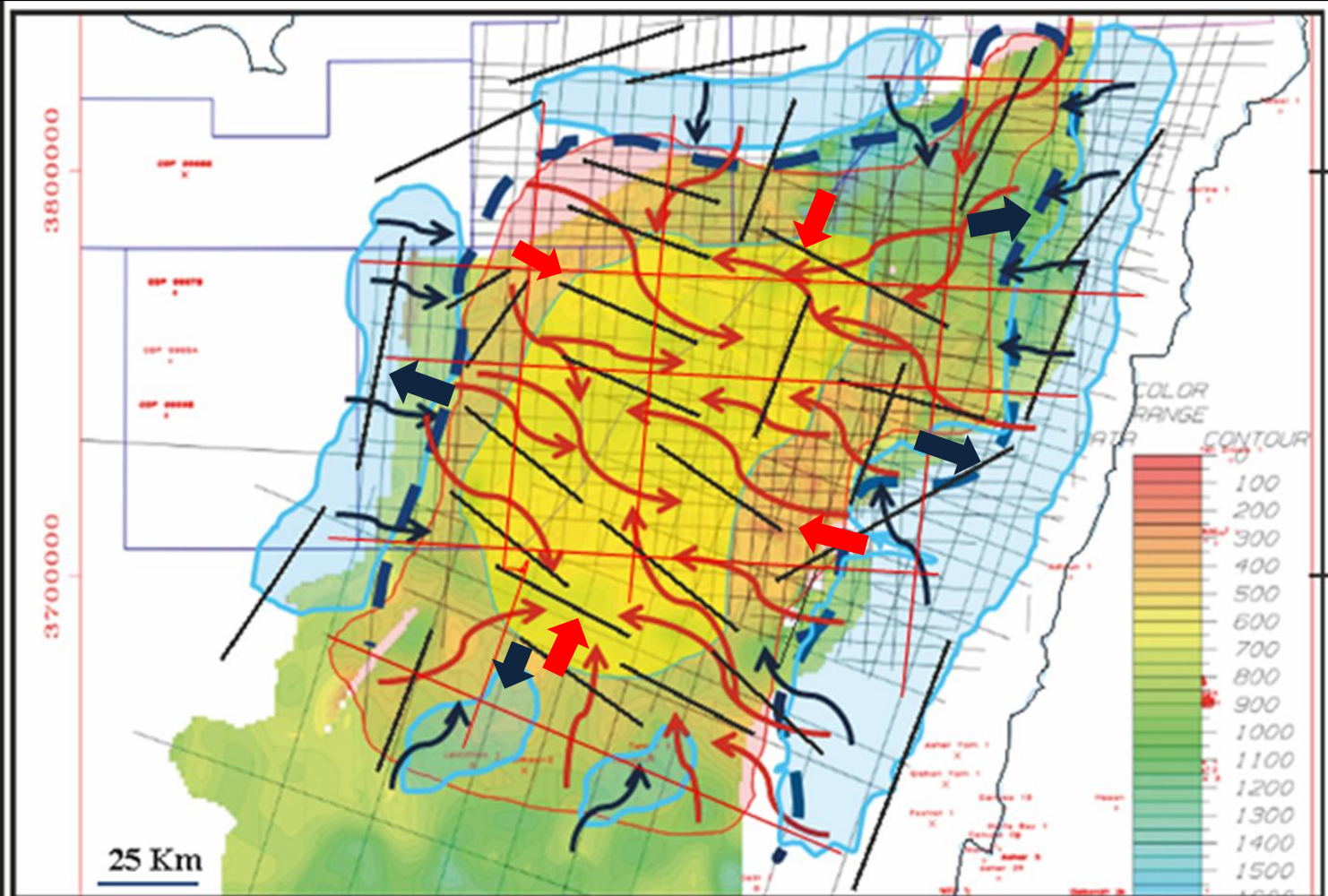
**N-S Seismic Stratigraphic Perspective View  
Sections Showing Basin Structuring  
and Lateral / Vertical  
Canyon Migration (Red Arrows)**



Seismic Sequence Boundaries – Global Eustatic Sea  
Level Cycles Calibration

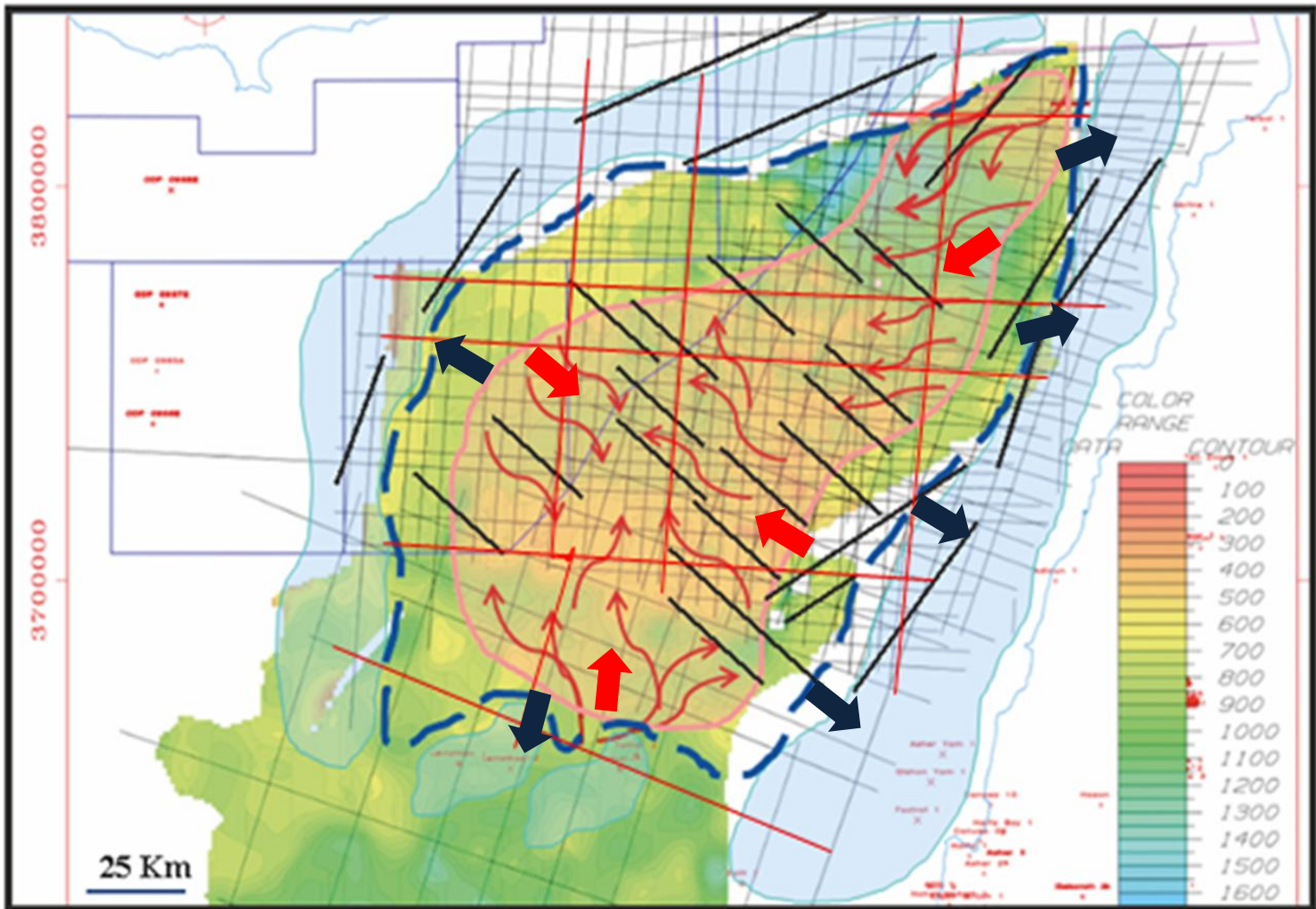
# PALEOGEOGRAPHIC RESERVOIR FAIRWAY MAPS DISTRIBUTION





 Downlap Directions
  Onlap Directions

Oligocene Depositional Early and Late Clastic Lowstand System Tracts on Time Map



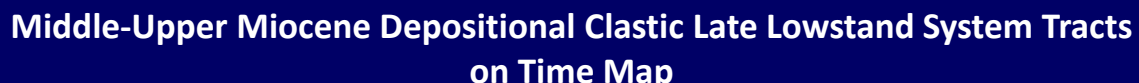
Downlap Directions



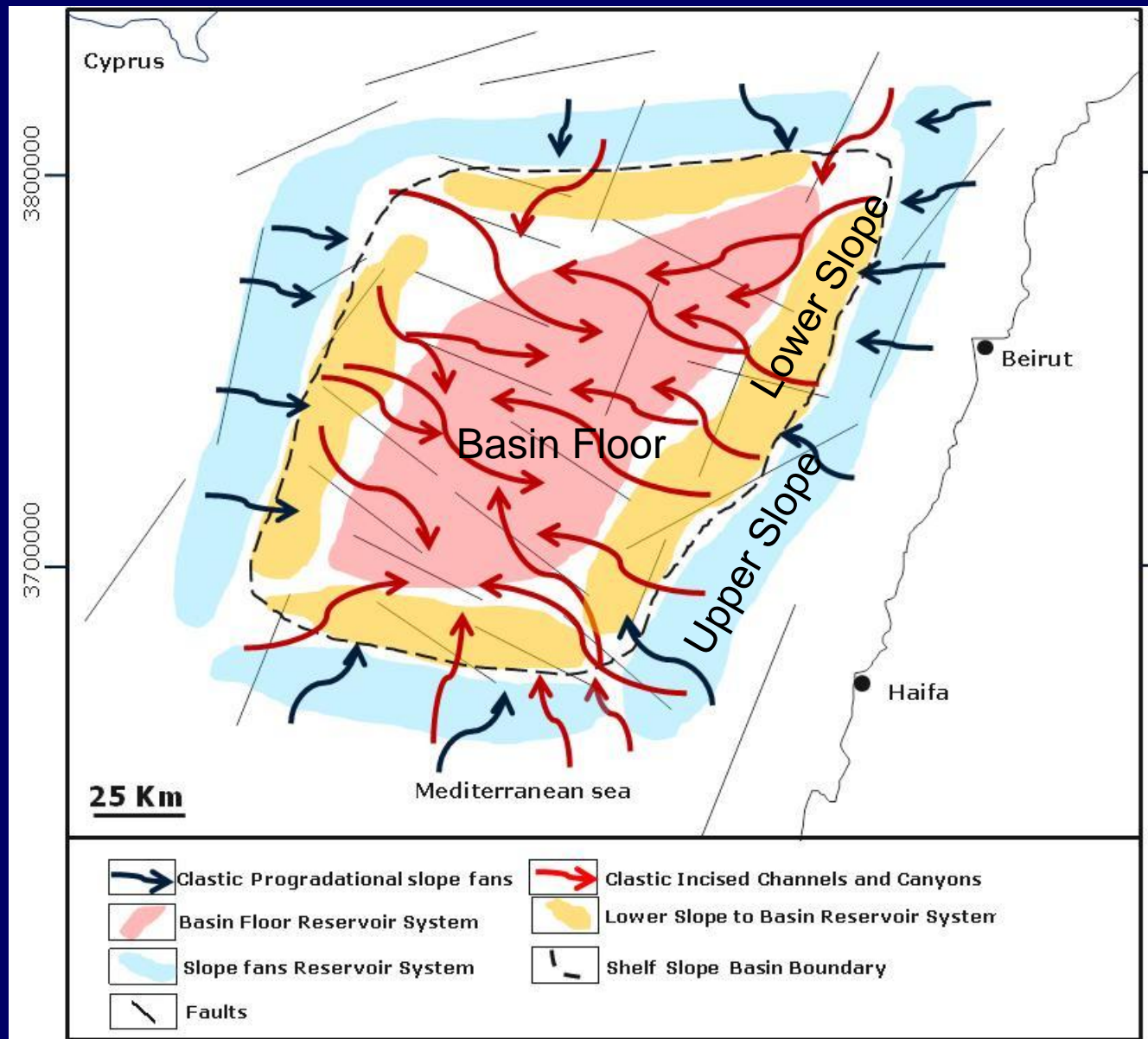
Onlap Directions

Lower Miocene Depositional Clastic Late Lowstand System Tracts on Time Map









**Synthetic Reservoir Fair Map of the Study Area showing the Main Oligocene and Miocene Potential Clastic Reservoir System zones**

# CONCLUSIONS

- Central subsiding area surrounded by uplifted shelves and slopes in eastern, western, northern and southern borders. Deepseated inherited subvertical NE-SW and NW-SE strike slip faults and folds affect Mesozoic and Cenozoic basin horizons
- Oligo-Miocene infilling shows 3 second order and 5 Oligocene, 4 Lower Miocene, and 5 to 7 Middle-Upper Miocene third order seismic sequences correlatable to the global eustatic sea level cycles
- Each Oligocene and Miocene sequence presents a downlap prograding sigmoid, oblique and mounded slope fans system tracts and basin floor mounds and large turbidites sheets and lobes, overlain and cutted by late lowstand incised channels, canyons and levees
- Principal source feeders are from eastern and northeastern continental shelf slopes, and more or less from western and southern areas. This basin can be classified as mobile substrate basin with large and small rivers fed
- Oligo-Miocene incised channels and canyons are generally flanked by NW-SE, NE-SW and N-S faults. They are from stacked single storey and multistory types showing space lateral and vertical migrations along E-W and N-S directions indicating their important sinuous pathways and proximal and distal positions

- Channels and canyons sizes range from 3 to 5, 10 and 15 kilometers width with an average in axis thicknesses between 100 to 350 meters reaching sometimes 1500 meters whereas deepsea mound lobes can reach 3 kilometers width and 100-150 meters in axis infill.
- Three main domains of reservoir systems related to the slope, lower slope and basin floor had been highlighted, containing respectively clastic deposits of progradational slope fans, channels, canyons and levees and basin floor lobes and sheets. They are vertically and laterally superposed and shifted.



THANK YOU FOR YOUR ATTENTION