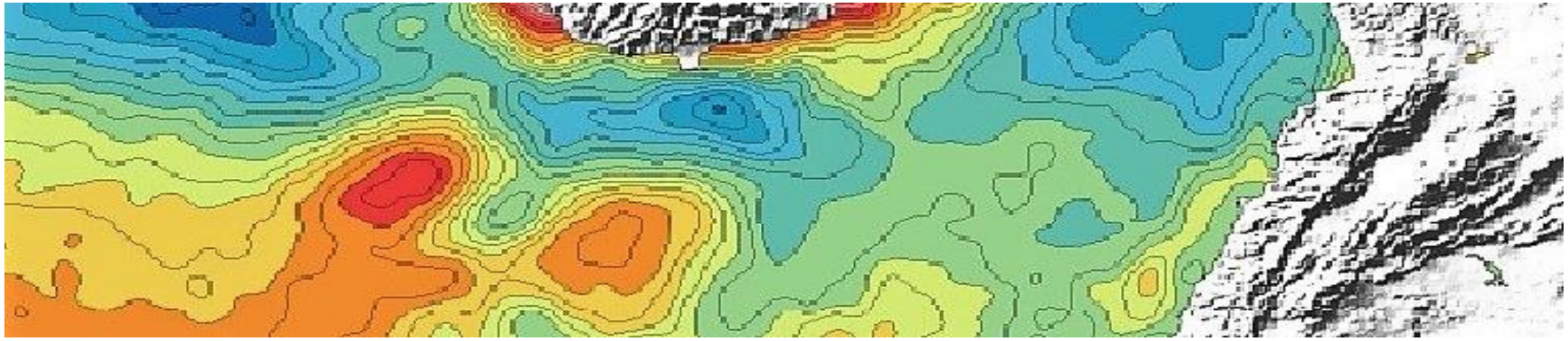
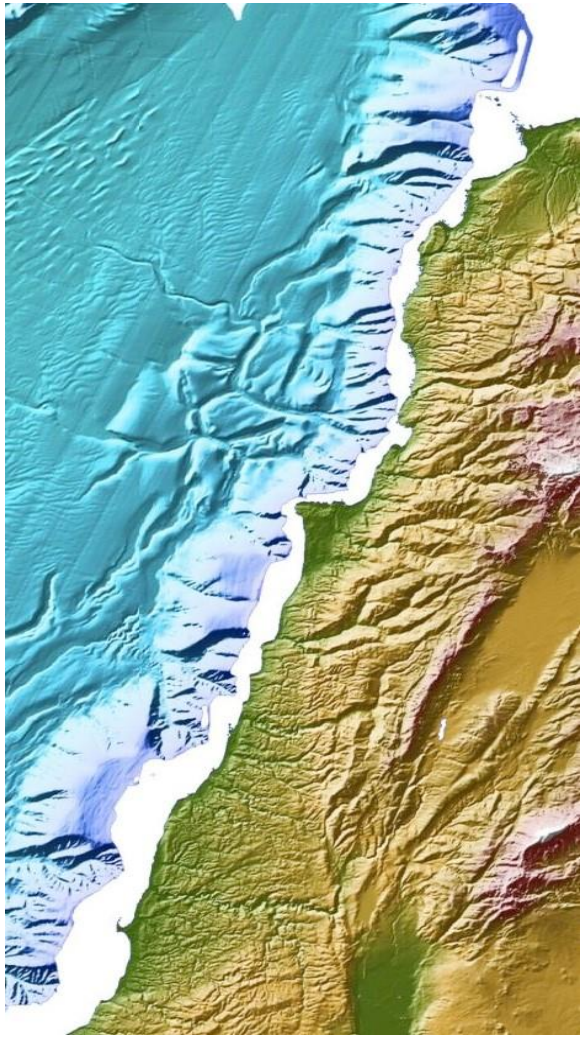




2D CRUSTAL MODELING OF THE LEVANT BASIN

(EASTERN MEDITERRANEAN REGION)

LAMA INATI [1],[2],[3],[4], HERMANN ZEYEN[5], FADI HENRI NADER[1], MATHILDE ADELINET[1], ALEXANDRE SURSOCK[2], MUHSEN RAHHAL[4], FRANÇOIS ROURE[1].

(1) IFP Energies Nouvelles, geology department, France

(2) National Center for Geophysical Research, CNRSL, Lebanon

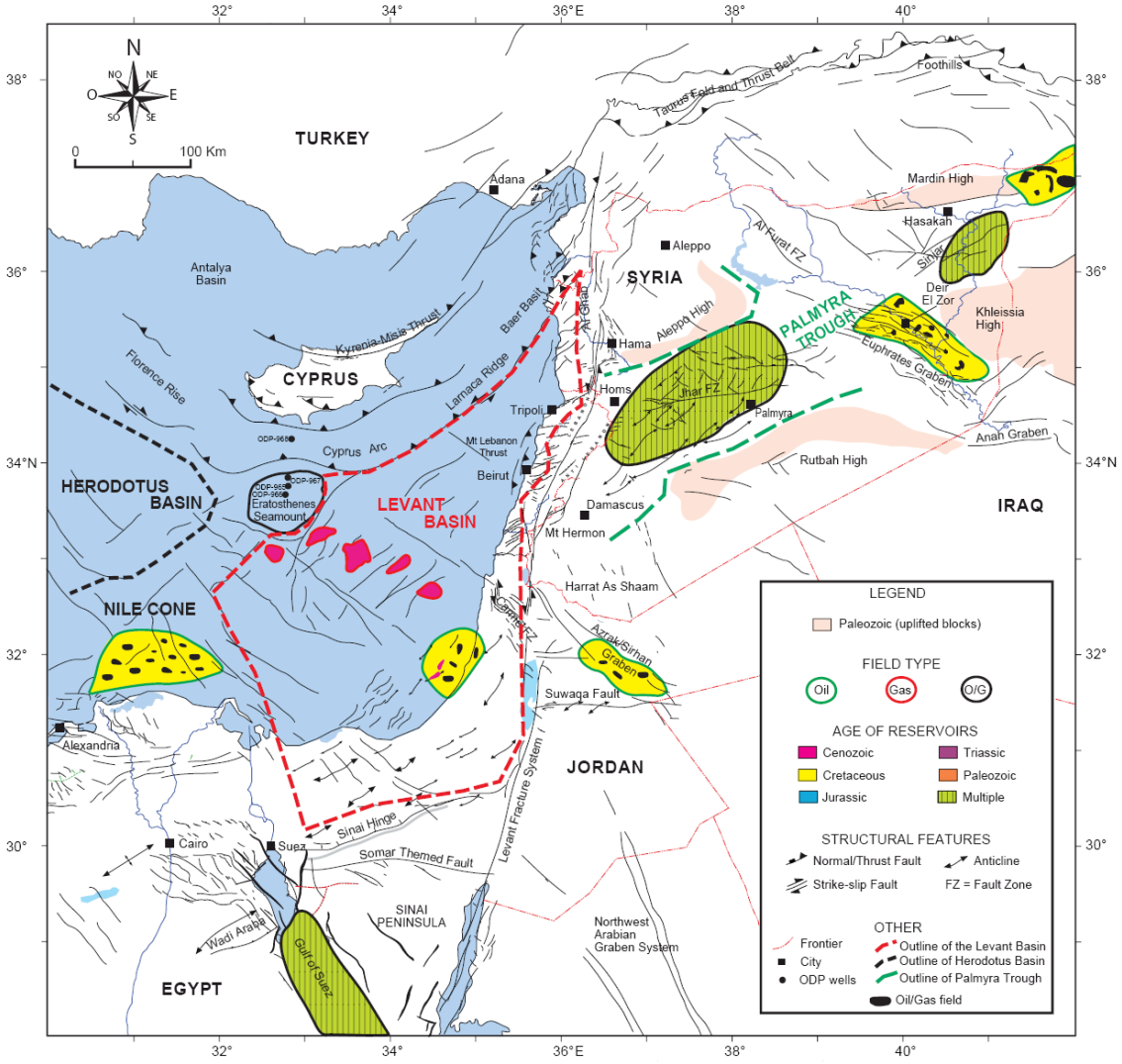
(3) Université Pierre et Marie Curie, France

(4) Ecole Supérieure des Ingénieurs de Beyrouth, Université Saint Joseph, Lebanon

(5) Université paris-sud, département des sciences de la terre, France

INTRODUCTION

RESPONSIBLE
OIL AND GAS

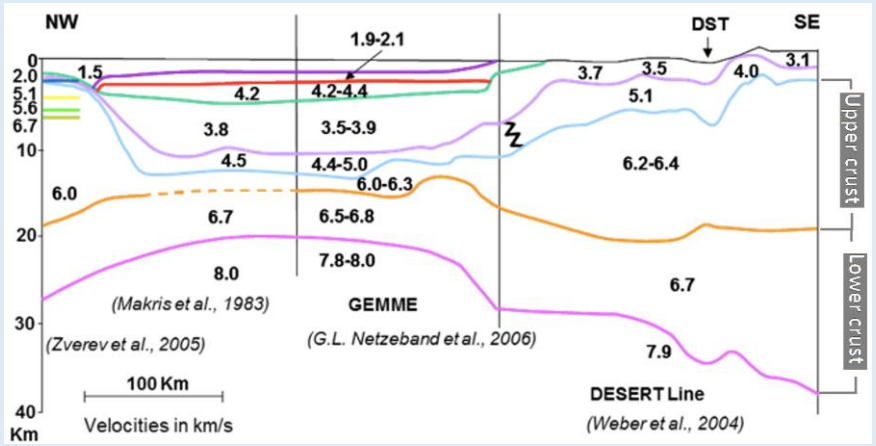


- The Eastern Mediterranean region proven to be world-class, frontier deepwater hydrocarbon province.
- More than 60 Tcf of natural gas were discovered in the region.
- New plays have been confirmed in un-explored areas; e.g. Zohr field (carbonates, offshore Egypt).
- The Levant Basin is characterized by a lack of data, a complex geodynamic history, and high exploration costs.

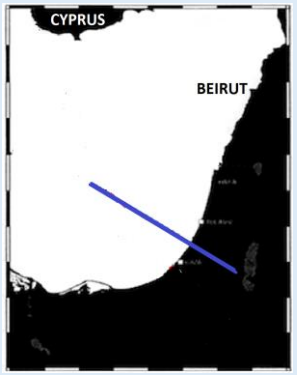
INTRODUCTION
PREVIOUS WORKS

RESPONSIBLE
OIL AND GAS

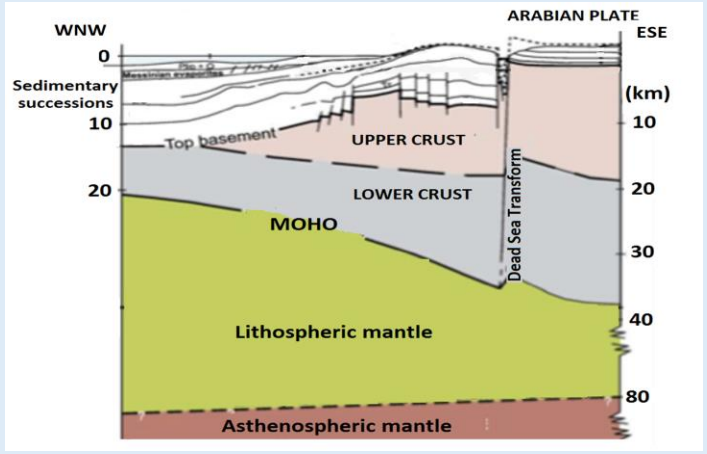
Netzeband et al., 2006
Seismic refraction showing a thinned continental crust in the southern part of the Levant basin



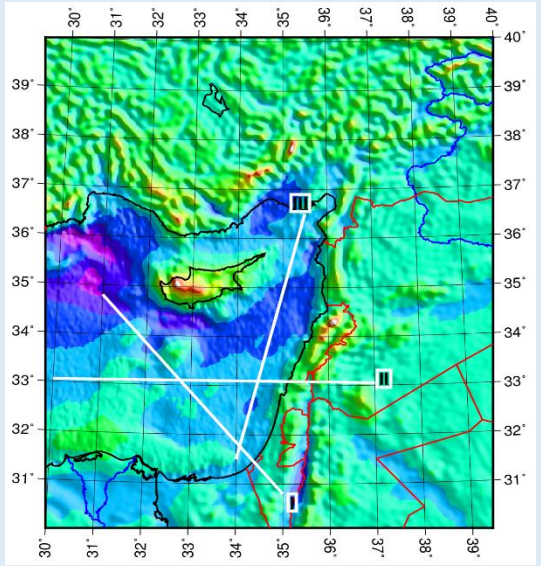
Netzeband et al., 2006



Segev et al., 2006
&
Ben Avraham et al., 2002
advocate for an oceanic crust



Segev et al., 2006



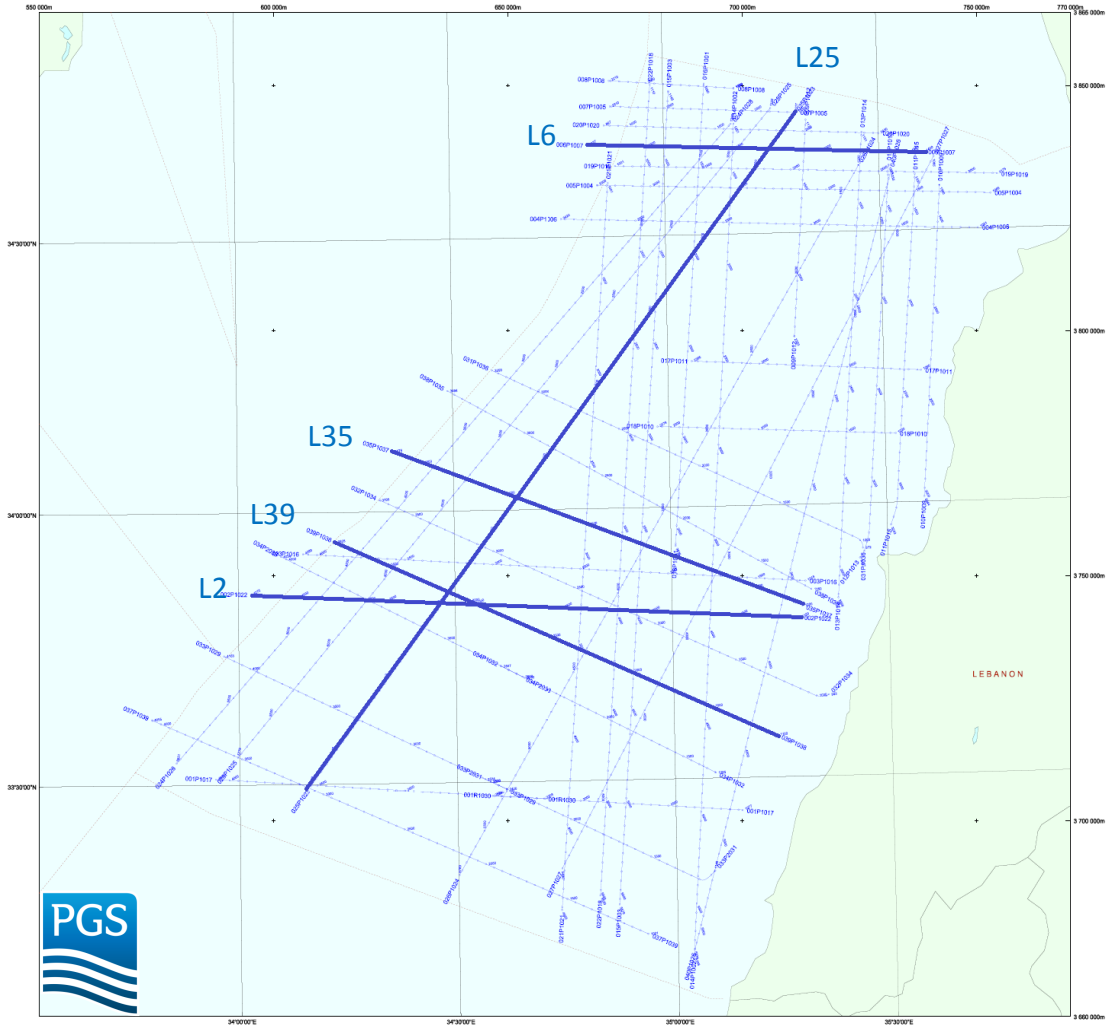
Inati et al., 2016
DOI:10.1016/j.tecto.2016.10.030
2D crustal modeling on a large scale showing a thinned continental crust in the Levant basin

METHODS & DATA

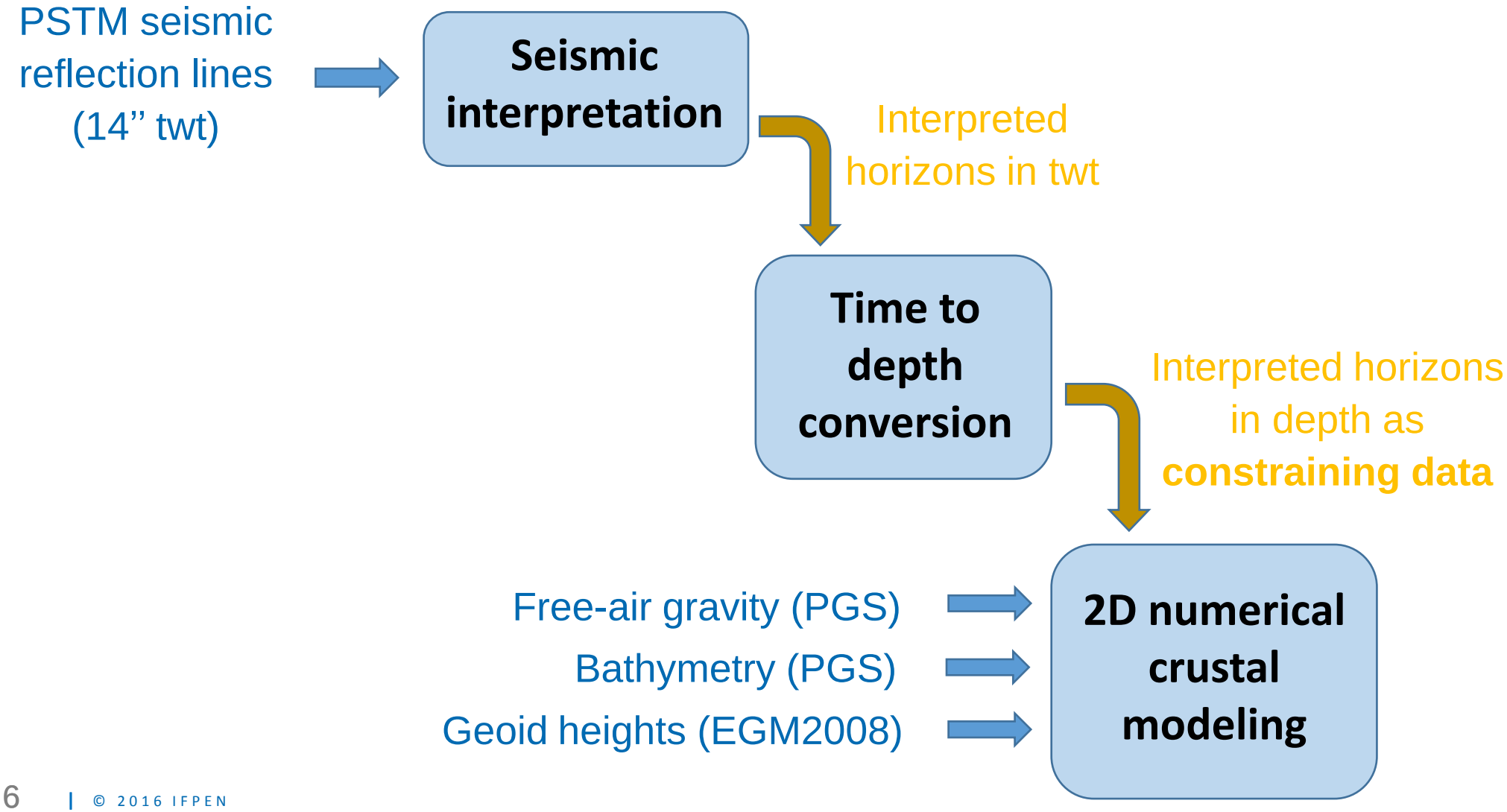
METHODS & DATA

RESPONSIBLE
OIL AND GAS

- Five 2D PSTM seismic reflection lines (14” twt) with gravity and magnetic data acquired by PGS (courtesy of LPA);
- Interpreted surface horizons including seabed (courtesy of PGS and LPA);
- Free-air gravity map (courtesy of PGS and LPA)
- Geoid heights from public domain EGM2008 (Pavlis et al., 2012)



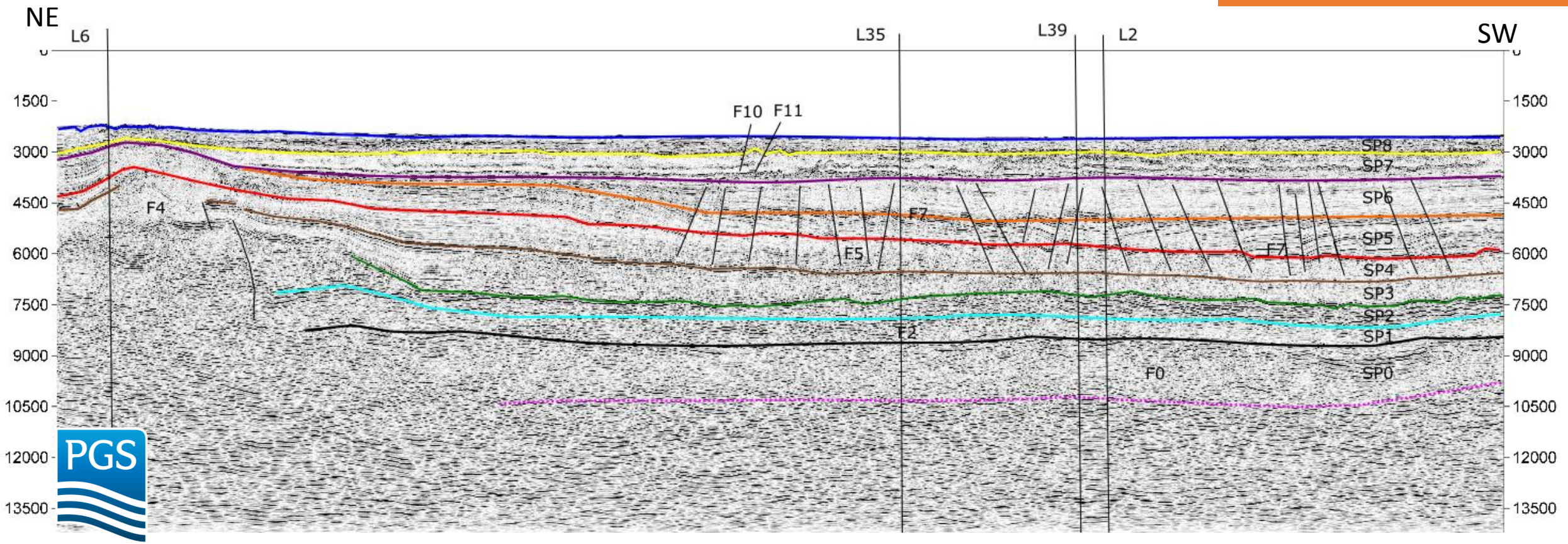
METHODS & DATA
METHODOLOGY



SEISMIC INTERPRETATION

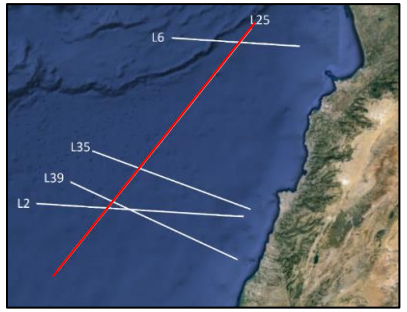
SEISMIC INTERPRETATION PROFILE L25 (NNE-SSW)

RESPONSIBLE OIL AND GAS



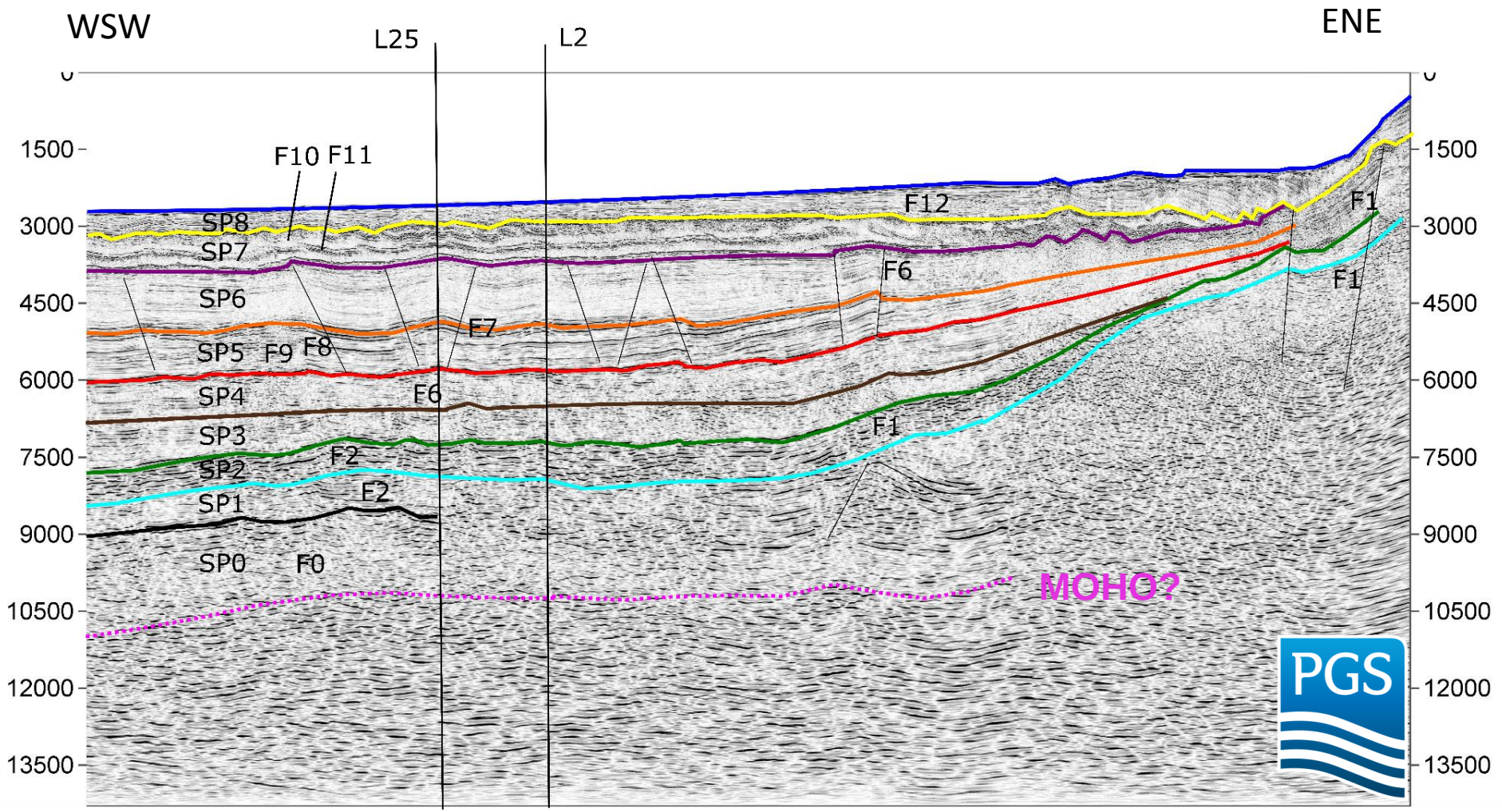
Based on seismic interpretation in Hawie et al., 2013

- Sea floor
- Base Pliocene
- Base Messinian
- Base Mid Miocene
- Top Oligocene
- Eocene Unconformity
- Senonian Unconformity
- Top Jurassic
- Mid Jurassic
- Moho?

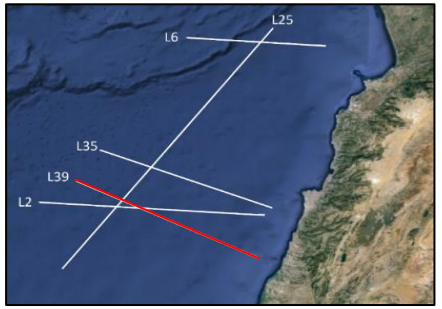


SEISMIC INTERPRETATION PROFILE L39

RESPONSIBLE OIL AND GAS

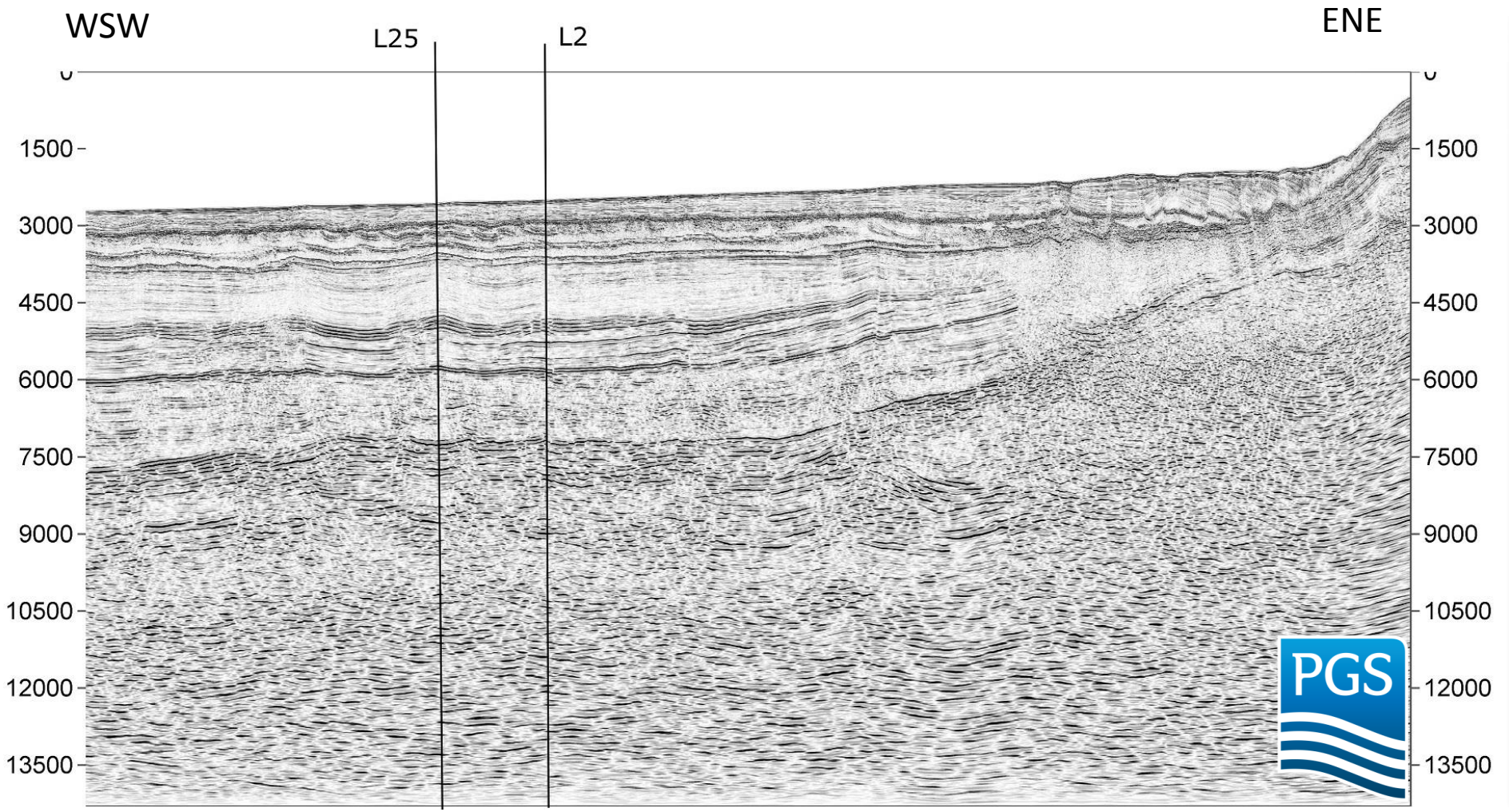


- Sea floor
- Base Pliocene
- Base Messinian
- Base Mid Miocene
- Top Oligocene
- Eocene Unconformity
- Senonian Unconformity
- Top Jurassic
- Mid Jurassic
- Moho?

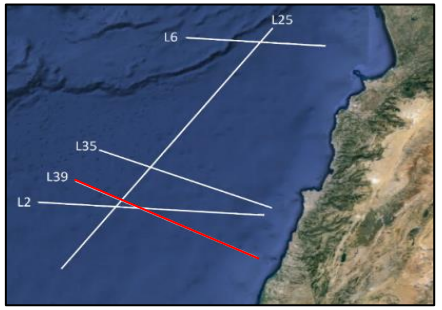


SEISMIC INTERPRETATION PROFILE L39

RESPONSIBLE OIL AND GAS

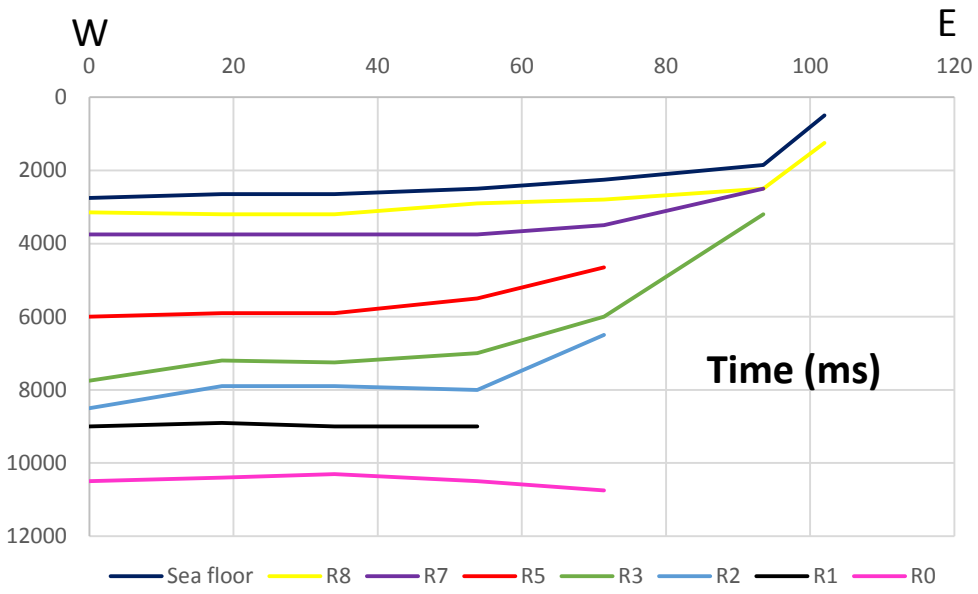


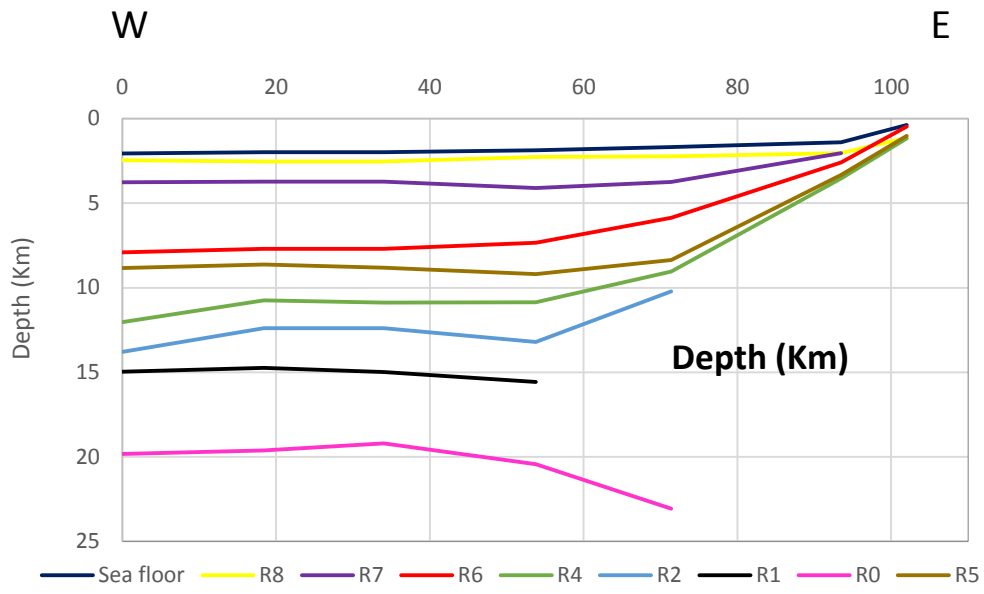
- Sea floor
- Base Pliocene
- Base Messinian
- Base Mid Miocene
- Top Oligocene
- Eocene Unconformity
- Senonian Unconformity
- Top Jurassic
- Mid Jurassic
- Moho?



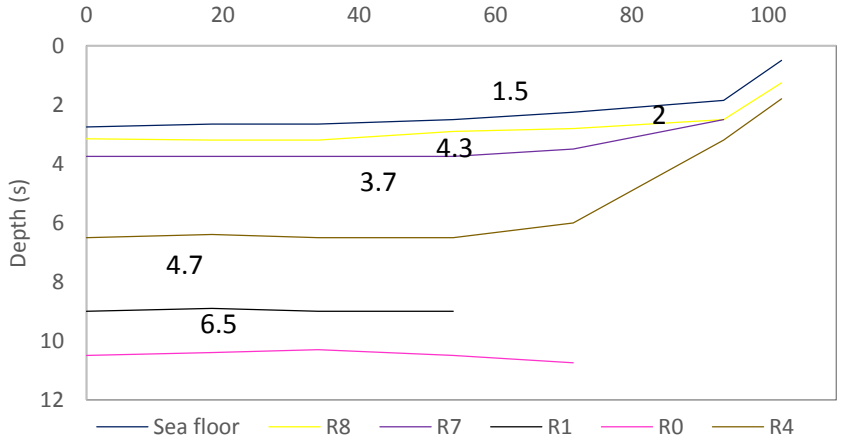
TIME/ DEPTH CONVERSION
HORIZONS DEPTHS ESTIMATION OF L39

RESPONSIBLE
OIL AND GAS





Velocity model (Km/s)

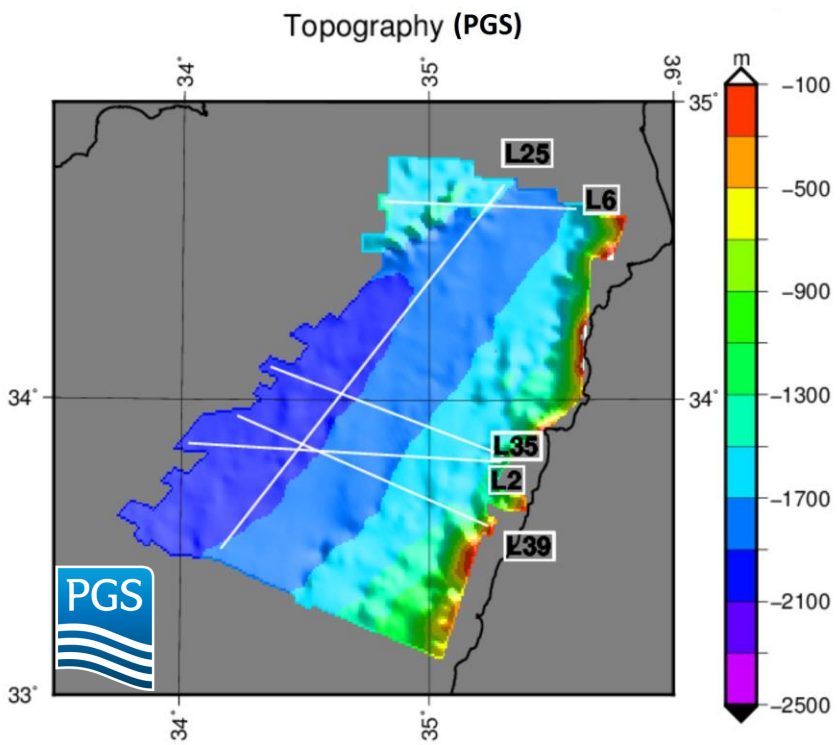


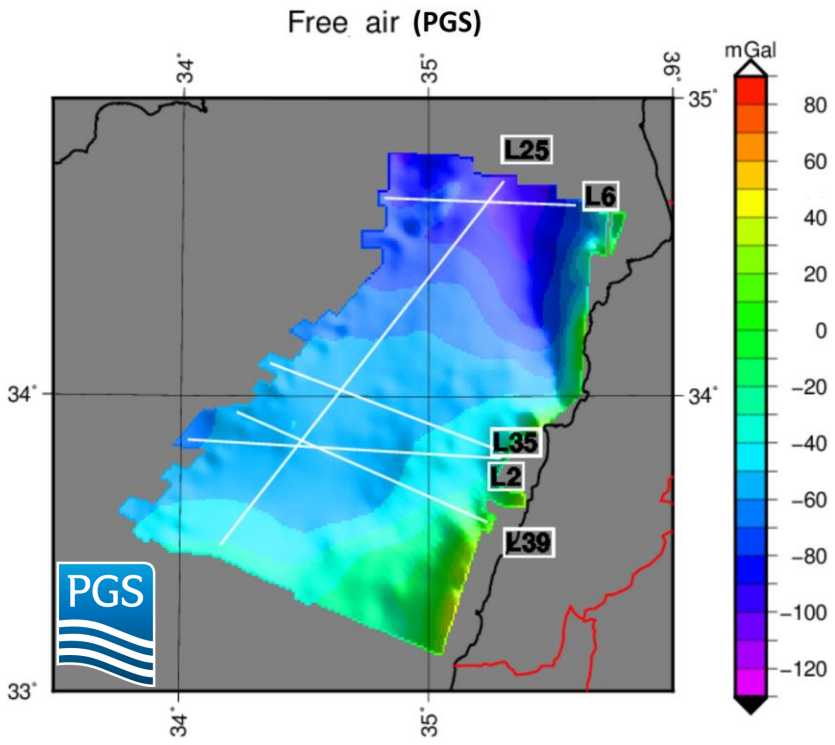
P wave velocities from refraction studies
(Netzeband et al., 2006)

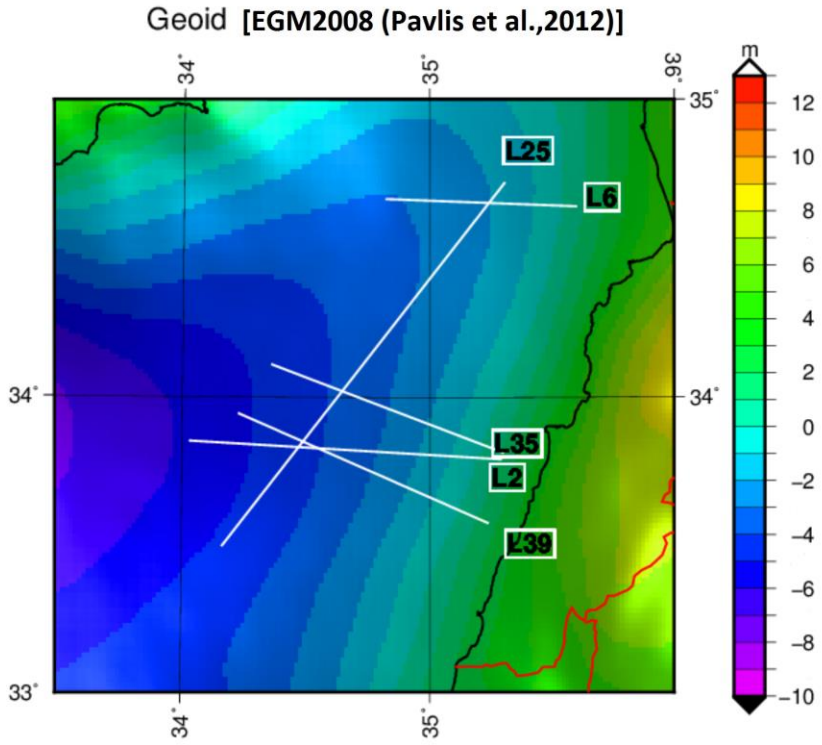
NUMERICAL CRUSTAL MODELING

NUMERICAL CRUSTAL MODELING
THE DATASET

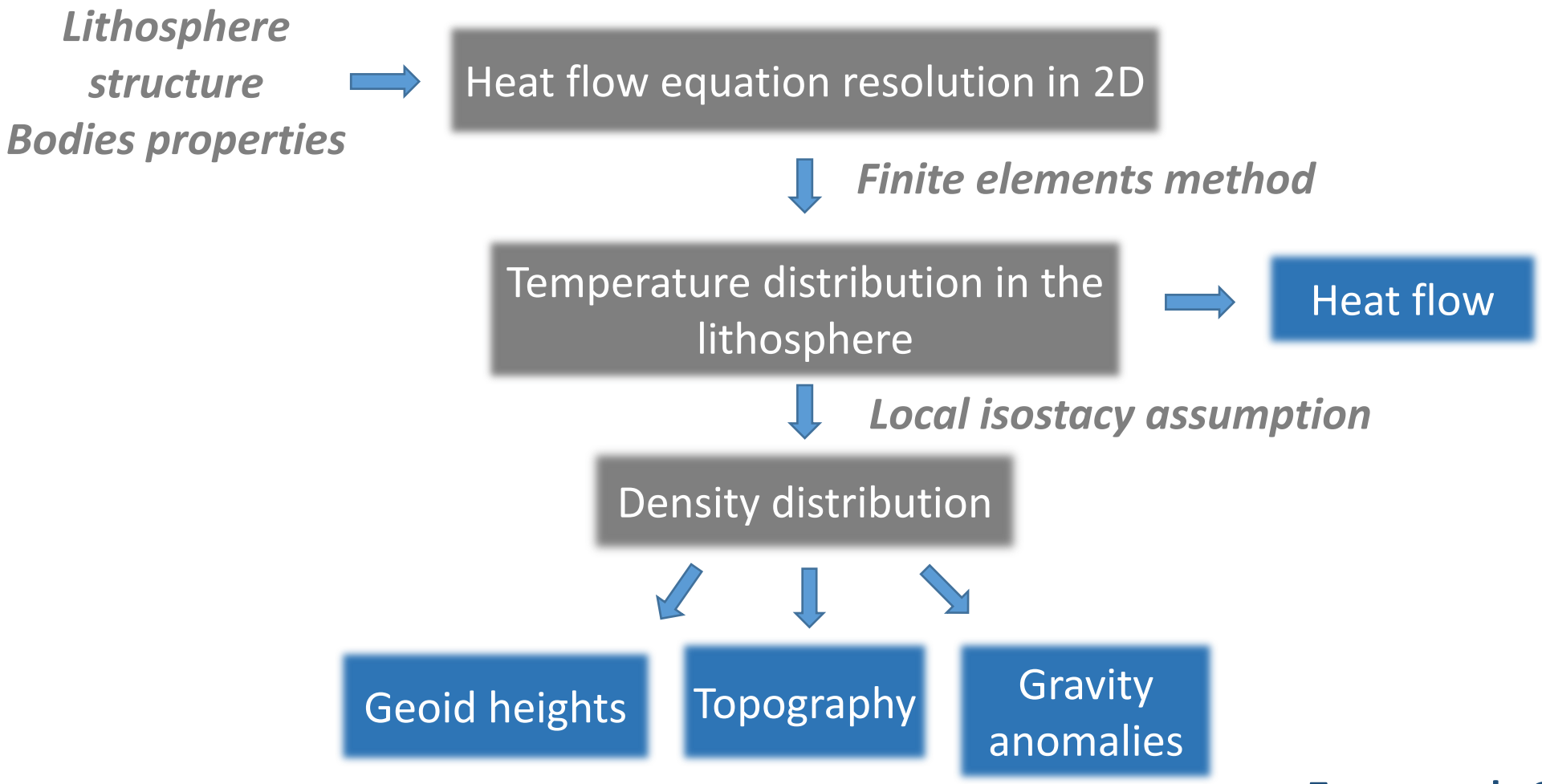
RESPONSIBLE
OIL AND GAS







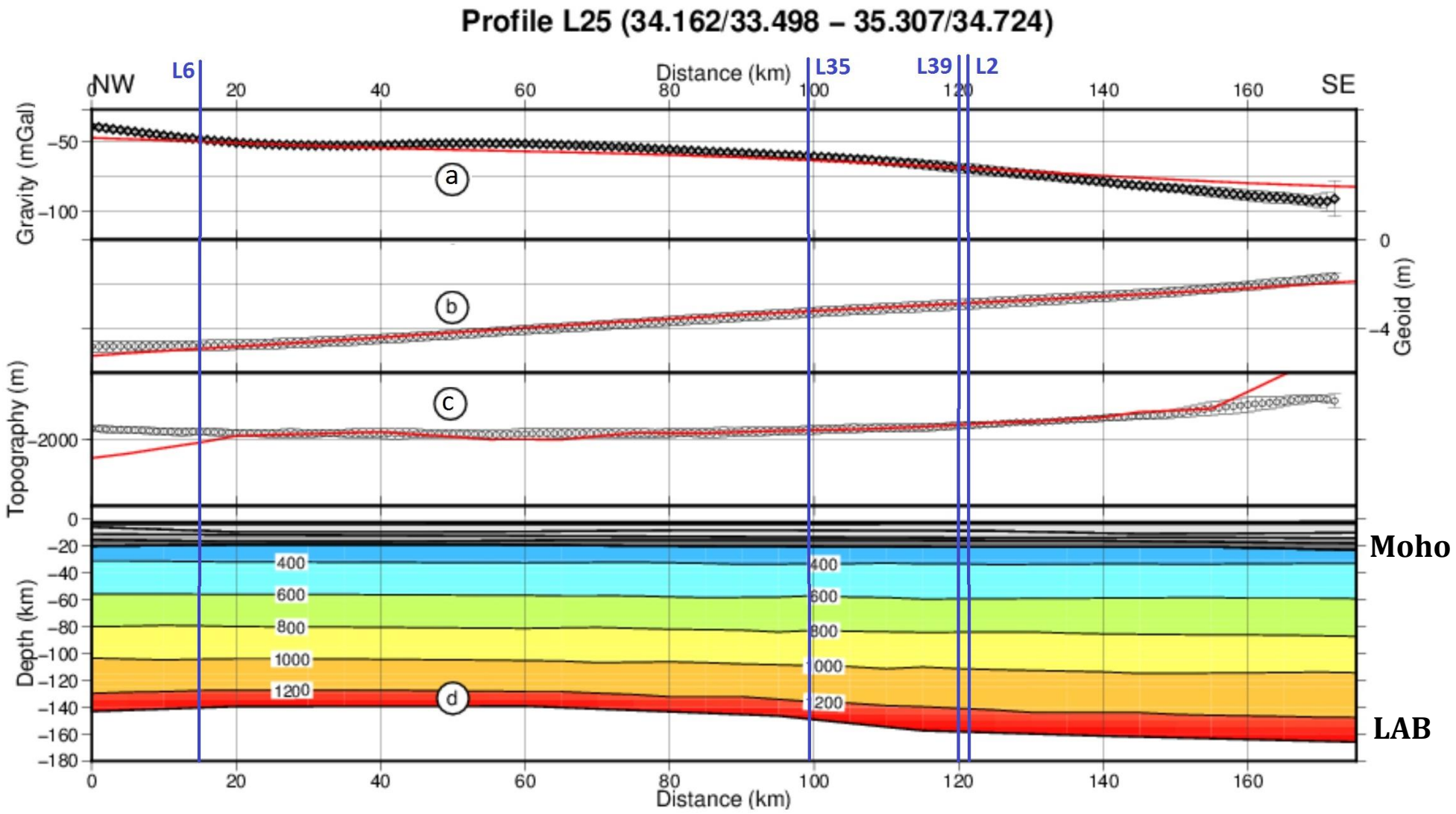
NUMERICAL CRUSTAL MODELING
THE ALGORITHM

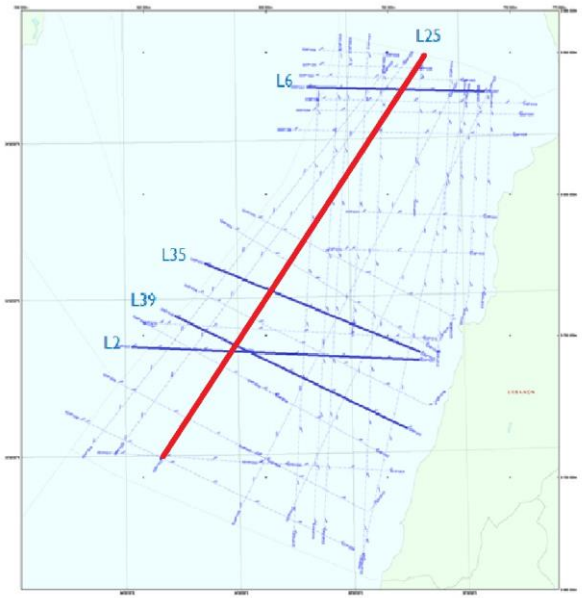


Zeyen et al., 2005

NUMERICAL CRUSTAL MODELING
PROFILE L25

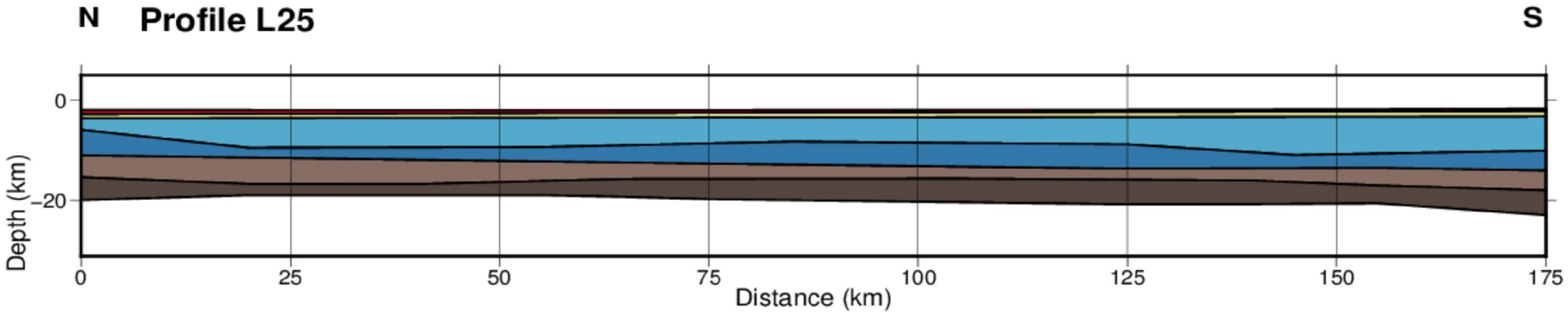
RESPONSIBLE
OIL AND GAS





NUMERICAL CRUSTAL MODELING
PROFILE L25-CRUSTAL MODEL

RESPONSIBLE
OIL AND GAS



Quaternary sediments

Messinian salt

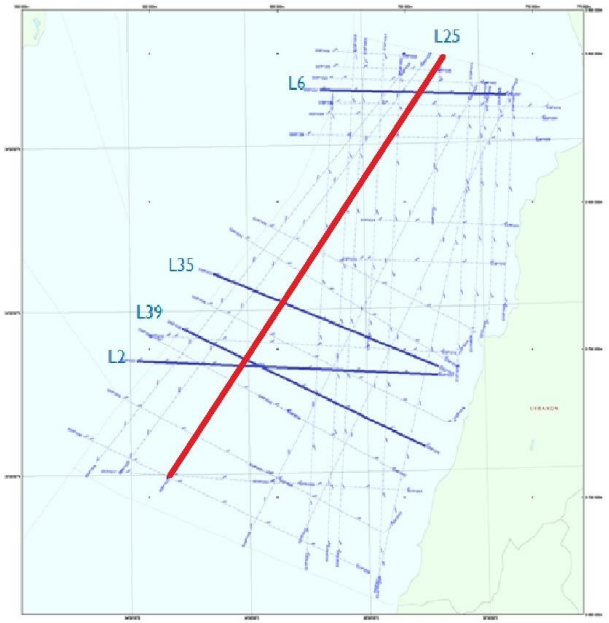
Siliciclastic sediments

Carbonates

Upper continental crust

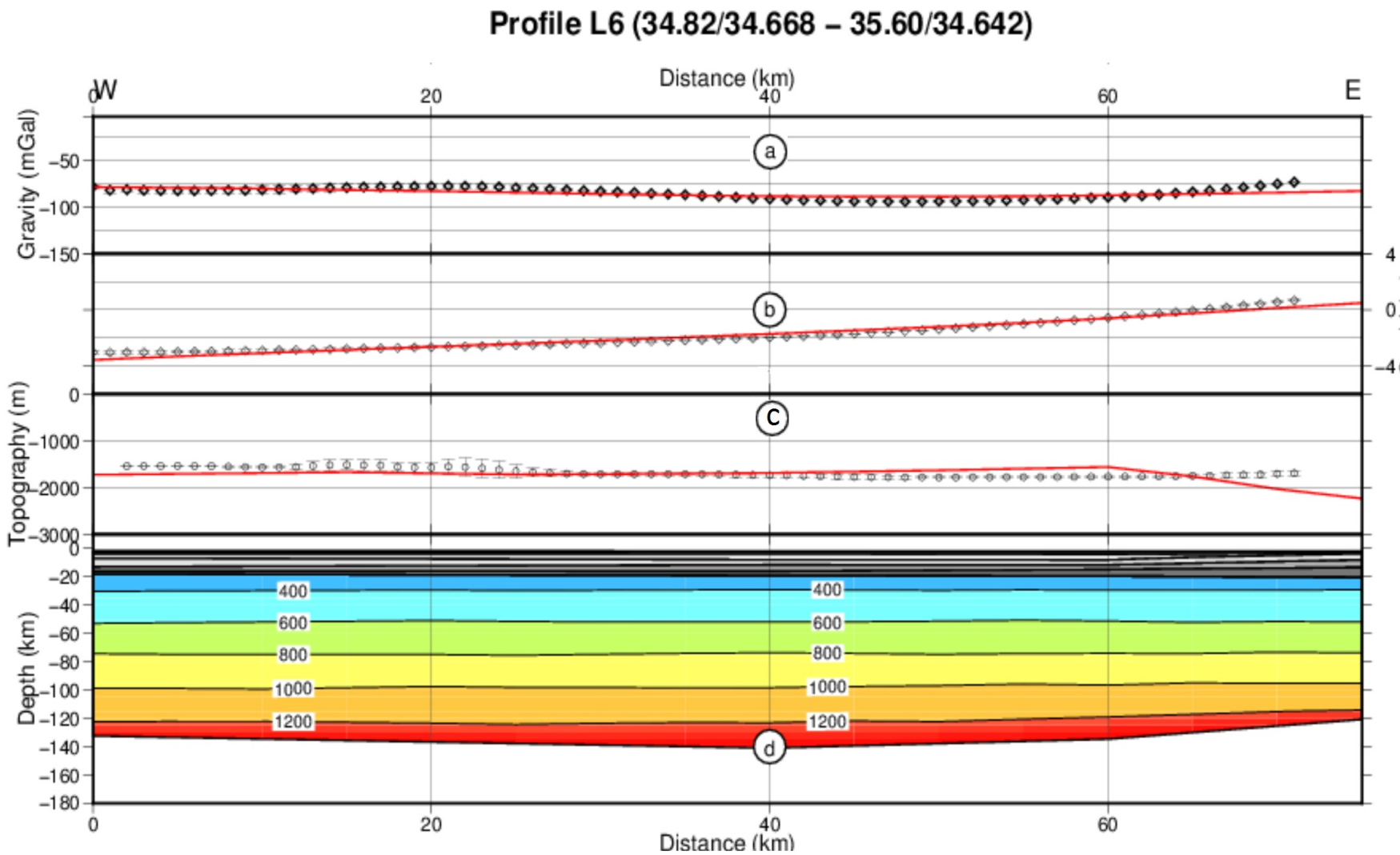
Lower continental crust

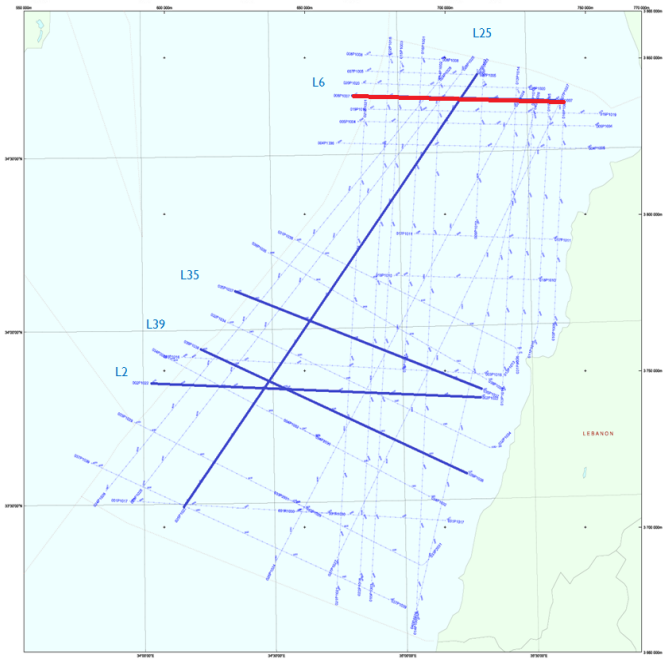
	Density (kg m^{-3})
Quaternary sediments	$2600 - 400e^{-z/2}$ (z in km)
Salt layer	2100
Siliciclastic sediments	2450
Carbonates	2550
Upper crust	2750
Lower crust	2900
Lithospheric mantle	T-dependent



NUMERICAL CRUSTAL MODELING
PROFILE L6

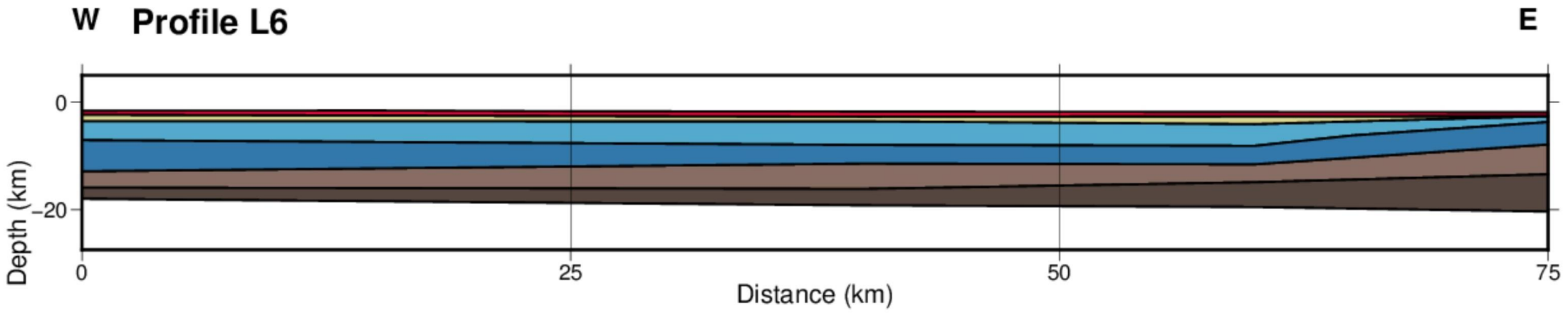
RESPONSIBLE
OIL AND GAS





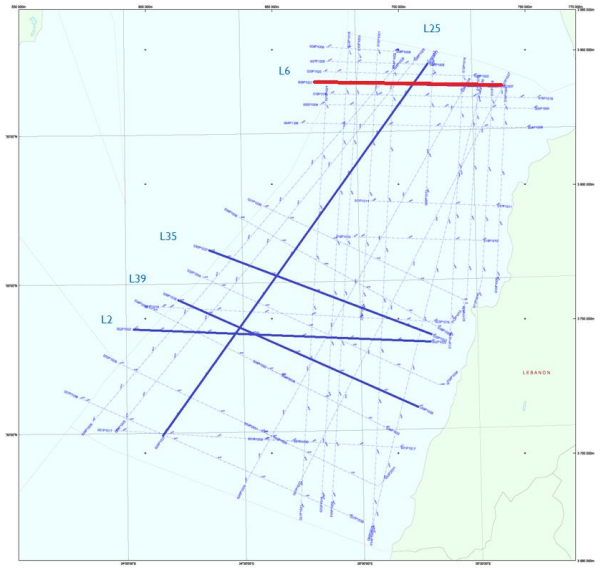
NUMERICAL CRUSTAL MODELING
PROFILE L6- CRUSTAL MODEL

RESPONSIBLE
OIL AND GAS



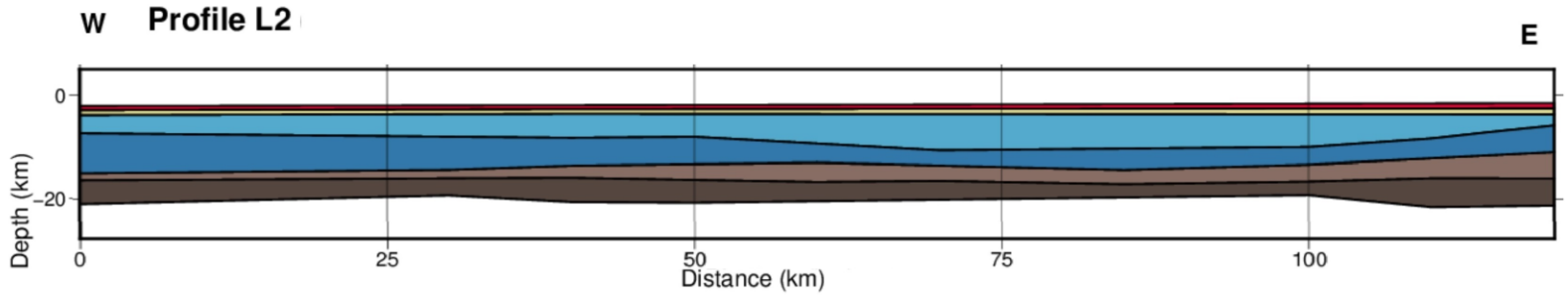
Quaternary sediments
Messinian salt
Siliciclastic sediments
Carbonates
Upper continental crust
Lower continental crust

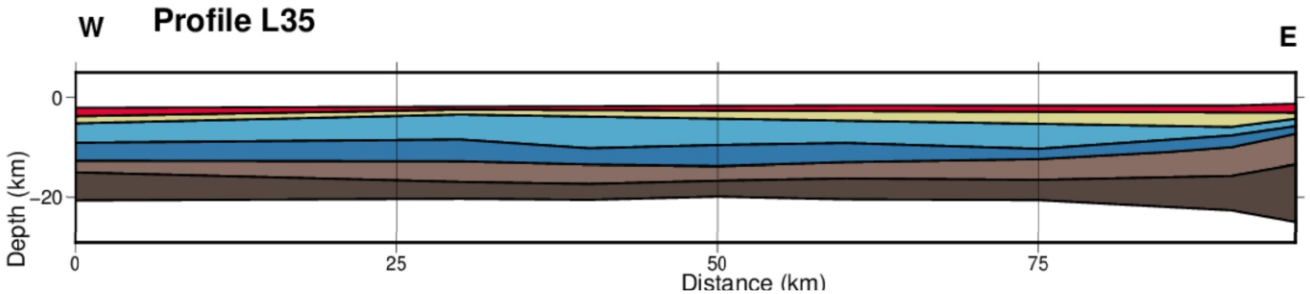
	Density (kg m^{-3})
Quaternary sediments	$2600 - 400e^{-z/2}$ (z in km)
Salt layer	2100
Siliciclastic sediments	2450
Carbonates	2550
Upper crust	2750
Lower crust	2900
Lithospheric mantle	T-dependent

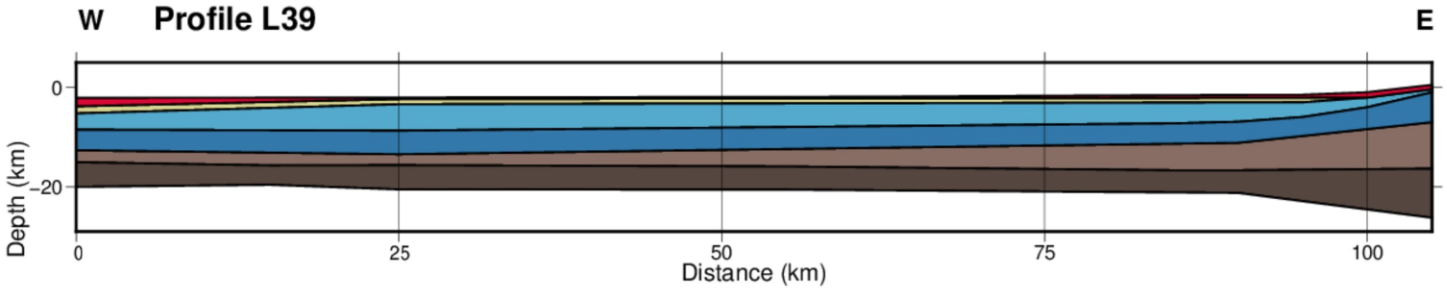


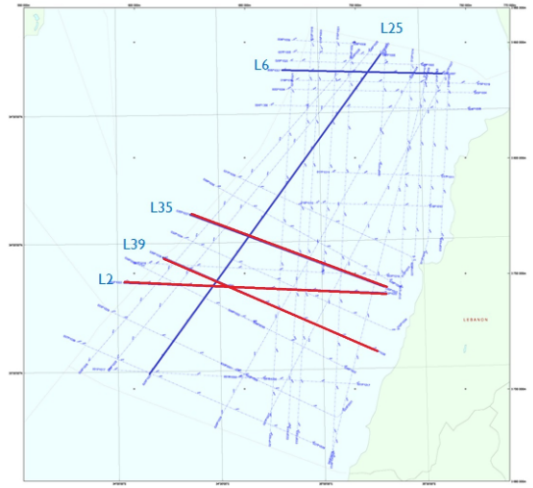
NUMERICAL CRUSTAL MODELING
OFFSHORE CENTRAL LEBANON EW CRUSTAL MODELS

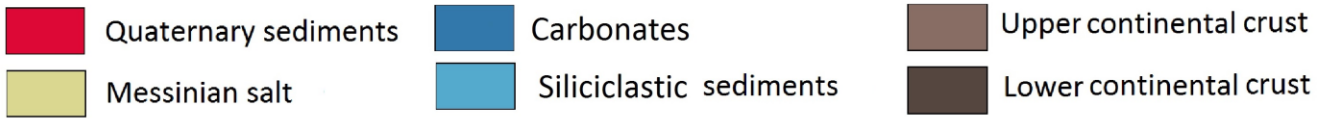
RESPONSIBLE
OIL AND GAS







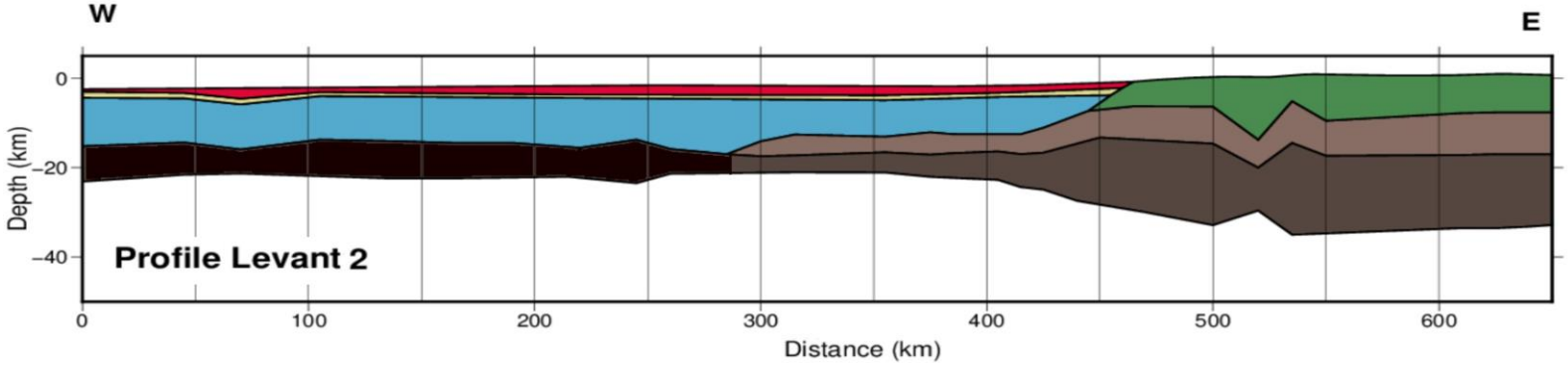


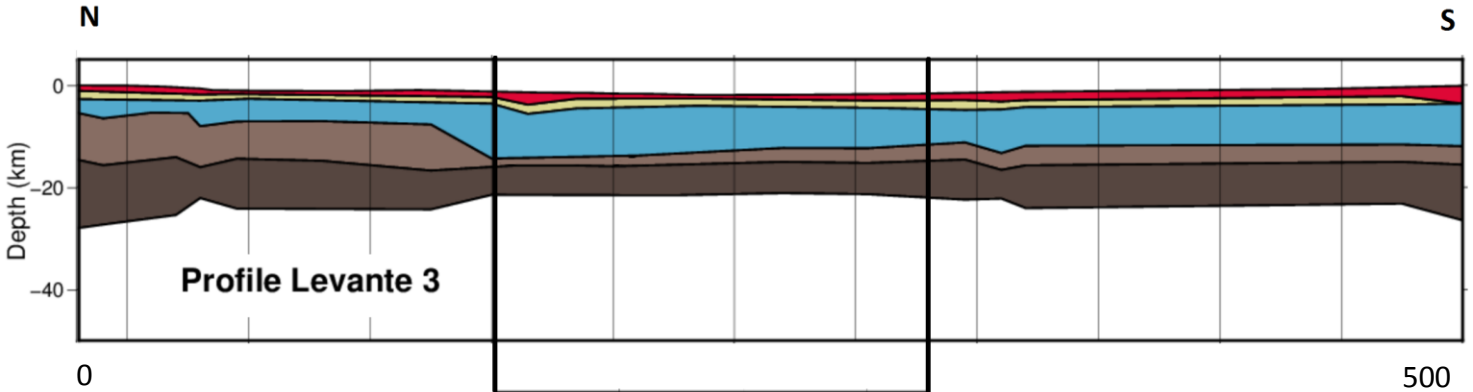


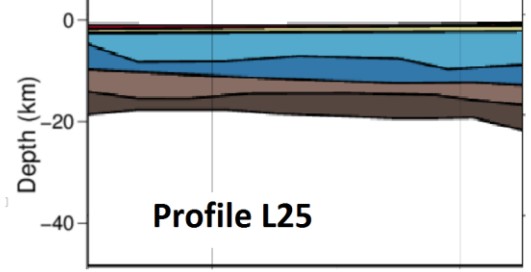
	Density (kg m^{-3})
Quaternary sediments	$2600 - 400e^{-z/2}$ (z in km)
Salt layer	2100
Siliciclastic sediments	2450
Carbonates	2550
Upper crust	2750
Lower crust	2900
Lithospheric mantle	T-dependent

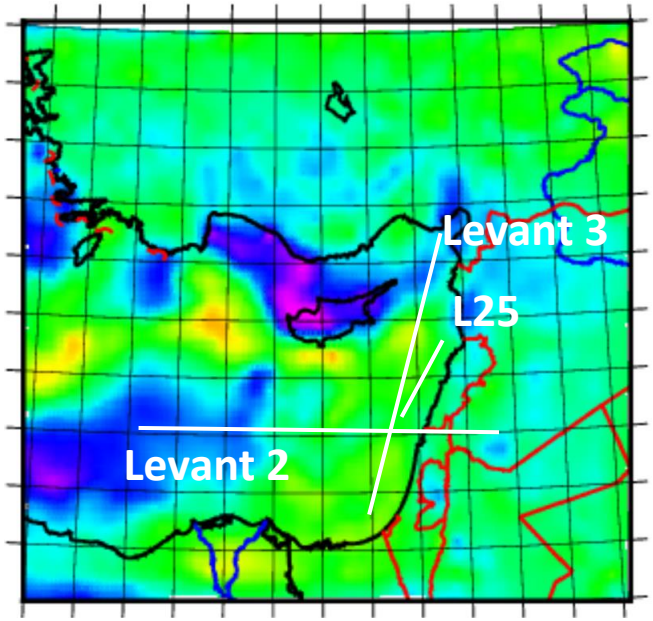
DISCUSSION OF PRELIMINARY RESULTS

- The models constrained by the seismic reflection endorse the results of the regional study presented in Inati et al.(2016), where the nature of the crust of the Levant basin was proposed as continental.









CONCLUSIONS

- The models representing five sections across the northern Levant basin, show a progressively attenuated crystalline crust in an EW direction.
- The crystalline crust is best interpreted as a strongly thinned continental crust under the Levant basin, represented by two distinct components, an upper and a lower continental crust.
- The Moho appears to be situated between 17 and 20 km towards the northern Lebanese coast and deepens to reach up to 23 km in the southern Lebanese offshore.
- The crustal models represent a quantification of the thinning of the crust from the margin towards the basin and thus can be used to understand the evolution of the heat flow and the subsidence history.

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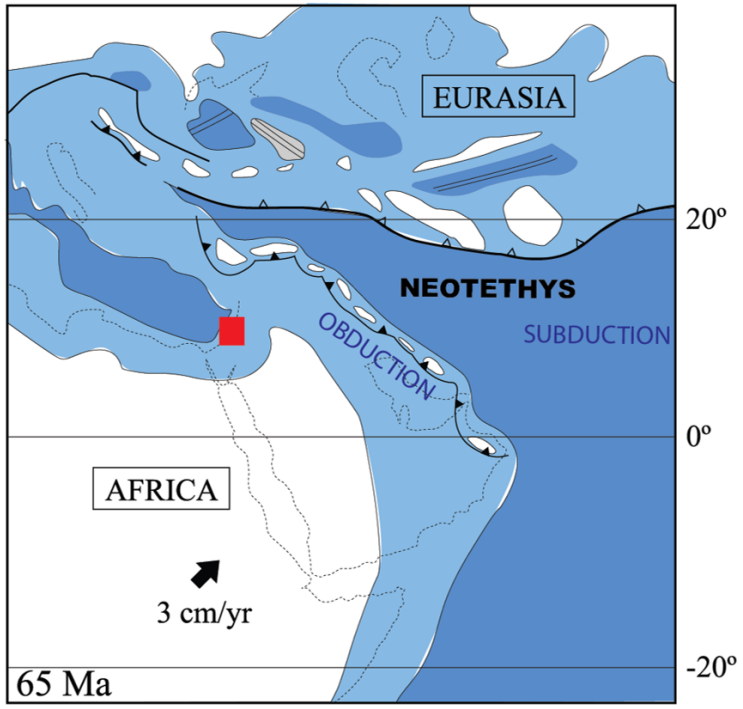
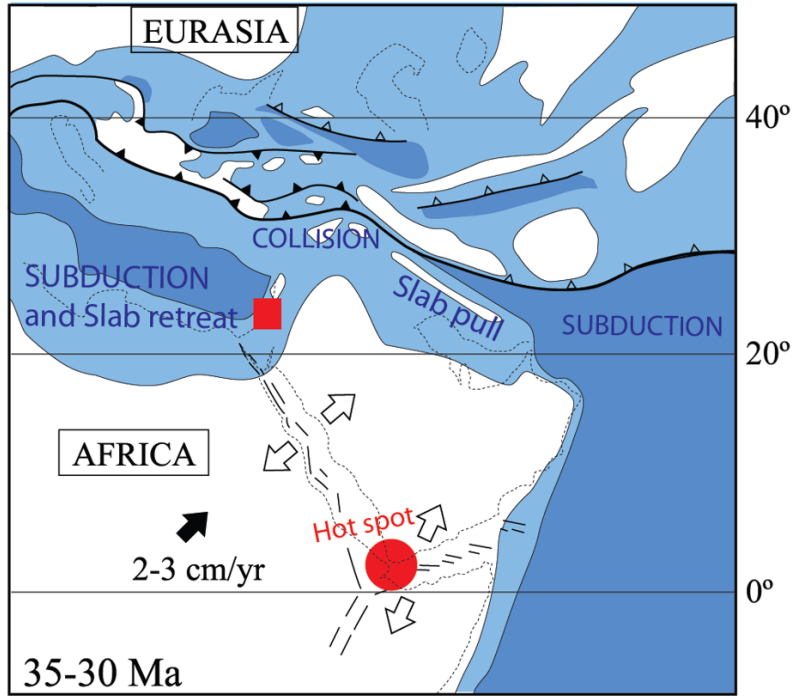
GEOLOGICAL SETTING
GEODYNAMICS

RESPONSIBLE
OIL AND GAS

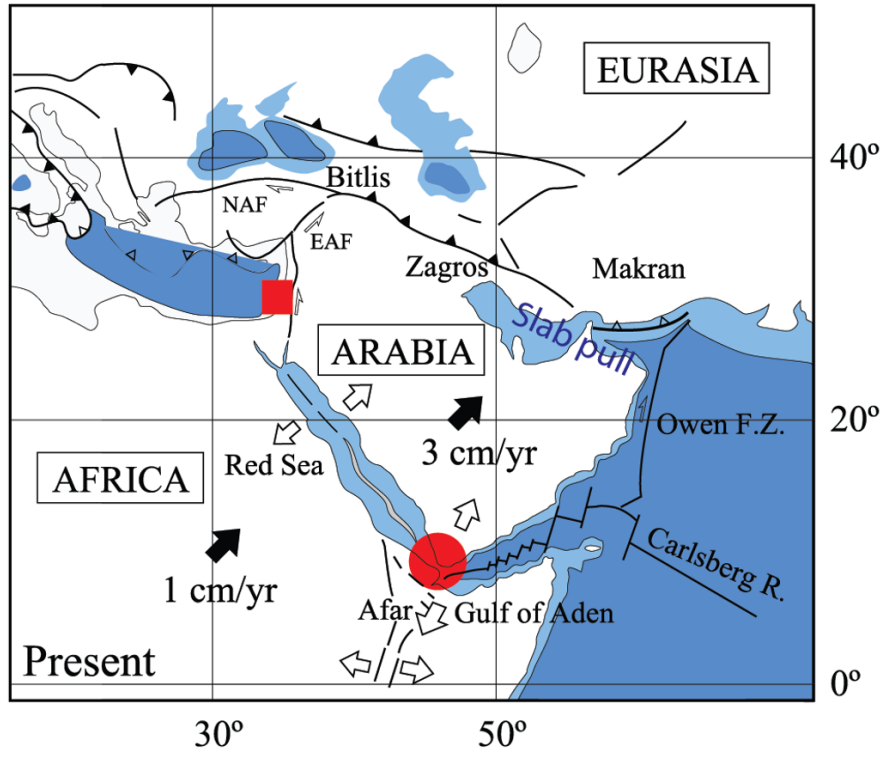
Late Maastrichtian



Oligocene



Middle Miocene to Present



Legend

Emergent

Continental platform to deep marine

Very deep marine

Levant region (study area)

Absolute plate movement

Modified from Bellahsen et al. (2003)
Hawie (2014)

INTRODUCTION
SCIENTIFIC QUESTIONS

RESPONSIBLE
OIL AND GAS

- What is the architecture and the nature of the crust in the Levant basin, especially the northern part?
- How can the crustal configuration be recreated with integrated geophysical data analysis?

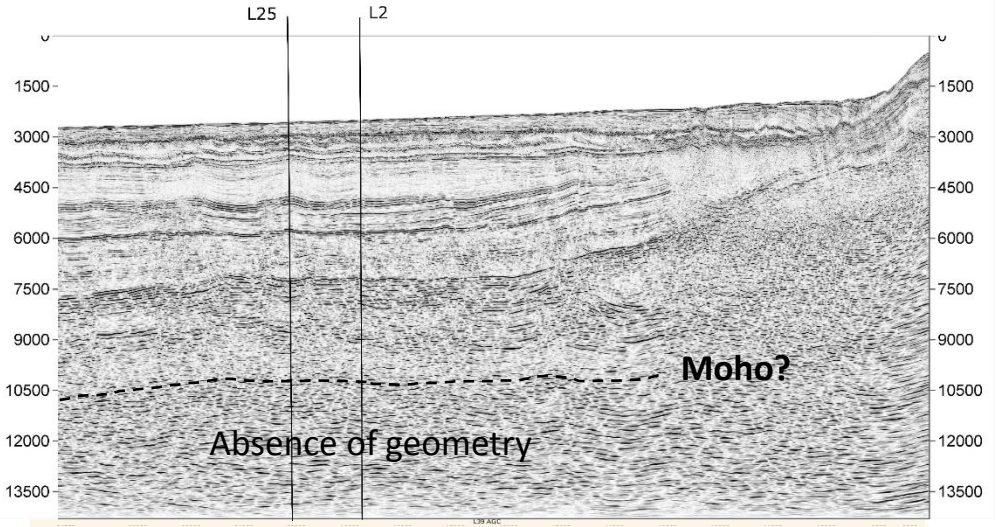
✓Constraining tectonic evolution

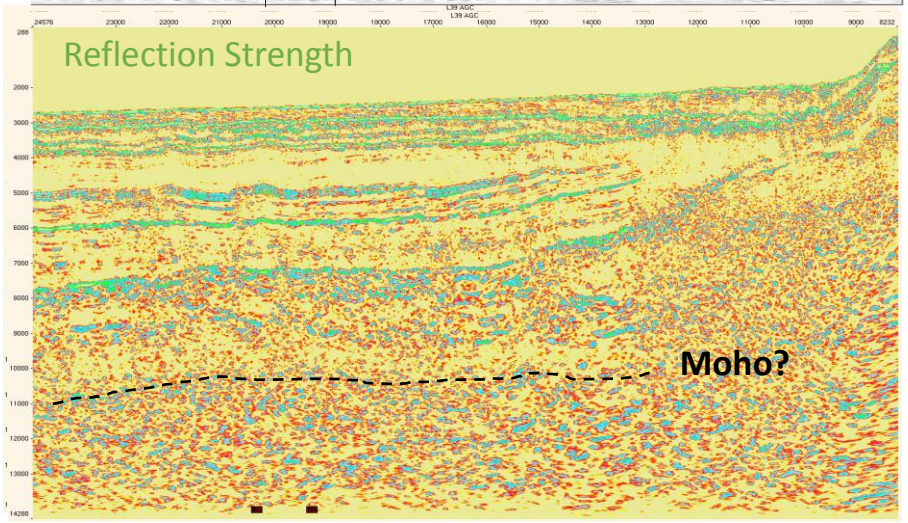
✓Improving earthquake evaluation

✓Properly assessing petroleum systems

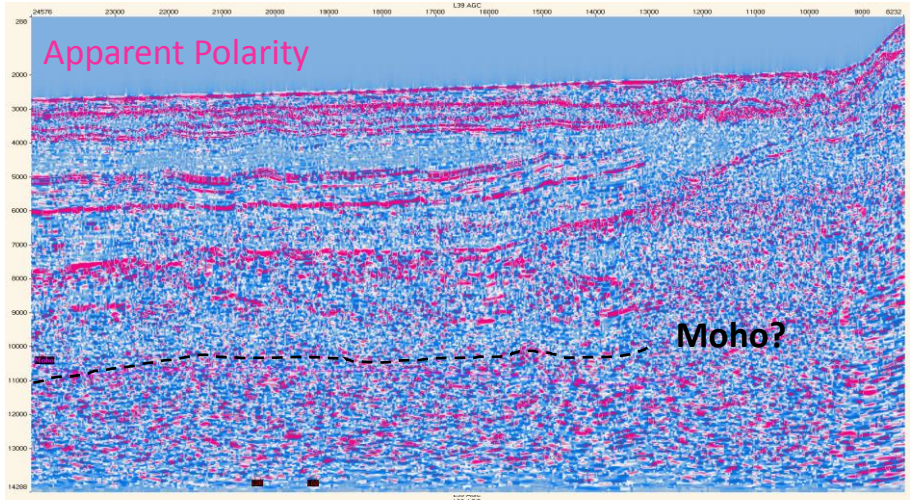
WHAT IS THE ADDED VALUE OF SEISMIC ATTRIBUTES? PROFILE L39

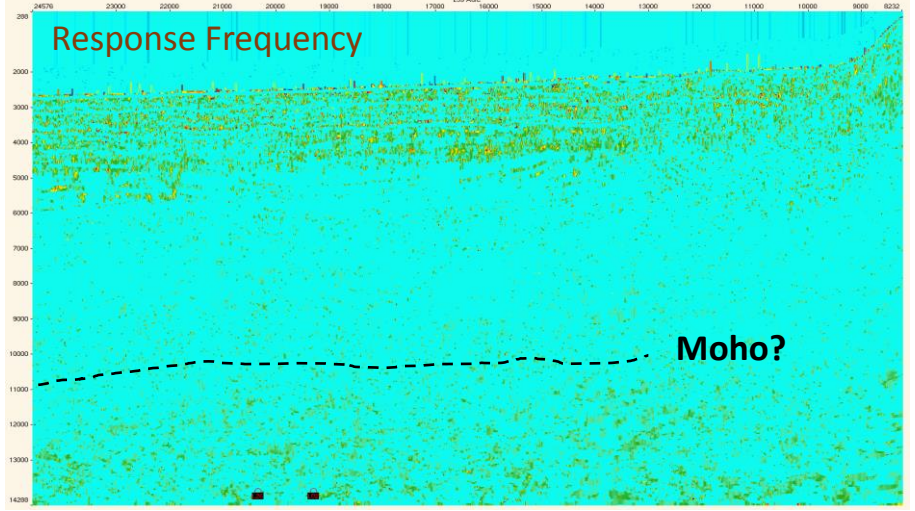
RESPONSIBLE OIL AND GAS





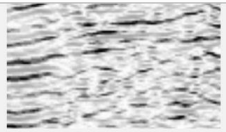
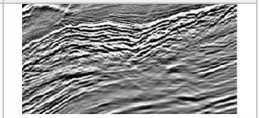
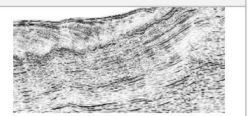
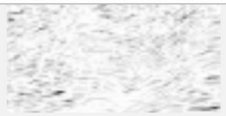
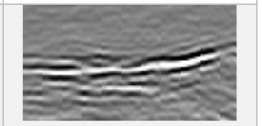
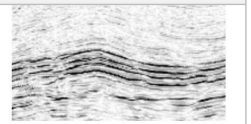
The limit between an upper unit of moderate amplitude and a homogeneous part of higher reflectivity that doesn't show any geometry could represent the Moho.

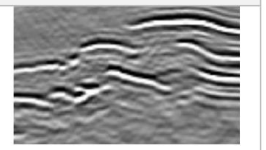
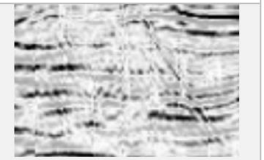
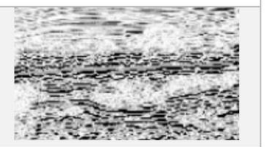
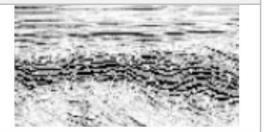




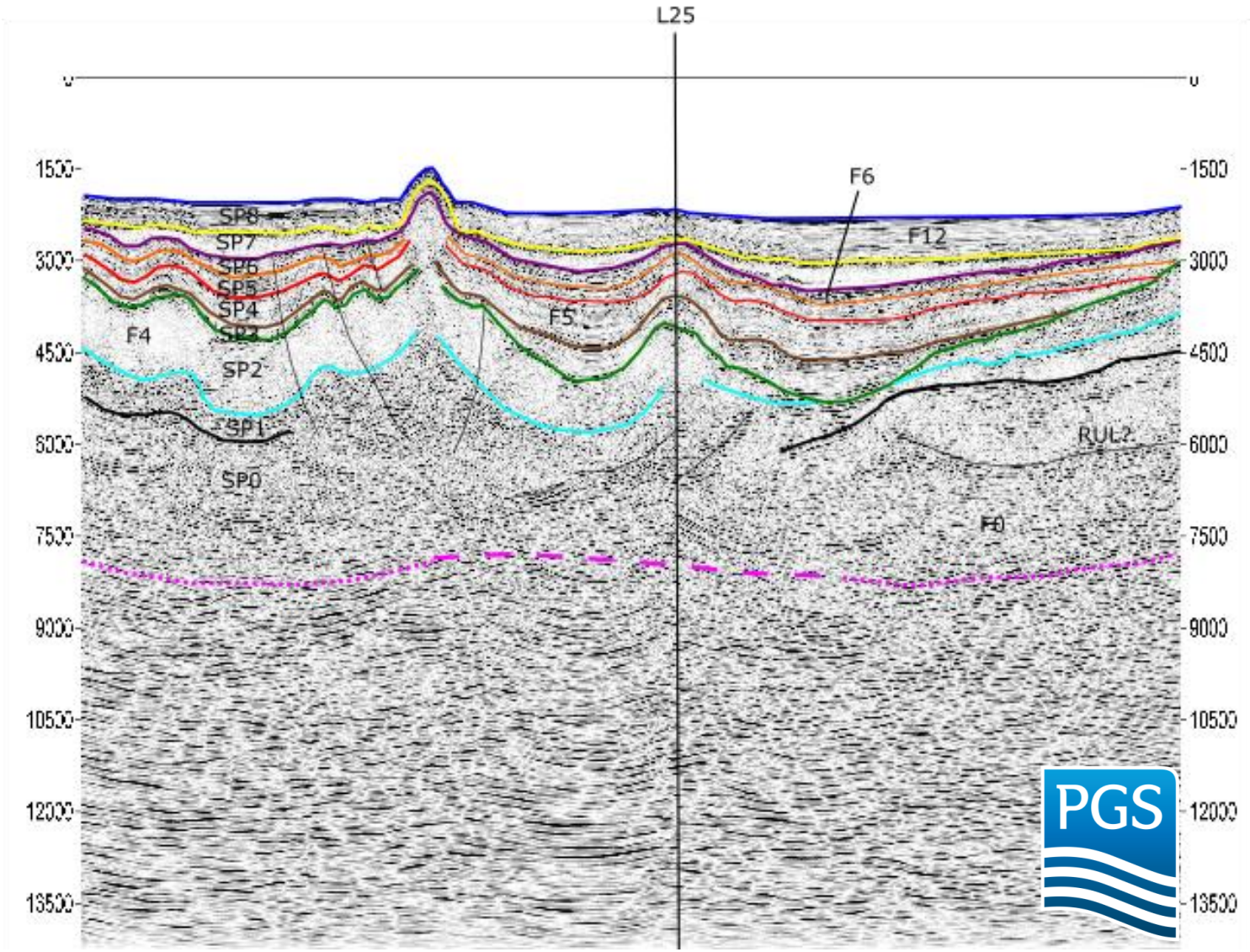
SEISMIC INTERPRETATION
SEISMIC FACIES

RESPONSIBLE
OIL AND GAS

Facies	Amplitude	Description	Pattern
F0	Moderate	Subparallel dimmed horizons intercalated higher reflectivity reflectors	
F1	high	Prograding configuration	
F2	Moderate	parallel reflectors	
F3	Moderate	wedge shaped depositions with parallel reflectors	
F4	Low	transparent facies	
F5	Moderate	hemipelagic/pelagic material	
F6	High	channel facies	
F7	High	set of high reflectivity horizons	

Facies	Amplitude	Description	Pattern
F8	Moderate	lobe- shaped bodies	
F9	Low	chaotic facies	
F10	Very low	Transparent unit in evaporitic section (Reflection free unit)	
F11	high	Aggrading configurations	
F12	low	Dimmed parallel reflectors	
F13	moderate	wavy facies	
F14	high	mounds facies	

Based on seismic interpretation in Hawie et al., 2013


L25
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4500
6000
7500
9000
10500
12000
13500
SP8
SP7
SP6
SP5
SP4
SP3
SP2
SP1
SP0
F4
F5
F6
F12
RUL2
F0
PGS