Hydrocarbon Potential of Ultra Deep Deposits in the South Caspian Basin*

I. Guliyev[1], E. Aliyeva[1], D. Huseynov[1], A. Feyzullayev[1] and P. Mamedov[1]

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[1]Geology Institute of Azerbaijan, Baku, Azerbaijan (e_aliyeva@yahoo.com)

Abstract

Deep hydrocarbon accumulations below 5,000 m have been discovered in the South Caspian basin at the end of 20th century (Bulla-deniz, Bahar, Janub-2, Shah-deniz). A unique geological-geophysical data set gained during last decade on the South Caspian basin containing results of studies of super deep wells, mud volcanic ejects from the depth up to 14 km, deep seismic, and advanced modeling technique allowed us predicting of accumulations below 7 km.

The burial history of the South Caspian basin central part is characterized by continuous sedimentation and stable subsiding from the Upper Jurassic to present. Avalanche sedimentation during Pliocene-Pleistocene (up to 3 mm/year) resulted in deposition of 10 km thick Pliocene-Quaternary succession. The total thickness of sedimentary cover in the SCB reaches more than 25 km.

Numerous data testify to a good generation potential of Oligocene-Lower Miocene sediments (Maykop Series), for an example, TOC – is 12.39%, HI – 588 mg HC/gCorg in mud volcanic breccia. Kerogen type of organic matter varies from II to III. Good source rock properties have been revealed in Middle-Upper Miocene sediments (Diatom Suite), and some intervals of middle Jurassic and Lower Cretaceous rocks. The South Caspian basin is characterized by the abnormally low-recorded values of geothermal gradient - 1.30C-1.80C /100 m. From T and R0 predicted values oil and gas “windows” in the western shelf and continental slope are located in interval 5-12 km; in the deep-water zone – 6-14 km. These zones are corresponded to the occurrence of the principal source- rocks in the South Caspian basin-Maykop Series and Diatom Suite.

Isotopic –chemical composition of fluids testifies to a wide temperature -pressure range of HC generation and migration. Subvertical migration of HC fluids in an extremely high scale and with a high rate is a typical feature of the South Caspian basin. Numerous deep faults, mud volcanoes channels and subvertical decompacted bodies traced to the basement might serve as channels of fluid migration from source to trap. Porous and permeable laterally connected sand bodies in some Lower Pliocene intervals (Productive Series-PS) create a fluid conduit network within the basin providing pathways for lateral HC fluid migration.

Interplay of large river systems, rapid sea level and sediment supply changes in the Early Pliocene played an important role in the accumulation of reservoir rocks. Southward progradation of PaleoVolga system in some PS stages (Pereriva, NKP Suites, and possible PK Suite) provides a good reservoir potential for these sediments. Existence of overpressure zones in the studied area enables preservation of reservoir quality in the deeply subsided horizons.

Results of basin modeling showing the vast (up to 8 km on the extent) petroleum source rocks in the deeply subsided central part of the South Caspian basin and existence besides large anticline structures the numerous lithological traps formed as a result of facial heterogeneity of PS sediments allow prediction of large ultra deep HC accumulations in this part of the basin that is confirmed by fluid flow recorded by geochemical survey. These data allow us to significantly increase the initial potential resources in the basin.

Selected References

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Hydrocarbon potential of ultra deep deposits in the South Caspian Basin

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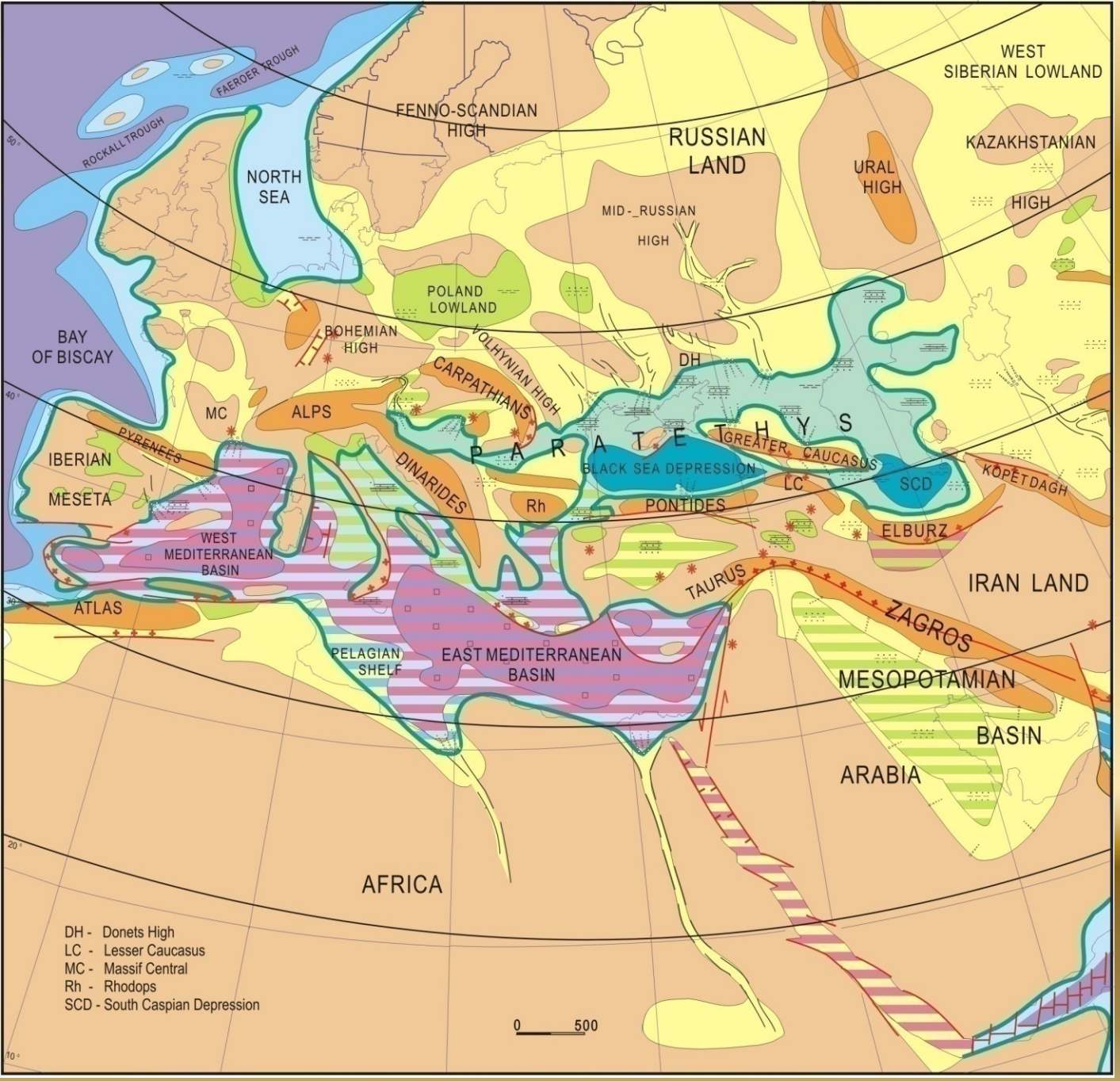
Geology Institute of Azerbaijan National Academy of Sciences
29A H.Javid avenue, Baku, AZ 1143, Azerbaijan

GEOLOGICAL, STRUCTURAL SETTING

Principal oil-gas basins all over the world

South Caspian basin is situated on the southern margin of the Euarasian in the central part of the Mediterranean-Himalayan folded zone. Its present shape and petroleum system were formed as a result of the interaction of Eurasian, Indian and Arabian plates starting from Triassic.



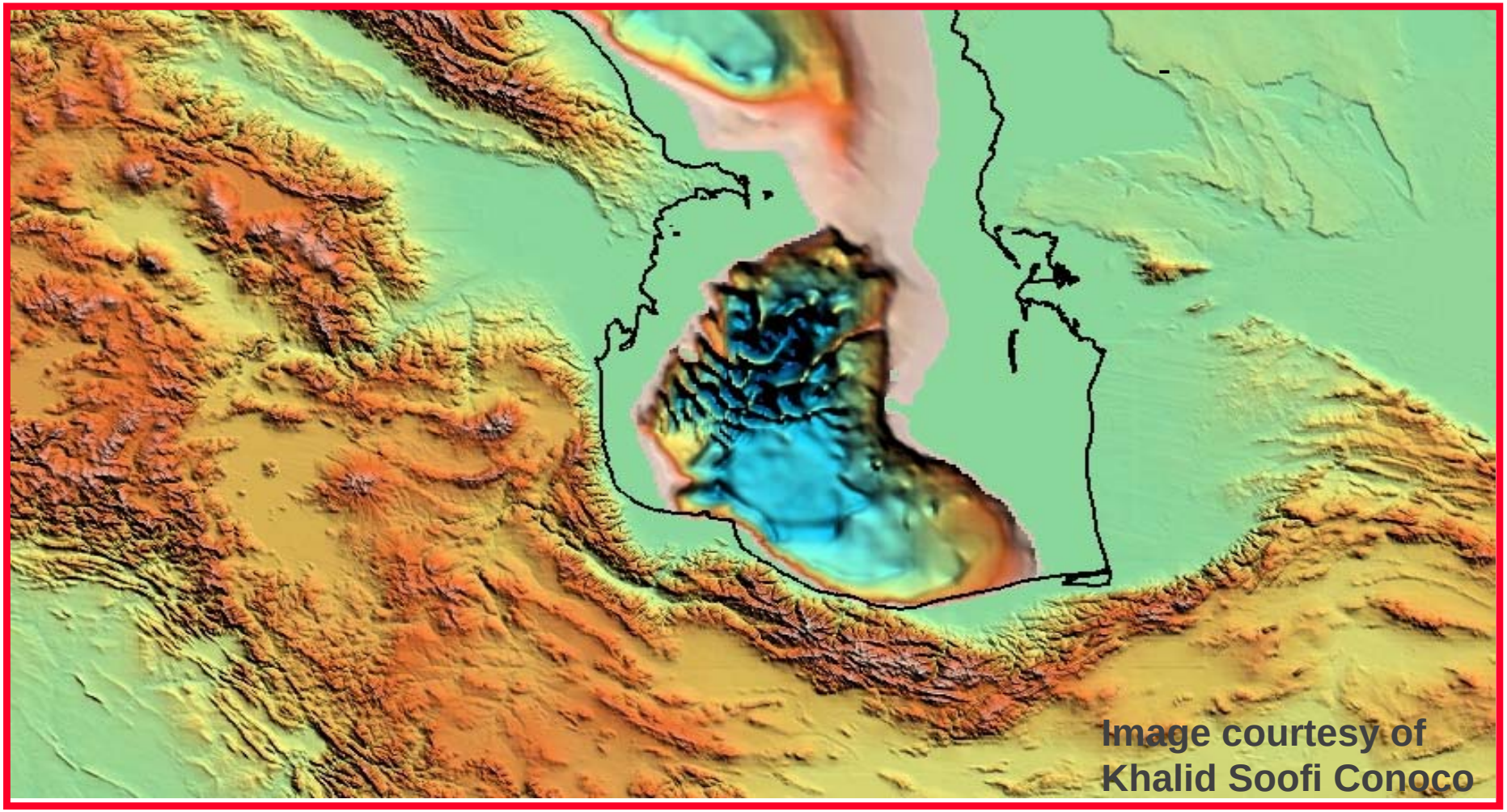
Lithological-paleogeographic map of Paratethys at the end of Messinian

Compiled by Khondkarian S.O., Sherba I.G., Popov S.V.
Paleontological Institute of RAS, 2003

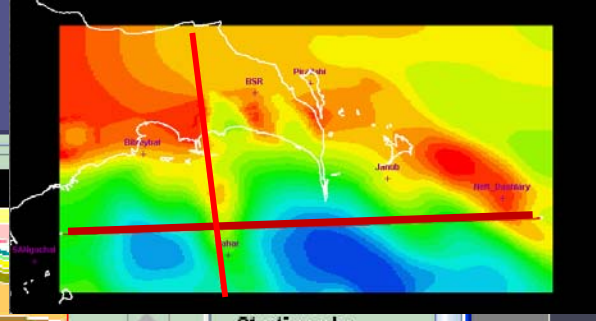
As a result of continental collision of relict fragments of Gondwana and EuroAsian plate in the Late Miocene the Caspian basin was isolated from the Paratethys

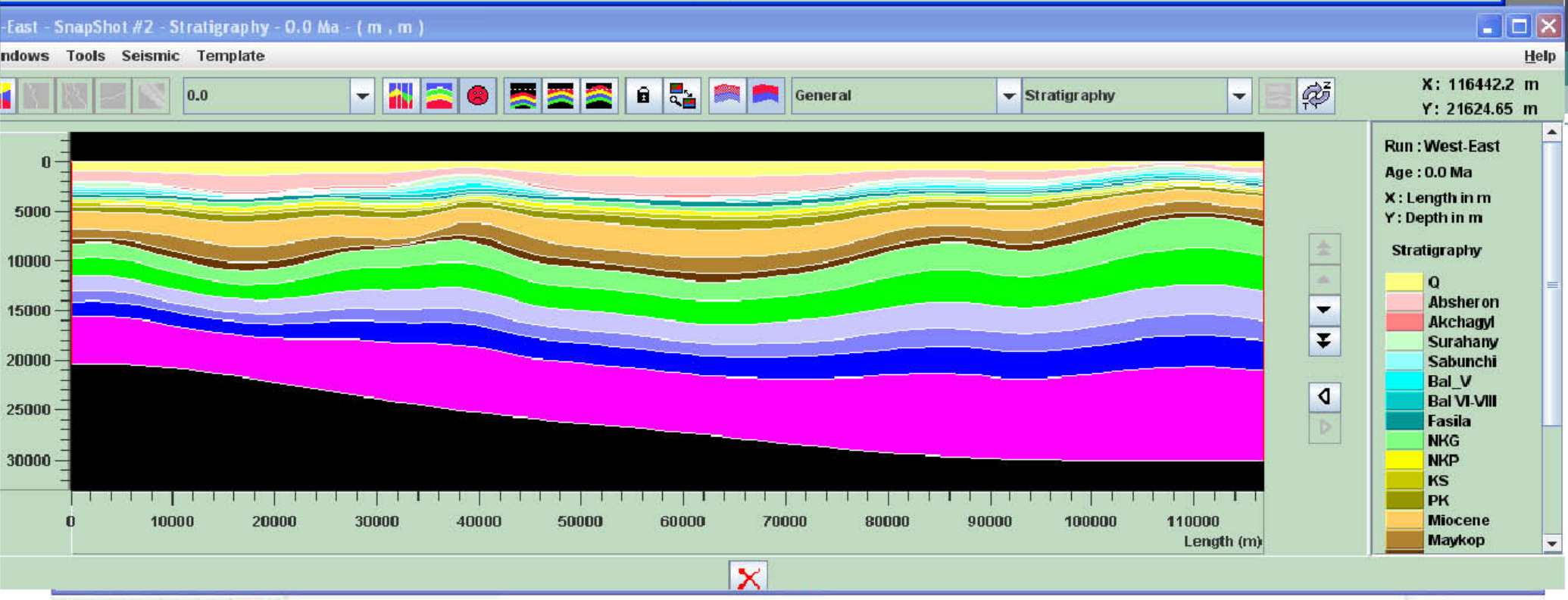
Structural setting

- **Typical features:**
- **Rapid uplifting –** the velocity of vertical movements on the anticlinal structures reaches 1.2 – 4.5 mm/year.
- **Rapid subsidence** – 25 to 50 mm/year



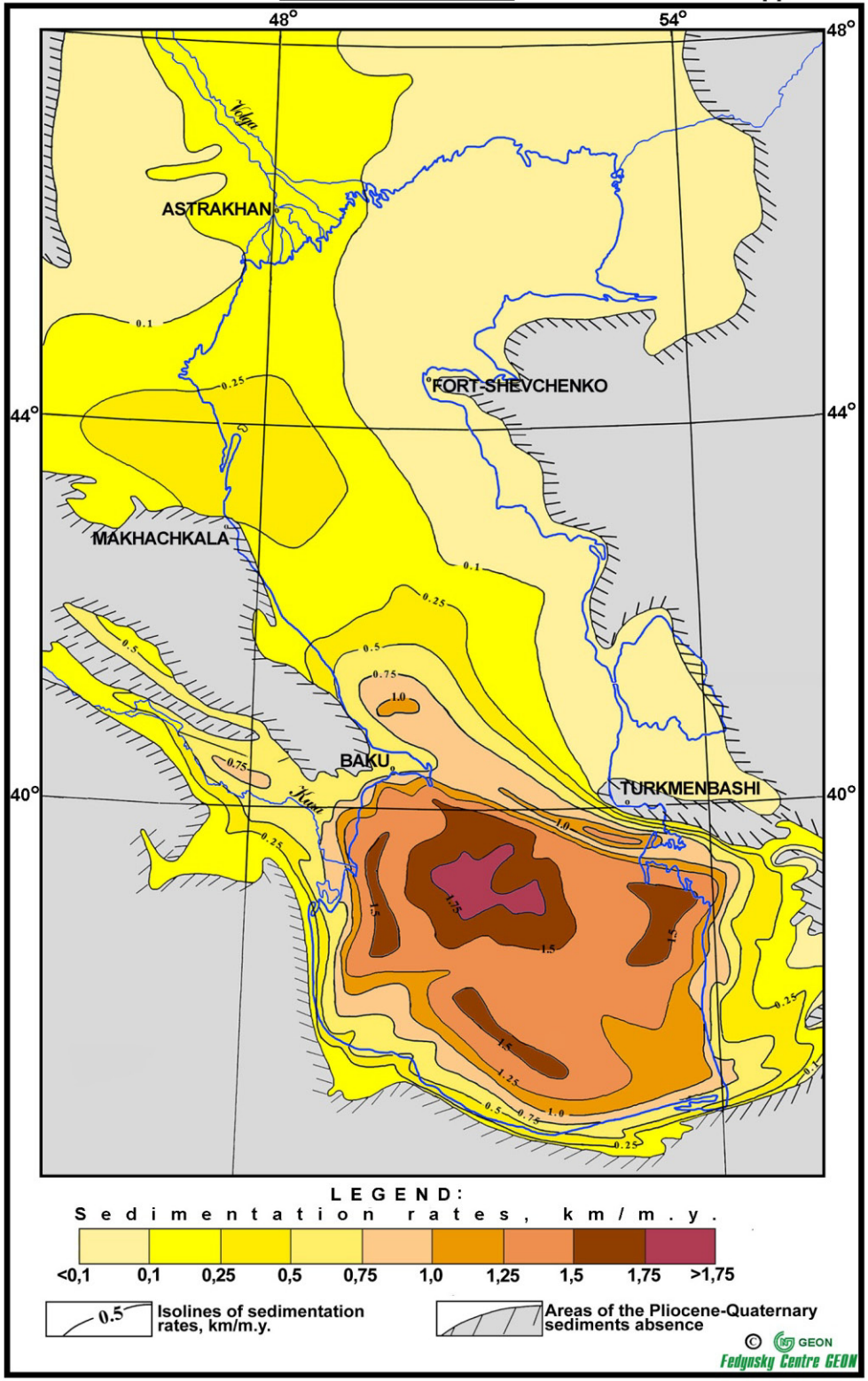
Subsiding history



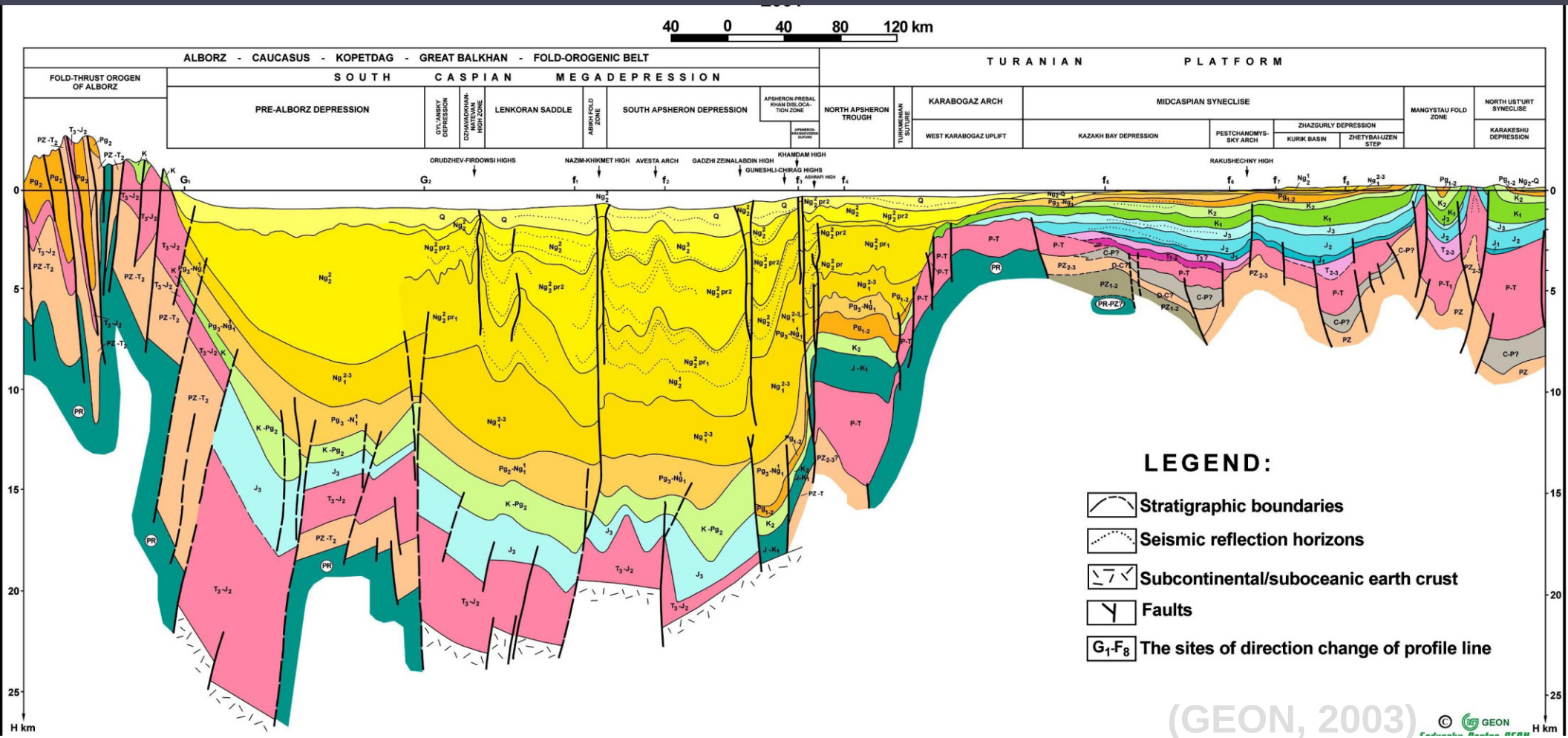


Burial history

Continuous sedimentation from the Upper Jurassic to present. Avalanche sedimentation during Pliocene-Pleistocene (3mm/year)

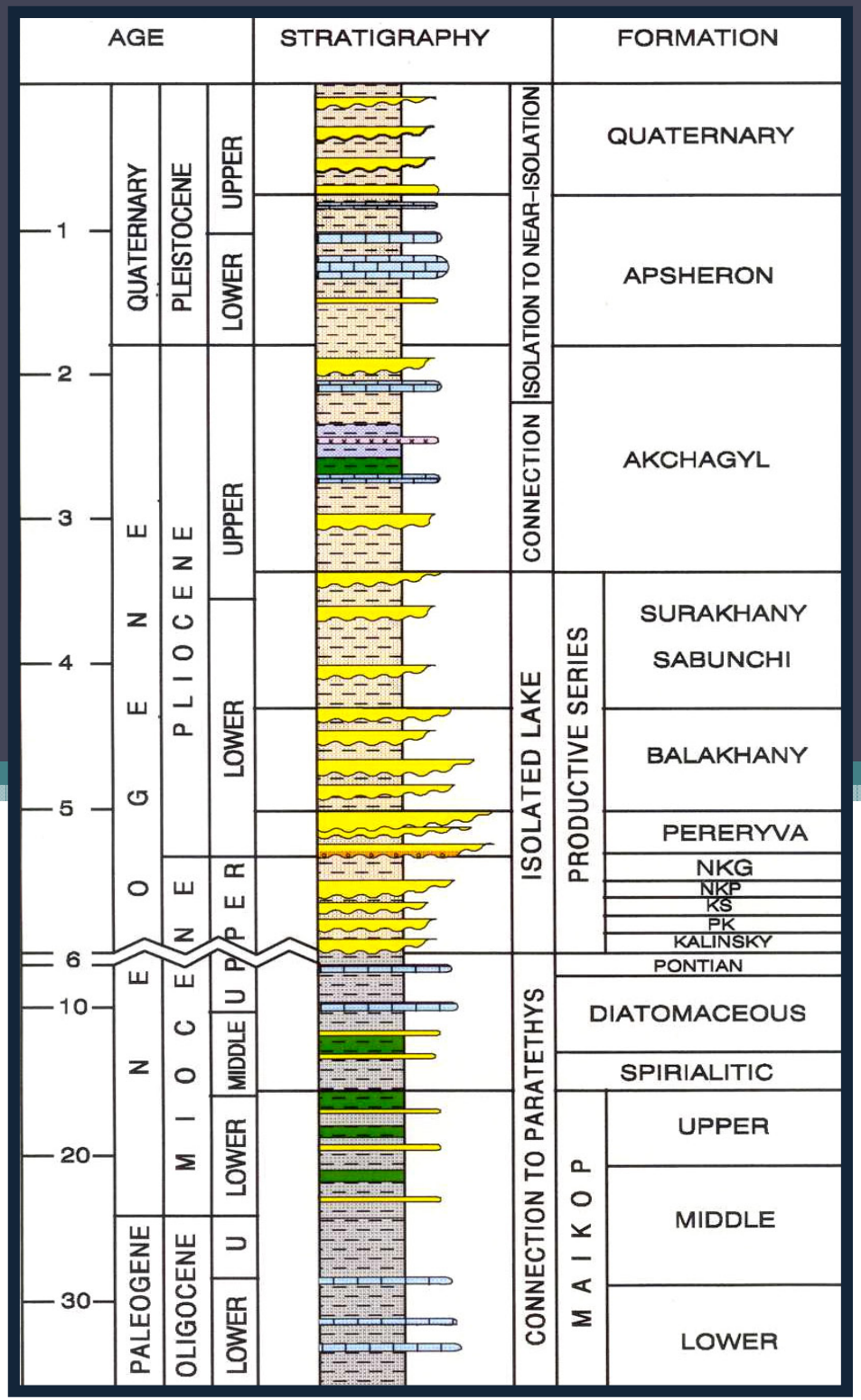


The map of sedimentation rate in Pliocene-Quaternary time



Typical feature:

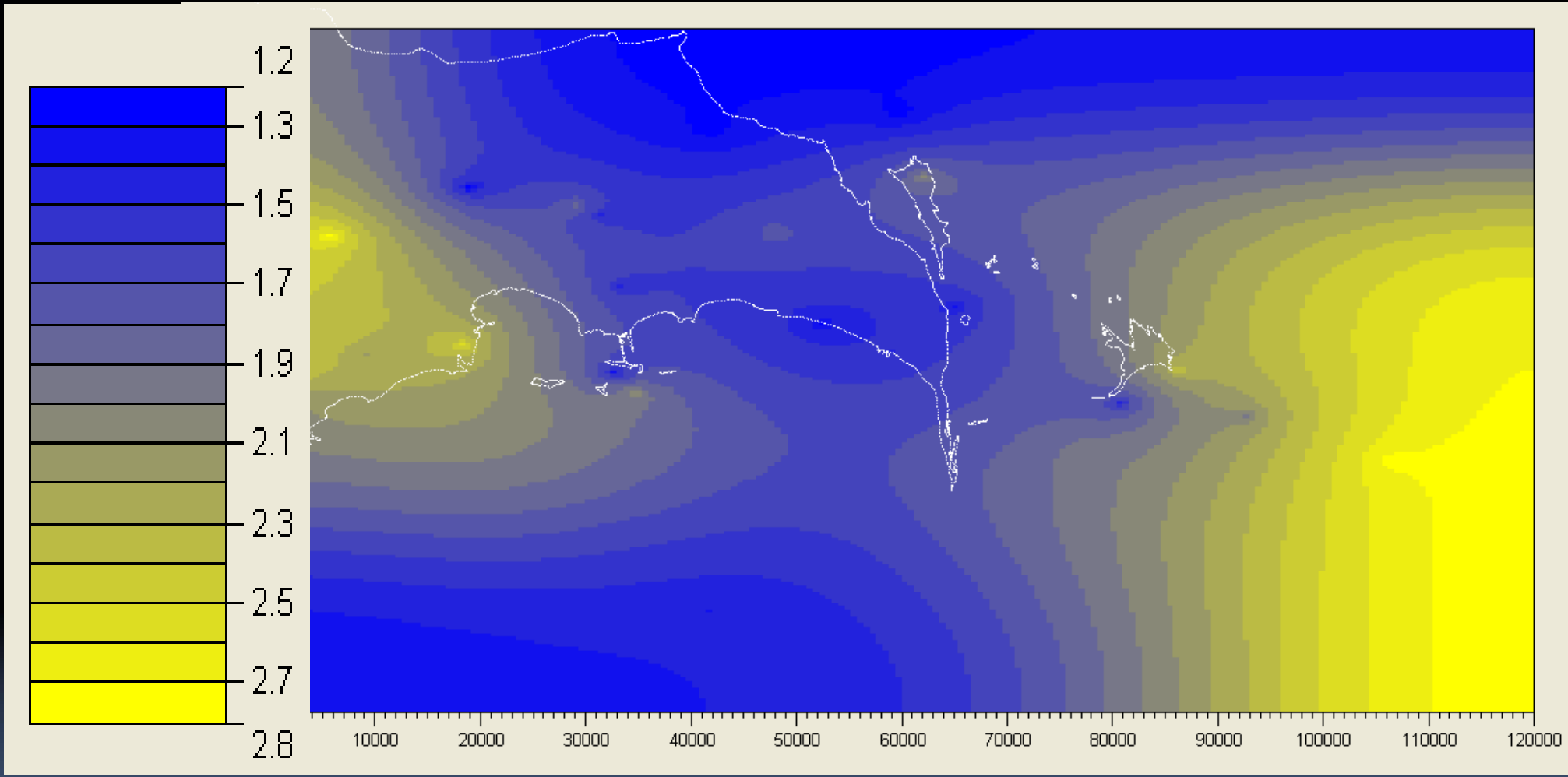
Due to large sediment input and rapid subsidence the sedimentary cover is as thick as 25-30 km



Typical feature:

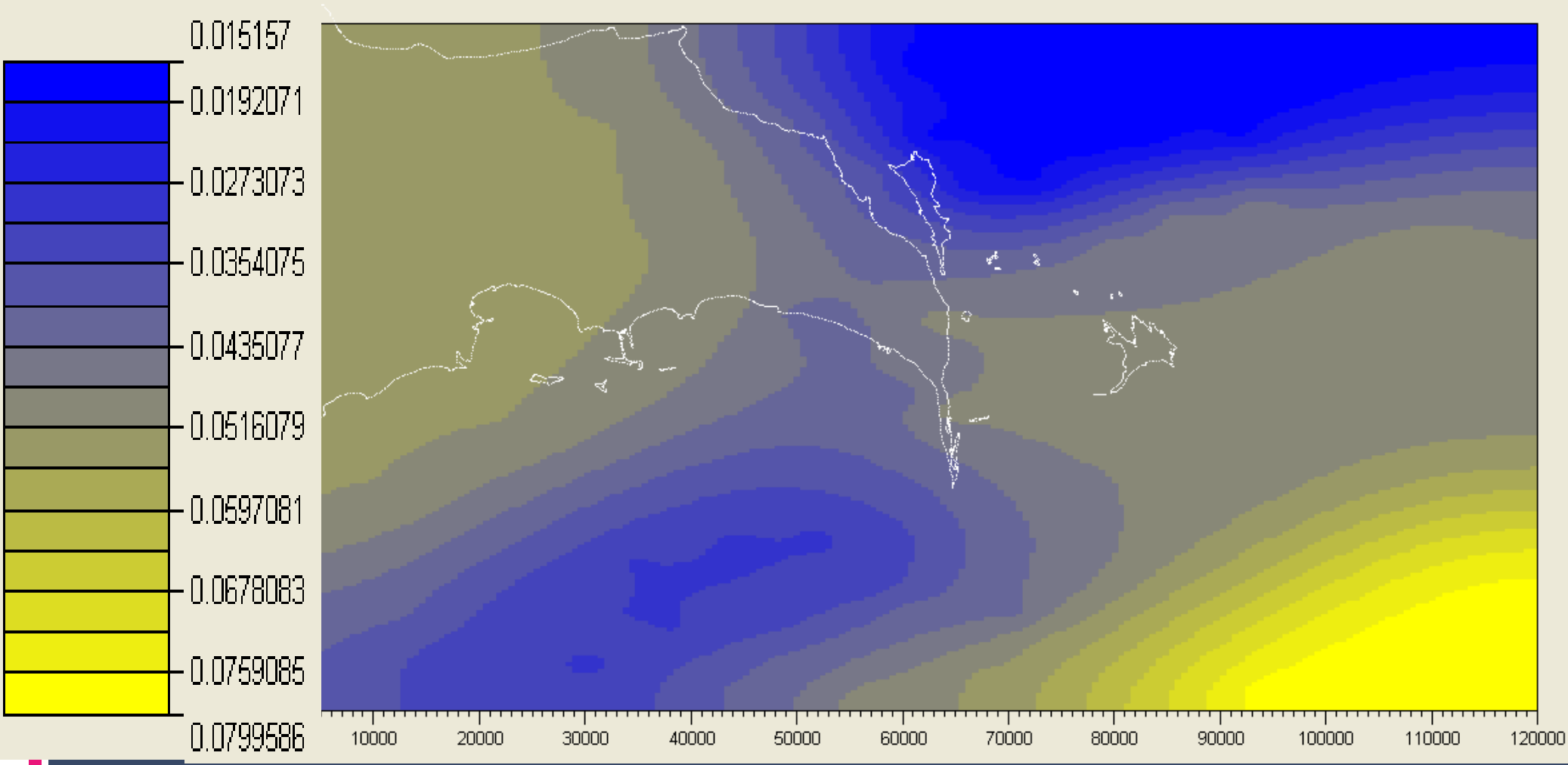
10 km thick Pliocene-Quaternary sediments,
large portion of mudprone intervals in the Cenozoic section (10- 25 km)

Absheron onshore-offshore geothermal gradient map



For deeply subsided zones with thick sedimentary cover and thick shielding mudprone Maycop Series the predicted data display very low geothermal gradient - 1,3^{0}C-1,5^{0}C /100м

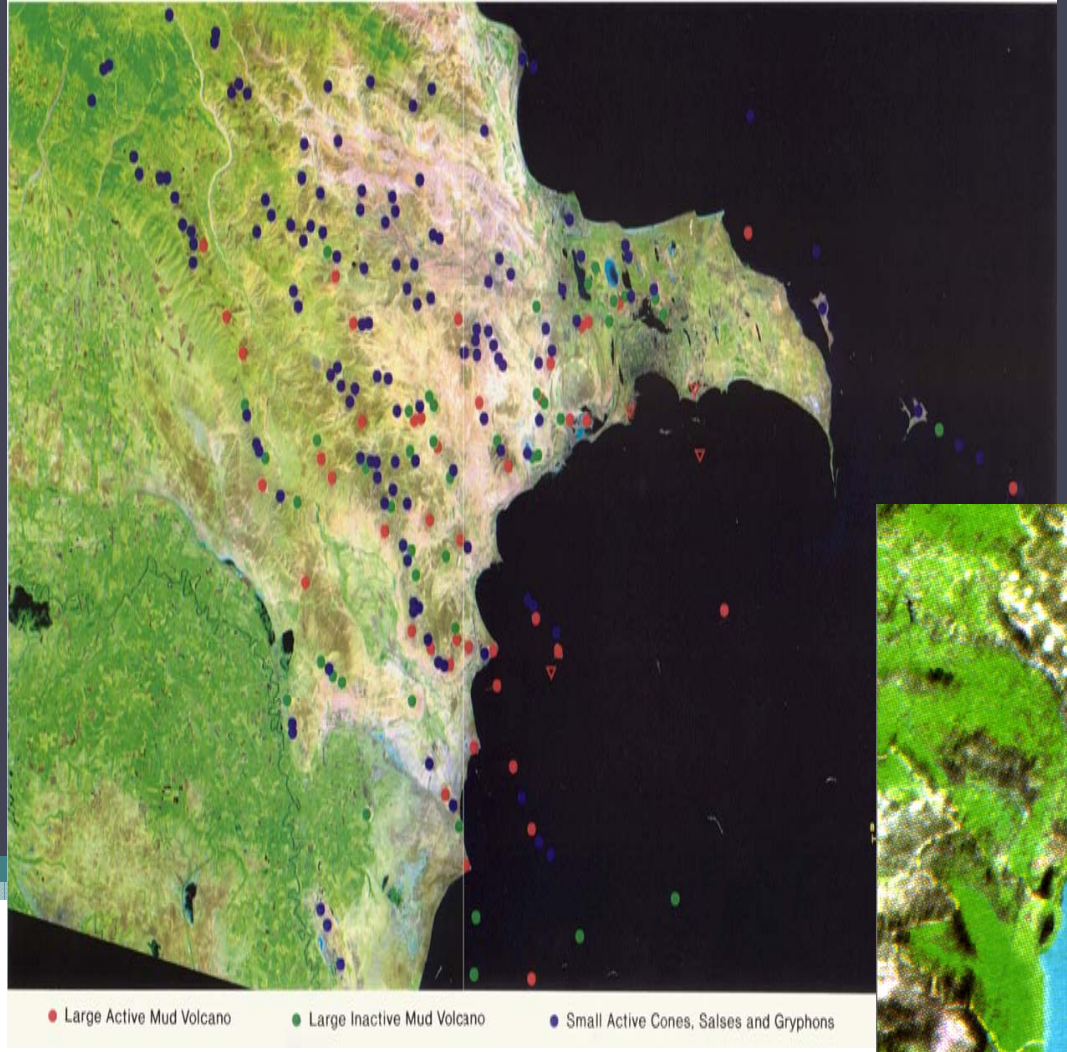
Absheron onshore-offshore heat flow map

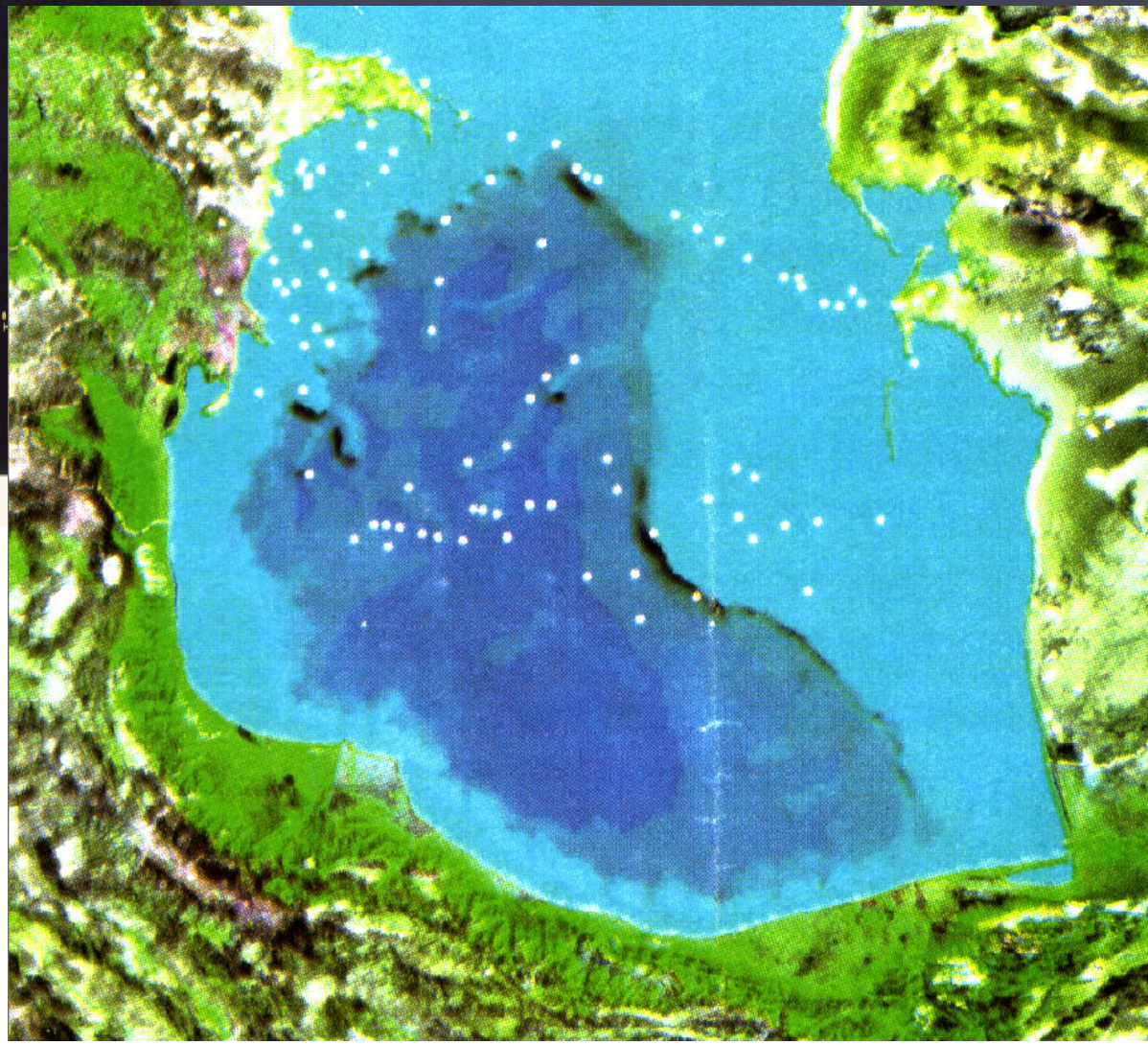


And very low heat flows less than 0,02 W/m²

Typical features:

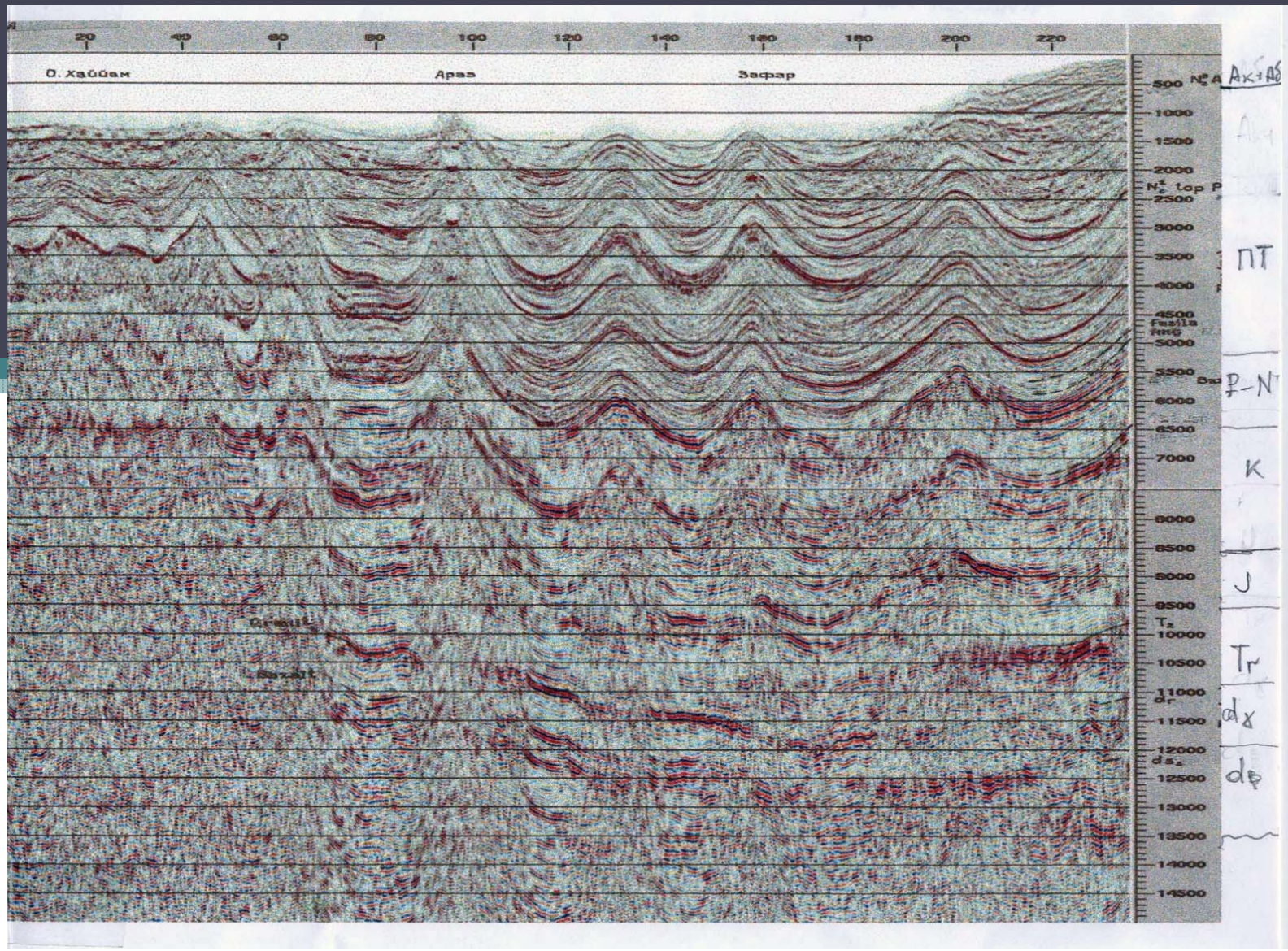
The highest in the world density of mud volcanoes





Location of mud volcanoes in the South Caspian Basin

And wide occurrence of subvertical bodies with deeply penetrating chimneys providing fluid migration pathways

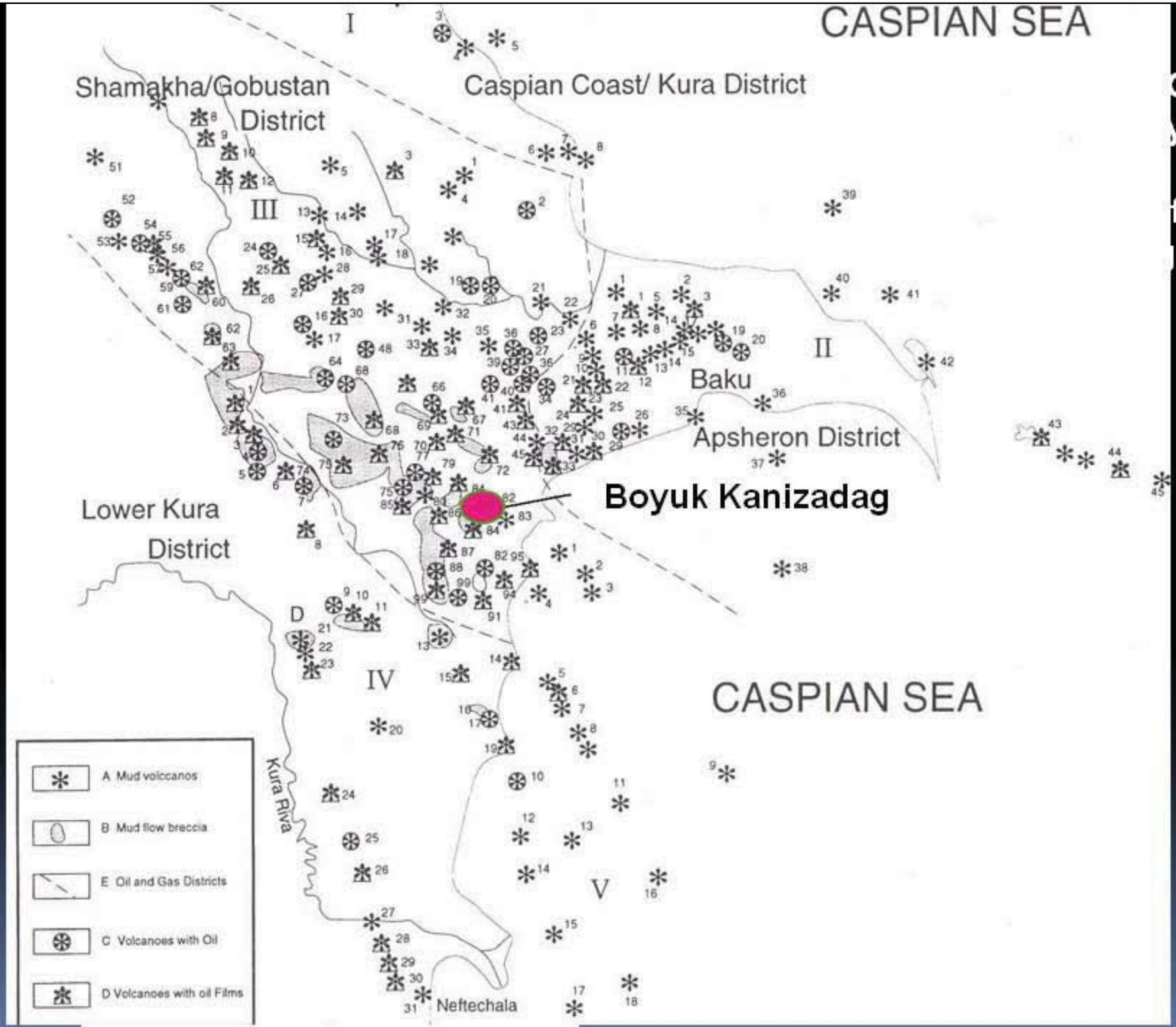


Fragment of seismic line across offshore part of the South Caspian basin

A. Gadjiyev, 2008

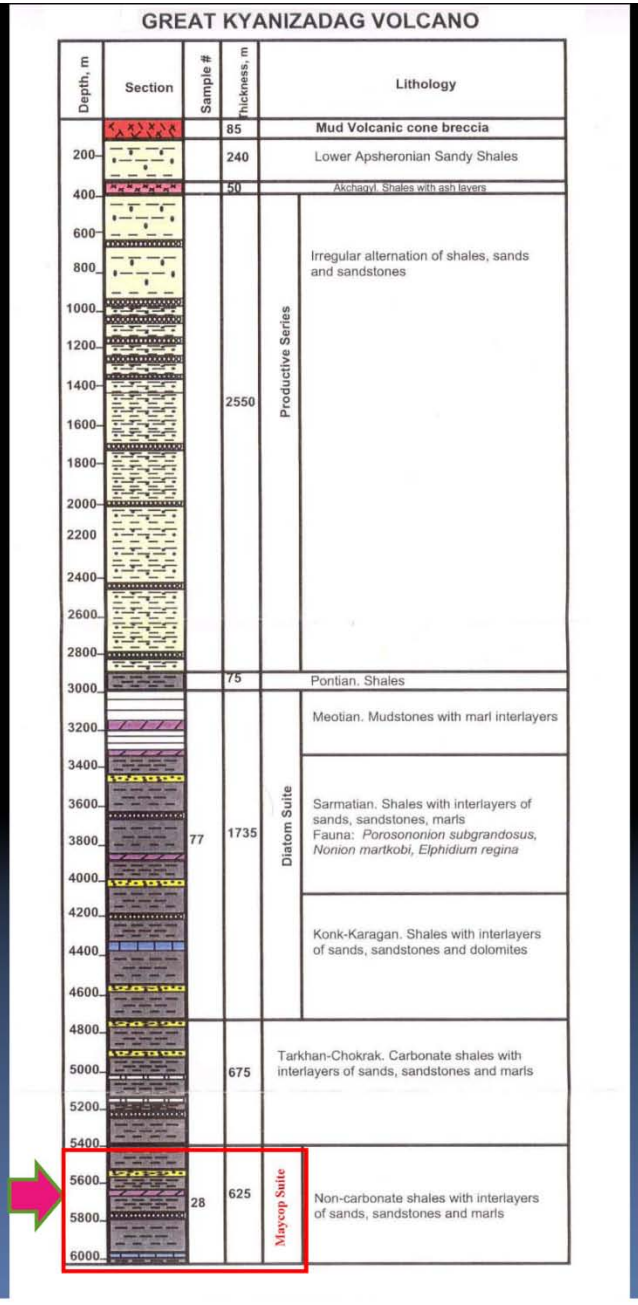
HC KITCHEN
and MIGRATION

A high generation potential of Oligocene-Lower Miocene sediments (Maycop Series).
In mud breccia of Maycop age from the volcano Boyuk Kyanizadag in the depth interval 5400-6100 m
it has been revealed



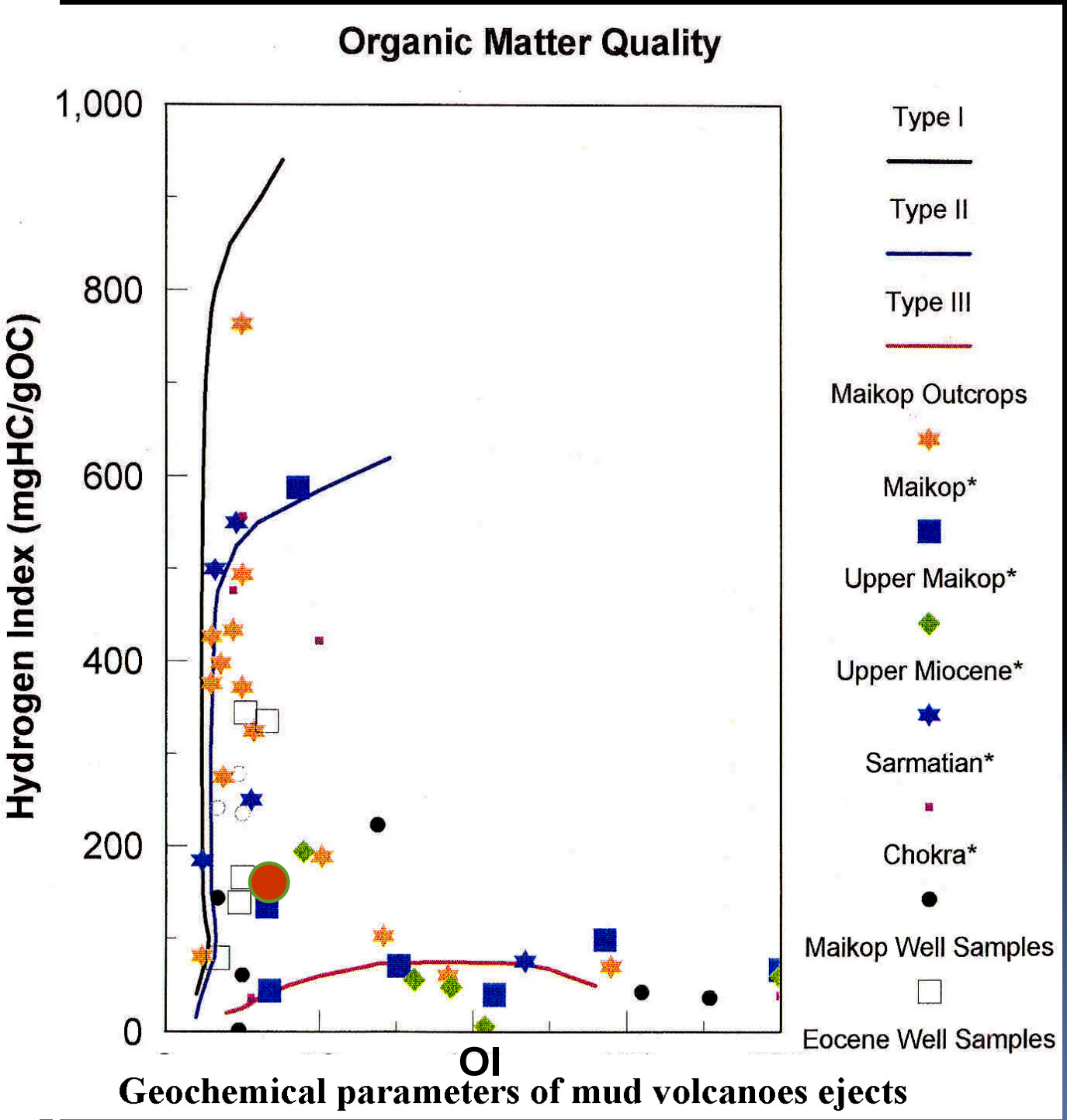
Oligocene-
ycop

from
in the



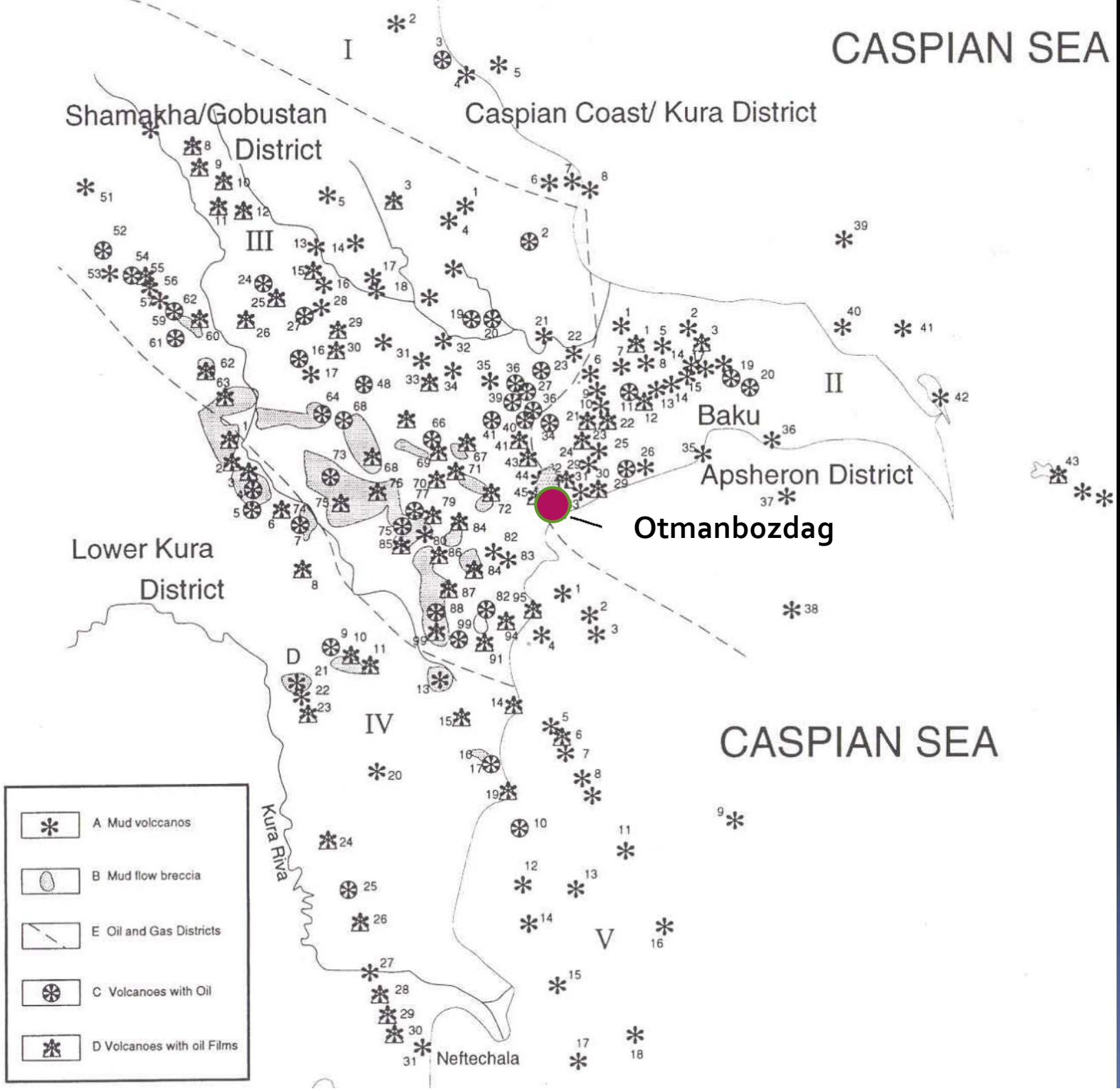
A high generation potential of Oligocene-Lower Miocene sediments (Maycop Series).
In mud breccia of Maycop age from the volcano Boyuk Kyanizadag in the depth interval 5400-6100 m it has been revealed

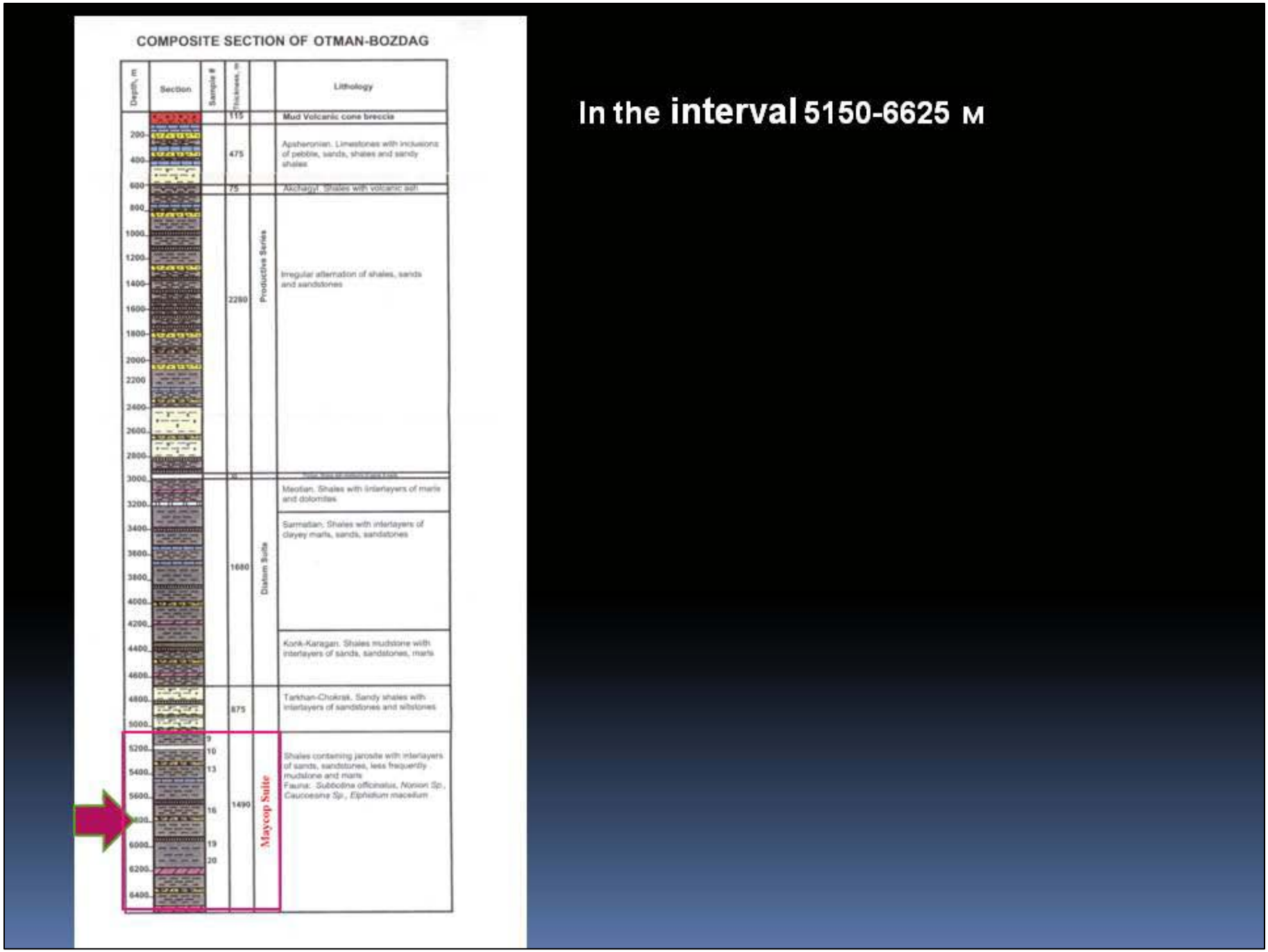
Notes by Presenter: Sediments of Maycop age (Oligocene- Lower Miocene) in the section of mud volcano Greater Kyanizdag occurs in interval 5400-6100 m.



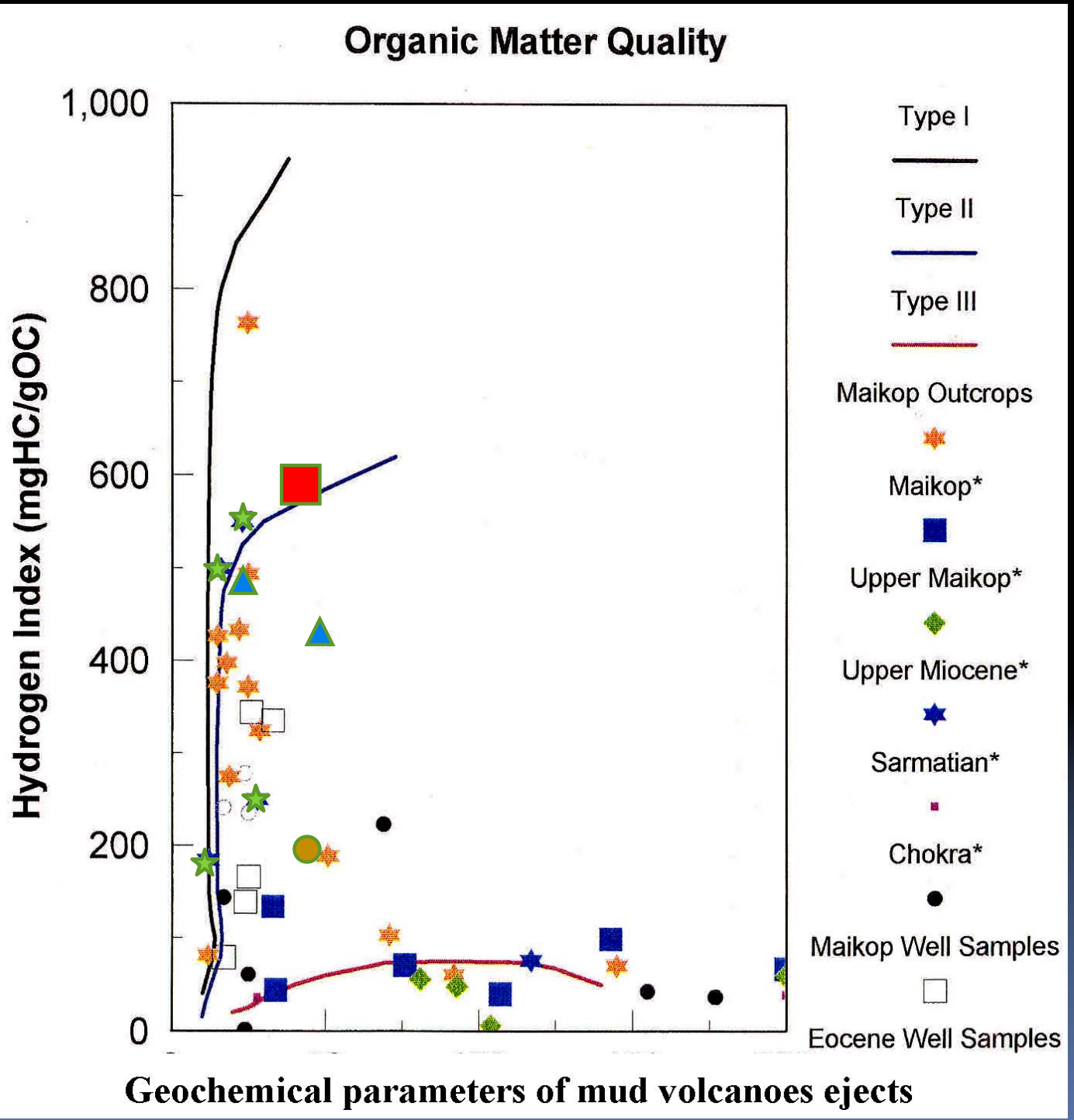
Geochemical parameters of mud volcanoes ejects

TOC =1,66%
HI – 140mg HC/gOC


CASPIAN SEA
Shamakha/Gobustan District
Caspian Coast/ Kura District
Baku
Apsheron District
Otmanbozdag
Lower Kura District
CASPIAN SEA
Kura Riva
Neftechala
I
II
III
IV
V
D
A Mud volccanos
B Mud flow breccia
E Oil and Gas Districts
C Volcanoes with Oil
D Volcanoes with oil Films

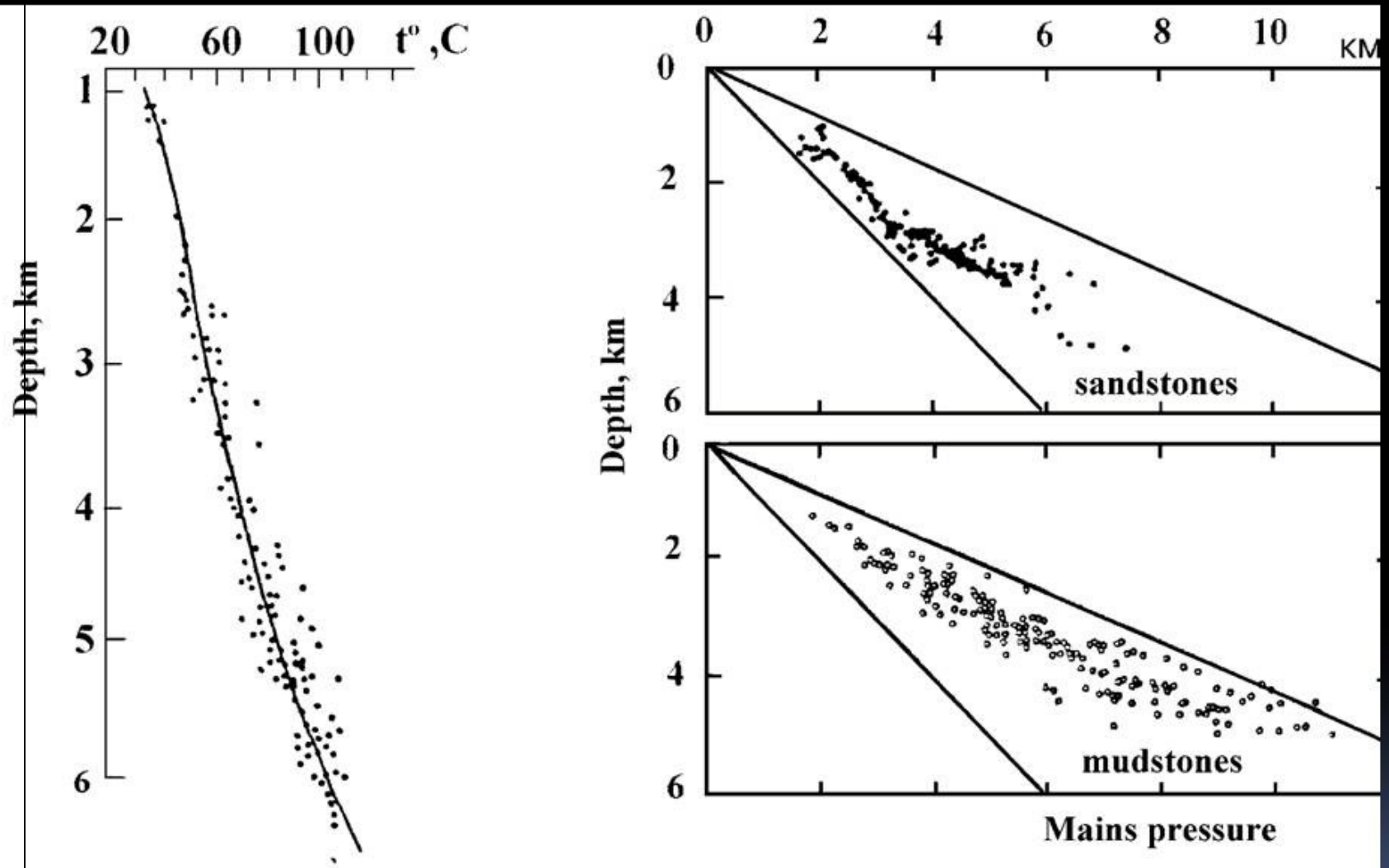


Notes by Presenter: Within location of other volcano – Otmanbozdag, Maycop series occurs here within interval 5150-6625 m.



Geochemical parameters of mud volcanoes ejects

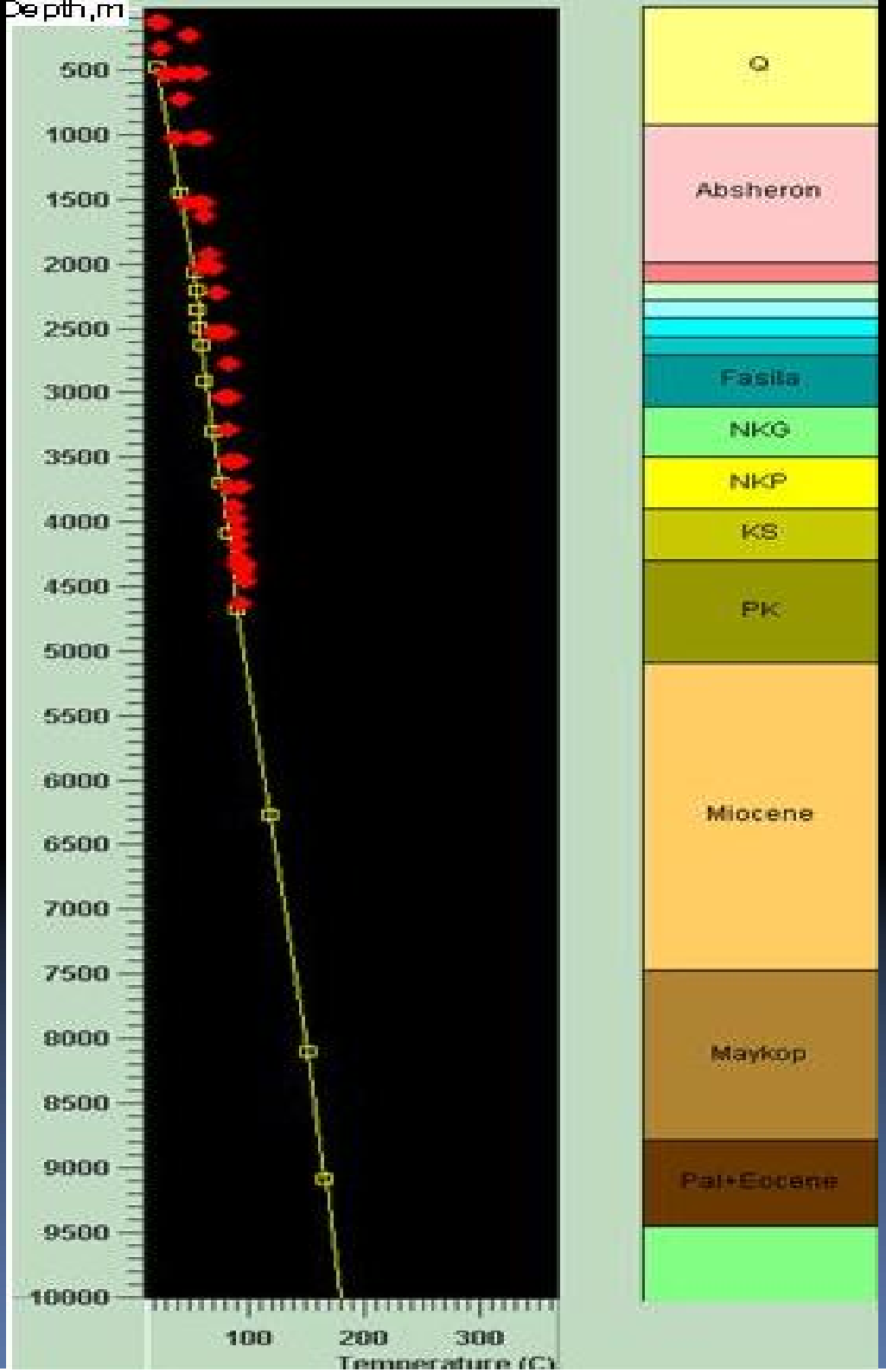
HI- 588мг HCmg/gOC
TOC= 1,92%

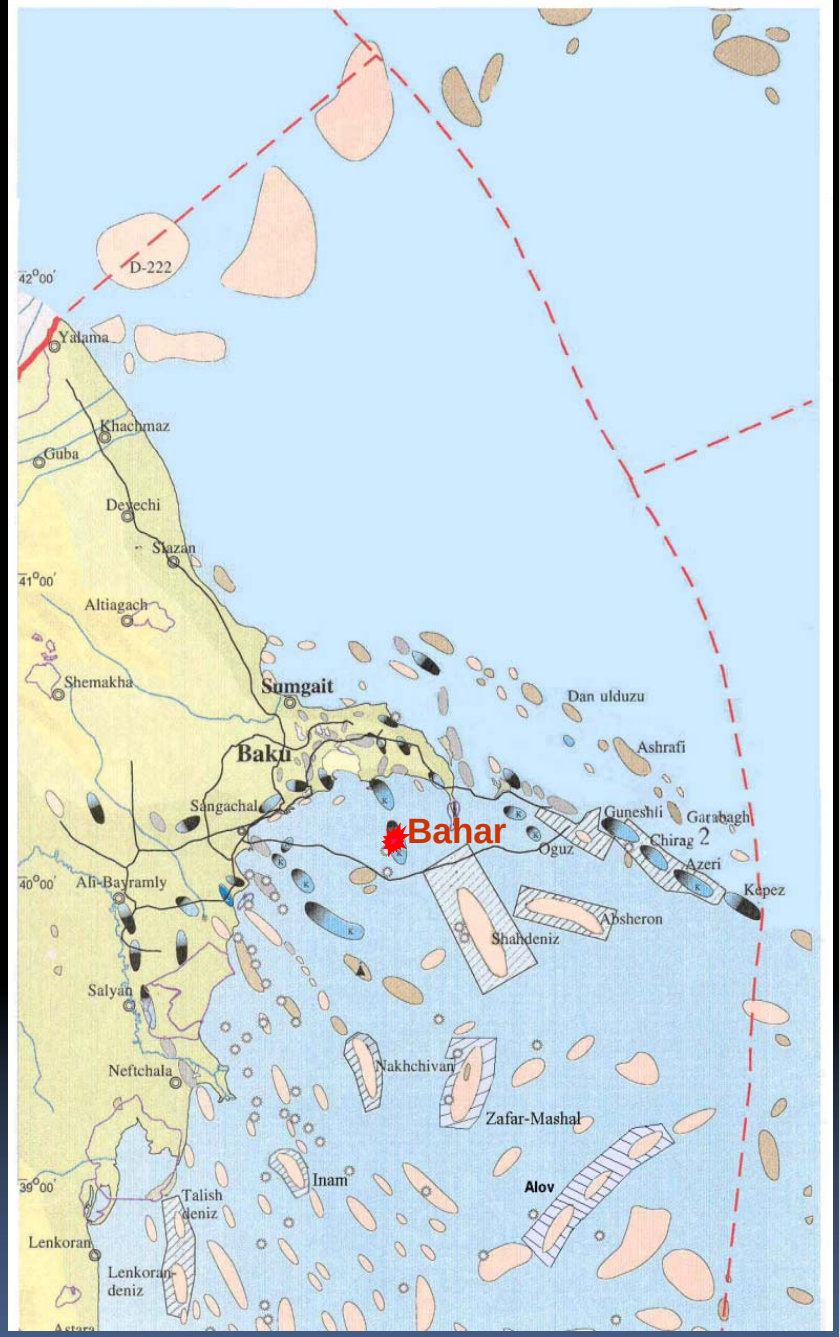


Values of mains pressure and temperature in the South Caspian basin

Bredehoeft, Djevanshir, Belitz, 1988

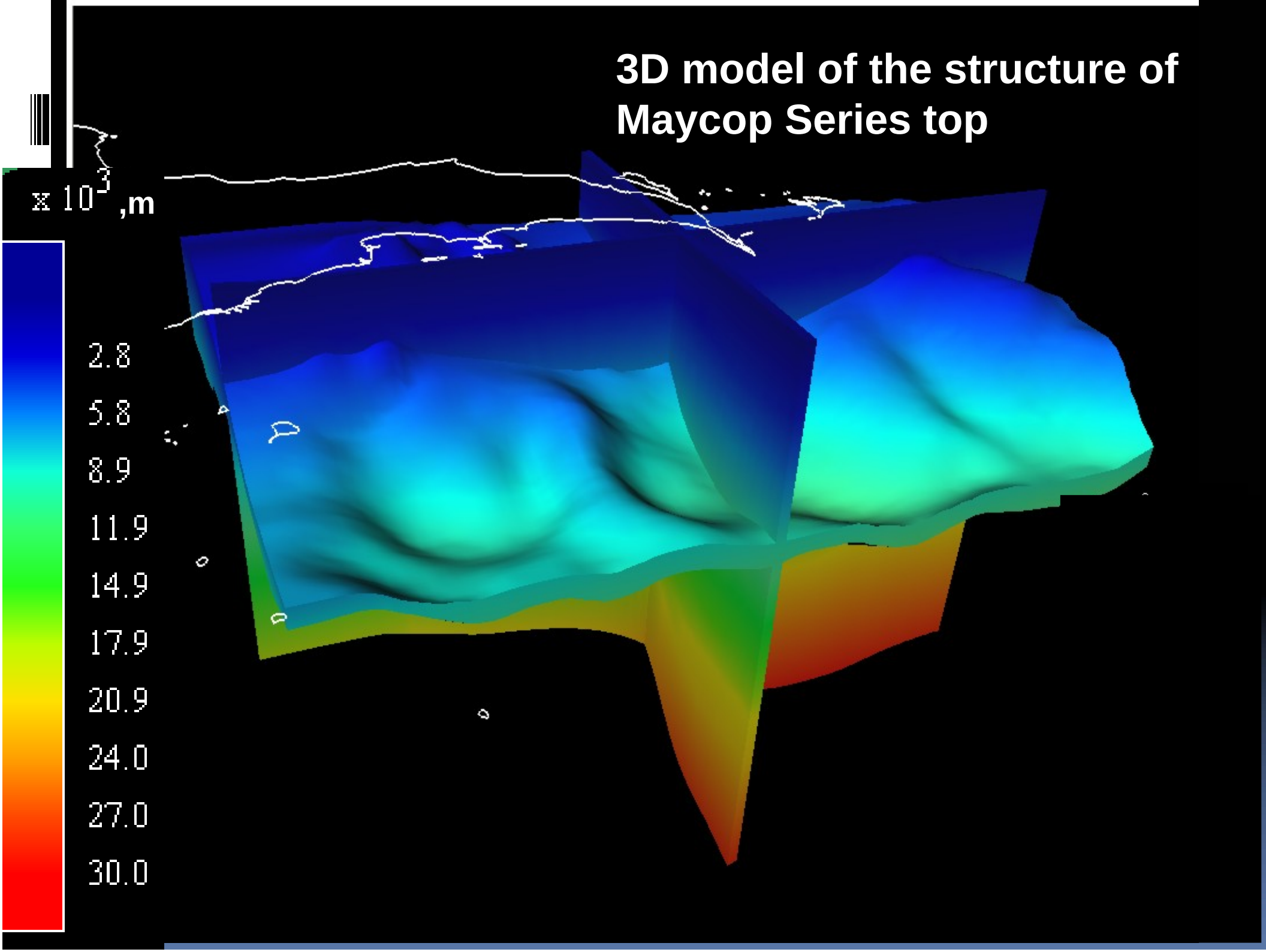
Notes by Presenter: According to cumulative curve compiling data from deep wells in the western flank of the South Caspian Basin temperature - 60^0 is marked at depth 4 km, 100^0-6,2 km**.** Abnormally high values of mainspressure reaching 1000 atm. and more at depth 5 km are also have been determined.

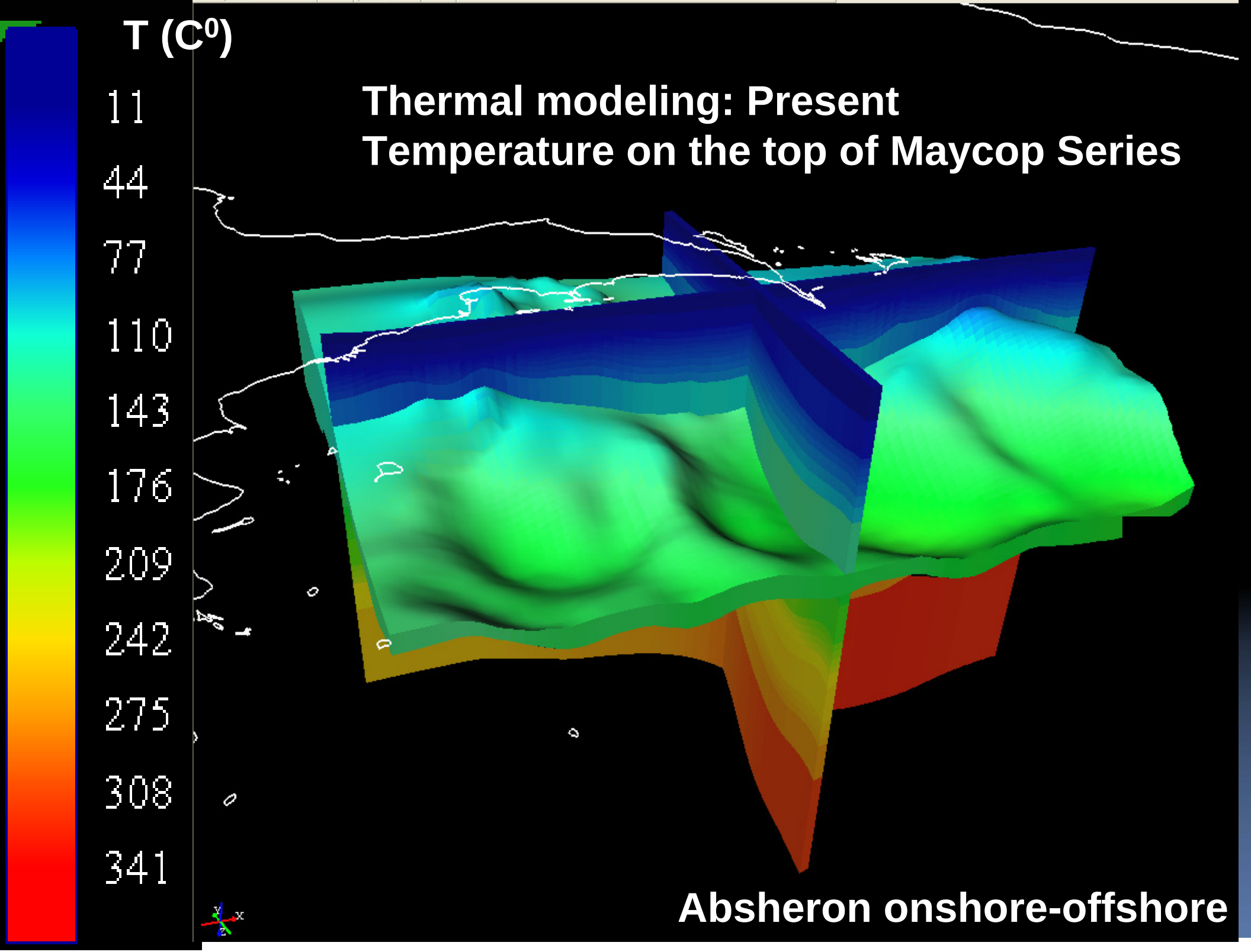




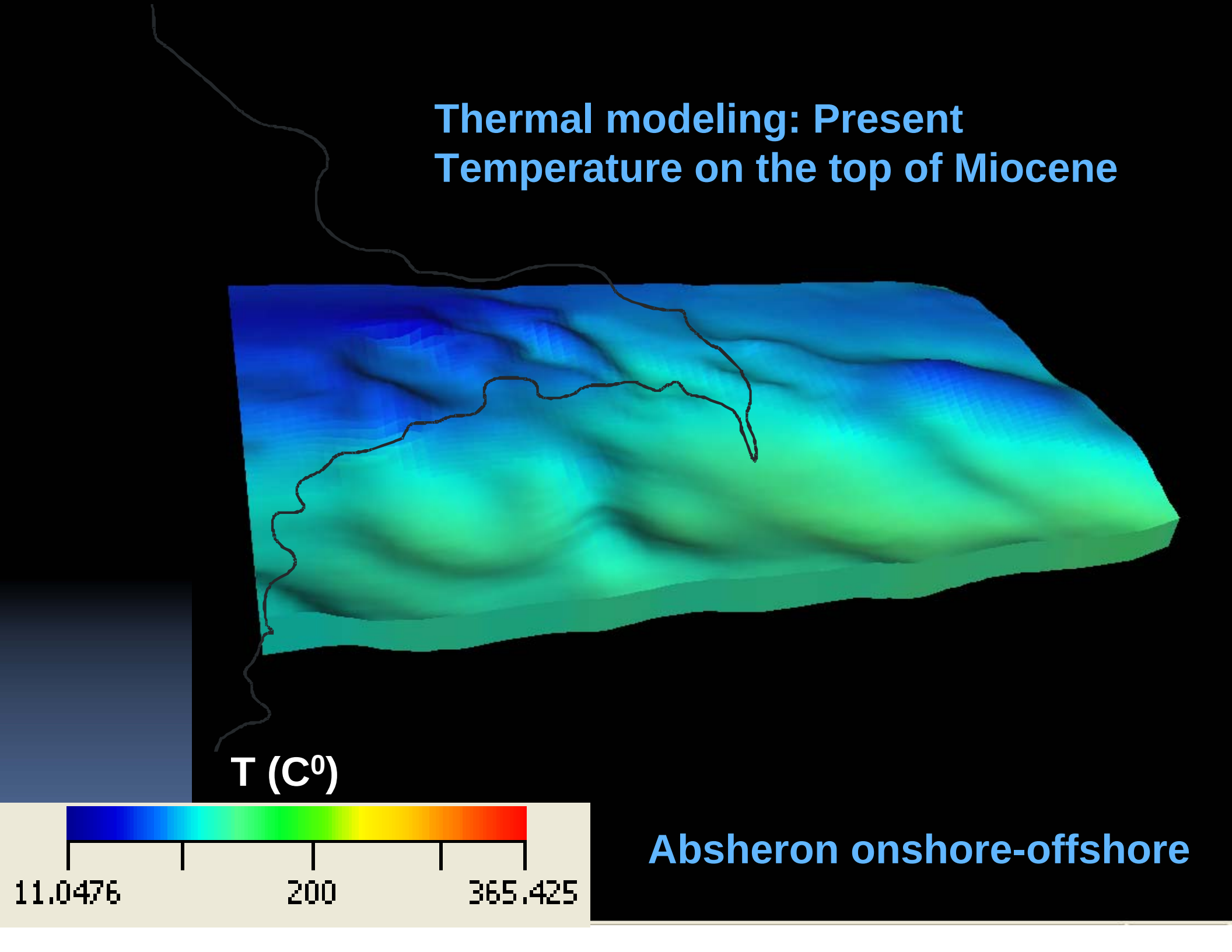
Predicted temperatures for Bahar field at the depth 10 km is 180^0 C

3D model of the structure of Maycop Series top

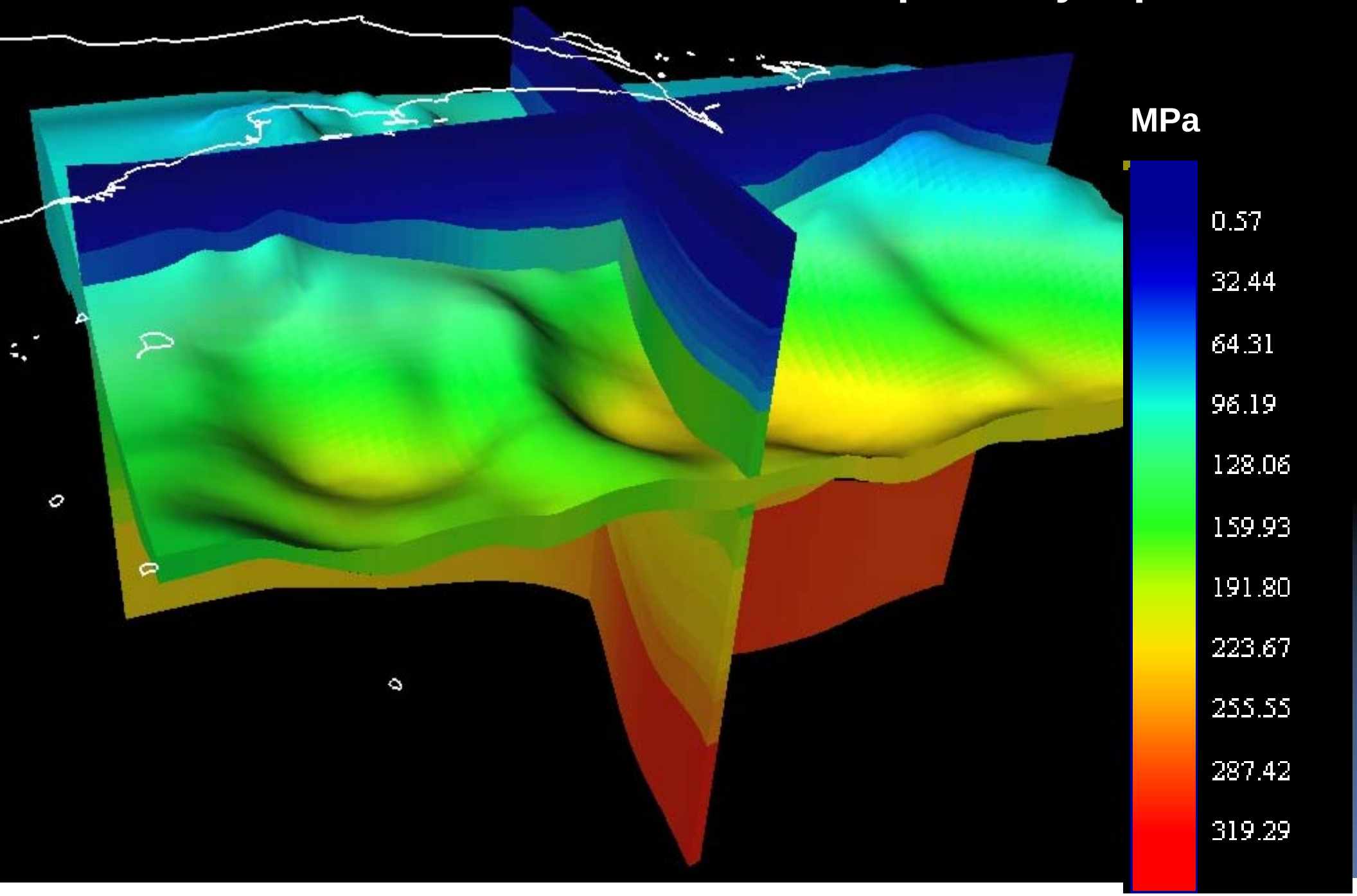



T (C0)
11
44
77
110
143
176
209
242
275
308
341
Thermal modeling: Present
Temperature on the top of Maycop Series
Absheron onshore-offshore

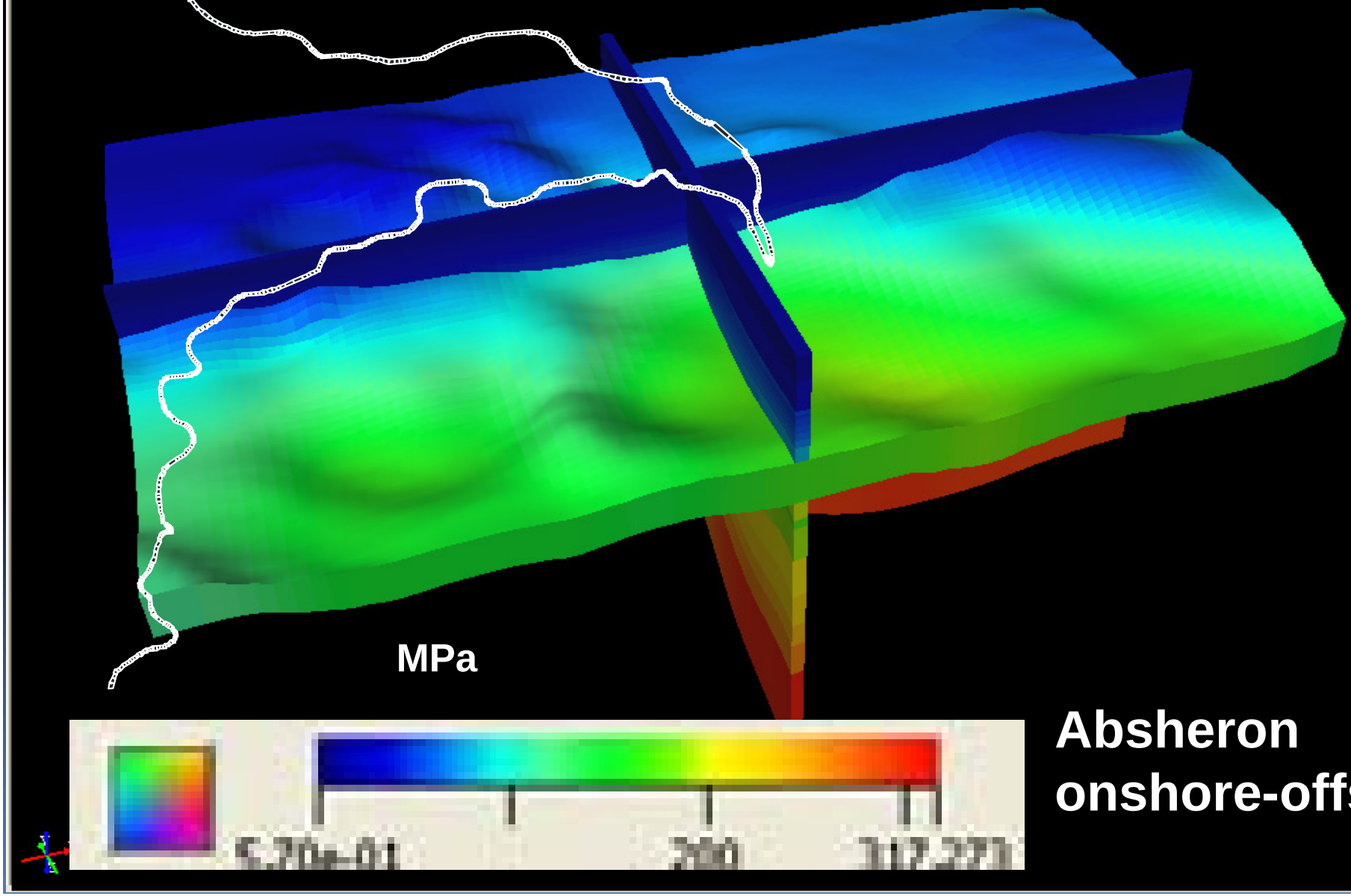
Thermal modeling: Present Temperature on the top of Miocene



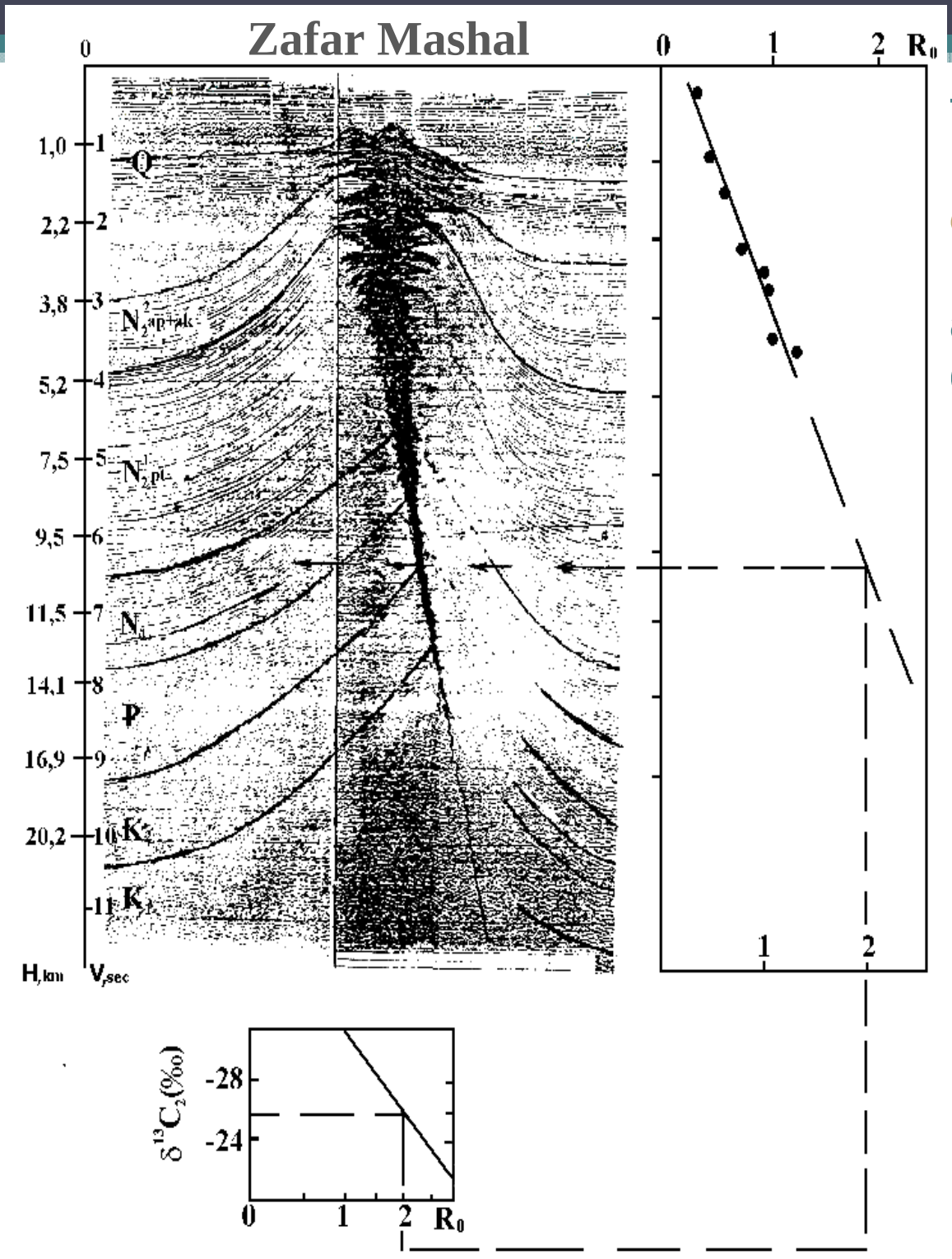
Pressure modeling: Present
Pressure on the top of Maycop Series



Pressure modeling: Present
Pressure on the top of Miocene

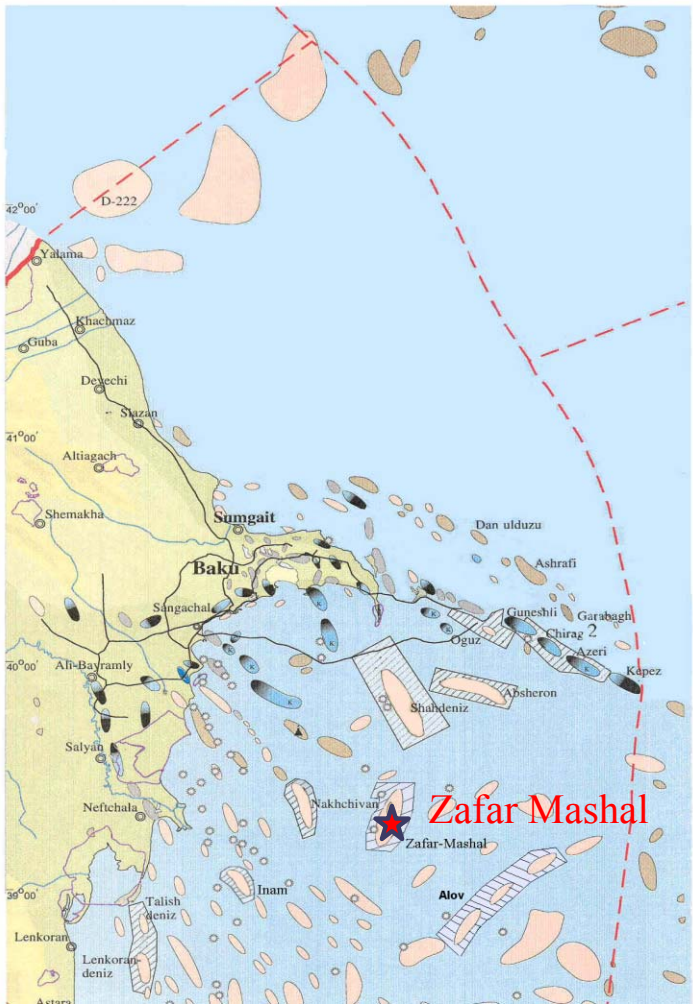


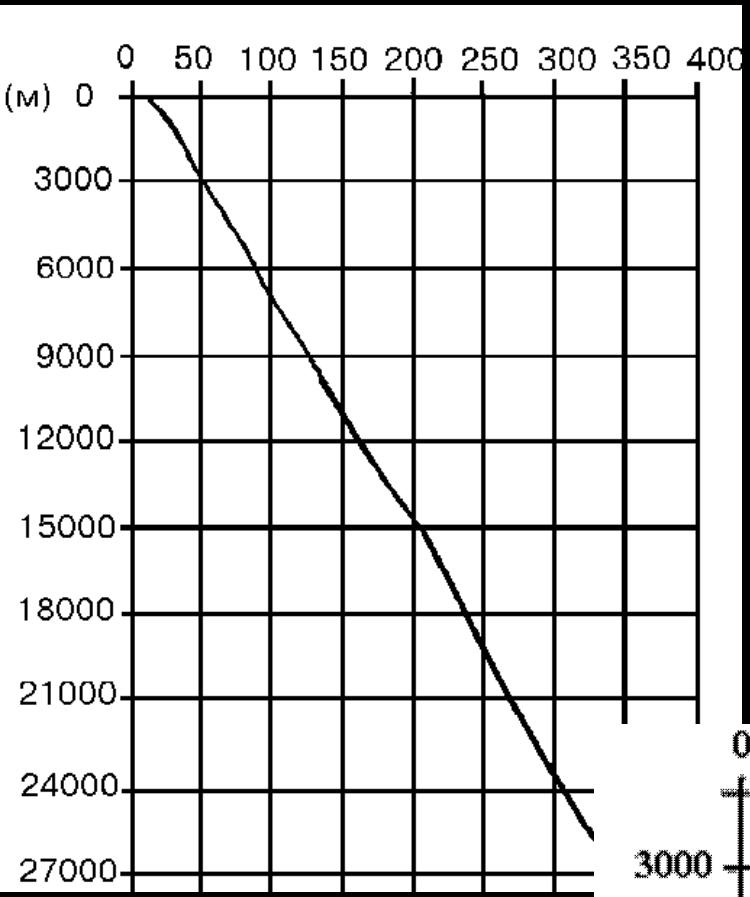
Absheron
onshore-offshore



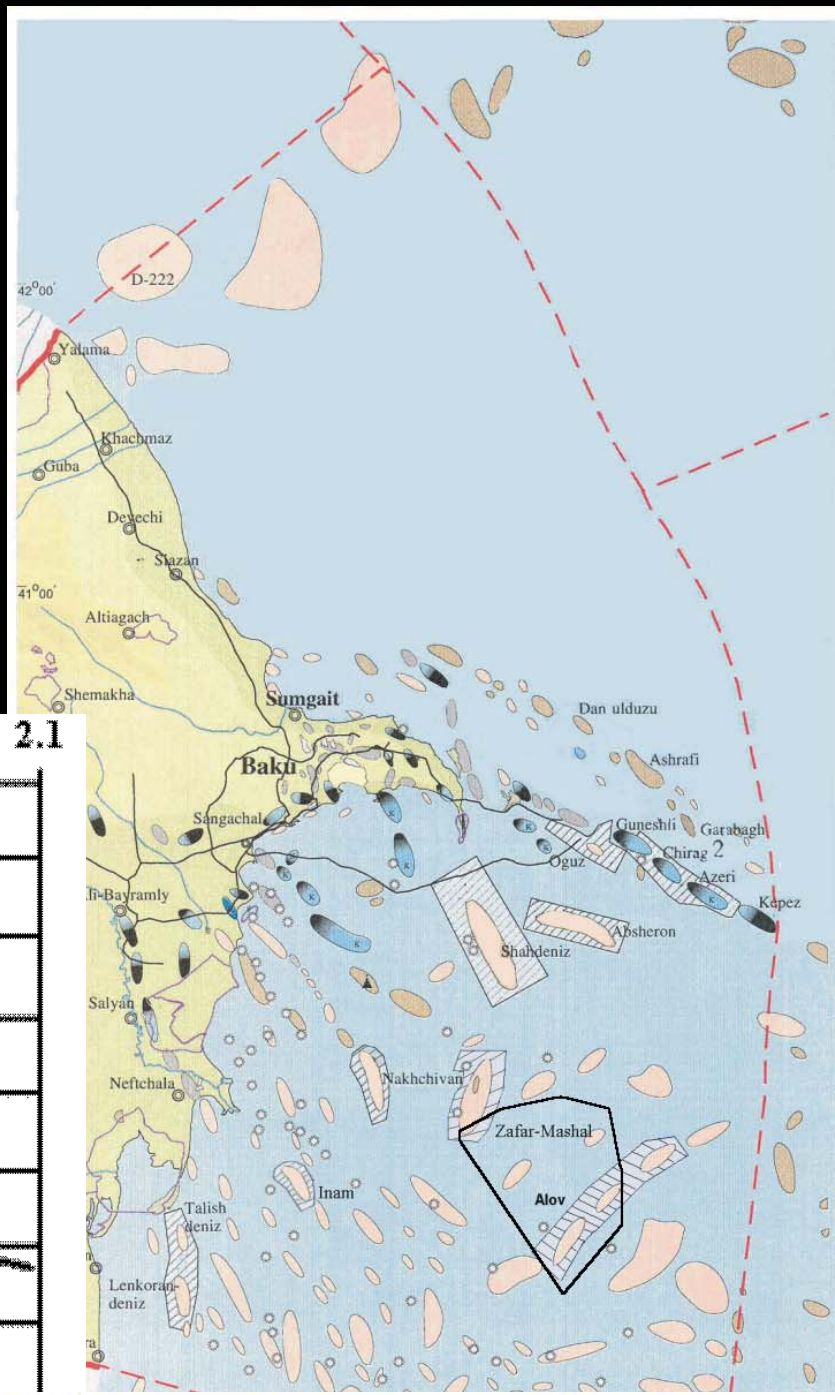
The estimated maturity of ethane of gas hydrates calculated on dependence $\delta^{13}CC_2H_6$ - Ro is 1.47-1.94%.

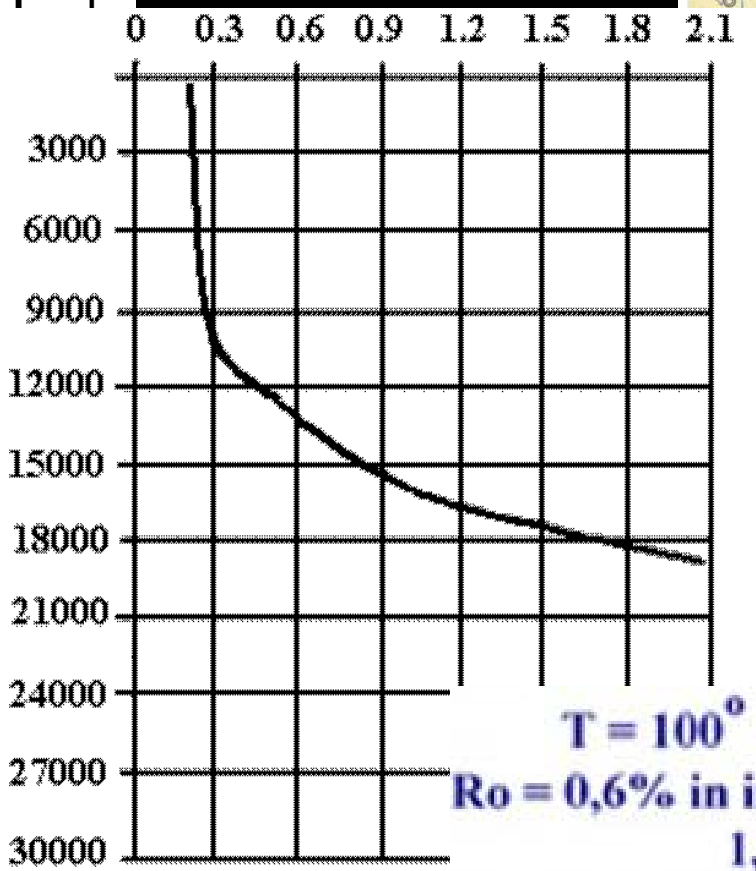
It is corresponded to the depth over 10 km and stratigraphical correspondence of gas generation centres to the Miocene-Paleogene deposits.





Temperature in the sedimentary cover of the South Caspian deep water part

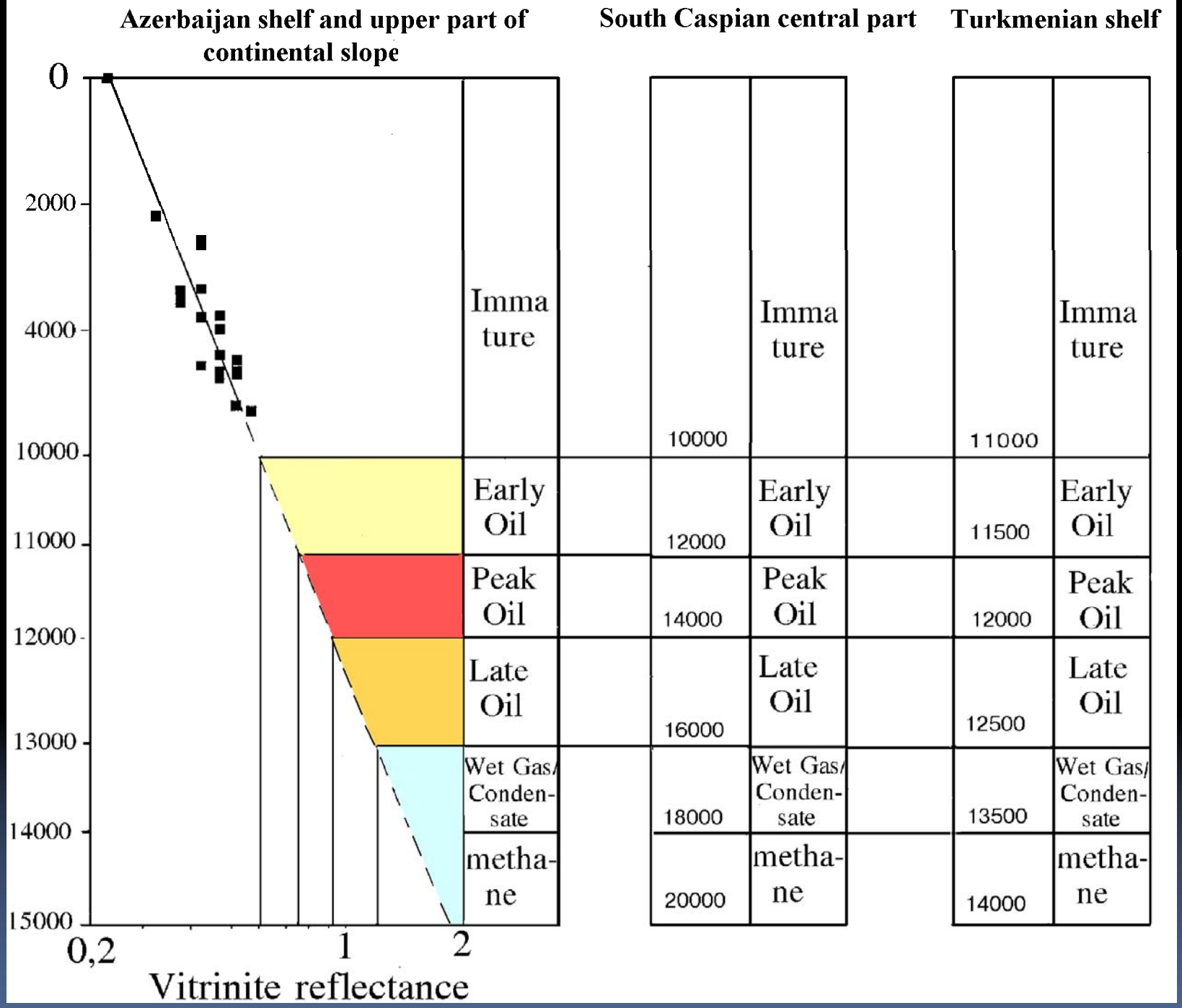




Vitrinite reflectance in the sedimentary cover of the South Caspian deep water part

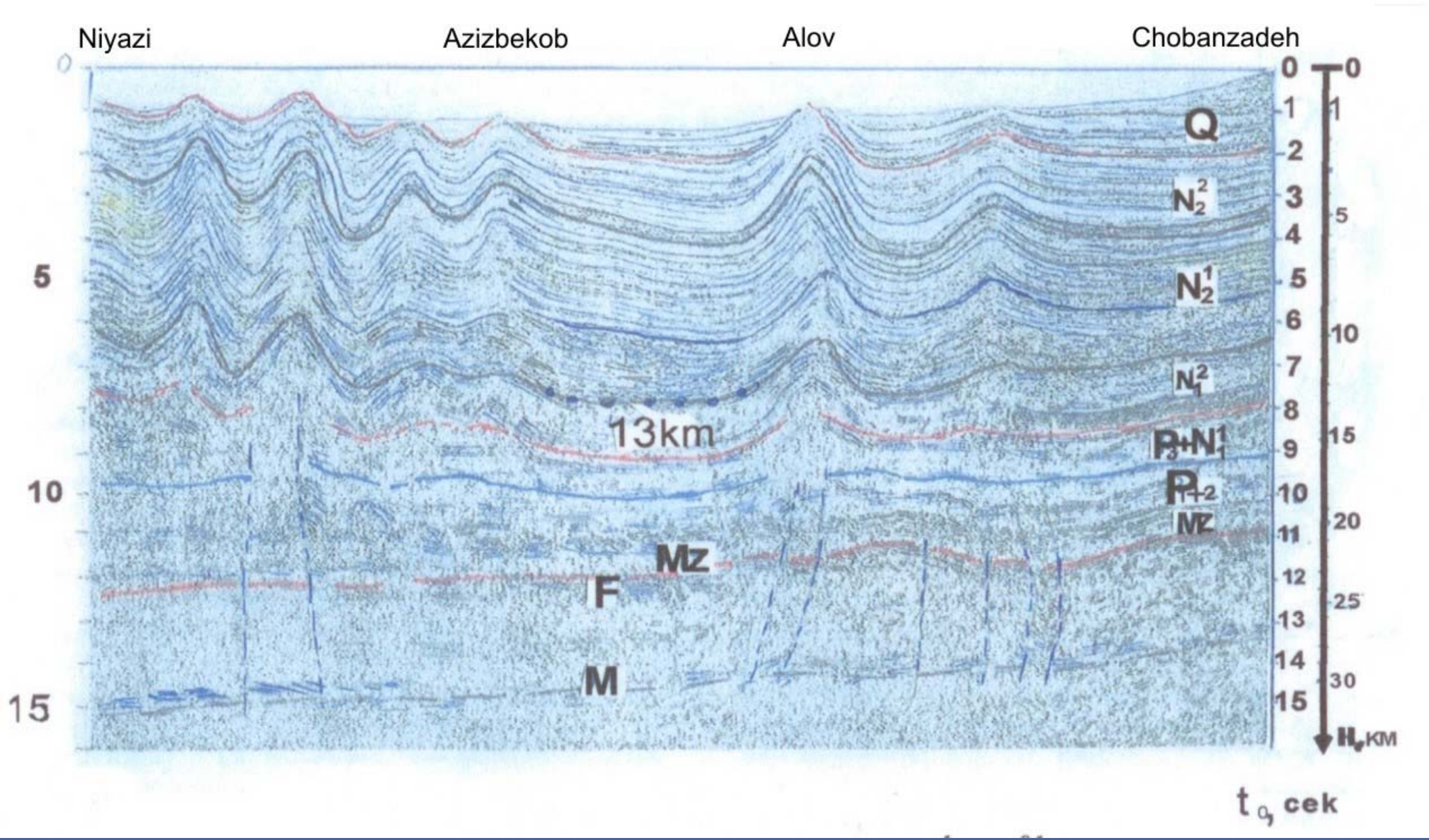
L.Lerche et al., 1997

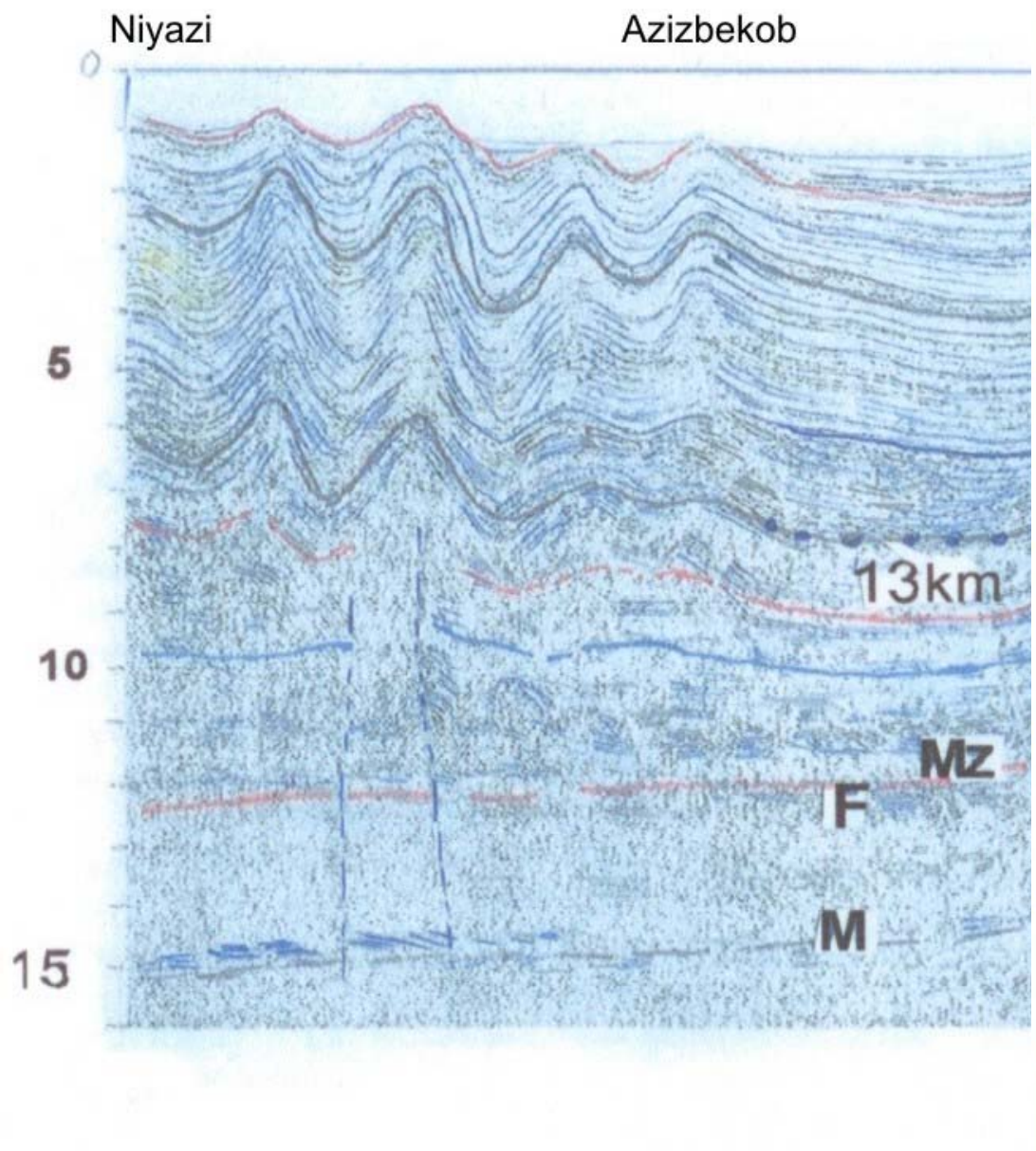
T = 100° - at depth 7-8 km; 200° - 15 km
Ro = 0,6% in interval 10-12 km; 0,9%-14-15 km; 1,3%-16km; 1,6% -17-18 km

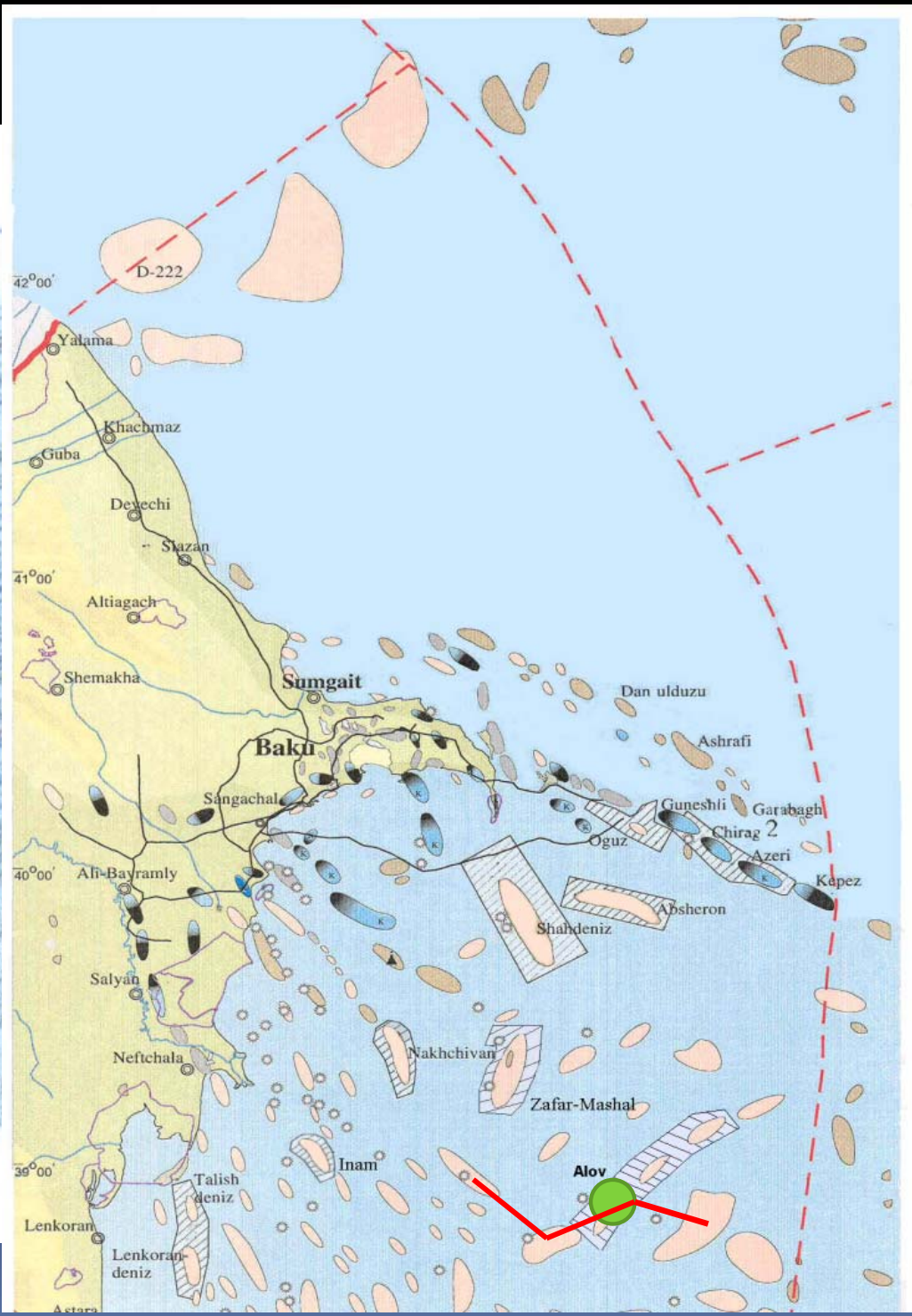


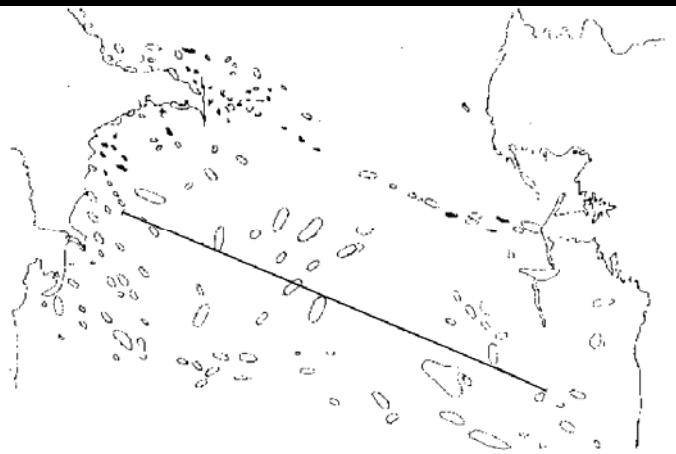
Organic matter maturity profile across the South Caspian basin

Modified after Wavrek et al., 1996

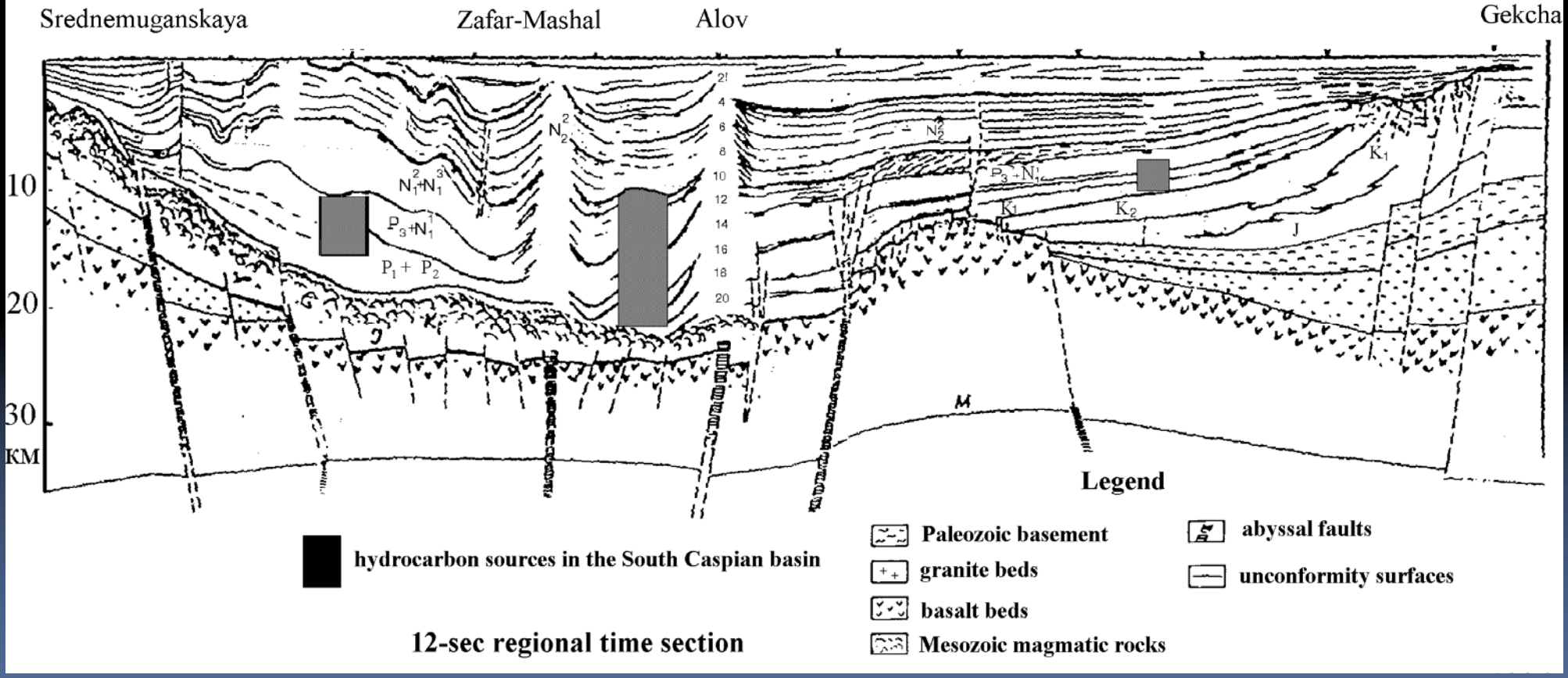

Niyazi
Azizbekob
Alov
Chobanzadeh
Q
N_2^2
N_2^1
N_1^2
$P_3+N_1^1$
P_{1+2}
MZ
13km
MZ
F
M
t_g, cek
H_g, KM

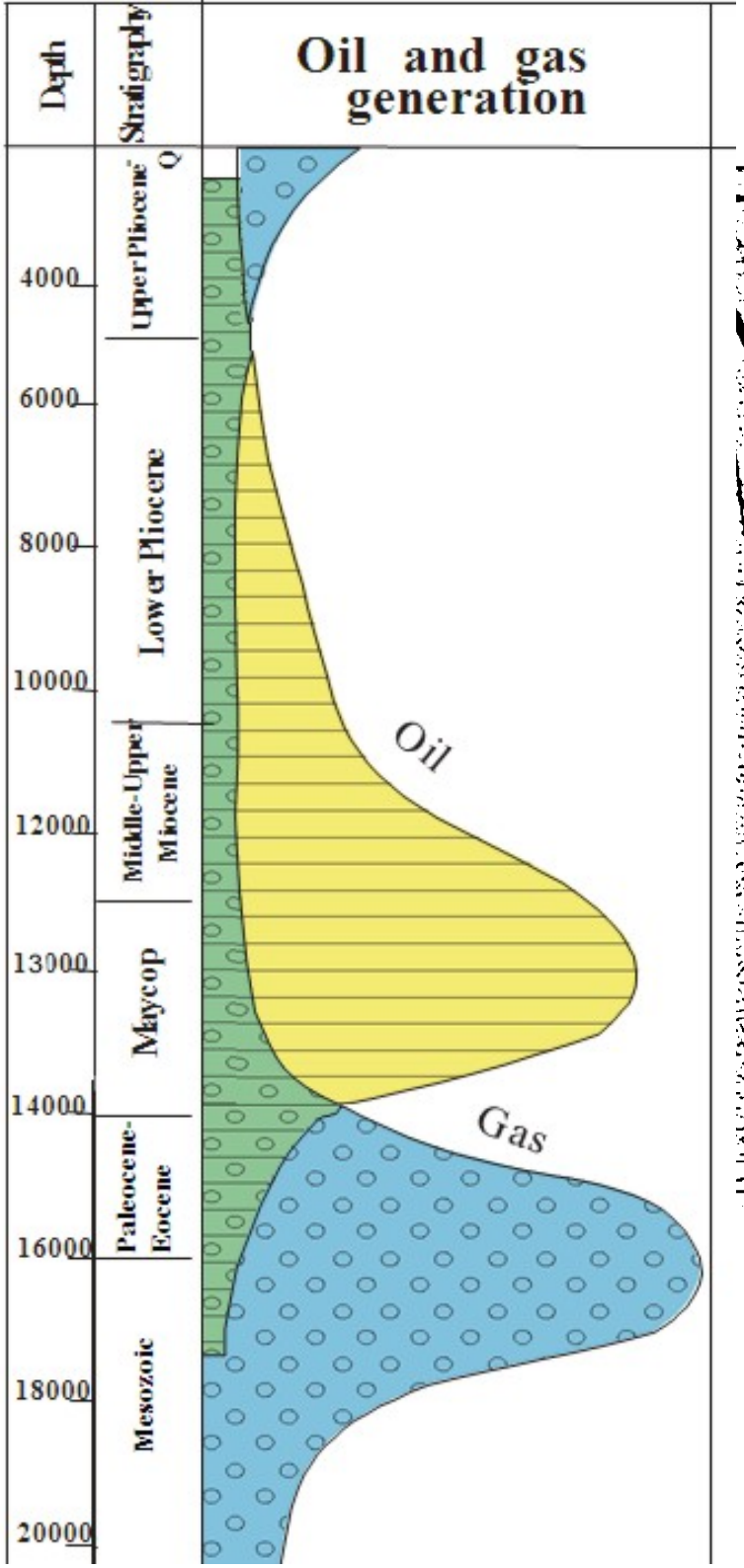

Niyazi
Azizbekob
0
5
10
15
13km
Mz
F
M


D-222
42°00'
Yalama
Khachmaz
Guba
Devechi
Siazan
41°00'
Altiagach
Shemakha
Sumgait
Baku
Dan ulduzu
Ashrafi
Sangachal
Guneshli
Garabagh
Chirag 2
Oguz
Azeri
40°00'
Ali-Bayramly
Kapez
Absheron
Shahdeniz
Salyan
Nakhchivan
Neftchala
Zafar-Mashal
Inam
Alov
39°00'
Talish deniz
Lenkoran
Lenkoran-deniz
Astara

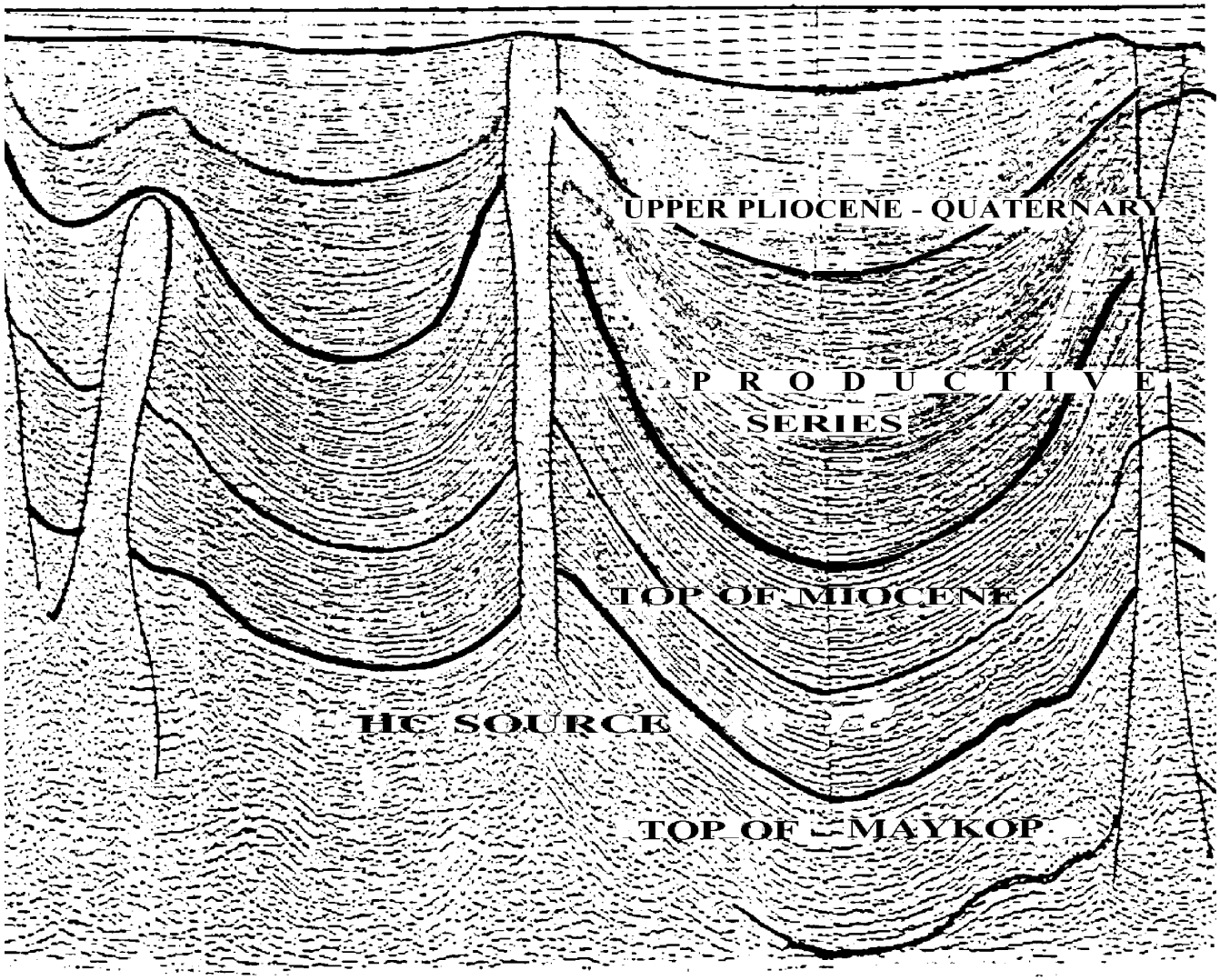


HYDROCARBON SOURCES in the SOUTH CASPIN BASIN

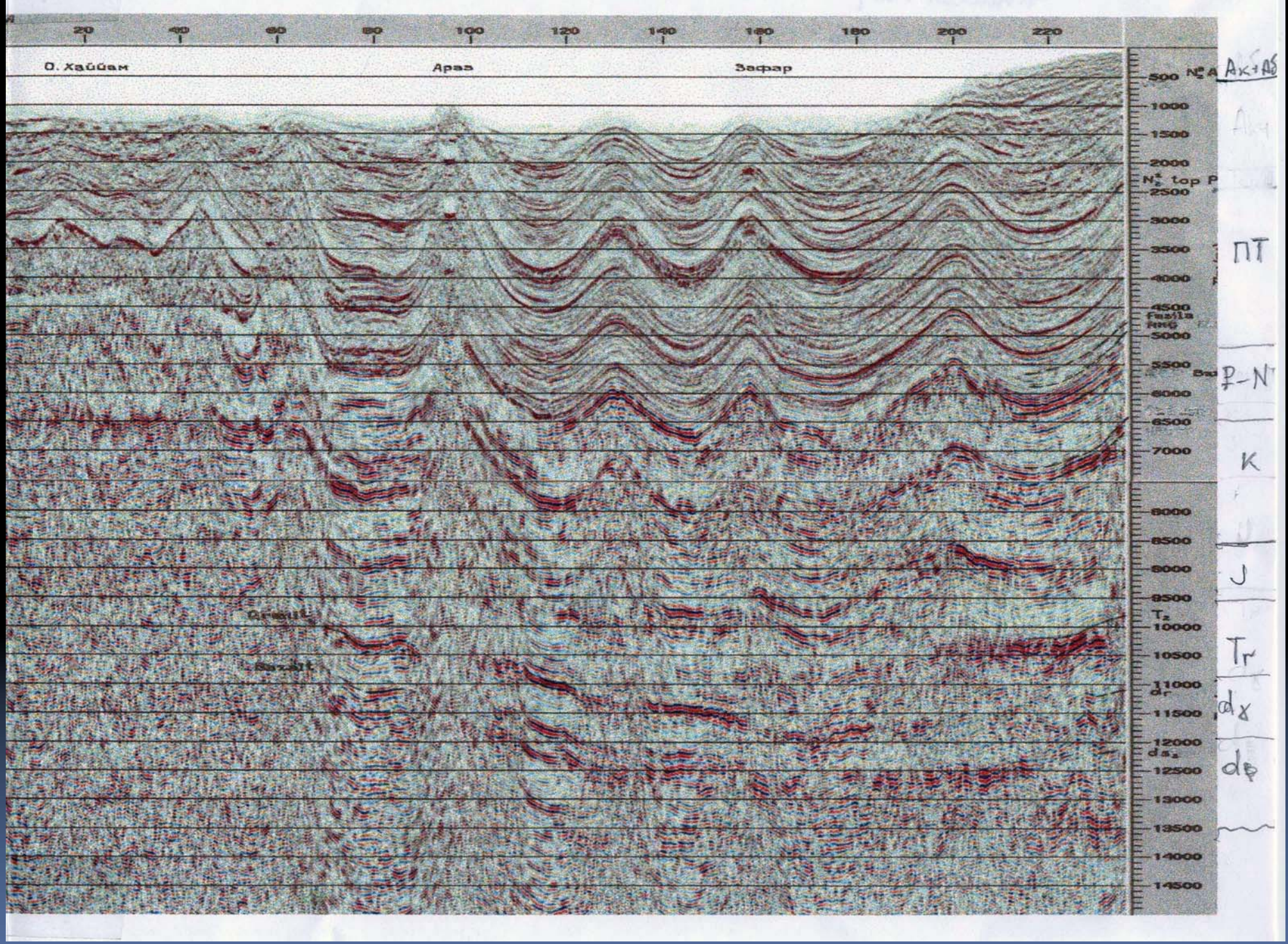




Channels of HC fluids migration

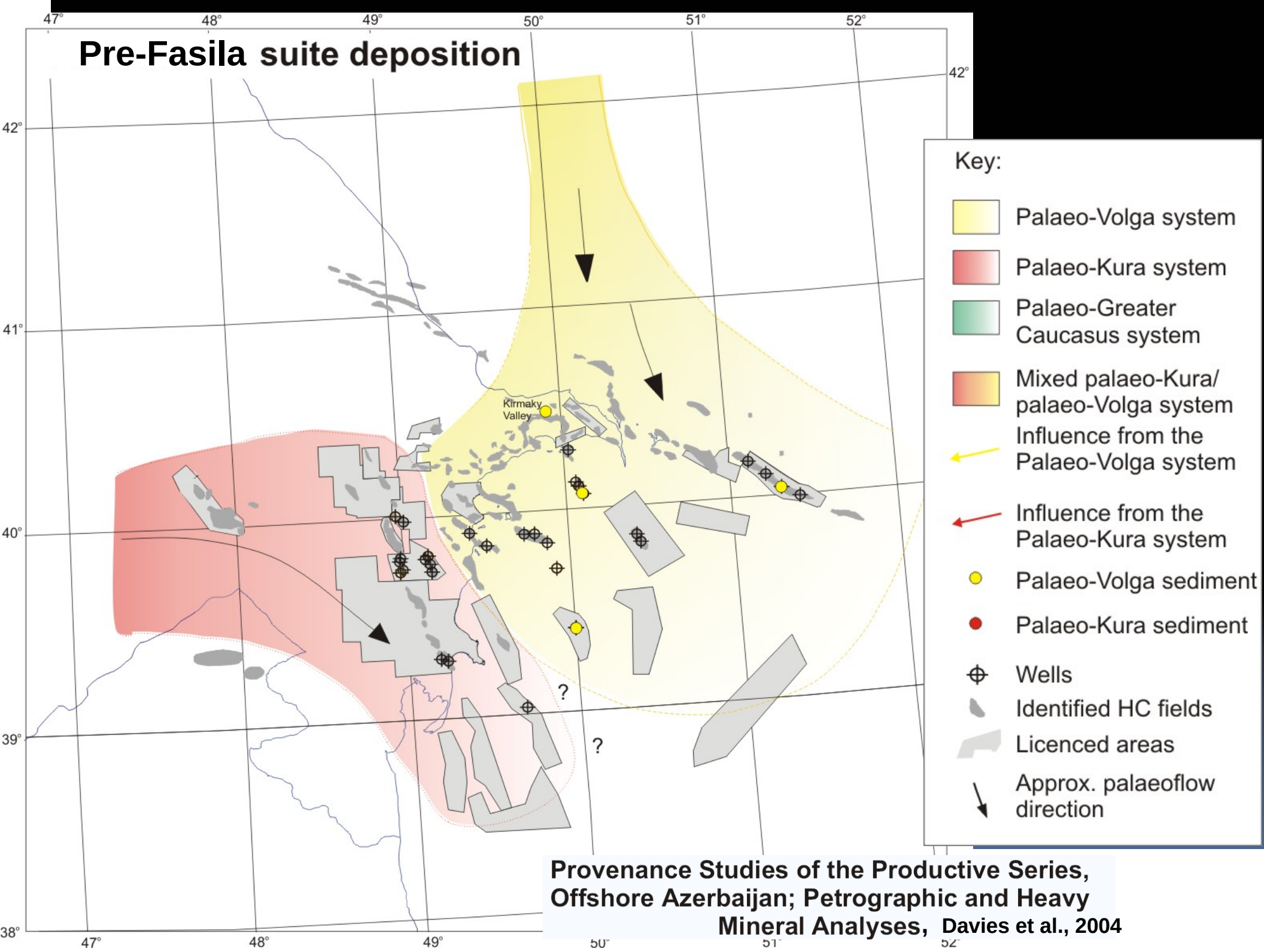


The vertical zonation of HC generation in deep water zone of the South Caspian



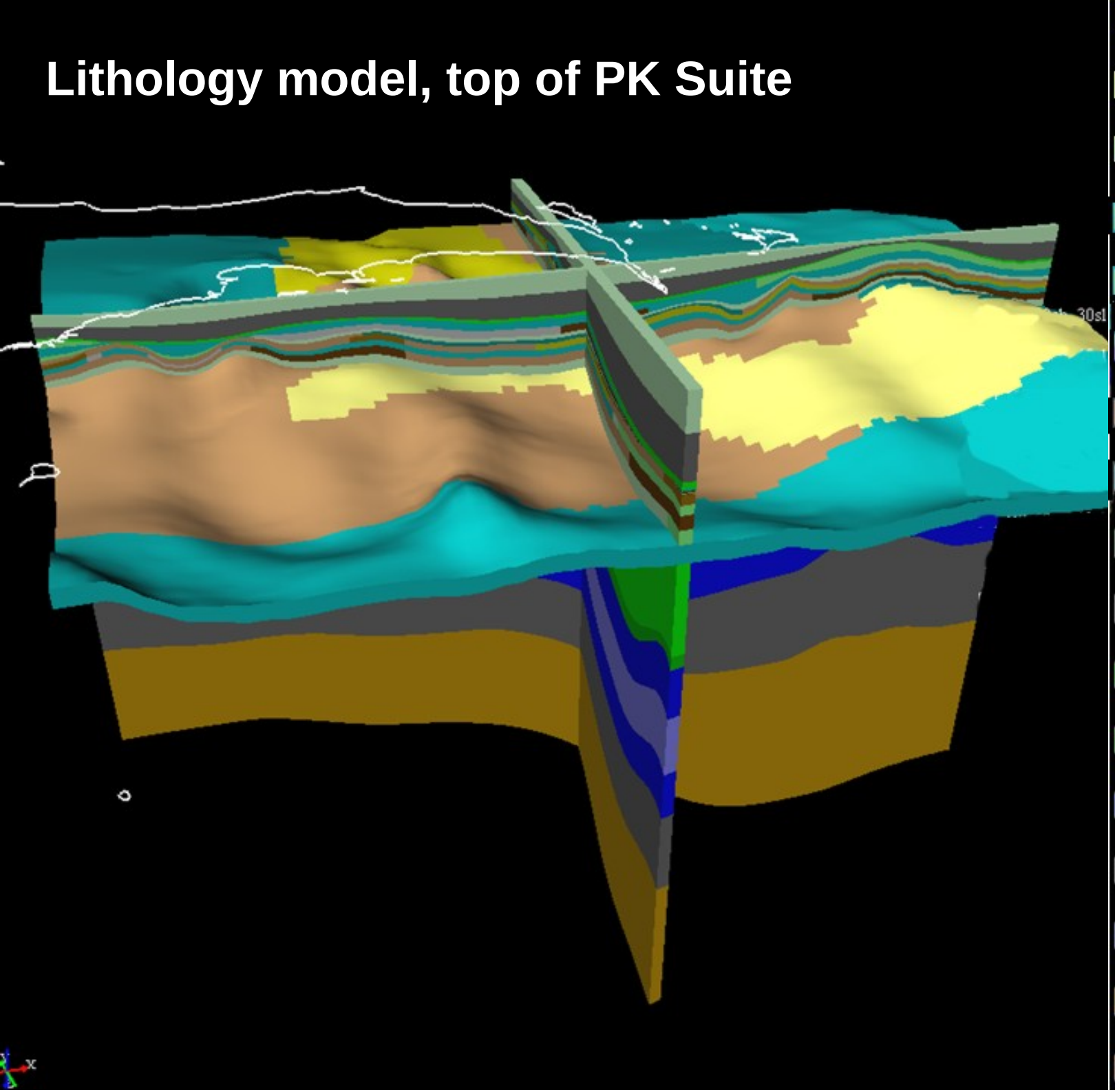
A. Gadjiyev, 2008

Do we have reservoirs at the big depth?

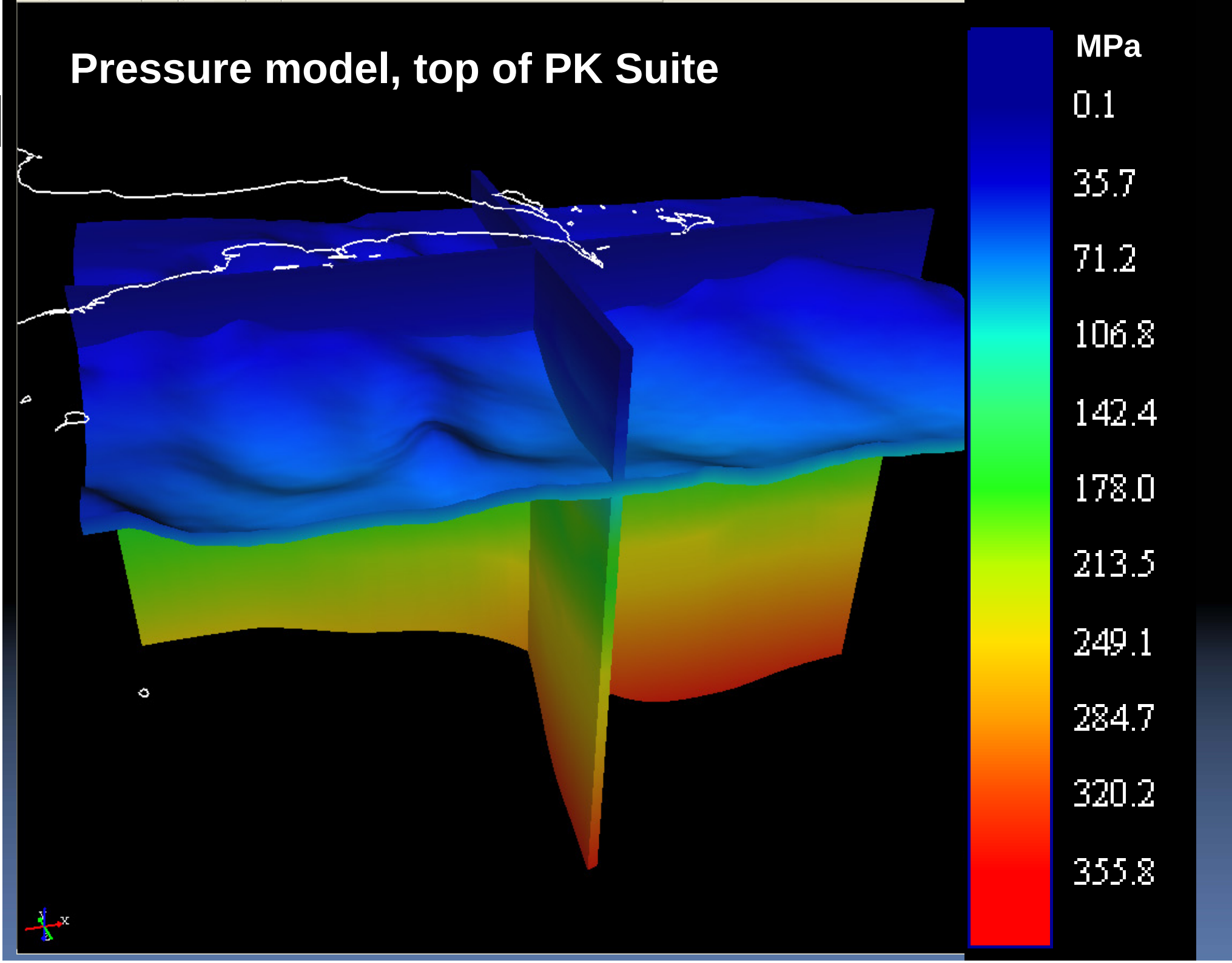


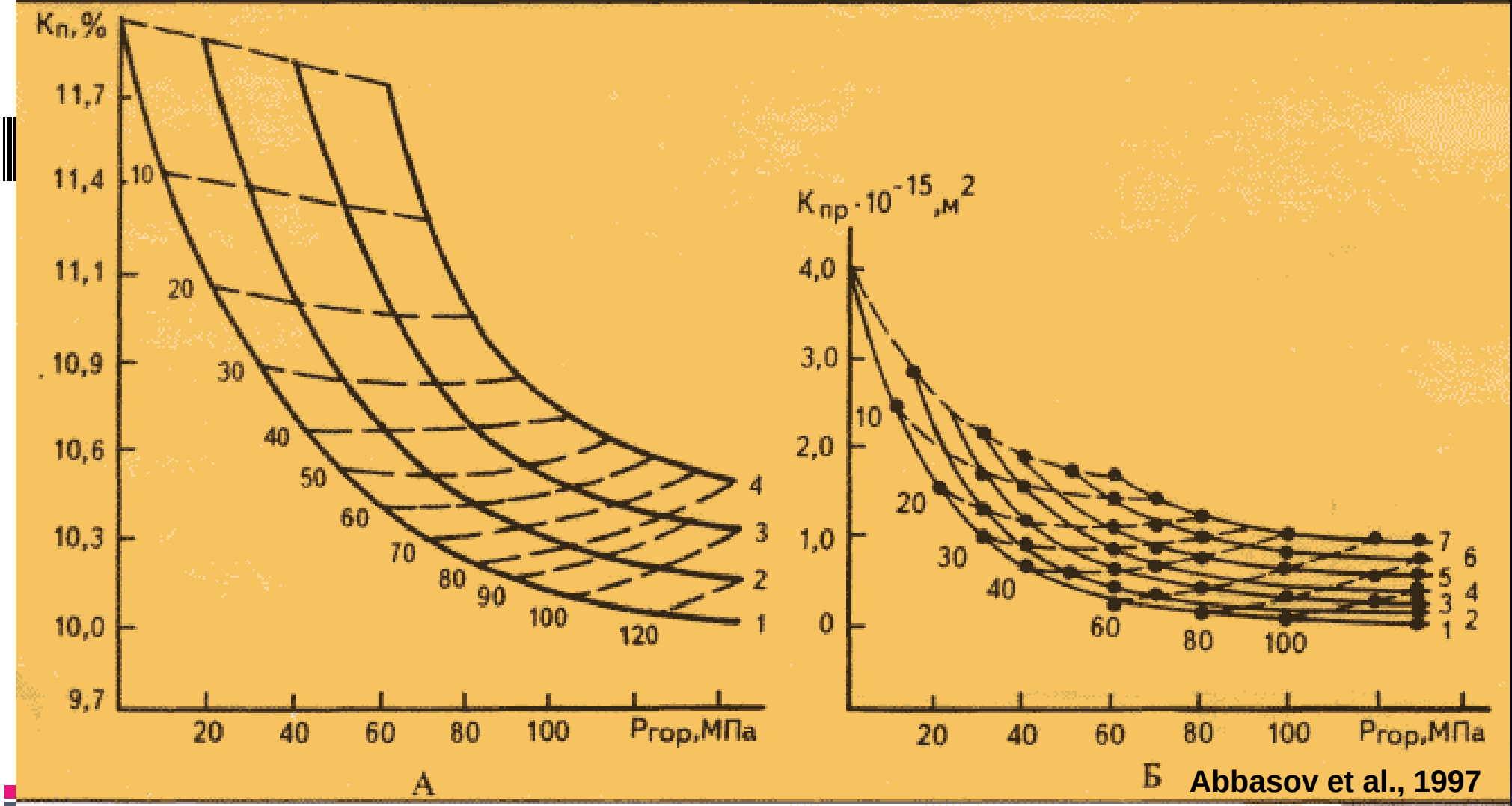
Provenance Studies of the Productive Series, Offshore Azerbaijan; Petrographic and Heavy Mineral Analyses, Davies et al., 2004

Lithology model, top of PK Suite



Pressure model, top of PK Suite





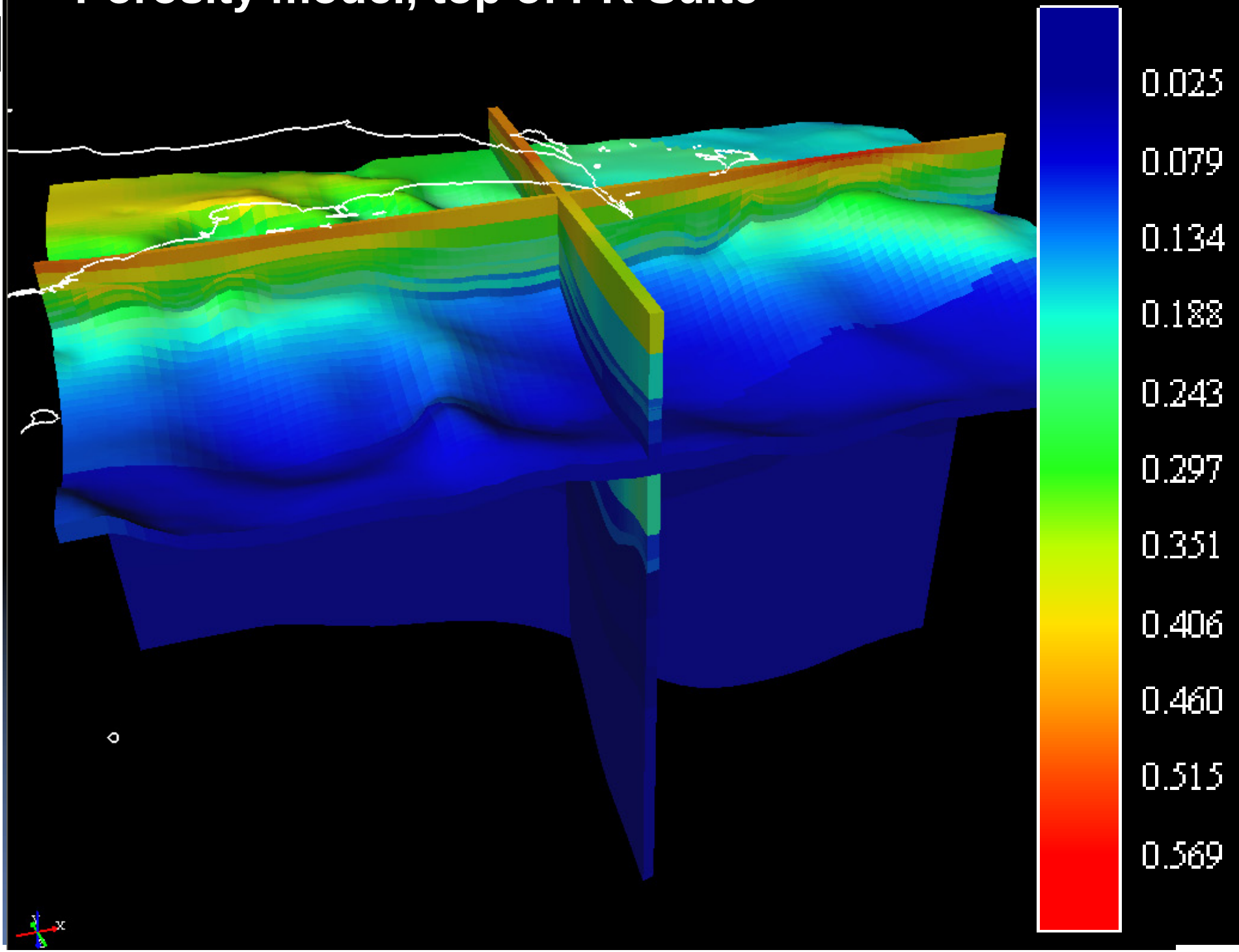
Abbasov et al., 1997

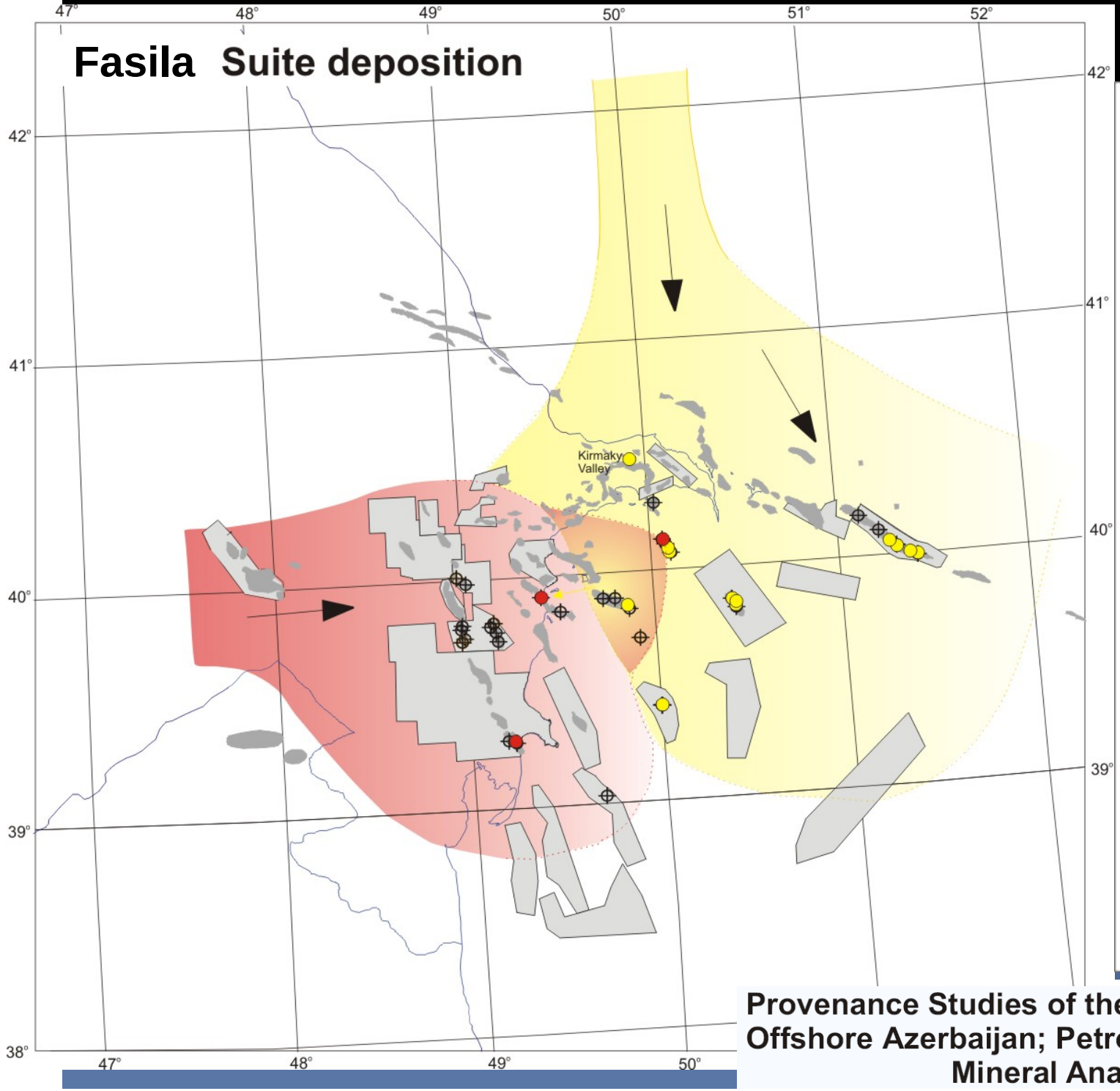
Experimental data on the porosity, permeability changes depending on the lithostatic pressure (pore pressure is constant)

A – porosity coef. , pore pressure is 0,1, 20; 40 и 60 MPa from curve 1-1 to 4-4 correspondingly;

B – permeability coef., pore pressure is 0,1; 10; 20; 30; 40; 50 и 60 MPa

Porosity model, top of PK Suite



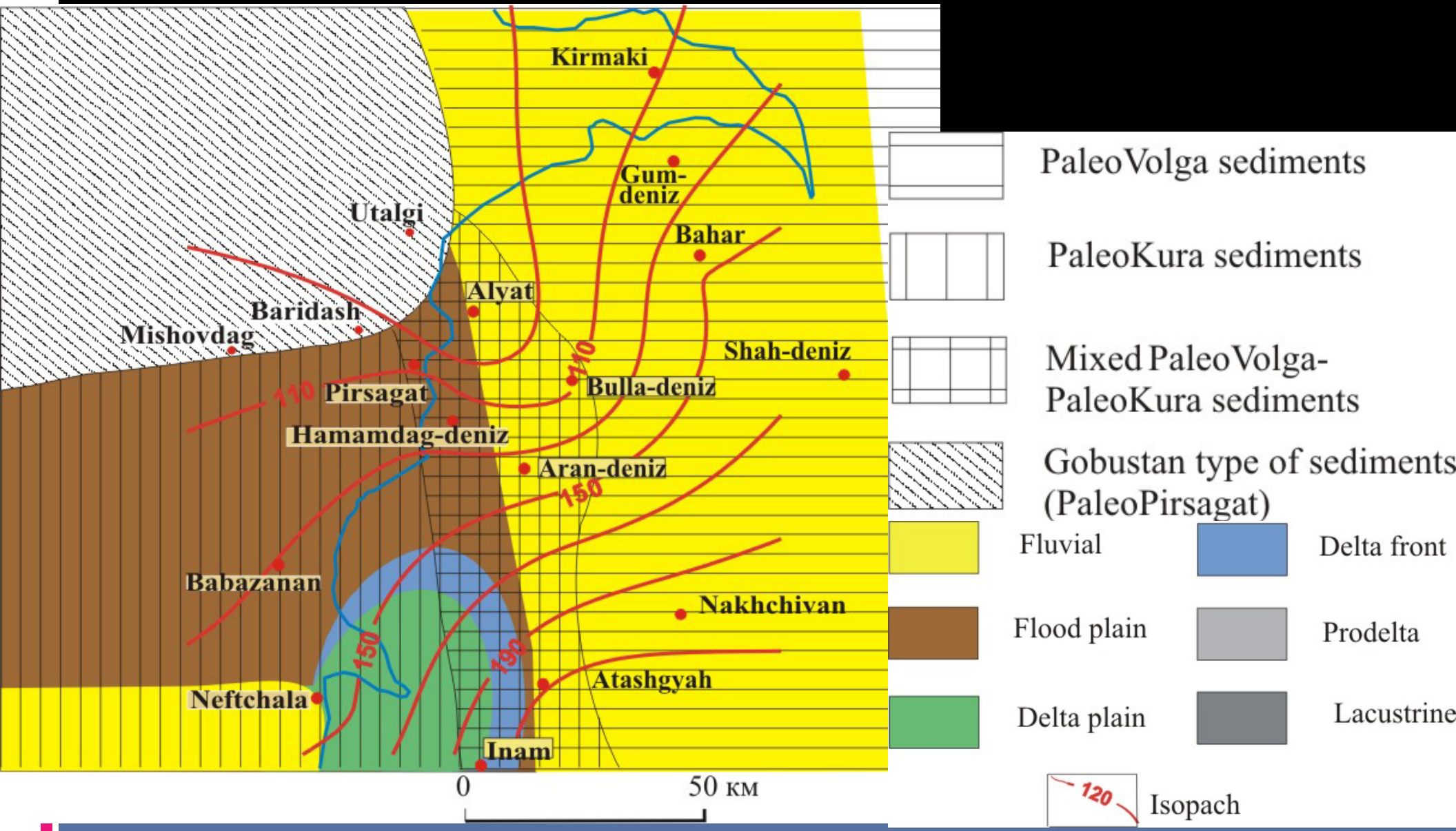


Key:

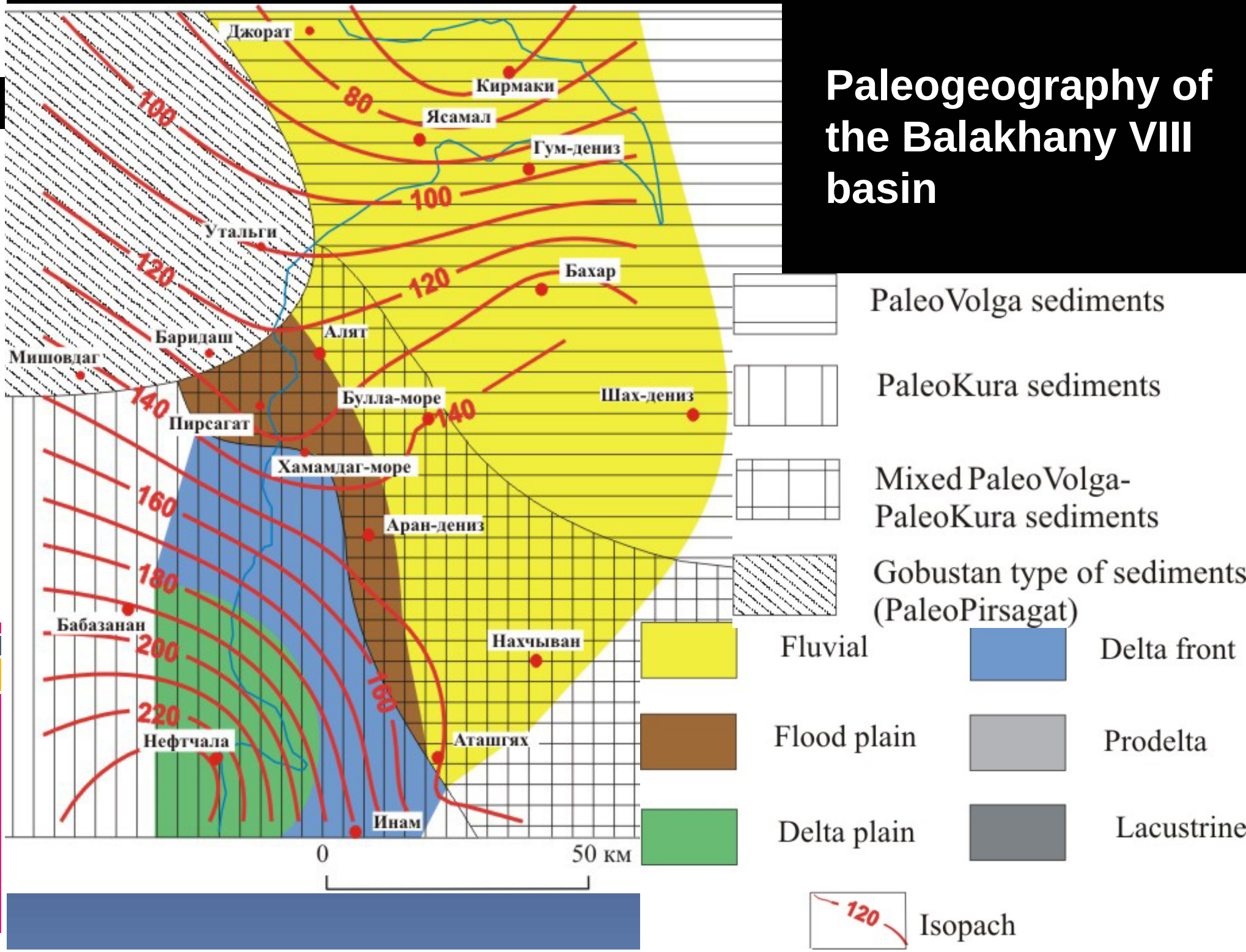
- Palaeo-Volga system
- Palaeo-Kura system
- Palaeo-Greater Caucasus system
- Mixed palaeo-Kura/ palaeo-Volga system
- Influence from the Palaeo-Volga system
- Influence from the Palaeo-Kura system
- Palaeo-Volga sediment
- Palaeo-Kura sediment
- Wells
- Identified HC fields
- Licenced areas
- Approx. palaeoflow direction

Provenance Studies of the Productive Series, Offshore Azerbaijan; Petrographic and Heavy Mineral Analyses, Davies et al., 2004

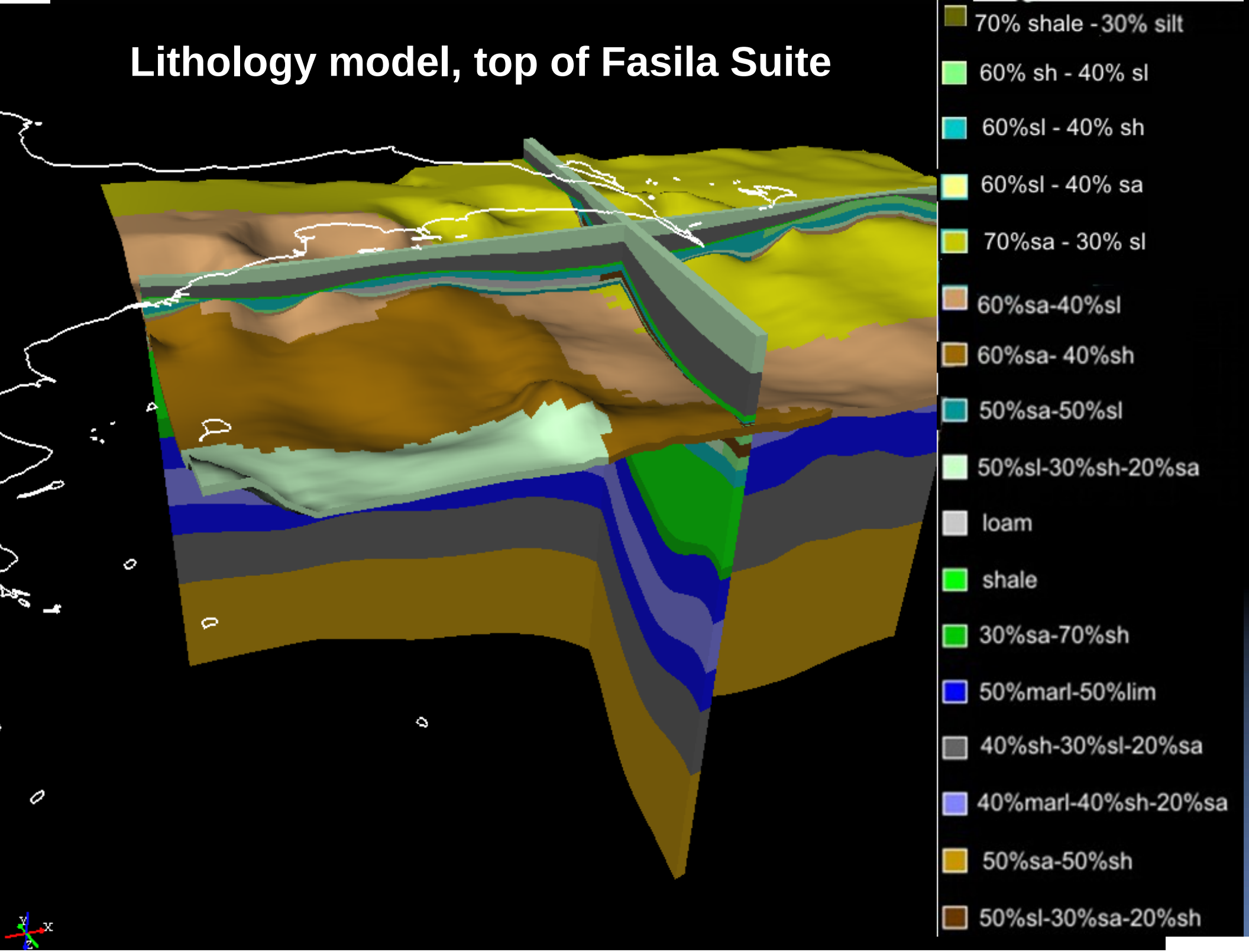
Paleogeography of the Fasila Suite basin based on the sandstones mineralogical composition, sedimentological data and log interpretation

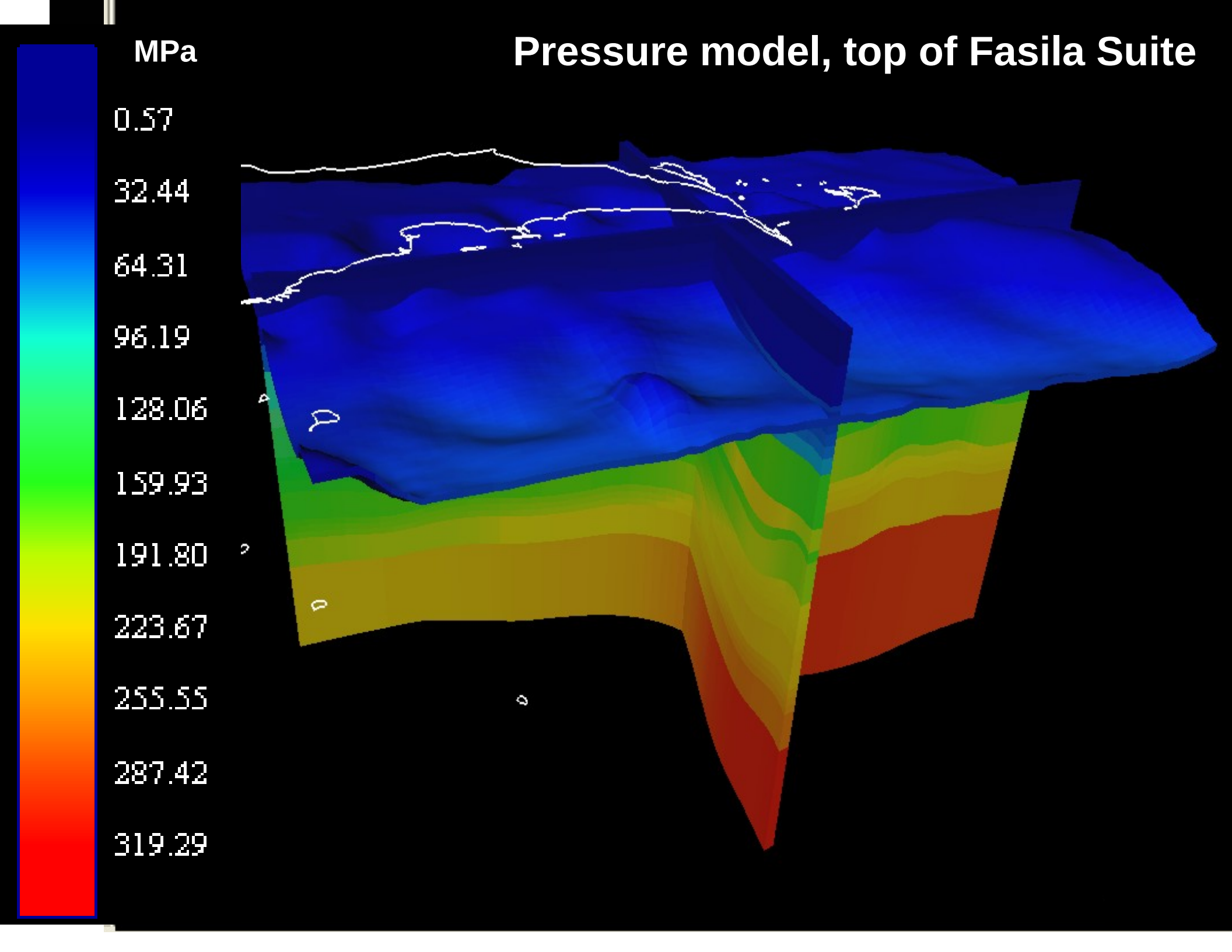


Paleogeography of the Balakhany VIII basin

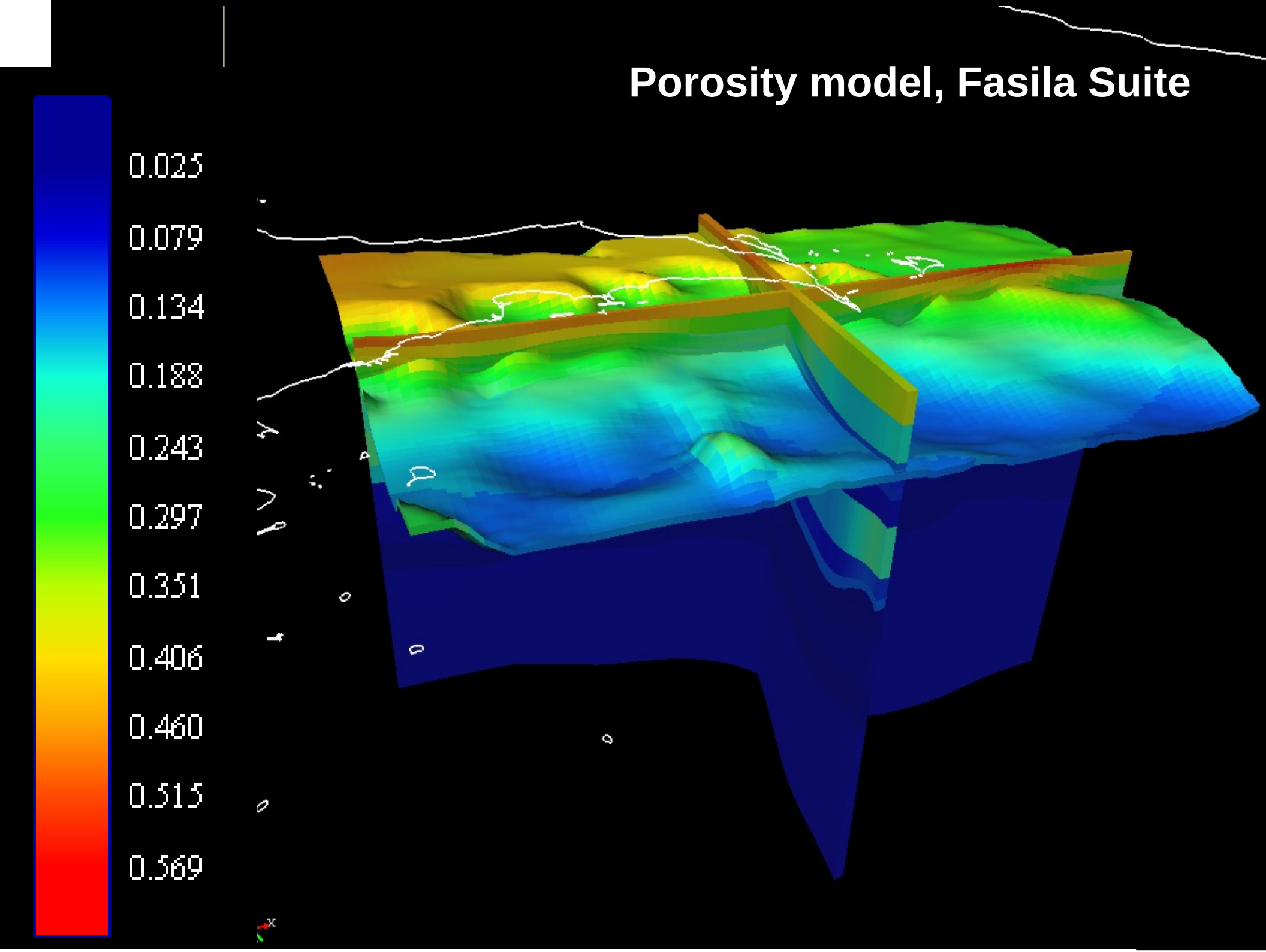


Lithology model, top of Fasila Suite

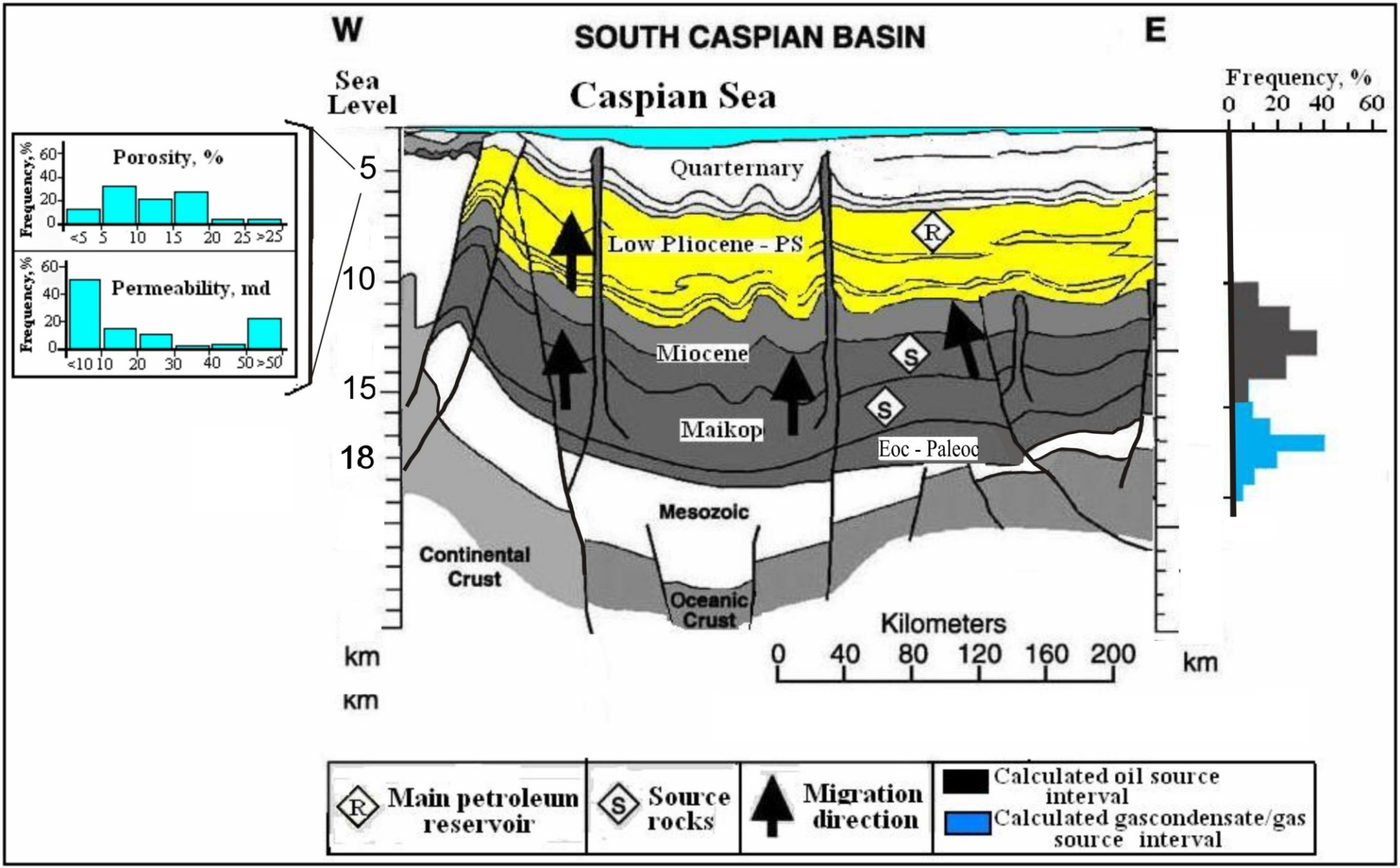



Pressure model, top of Fasila Suite
MPa
0.57
32.44
64.31
96.19
128.06
159.93
191.80
223.67
255.55
287.42
319.29

Porosity model, Fasila Suite



Model of Petroleum Systems in the South Caspian basin



Modified after Narimanov, Abrams, 1996

POSSIBLE HC ACCUMULATIONS

0

500

1000

1500

2000

2500

3000

3500

4000

4500

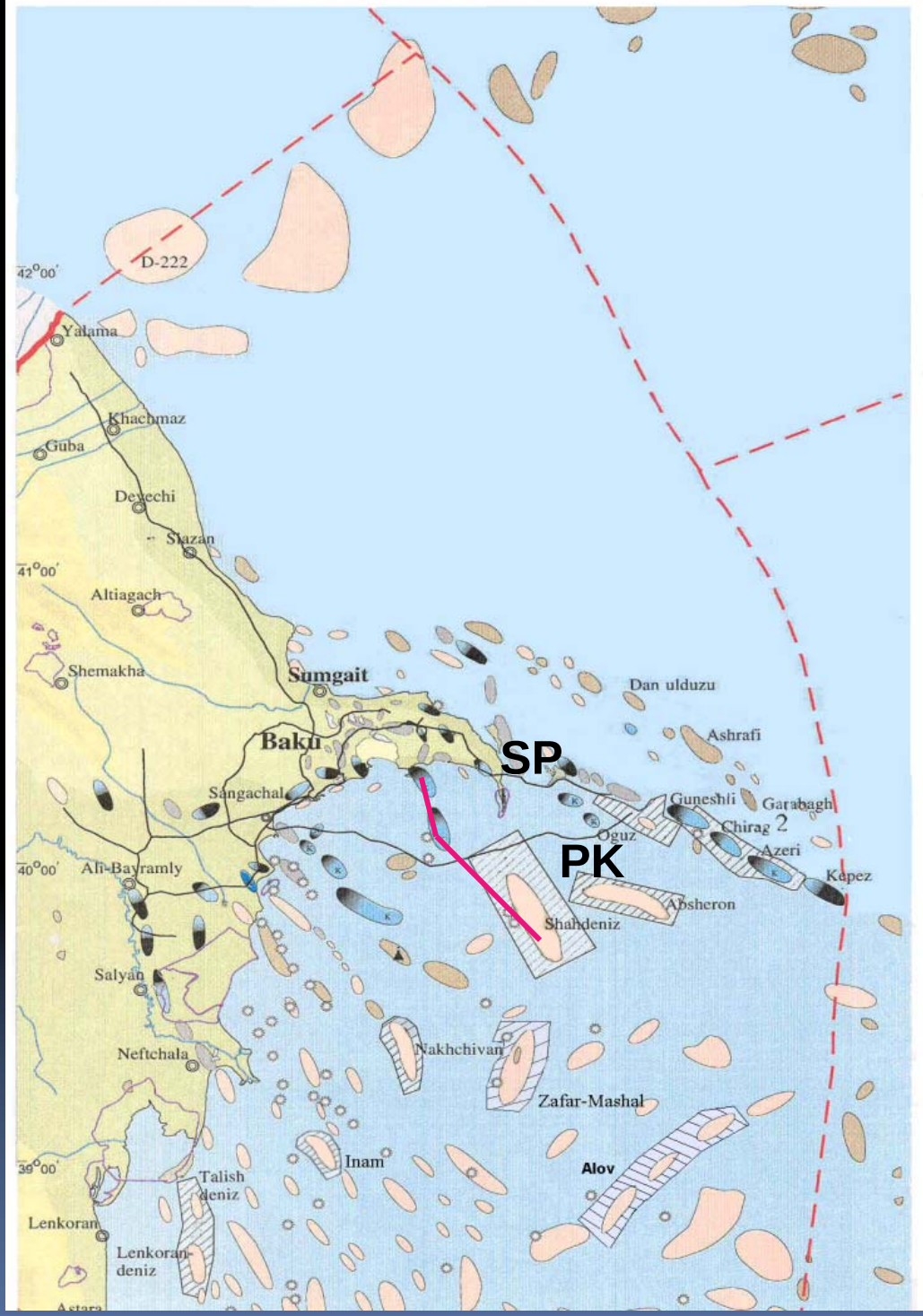
5000

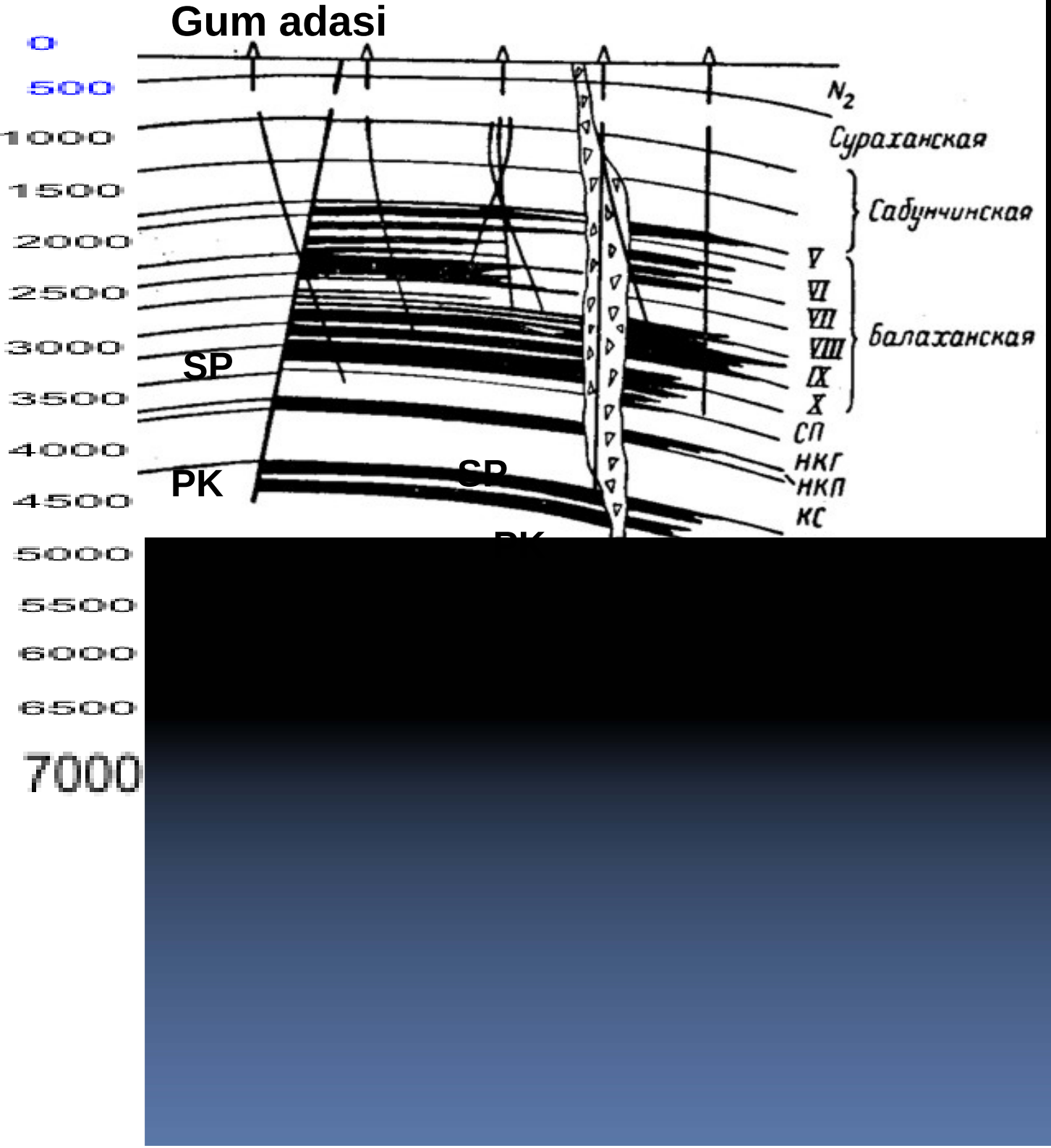
5500

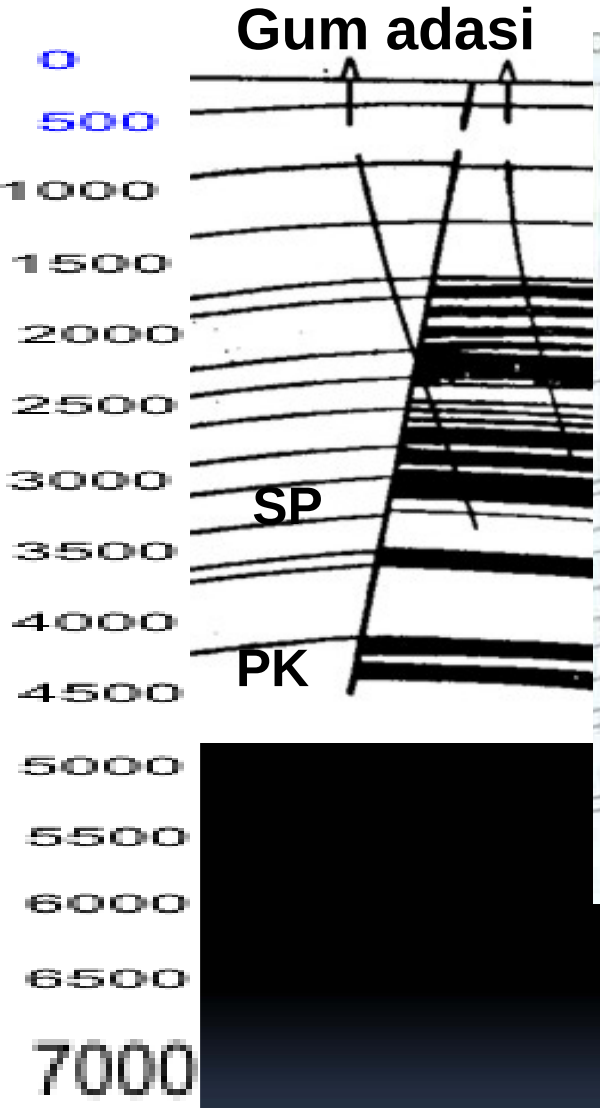
6000

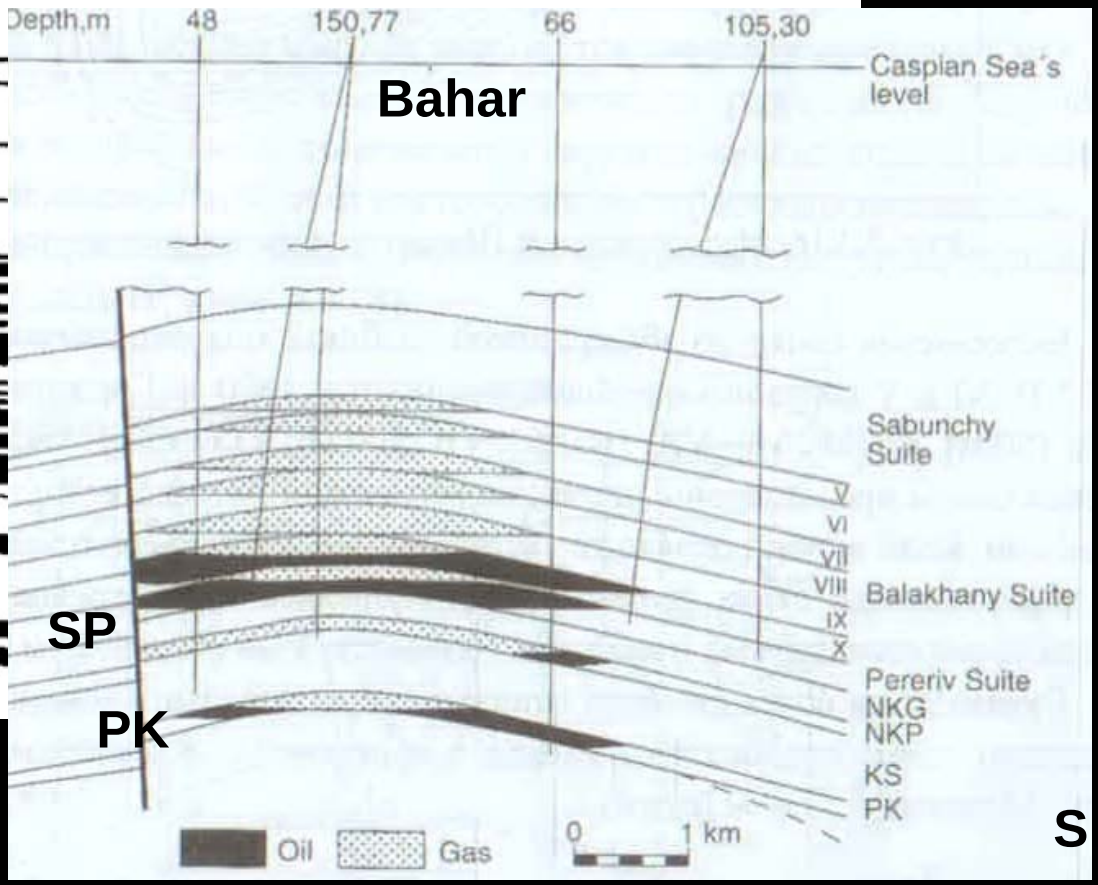
6500

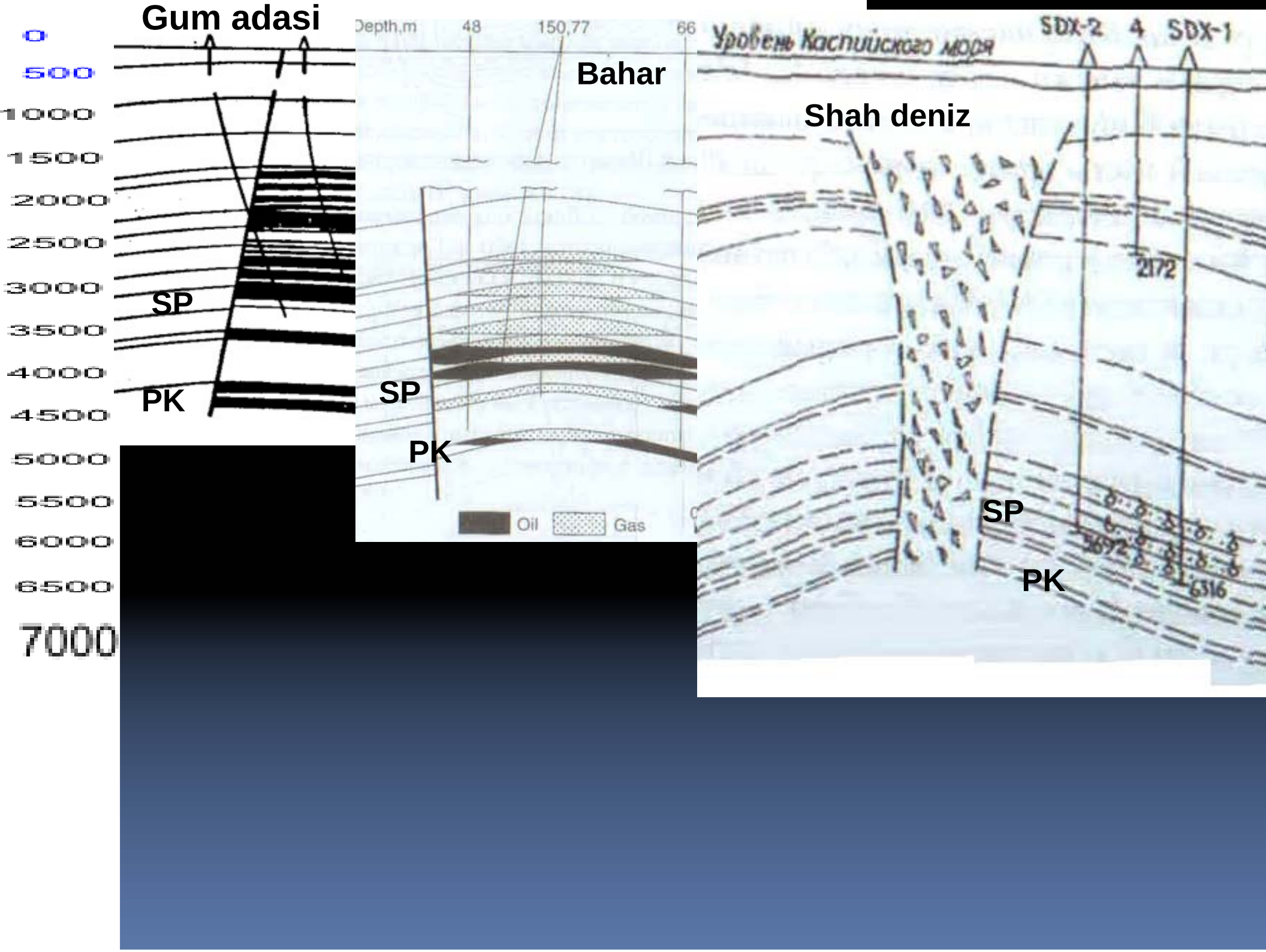
7000

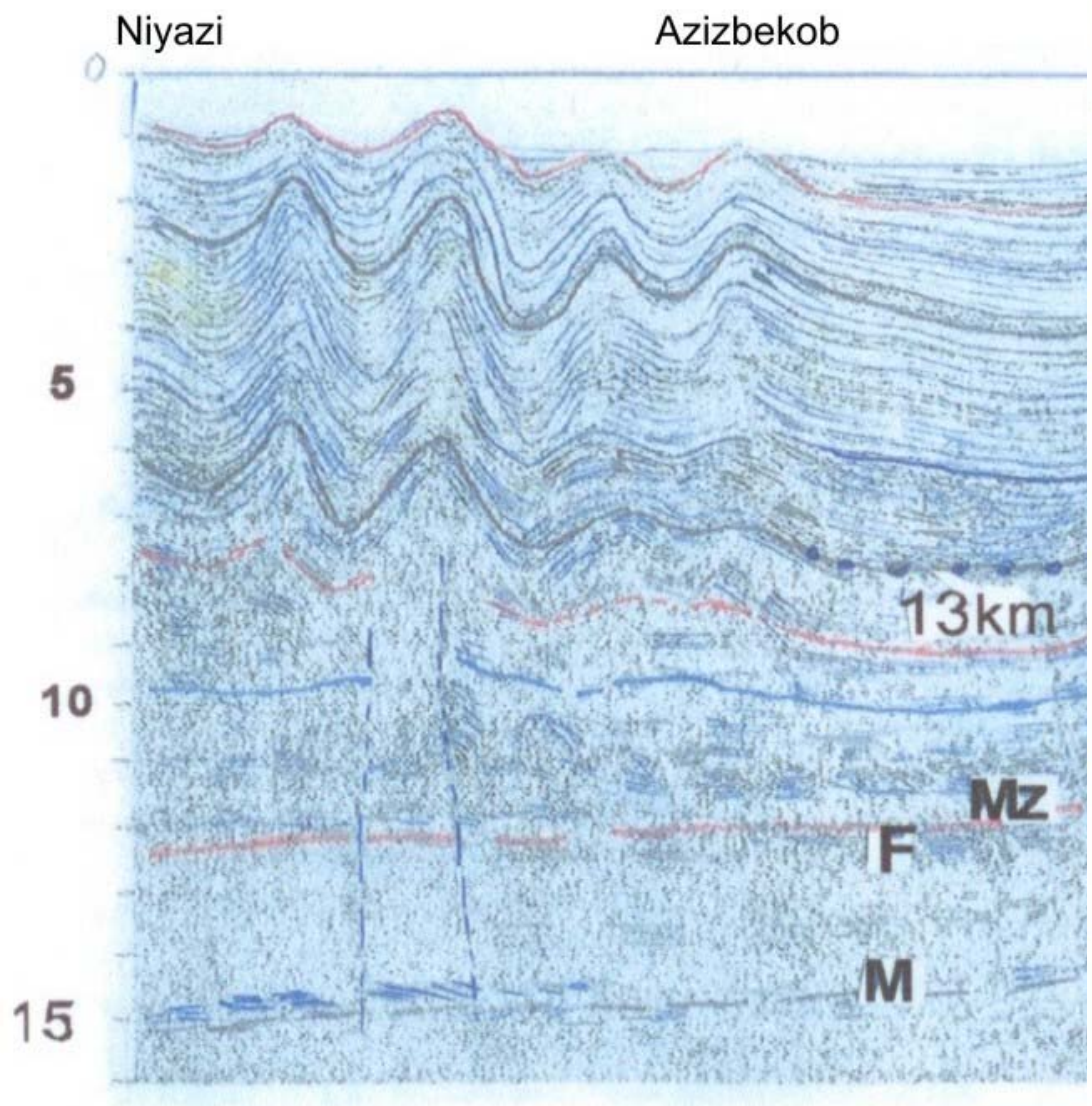


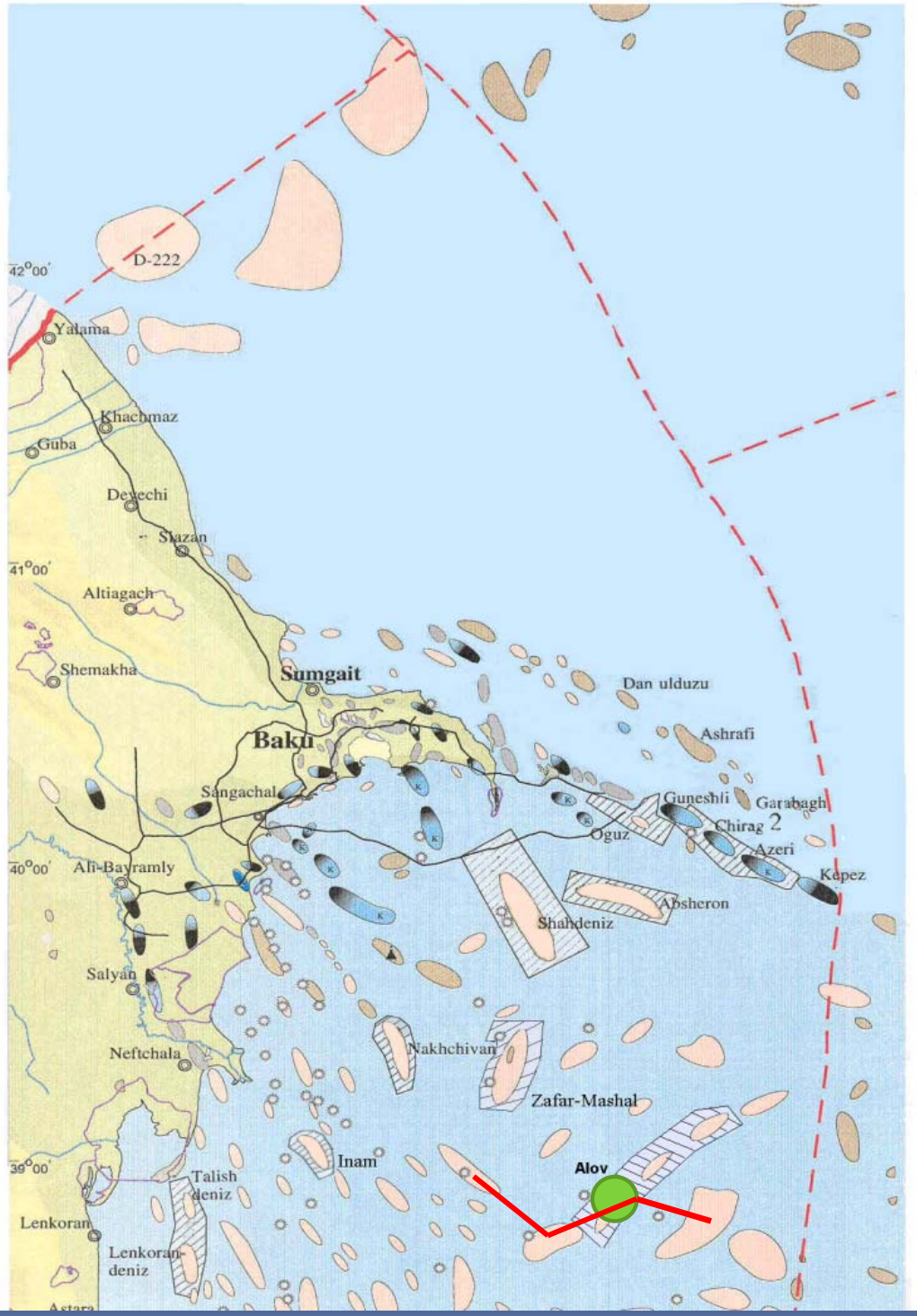

Gum adasi
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
SP
PK
SP
PK
N2
Сураханская
Сабунчинская
V
VI
VII
VIII
IX
X
балаханская
СП
НКГ
НКП
КС


Gum adasi
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
SP
PK

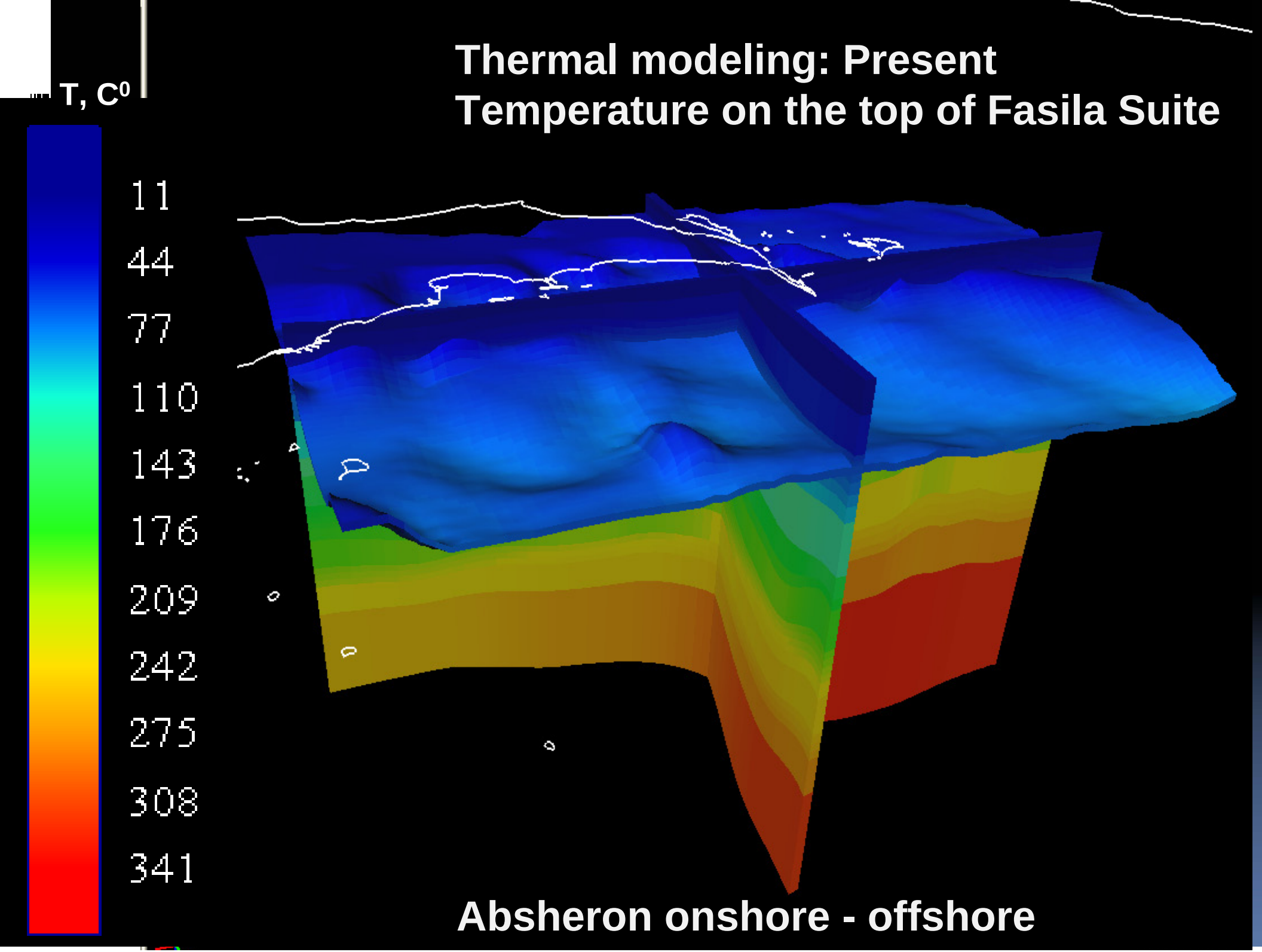

Depth,m
48
150,77
66
105,30
Bahar
Caspian Sea´s level
Sabunchy Suite
V
VI
VII
VIII
IX
X
Balakhany Suite
Pereriv Suite
NKG
NKP
KS
PK
SP
PK
Oil
Gas
0
1 km
S

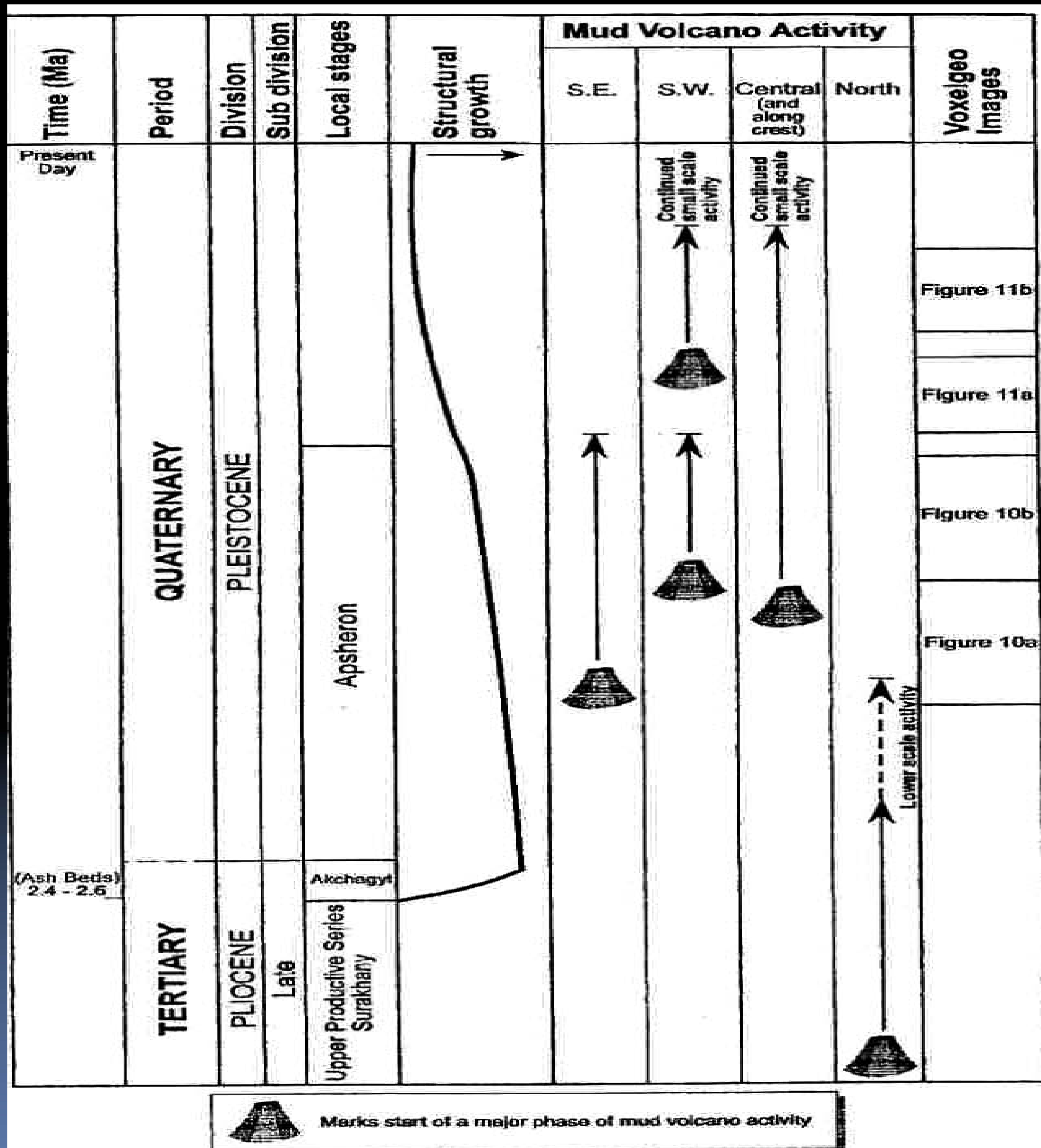

Gum adasi
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
SP
PK
Depth,m
48
150,77
66
Bahar
SP
PK
Oil
Gas
Уровень Каспийского моря
SDX-2
4
SDX-1
Shah deniz
2172
SP
PK
3672
6316


Niyazi
Azizbekob
0
5
10
15
13km
Mz
F
M

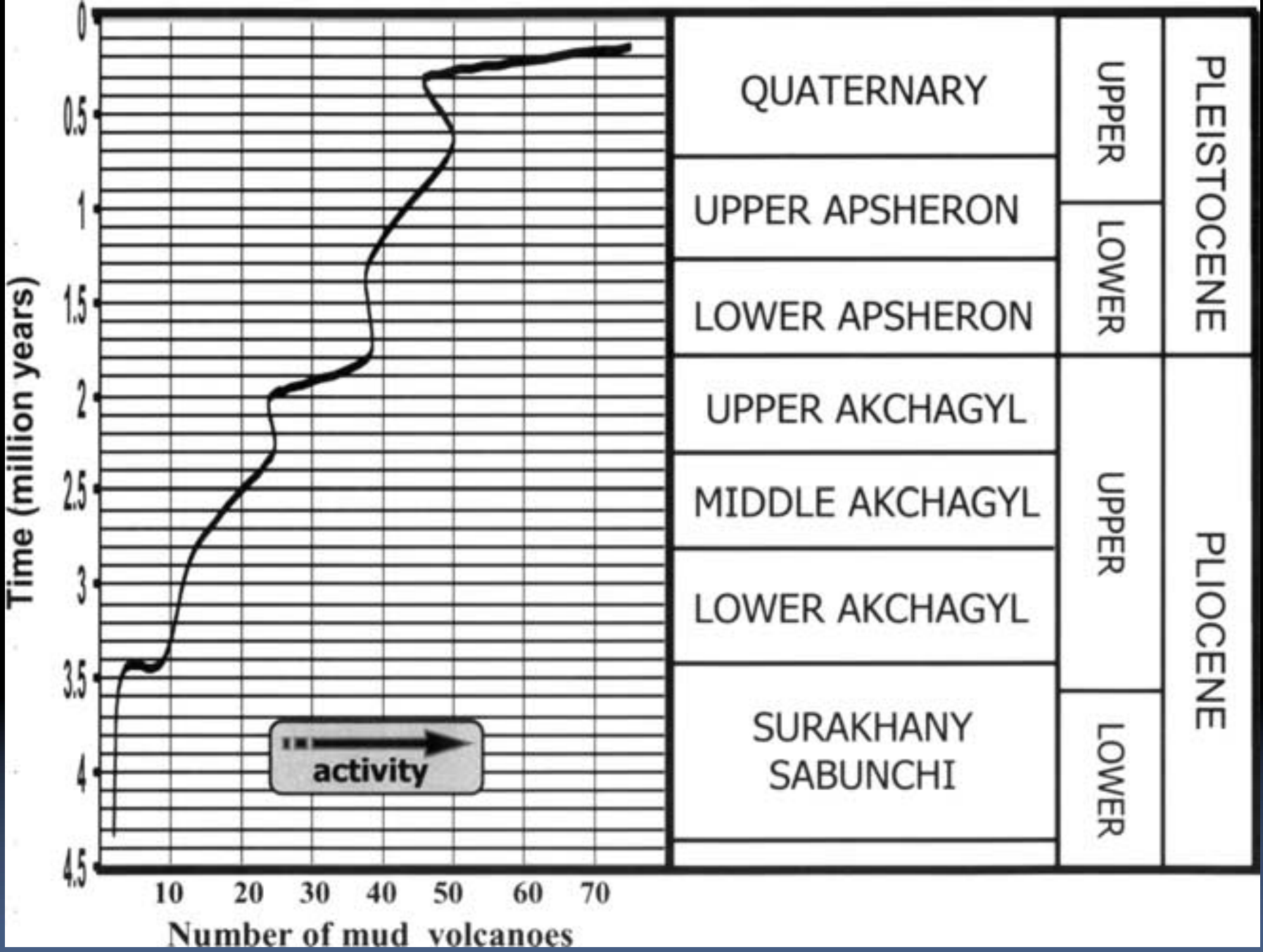

D-222
42°00'
Yalama
Khachmaz
Guba
Devechi
Siazan
41°00'
Altiagach
Shemakha
Sumgait
Baku
Dan ulduzu
Ashrafi
Sangachal
Guneshli
Garabagh
Chirag 2
Azeri
Oguz
Kapez
40°00'
Ali-Bayramly
Absheron
Shahdeniz
Salyan
Nakhchivan
Neftchala
Zafar-Mashal
Inam
Alov
39°00'
Talish deniz
Lenkoran
Lenkoran-deniz
Astara

Thermal modeling: Present
Temperature on the top of Fasila Suite





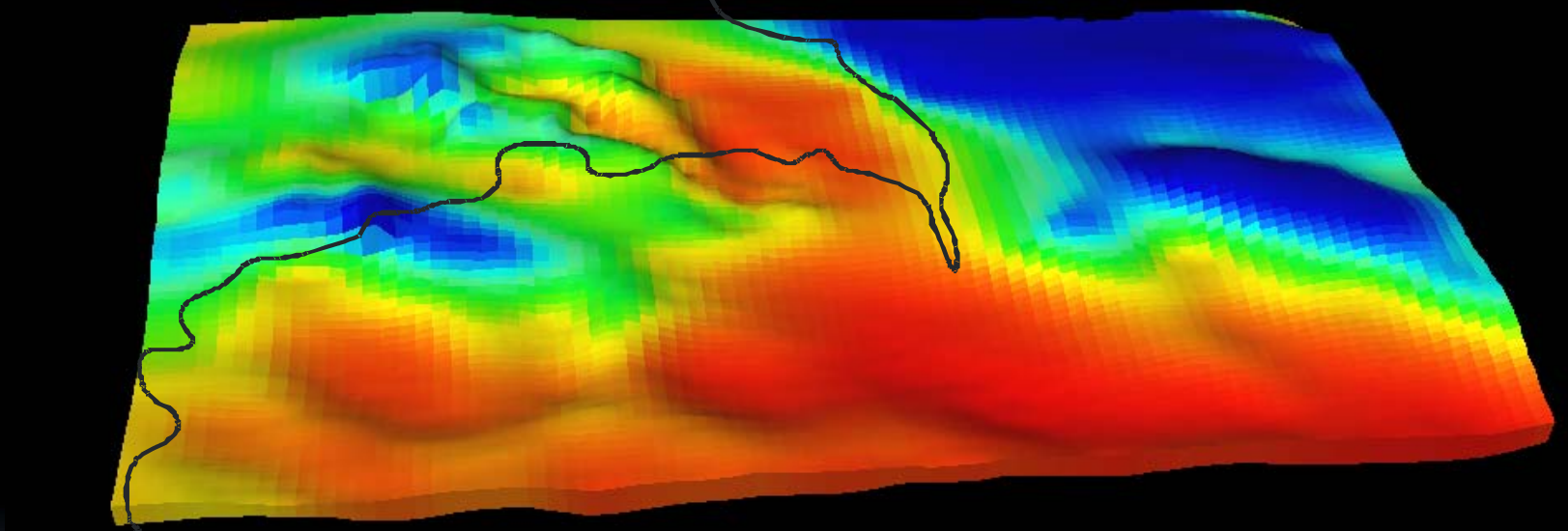
S.R. Fowler, et al., 2000

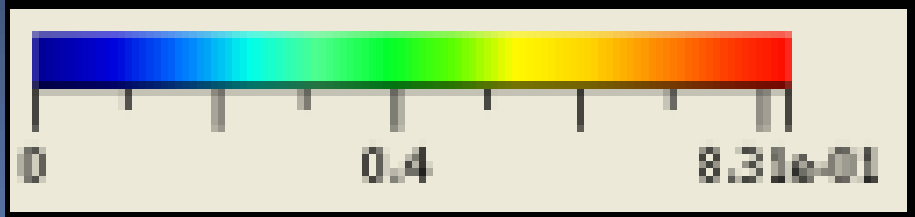


Cumulative chart of mud volcano activity from Lower Pliocene to Quaternary

Yusifov, Rabinowitz, 2004

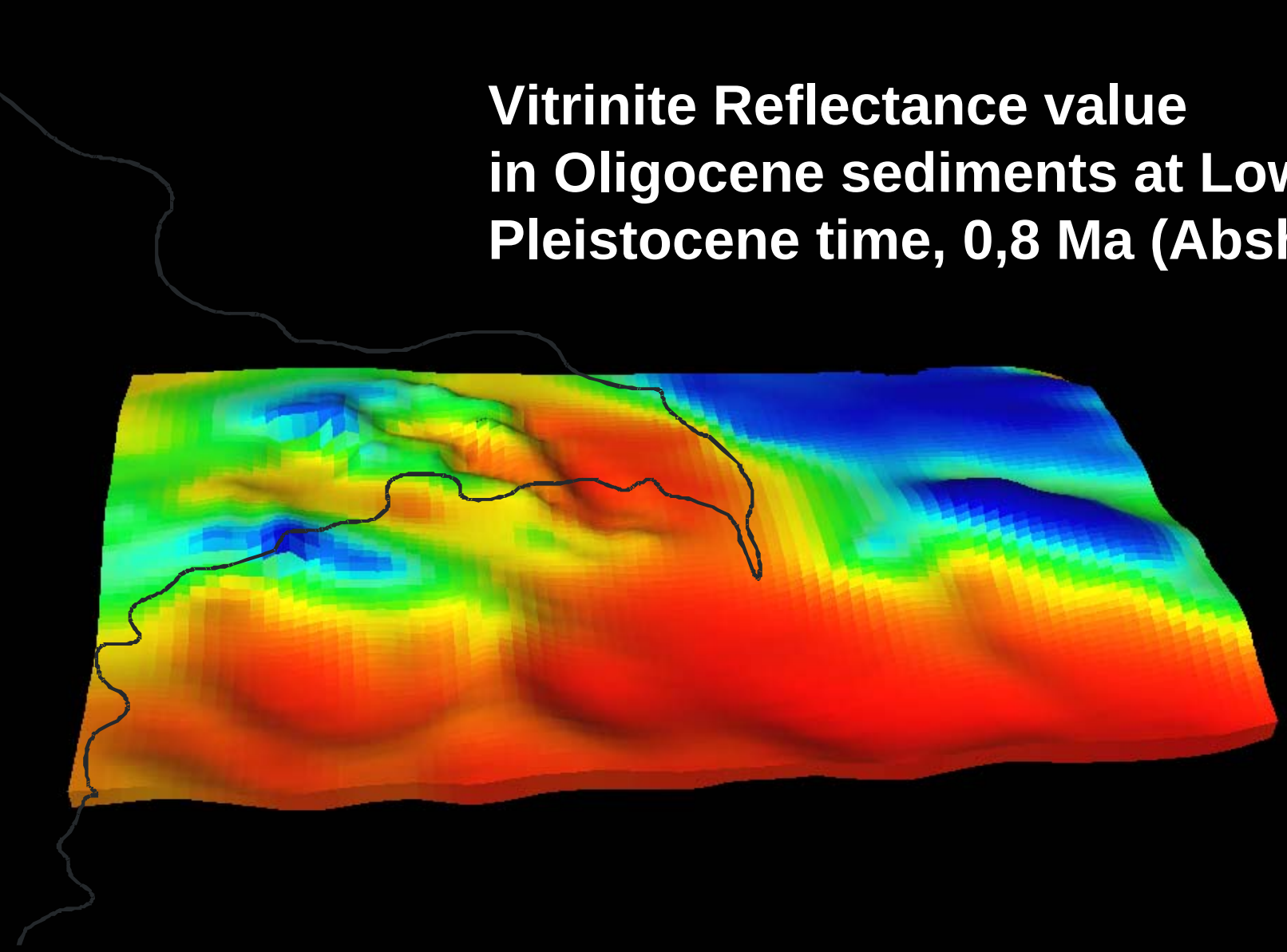
Vitrinite Reflectance value in Oligocene sediments at Upper Pliocene time, 1.8 Ma Akchagyl

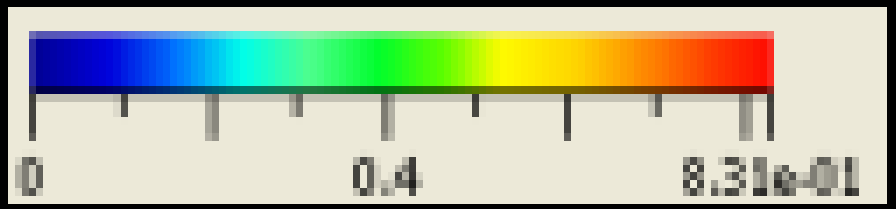




Absheron onshore-offshore

Vitrinite Reflectance value in Oligocene sediments at Lower Pleistocene time, 0,8 Ma (Absheron)





Absheron onshore-offshore

Geochemical survey was carried out within the North, Middle and South Caspian

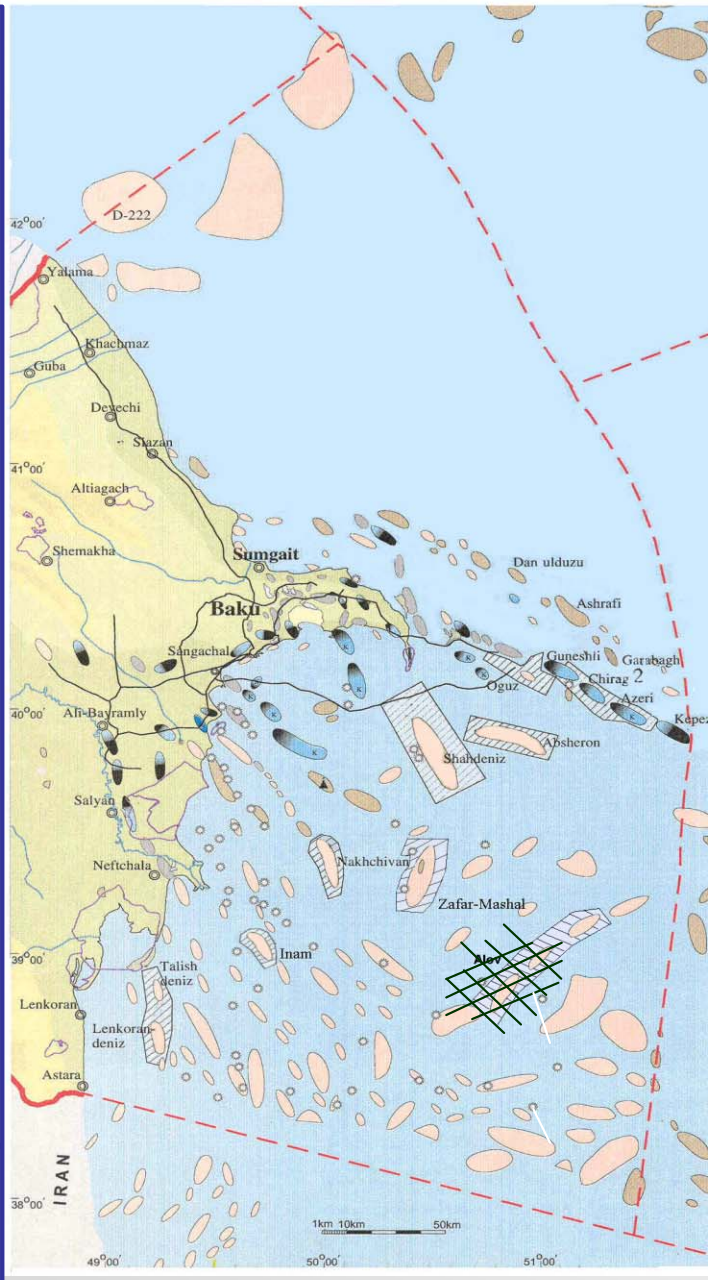
Bitumem coef

N_{NH4}^{+} / J^{-}

Ni

V

HC gases



Thank you for attention