

Understanding of the Petroleum System(s) of the Western Black Sea: Insights from 3-D Basin Modeling*

Radu Olaru-Florea¹, Cristina Ungureanu², Thomas Martin Rainer³, Valentin Turi², Adriana Raileanu², Veronica Borosi², Csaba Krezsek², and Gabor Tari³

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¹OMV PETROM, Bucharest, Romania (radu.olaru@petrom.com)

²OMV PETROM, Bucharest, Romania

³OMV, Vienna, Austria

Abstract

Several hydrocarbon accumulations have been found in the Western Black Sea Basin (WBSB) to date, proving the presence of both thermogenic and biogenic petroleum systems. Whereas most accumulations are located on the present day shelf the recent Domino-1 gas discovery was drilled in the deep-water of the Romanian Black Sea. The presence of oleanane biomarker in all oil fields on the Romanian shelf proves the existence of a Tertiary thermogenic petroleum system likely sourced by the Latest Eocene(?) to Miocene black shales (Maykop succession). In addition, older source rocks may be locally present in different parts of the basin. The relative contribution of these different source rock intervals to the petroleum system and the hydrocarbon migration itself in time and space are poorly understood. In this study, we performed 3D basin and petroleum system modeling to evaluate the charge model of the WBSB focusing on the Maykop section. The model is built on the regional-scale interpretation of recently acquired long-offset 2D reflection seismic data sets and is calibrated with proprietary and publicly available well, geochemical, and temperature data. The sensitivity of the thermal models on source maturity has been tested. The basin models considered fit between two end member scenarios (a “hot” and a “cold” model). Whereas the “hot” model provides good results in the shallow water areas, the “cold” model is considered more valid for the deep-water areas of the WBSB. Hydrocarbon expulsion maps were calculated for both scenarios at various stratigraphic levels. In order to simulate the migration pathways, facies maps were constructed for key stratigraphic horizons based on well, seismic facies and outcrop data.

These basin-scale facies maps were used as the input to constrain the lateral (facies properties) and the vertical (i.e. seal) migration capacity of various sedimentary units driving the migration. In our models, the preferential migration directions and drainage areas were identified and potential hydrocarbon accumulations have been outlined. The results highlight the vastly underexplored exploration potential associated with the deep Maykopian section of the WBSB.

Reference Cited

Georgiev, G., 2012, Geology and Hydrocarbon Systems in the Western Black Sea: Turkish Journal of Earth Sciences, v. 21, p. 723-754.

Understanding of the Petroleum System(s) of the Western Black Sea: Insights from 3-D Basin Modeling

Istanbul, September 17th, 2014

Autors:

R. Olaru - Florea, C. Ungureanu,
T. Rainer, V. Turi, A. Raileanu, V.
Borosi, C. Krezsek, G. Tari



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Presenter's notes: Several hydrocarbon accumulations have been found in the Western Black Sea Basin (WBSB) to date, proving the presence of both thermogenic and biogenic petroleum systems.

Most of thermogenic accumulations are located on the present day shelf. The recent Domino (biogenic) gas discovery was drilled in the deep-water of the Romanian Black Sea.

The study underlying this presentation tried to identify the main petroleum systems of WBS. This is the joint effort of a exceptional team.

Agenda

➤ **Which are the Source Rocks in WBS ?**

Source rock characteristics based on oil and rock geochemistry data

➤ **What's Behind the Model?**

Input data and method

➤ **Cold or Warm ?**

Thermal regime

➤ **Oil and Gas, from Where to Where ?**

Source Rock maturity and hydrocarbon migration

➤ **Too Late or Too Early ?**

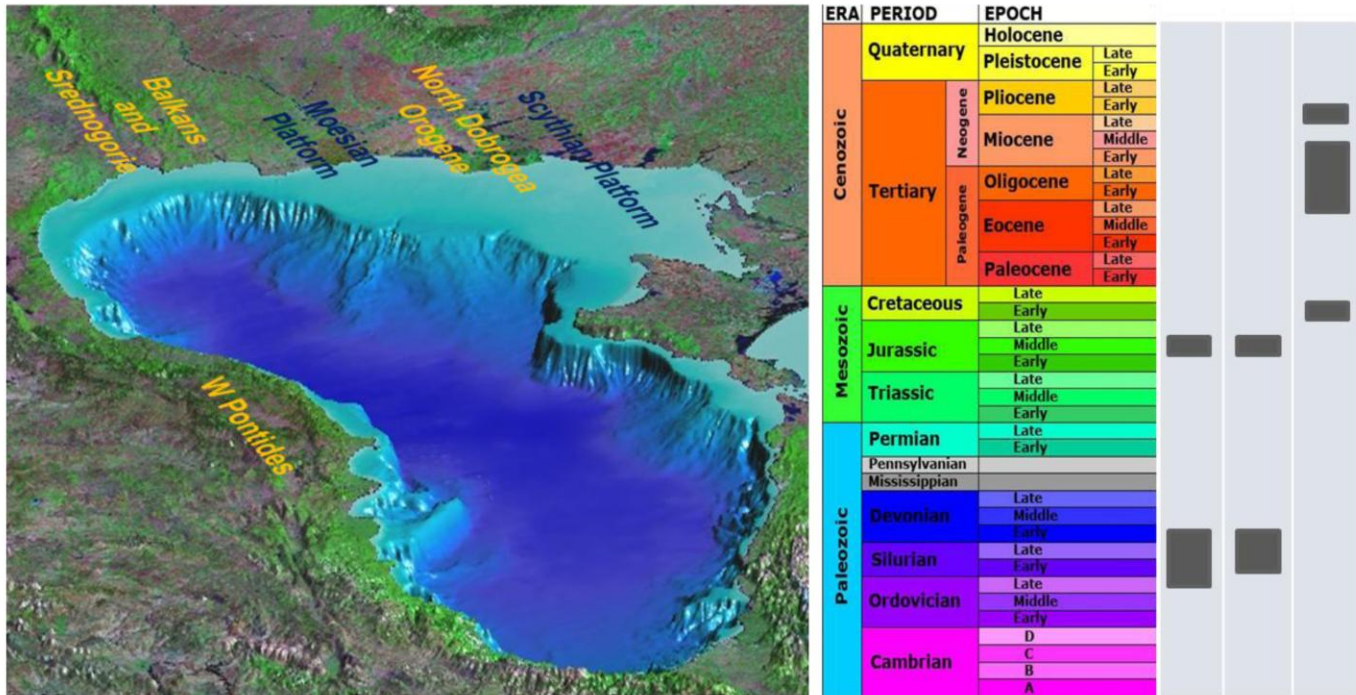
Timing of the HC Expulsion

➤ **Conclusions**

Presenter's notes: We have proposed in this presentation to:

- Identify the main Source Rocks and emphasize their characteristics based on oil and rock geochemistry data
- Present the main input data and the method used in modeling
- Define the proper thermal regime in space and time
- Present few results regarding the source rock maturity and the hydrocarbon migration
- Discuss the timing of the hydrocarbon expulsion
- And finally Conclusions

Which are the source rocks in WBS ?



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Presenter's notes: The source rock presence was related to the opening of the Black Sea. There are three main source rock categories:

- pre-tectonic, related to the basement units of WBS (East European, Scythian and Moesian platforms), represented by Paleozoic – “graptolites” black shale and mid Jurassic black shale.
 - sin-tectonic, represented by Lower Cretaceous argillites.
 - post-tectonic, represented by Upper Eocene to Lower Miocene shale (Maikop) and Upper Miocene – Lower Pliocene deposits
- (Presenter's notes continued on next slide)*

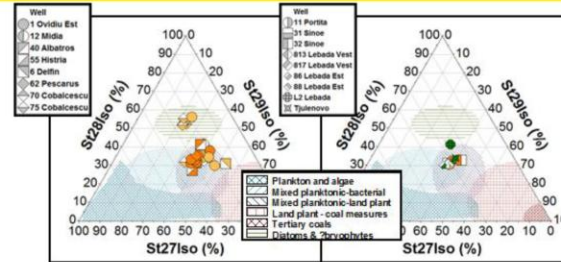
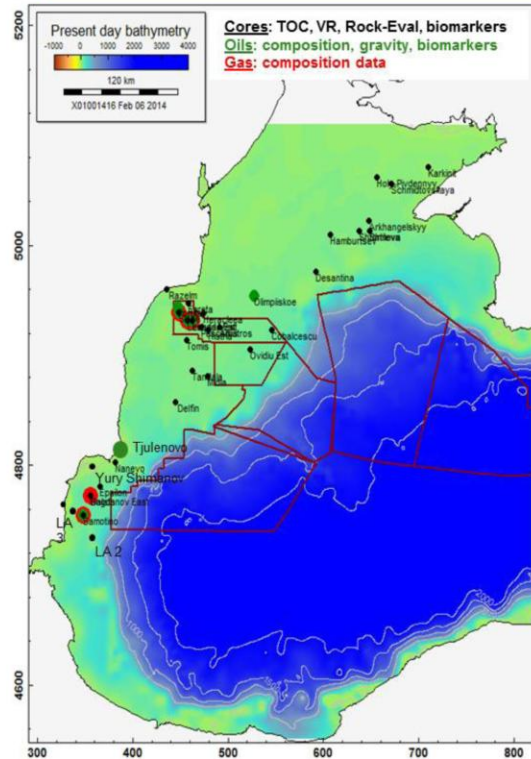
(Presenter's notes continued from previous slide)

Other possible source rocks are referred (Georgiev, 2012) in Jurassic, Lower Cretaceous (Kamchia and Varna basins), Paleocene, Eocene- Oligocene, and Miocene (Bourgas Basin).

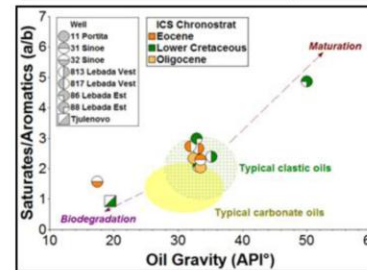
Note that the orogen system in the WBSZ includes the following units: North Dobrogea thrust-fold belt, Eastern Balkan and Srednogorie thrust-fold belt, and Western Pontides thrust-fold belt.

Which are the source rocks in WBS ?

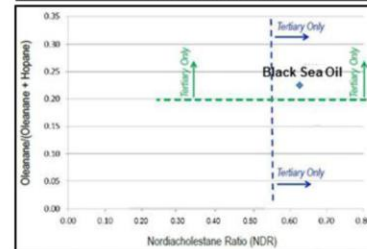
Oils on the Shelf Charged are Charged by Maykop



➤ Single oil family, better fit with the Oligocene and Eocene (Maykop) SR



➤ Oils originated in typical clastic source rocks (Maykop shale)

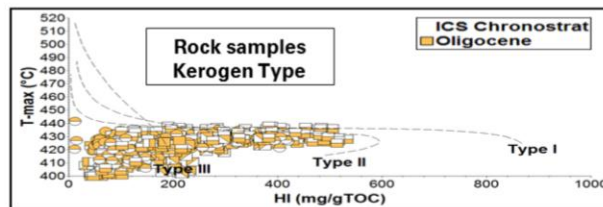
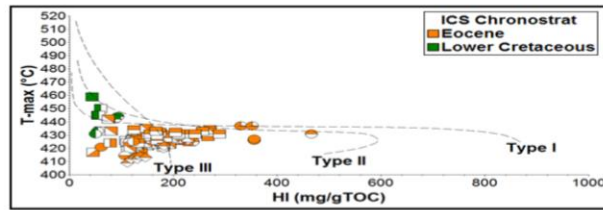
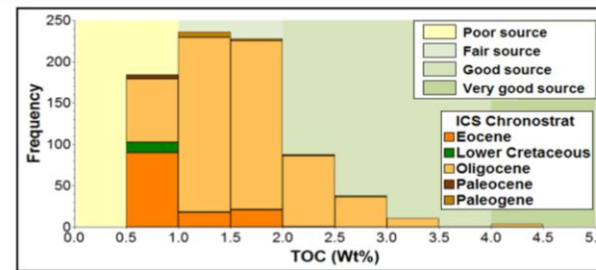
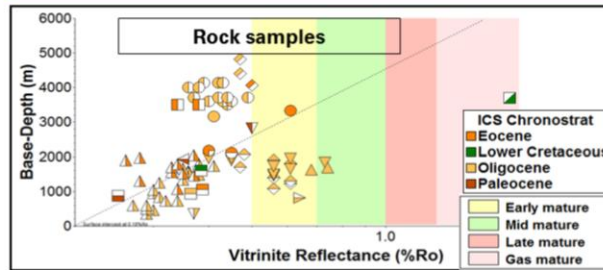


➤ Only Tertiary SR

Presenter's notes: A large geochemical data base containing data from cores, oils and gas was used for interpretation. According to the Ternary Sterane diagram a single oil family was identified having a very good fit with Oligocene and Eocene rocks mixed containing planktonic and land plant kerogene type. According to the Saturates-Aromatics ratio vs. Oil gravity, most of the oils were generated by a typical clastic source rock. Based on biomarker analyses on Romanian oils, the Oleanane index vs. Nordiacholestane ratio diagram accurately pinpoint the Tertiary age for the source rock.

Which are the source rocks in WBS ?

Maturity & Organic Matter Type



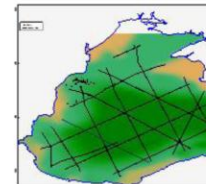
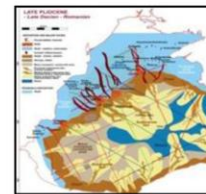
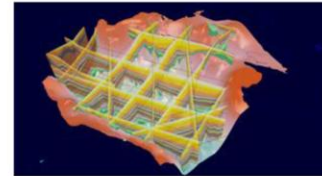
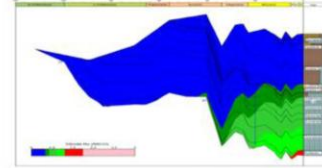
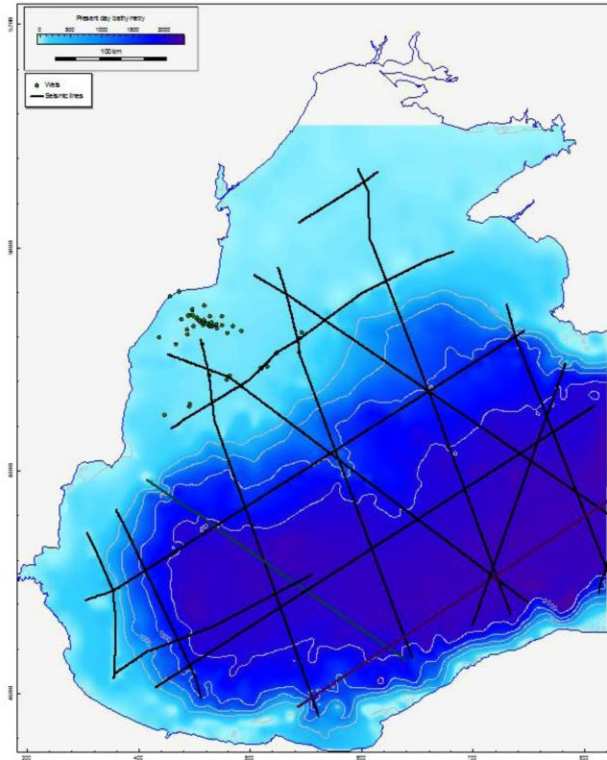
- Most samples are immature for hydrocarbon generation;
- Eocene and Oligocene (Maikop) samples are fair to good SR (TOC = 0.5 – 4.5 wt%)
- Eocene and Oligocene (Maikop) samples are represented by a Mixture of Kerogen type II & III (marine with terrestrial input).

Presenter's notes: Other geochemical analyses (TOC, VR, Tmax, HI) proved that the most of the Eocene – Oligocene rock samples are immature or early mature for hydrocarbon generation. Eocene – Oligocene rock samples are fair to good source rock. Eocene – Oligocene rock samples are represented by a mixture of kerogen type II & III (marine with terrestrial input).

Geochemical data lead to define a Tertiary (Late Eocene Aquitanian; Maikop equivalent) typical clastic source rock containing a mixture of type II and type III of kerogen. The TOC content is between 0.5 and 4.5 wt%.

What's behind the model?

Petroleum system modeling - Input Data



➤ Primary data (markers, lithology, t^0 , VR, etc.) from wells

➤ 1D models using Genesis software on 21 wells

➤ Structural maps (based on GTX regional 2D seismic grid interpretation)

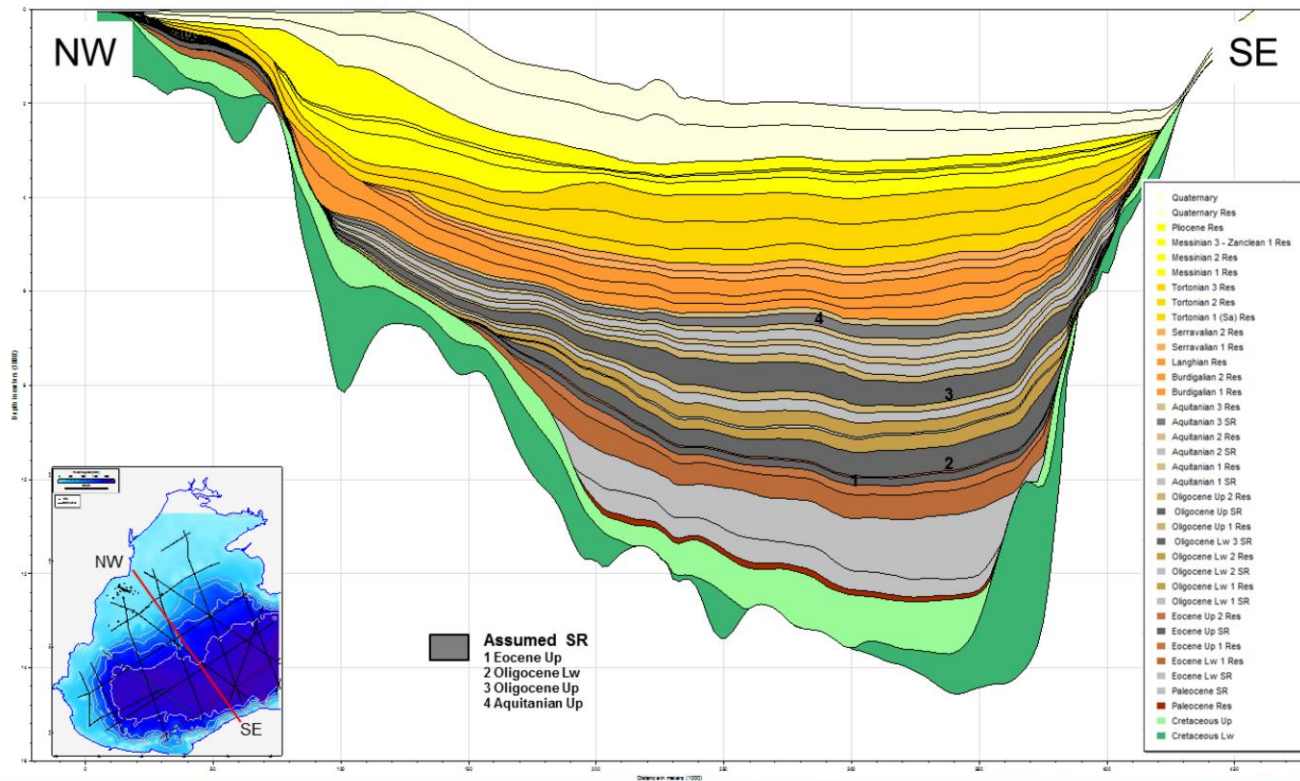
➤ Capillary pore pressure (facies & top seal) maps (based on sedimentological interpretation)

➤ Source rock properties maps (based on facies maps and geochemical data)

Presenter's notes: The basin modeling used Trinity (3D) – Genesis (1D) software package. Primary data consisting in stratigraphic markers, lithology, borehole temperature, vitrinite reflectance were used to generate 1D models on more than 20 wells, in order to obtain the proper thermal regime for WBS. Structural maps was interpreted based on GTX regional 2D seismic. Facies and Top Seal maps have been obtained based on sedimentological interpretation. Source rock properties maps have been generated based on thickness and facies maps.

What's behind the model?

Assumed Source Rocks



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Presenter's notes: 36 horizons are defined in the structural model.

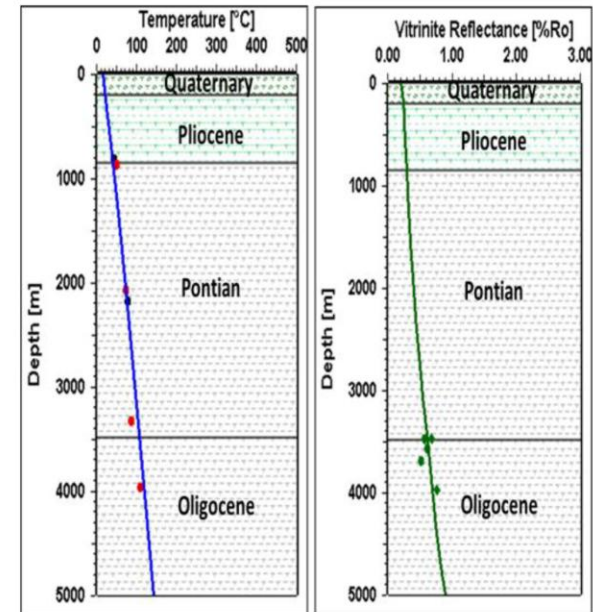
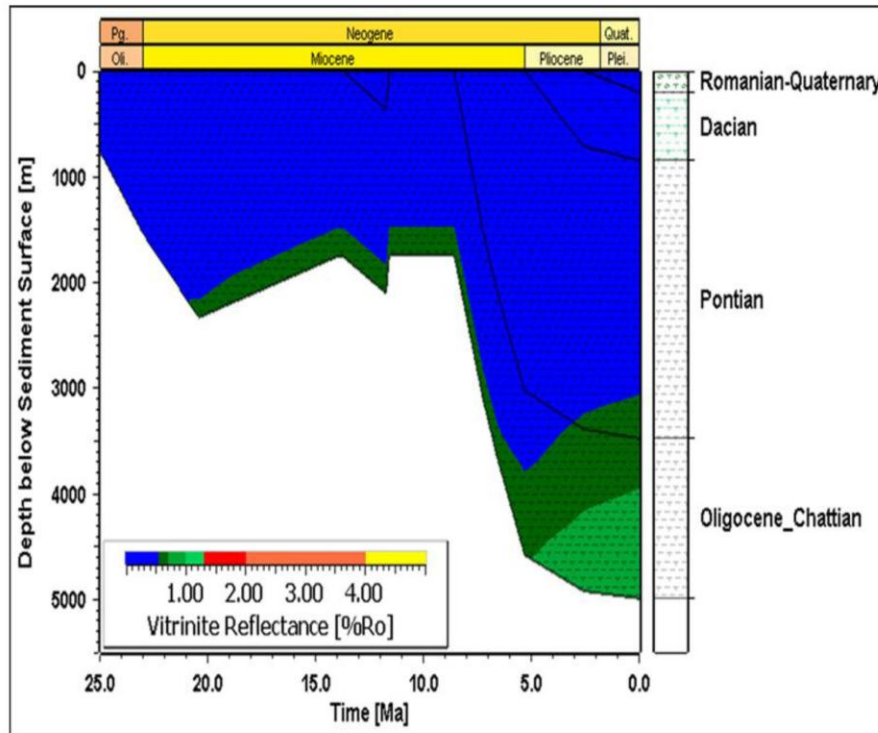
The assumed source rocks are: Upper Eocene, Lower Oligocene, Upper Oligocene, and Upper Aquitanian, in order to define the maturity for the top, the base, and inside the Maikop equivalent source rock.

The source rock is characterized by

- a TOC ranking between 0.5% and 4.5 wt% and
- a mixture of marine (type II) and land plant (type III) kerogene.

Cold or Warm? 1D model thermal calibration

Burial history and maturity

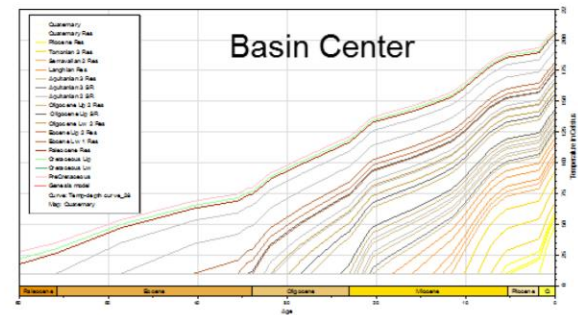
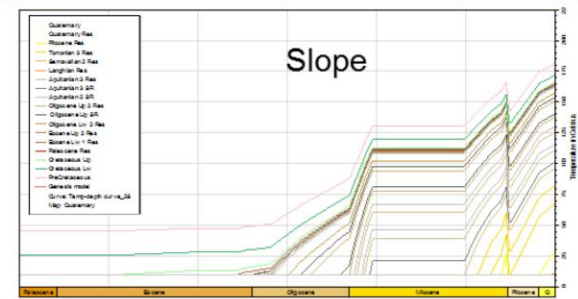
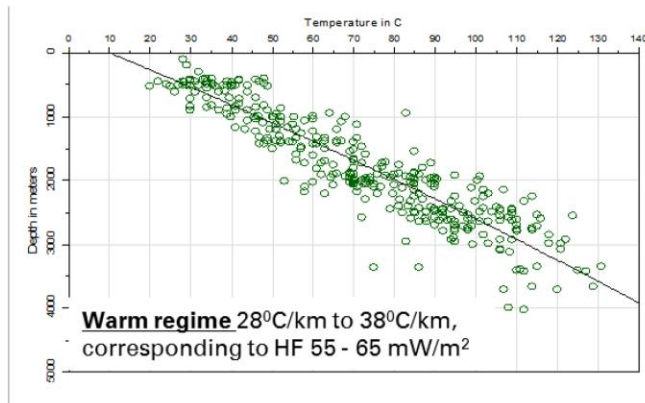
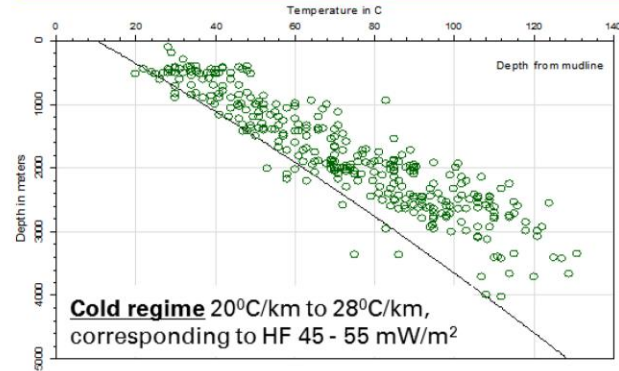


Borehole temperature and Vitrinite reflectance calibration.

Presenter's notes: More than 20 wells are used to be modeled in Genesis in order to calibrate the thermal regime in WBS. We present to you an example of 1D model based on one of the deepest well drilled on the Romanian Black Sea shelf. Notice the good calibration with borehole temperature and vitrinite reflectance.

Cold or Warm?

Thermal regime based on borehole temperature



- maximum temperature was reached in present day
- no remarkable heat flow fluctuation during the Paleogene - Pliocene time

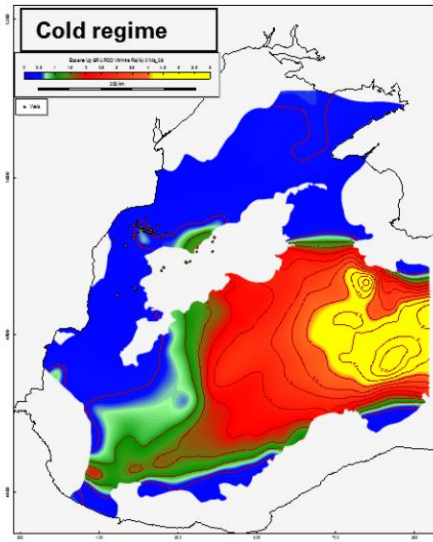
Presenter's notes: Based on the 1D models and the BHT, two thermal regimes was established:

- Cold regime represented by a thermal gradient between 20 to 28°C/km, corresponding to an HF ranking 45 - 55 mW/m² for slope.
- Warm regime represented by a thermal gradient between 28 to 38°C/km, corresponding to HF ranking 55 - 65 mW/m² for shelf.

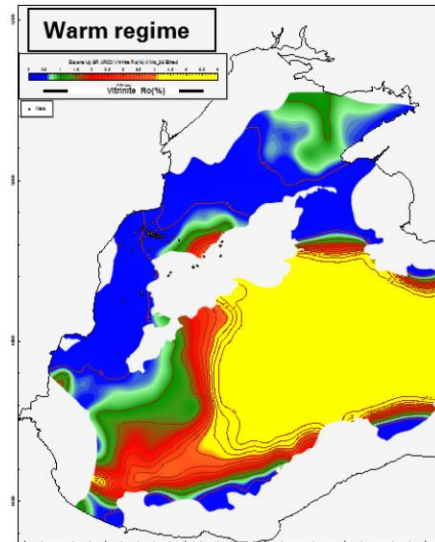
The maximum temperature was reached in the present day and no remarkable heat flow fluctuation during the Tertiary.

Oil and Gas, from Where to Where ?

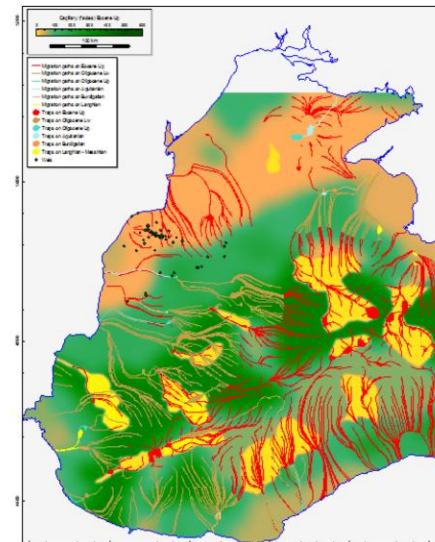
Upper Eocene SR Present Day Maturity / Migration



Type of generated HC: oil & gas (wet & dry);
Overmature area in the deepest parts



Type of generated HC: oil & gas (wet & dry);
Large overmature area



Main migration paths: on Upper Eocene & Lower Oligocene

Main traps: in Upper Eocene

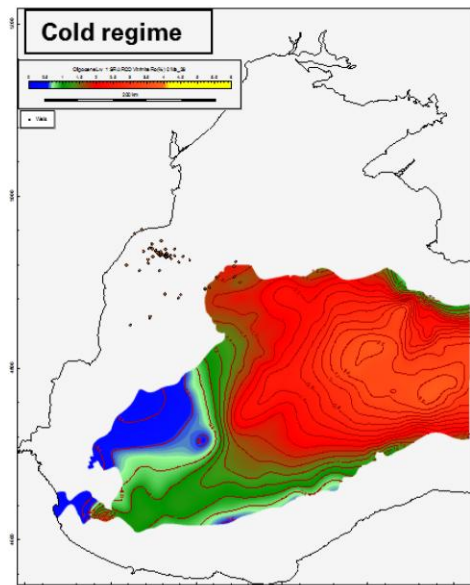
Presenter's notes: In the next few slides, I will present some results of the petroleum system modeling expressed in the source rock maturity maps (in terms of vitrinite reflectance) and 3D migration maps. The facies maps of the main migration surfaces are set as background, green colors representing shale and brown to yellow representing silt and sand.

The Upper Eocene (base Maikop) source rock is immature on the shelf (blue) and oil and gas mature (green and red) to overmature (yellow) in the basin. Note the large overmature area in the warm regime.

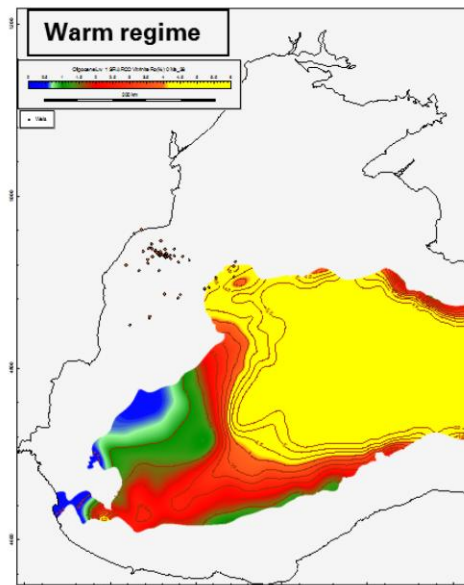
Long lateral hydrocarbons migration is favorable along Upper Eocene and Lower Oligocene carrier beds (the red and light brown vectors). The main hydrocarbon accumulations seem to be located in Upper Eocene reservoirs.

Oil and Gas, from Where to Where ?

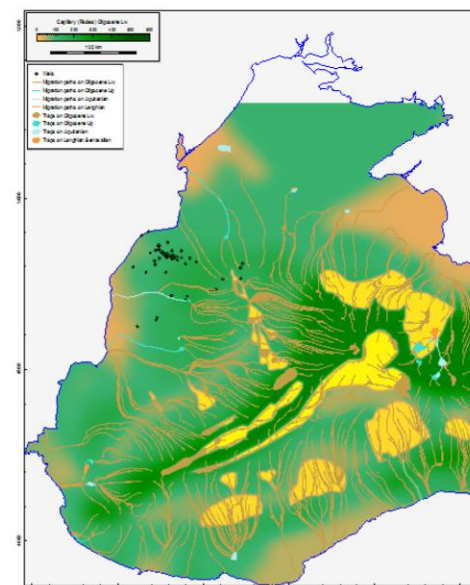
Lower Oligocene Source Rock Present Day Maturity



Type of generated HC: oil & gas
(wet & dry);



Type of generated HC: oil & gas
(wet & dry);
Overmature area in the deep basin



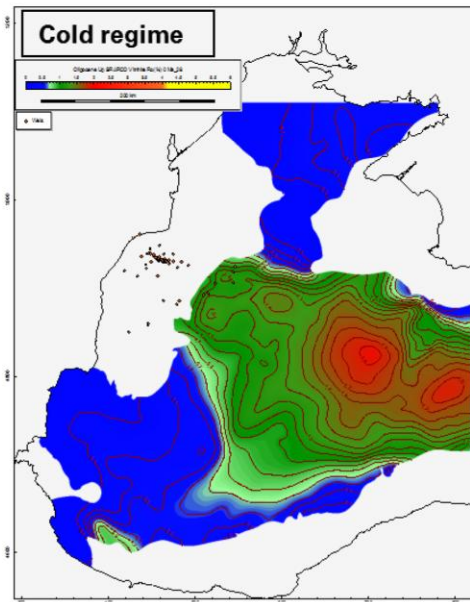
Main migration paths: on Lower Oligocene.

Main traps: in Lower and Upper Oligocene

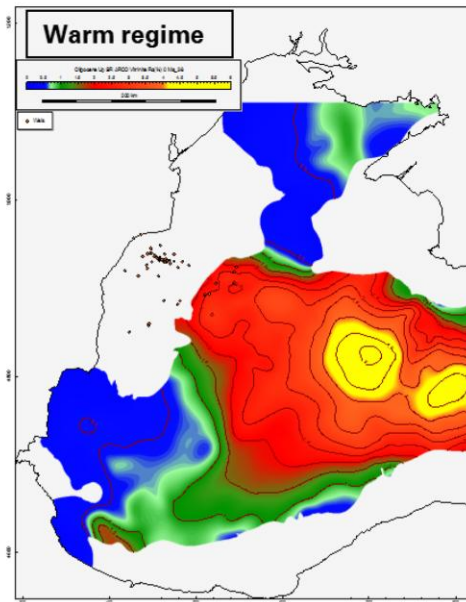
Presenter's notes: The Lower Oligocene (Lower Maikop) source rock is present only in the basin. In the Cold Regime the source rock is oil to gas mature (green and red) while in the Warm Regime, large area become overmature in the central part of the basin. Long lateral hydrocarbons migration is favorable along Lower Oligocene carrier beds (the light brown vectors). The main hydrocarbon accumulations seem to be located in Lower and Upper Oligocene reservoirs.

Oil and Gas, from Where to Where ?

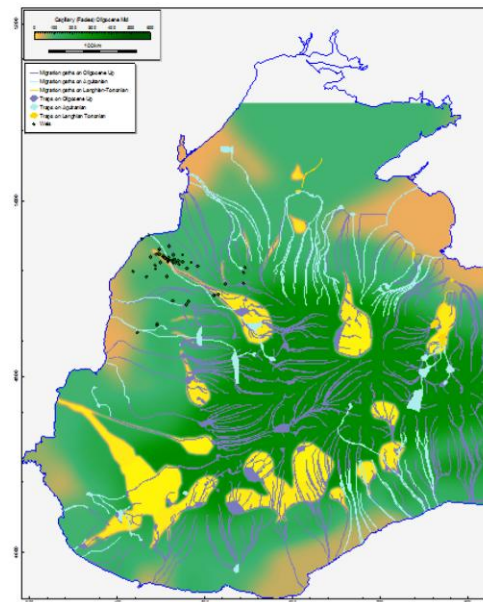
Upper Oligocene Source Rock Present Day Maturity



Type of generated HC: oil & wet gas



Type of generated HC: oil & gas (wet & dry);
Overmature area in the deepest parts



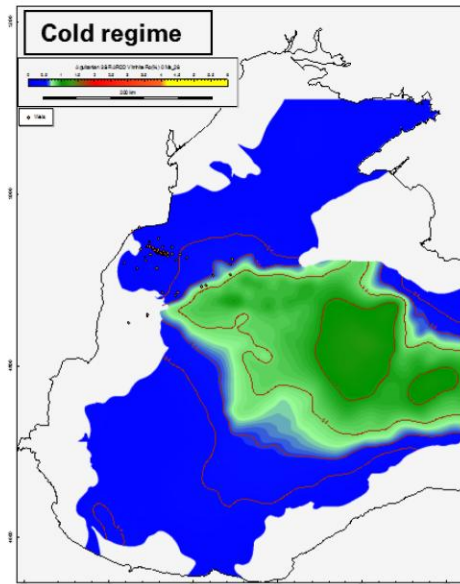
Main migration paths: on Upper Oligocene & Aquitanian

Main traps: in Upper Oligocene & Aquitanian

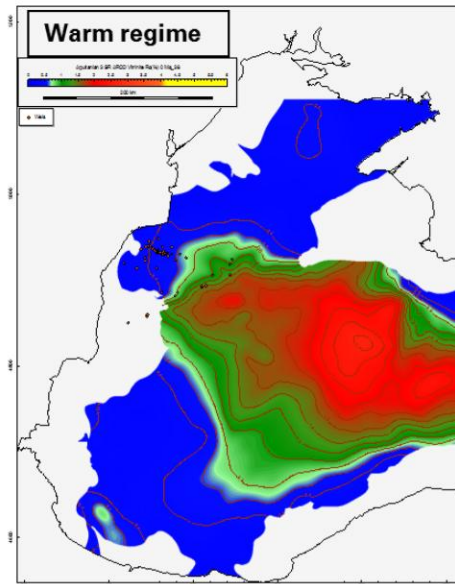
Presenter's notes: The Upper Oligocene (Intra Maikop) source rock is oil and wet gas mature in the center of the basin for the Cold Regime and oil to gas mature for the Warm Regime. Small area can be overmature in the deepest part of the basin. Long lateral hydrocarbons migration is favorable along Upper Oligocene and Aquitanian carrier beds (the purple and light blue vectors). The main hydrocarbon accumulations seem to be located in Upper Oligocene and Aquitanian reservoirs.

Oil and Gas, from Where to Where ?

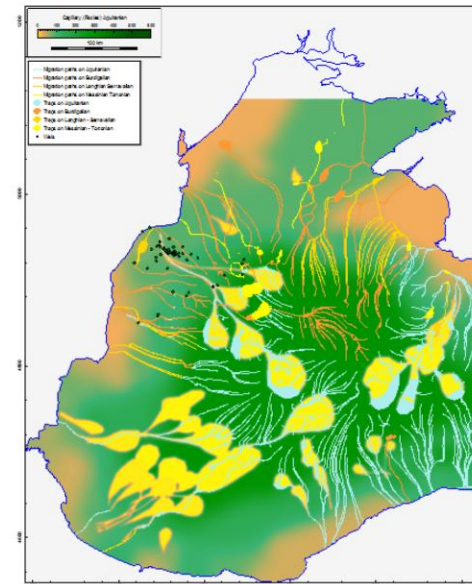
Aquitanian Source Rock Present Day Maturity



Type of generated HC: oil



Type of generated HC: oil & wet gas



Main migration paths: on Aquitanian, Burdigalian & Langhian-Serravalian

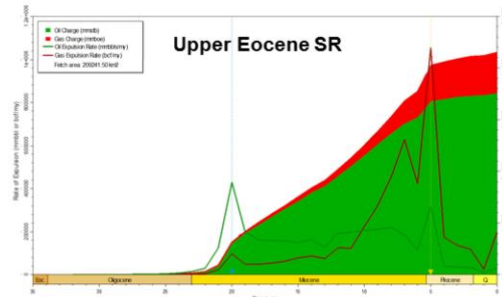
Main traps: in Aquitanian

Presenter's notes: The Aquitanian (Top Maikop) source rock is oil mature in the center of the basin for the Cold Regime and oil to wet gas mature for the Warm Regime.

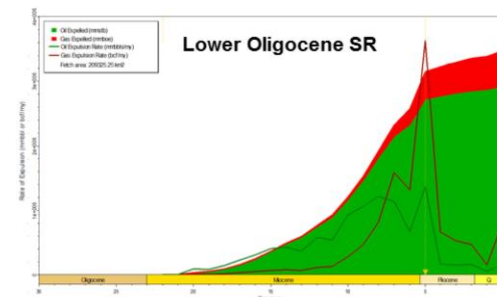
Long lateral hydrocarbons migration is favorable along Aquitanian, Burdigalian and Langhian Serravalian carrier beds (the light blue, orange and yellow vectors).

The main hydrocarbon accumulations seem to be located in Aquitanian reservoirs.

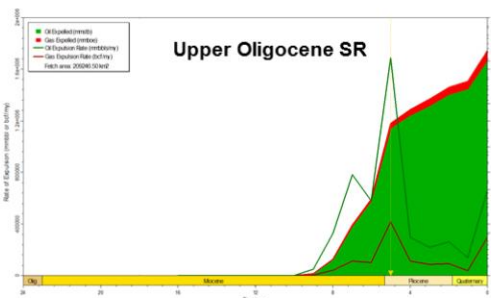
Too Late or Too Early ? Timing of the HC Expulsion



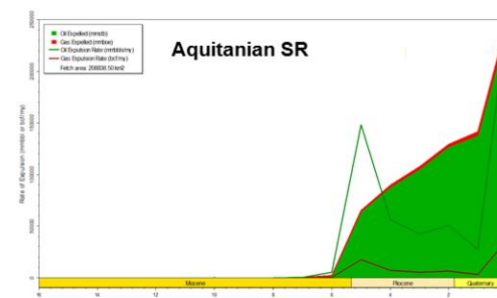
- Expulsion onset in Earliest Miocene
- Peak of expulsion at 5my



- Expulsion onset in Early Miocene
- Peak of expulsion at 5my



- Expulsion onset in Late Miocene
- Peak of expulsion at 5my



- Expulsion onset in Latest Miocene
- Peak of expulsion not yet reached

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Presenter's notes: For the base of the Maikop (Upper Eocene) source rock the hydrocarbon expulsion started in Early Miocene. For the top of Maikop (Aquitanian) source rock the hydrocarbon expulsion started in Latest Miocene.

The Peak of expulsion was reached 5 my ago for Eocene and Oligocene source rock. The Peak of expulsion was not yet reached for Aquitanian source rock.

Upper Eocene and Lower Oligocene source rock are the main gas contributors. The best oil and gas contributor seems to be Oligocene source rock. Aquitanian source rock expelled modest amount of oil compared to the other Maikop source rock

Large hydrocarbon quantities were still expelled after the Messinian event when most of the traps were formed.

Conclusions

Oligocene is the most favorable source rock responsible to oil and gas generation in WBS.

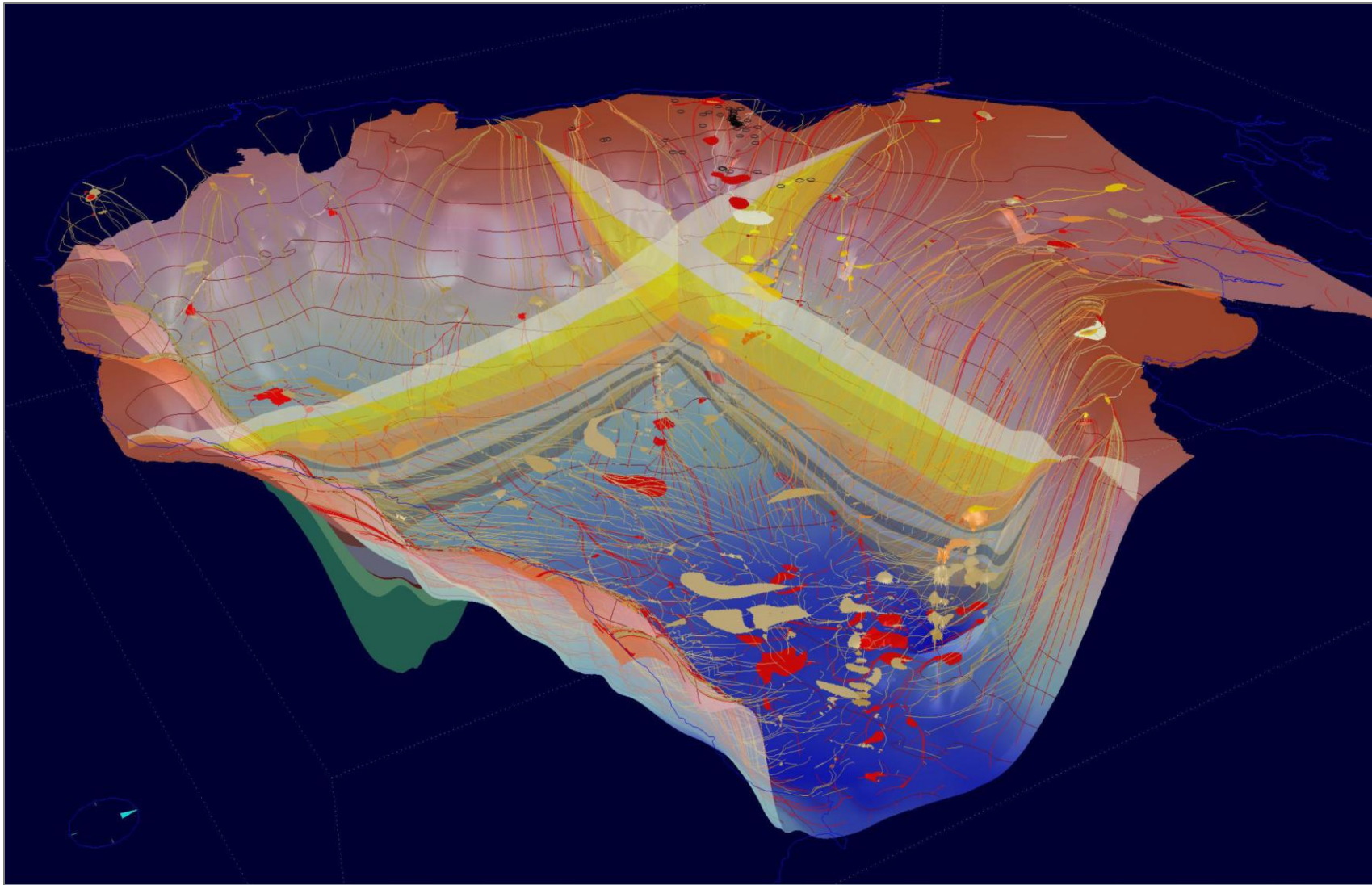
The warm thermal regime (28-38°C/Km) is the most reliable on the shelf, and the cold thermal regime (28-20°C/Km) on the basin center.

**Eocene and Lower Oligocene source rocks are late oil to gas mature in present day
Upper Oligocene and Aquitanian Source rocks are oil mature in present day.**

Oligocene and Aquitanian sandy facies are the most favorable for long lateral migration pathway.

Expulsion onset is in earliest Miocene for Eocene (base Maikop) source rock and latest Miocene for Aquitanian (top Maikop) source rock.

Large quantities of hydrocarbons was generated in the last 5 my (post Messinian event).



Thank You!

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Presenter's notes: Of course, the phenomenon of expulsion, migration, and entrapping is by far the most complex and less controllable in the modeling process. A 3D migration image looks more complex than a spider web.



Contact

Radu.Olaru@petrom.com

OMV Petrom S.A.

www.petrom.com

Coralilor 22, Sector 1

Bucuresti



OMV Petrom