# Petroleum Systems of Romania*

**Csaba Krézsek**[1]

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[1]OMV Petrom, Bucharest, Romania (csaba.krezsek@petrom.com)

## Introduction

Romania is one of the most important hydrocarbon provinces of Eastern Central Europe (Figure 1). Oil Production started in 1854 and since then 465 oil pools and 430 gas pools have been discovered. The cumulative oil production in 2007 was about 5 billion bbl, whereas the gas production exceeded 40 TCF.

Petroleum Geology of Romania is strongly linked to the development of the Carpathian Orogen (Figure 1). The Carpathians are a fold and thrust belt formed by thick-skinned internal nappes assembled during the Cretaceous (i.e., Inner Carpathians) and by thin-skinned external nappes of Cretaceous to Miocene age (i.e., External Carpathians) (Figure 2a,b). The latter is an accretionary wedge that overrides the relatively undeformed Eastern European plate margin.

Hydrocarbon exploration in Romania focuses on conventional and unconventional plays. Conventional plays are explored in the following (with numbers corresponding to those in Figure 1):

- External Carpathians (1):
- Getic Basin (2)
- Foreland of the Carpathians and the undeformed parts of the East European Margin (3)
- Basins developed on top of the Inner Carpathians
  - Pannonian Basin (4)
  - Transylvanian Basin (5)
- Black Sea (6)

 

Unconventional plays are present in the East European Margin (3, 3a) and Maramures (4a) (Figure 1). Each of these tectonic units typically contains several petroleum systems, which will not be addressed in detail here. Instead, emphasis will be given to the status of exploration and remaining exploration potential.

Exploration in the past typically consisted in drilling relatively shallow (2-3 km deep) structural closures, based on 2D seismic data, but often without seismic control. New 3D seismic surveys will likely shed light on smaller accumulations near major fields. On the other hand, deep structural and stratigraphic plays were not explored systematically. Major breakthrough are expected with the use of more advanced acquisition, processing and interpretation technologies, including long-offset seismic, AVO, etc.

## Carpathians and Its Foreland

The External Carpathians are thin-skinned nappes built by Cretaceous to Miocene sediments, which were thrusted over the undeformed Eastern European Margin and Moesia during the mid-Miocene (Figure 2a,b). Exploration targeted mostly the external nappes, where Paleogene and Miocene source rocks represented by paper-shales (dysodiles) and bituminous silicolites (menilites) provide charge for Paleogene to Pliocene sandstone reservoirs in structural closures, mostly faulted anticlines.

In the Carpathians and its foreland, often the rule is mixing of black and cracked oils, many times with different isotopic composition, which suggest complex maturation and migration history. Cretaceous source rocks are present in the internal nappes, but their effectiveness is not known.

Exploration targeted relatively shallow traps in the outer nappes with more than 50 oil and a few gas fields discovered (Figure 1). Current exploration continues to look for opportunities in the shallow section, but it also considers going deeper, where potentially large gas structures exist, as suggested by long-offset 2D seismic lines and structural balancing. One key aspect of the exploration is to understand the effect of the Pliocene out-of-sequence deformation on the petroleum systems and the trap integrity.

The Miocene foreland of the Carpathians hosts several oil and gas fields typically represented by tilted fault blocks on the foreland plate (Figure 2a). The middle Miocene deep-marine shales buried deep in the internal foredeep charges shallow-marine sandstones on the foreland. Most hydrocarbons are thermogenic, but local biogenic sources are present as well.

The Miocene foreland of the Southern Carpathians includes the Getic “Depression” (Figure 1). The latter is a Paleogene to early Miocene right-lateral pull-apart basin (i.e., the Getic Basin) formed at the sheared contact between the Carpathians and Moesia and inverted during the mid-Miocene (Figure 2b). The petroleum system is similar to the External Carpathians. The deep potential of this inverted basin lies in understanding the distribution of extensional rollovers with lower Miocene and older sandstone reservoirs locally sealed by salt.

## East European Margin

In Romania, the East European Margin consists of different tectonic units (locally known as the Moldavian Platform, Scythian Platform, North Dobrogea Orogen, and the Moesian Platform, Figure 1) delimited by crustal-scale fault zones. These tectonic units were involved in Paleozoic and Triassic compressional deformations, Permian-Triassic and Jurassic extension, and were weakly affected by the closure of the Alpine Tethys (Figure 2a). In general, the sedimentary succession is formed by tectonic megasequences delimited by regional unconformities: Paleozoic, Permian-Triassic, Jurassic-Cretaceous and Miocene-Pliocene. Reservoirs may be found in all of these sequences, but the most effective are Triassic and Lower Cretaceous limestones, and Middle Jurassic and Miocene sandstones.

Effective source rocks are located in the Silurian, Devonian, Dogger, and middle Miocene. Exploration in the past targeted tilted fault blocks and various stratigraphic traps (toplaps, onlaps, reefs, incised channels). Likely, several more, but relatively small traps of these plays remain unexplored, but they will be identified with 3D seismic surveys.

The tilted fault block play of Moesia, in the reach of deep drilling, is present under the outer nappes of the Carpathians (Figure 2b). This has been identified on regional long-offset 2D seismic surveys recently shot by OMV Petrom and will be explored in the near future.

Two new plays may also emerge, as follows: 1) the unconventional shale gas play and 2) subtle, but potentially large and deep traps related to the Cimmerian folds. Successful exploration of the Paleozoic will have to address the consequence of the large-scale Hercynian exhumation present in certain areas.

## Transylvanian Basin

The Transylvanian Basin is a biogenic gas province. The biogenic gas is sourced from deep-marine middle Miocene shales and is stored in multistory turbidite reservoirs in structural traps, frequently salt-cored folds (Figure 2a-b, 3).

Exploration started more than 100 years ago, and about 30 TCF of gas has been produced. Limited exploration potential is left in structural closures. One such area could be the eastern margin of the basin that is covered by back-arc volcanics (Figure 2a). In addition, stratigraphic traps, mapped with 3D seismic and AVO, will likely shed light on more accumulations. Most prospective areas are the basin-floor fans in the central parts of the basin, and slope channels and fans in the northern and eastern part of the basin. Thin-bedded reservoirs in the western part of the basin could add resources as well.
Another, however not yet proven, petroleum system may be present, located deeper (sub-salt) in the basin. The only indication of this is a deep well that found Jurassic dolomites above the basement of the basin. The source of this oil is not known. The effectiveness of the deep petroleum system is questionable, because of the lack of thermogenic components of the gas in the post-salt section, but above the Late Cretaceous grabens (Figure 3).

## Pannonian Basin

The Pannonian Basin is a Miocene extensional back-arc basin system formed on top of the Inner Carpathians and their tectonic equivalents (Figure 4). The petroleum system is represented by Miocene oil-prone lacustrine shales, which sourced altered basement rocks, shallow-marine syn-rift reservoirs, and upper Miocene (Pannonian) sands.

Only, the easternmost shallow margin of the Pannonian Basin extends to Romania, where successful exploration has been conducted for many years (Figure 1). Most discoveries are in structural closures, such as tilted fault blocks or drape folds over basement highs.

Stratigraphic plays drilled in the last few years in the Hungarian part of the basin using AVO attributes have not been tested yet. These are upper Miocene (Pannonian) turbidites that onlap basement highs. However, the exploration risks on the Romanian part are higher, because of the relatively thin and shallow sedimentary section, the late tilt of the basin margins, and the presence of volcanic gases in some areas. The tight gas play currently explored in the Hungarian part of the basin most likely extends into Romania as well.

### Maramureş

Maramureş is part of the Pannonian Basin (Figure 1). However, its petroleum system differs from the Pannonian Basin, because the basement is formed by a thrust-and-fold belt of Oligocene to early Miocene in age, known as the Pienides (Figure 3). A working petroleum system is indicated by several oil seeps and small accumulations in Paleogene reservoirs, which are sourced from Oligocene paper-shales.

The sub-salt play that works in Ukraine just across the border is yet to be proven in the Romanian side. Similar play elements are present in Romania, in western Maramureş.

A new play that may emerge in Maramureş is the shale oil play. Reasonable quality Oligocene source rocks are located in the oil generation window. Most of these shales are conveniently situated at shallow-depths due to the Pliocene uplift and exhumation of the Carpathians.

## Black Sea

The Western Black Sea Basin is the Cretaceous back-arc of the Pontides. The basin suffered several phases of strike-slip deformation and inversion during the Paleogene. The mid-Miocene (Badenian-Sarmatian) is characterized by low amounts of subsidence with carbonate platforms and intervening deeps. This was followed by a large-scale progradation of the clinoforms during the Meotian–Pliocene (Figure 5).

At least two different petroleum systems are recognized on the present-day shelf: Mesozoic (thermogenic) and Pontian (biogenic and thermogenic?). The Mesozoic system consists of an oil-rich source, likely Early Cretaceous in age, which charge Mesozoic and Eocene limestones. This system is likely overmature in the deep offshore.

The Pontian petroleum system is formed by dry-gas found in deltaic sands on clinoform topsets. Some of this gas is biogenic sourced by Pontian shales, but thermogenic components are present, likely charged by the Oligocene. Current exploration continues in the shallow section, but there are attempts to open new plays represented by slope and basin-floor fans located farther offshore in the basin.

## Conclusion

Significant exploration potential is left in Romania. The general trend is to go deeper while applying state-of-the-art exploration methods. Among others, these include 3D seismic surveys over traditionally explored regions, regional long-offset 2D lines for structurally complex and deep leads, AVO analysis of shallow targets and 2D/3D structural balancing. The potential reward could be significant discoveries (likely gas) in the coming years in the Carpathians and the offshore of the Black Sea.


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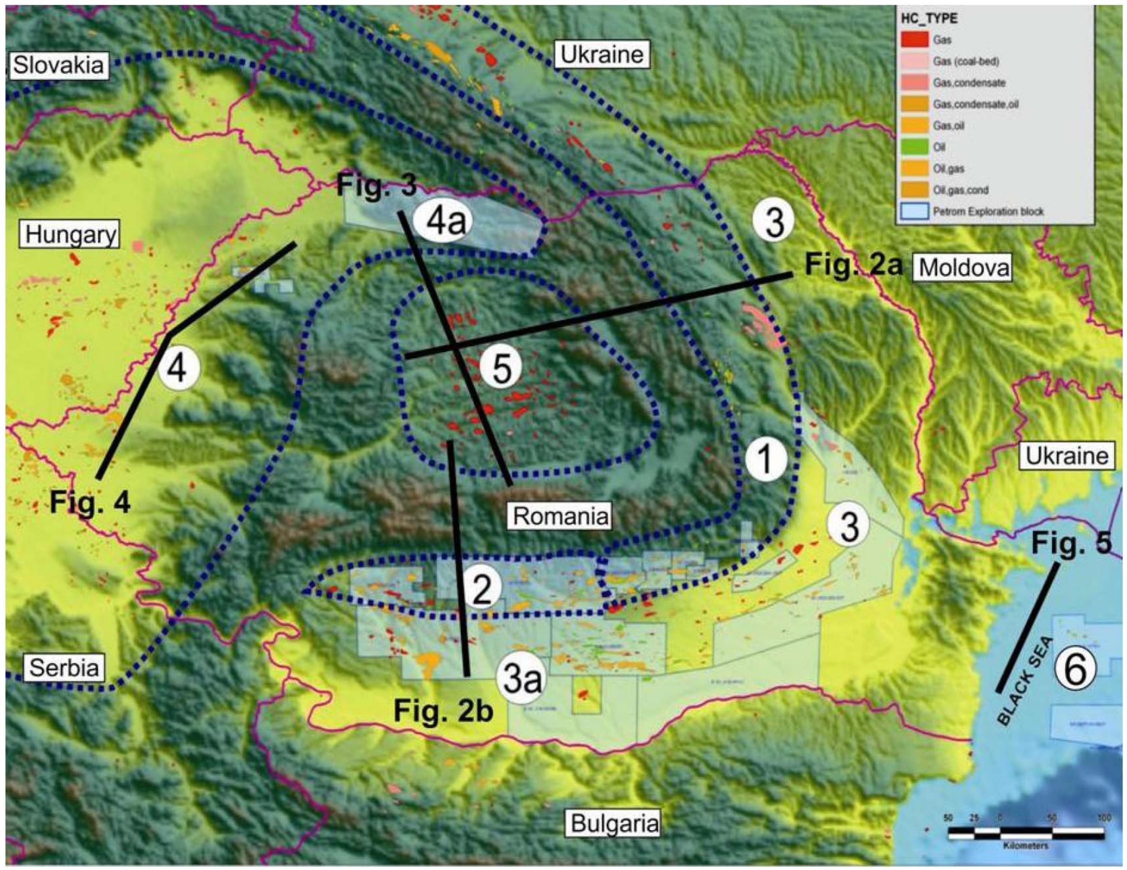


Figure 1. Map of Romania and neighboring countries. The dashed blue line indicates the explored areas. Annotations: External Carpathians (1), Getic Depression (2), undeformed part of the East European margin (3) including the Moesian platform (3a), the Romanian part of the Pannonian Basin (4) and its sub-basin in Maramures (4a), the Transylvanian Basin (5), and the Western Black Sea (6). Black lines show the location of regional sections presented in Figures. 2-5.

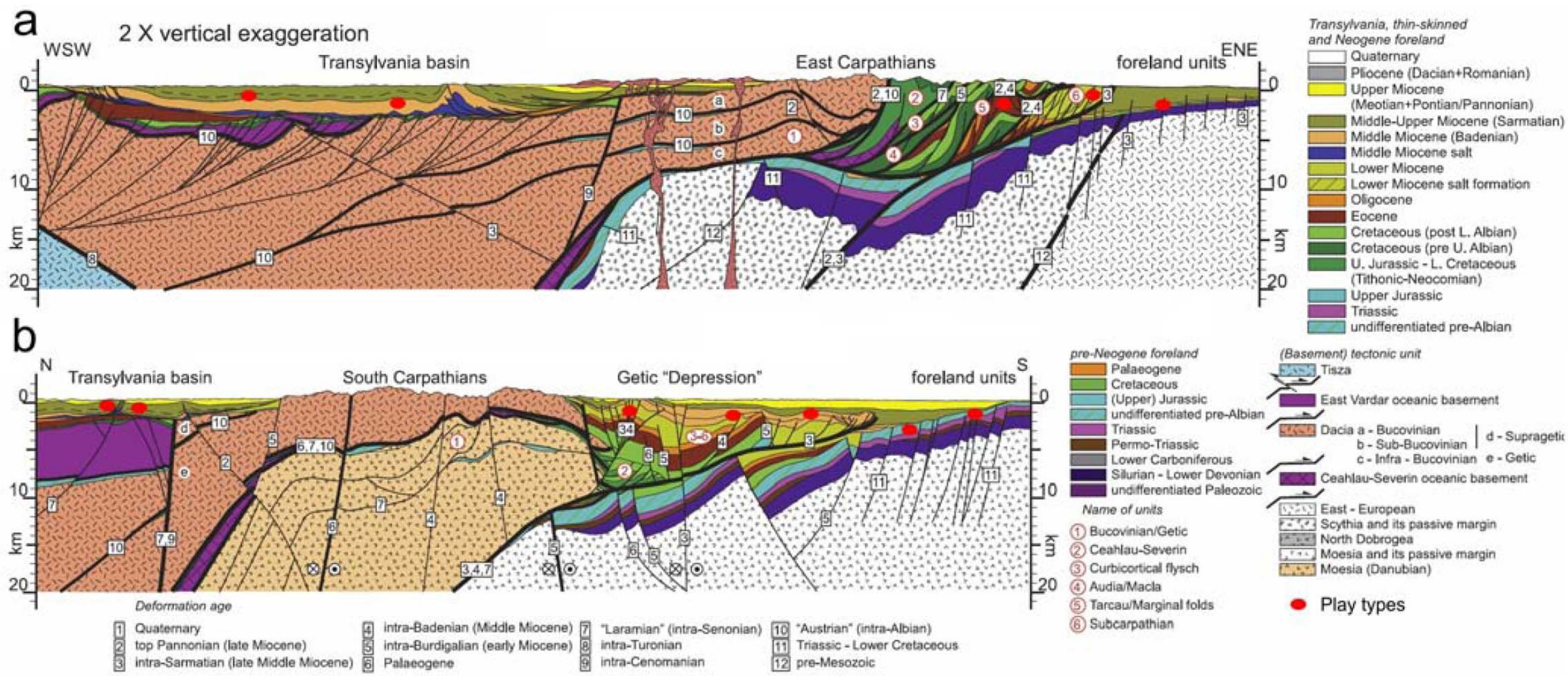


Figure 2. Regional cross-sections of the Carpathians and its foreland and the Transylvanian Basin, adapted from Maţenco et al. (2010). Note the differences in scale and structural style between the External Carpathians (a) and the Getic Depression (b). Location is shown on Figure 1.

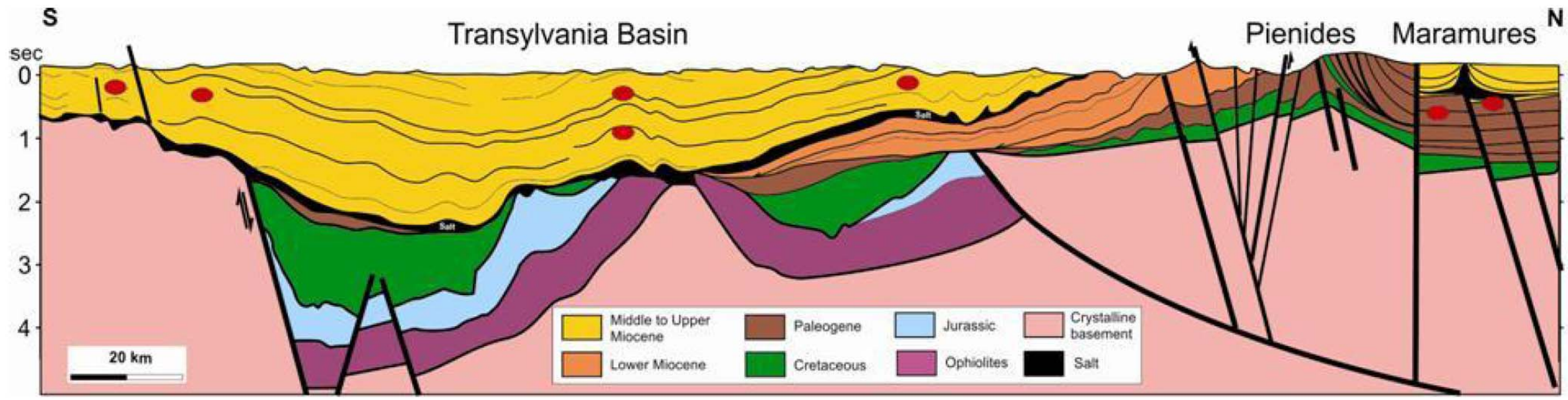


Figure 3. Regional cross-section from Marmureş to Transylvania Basin, adapted from Krézsek and Bally (2006). The mid-Miocene salt is in black. The red dots suggest the main play types.

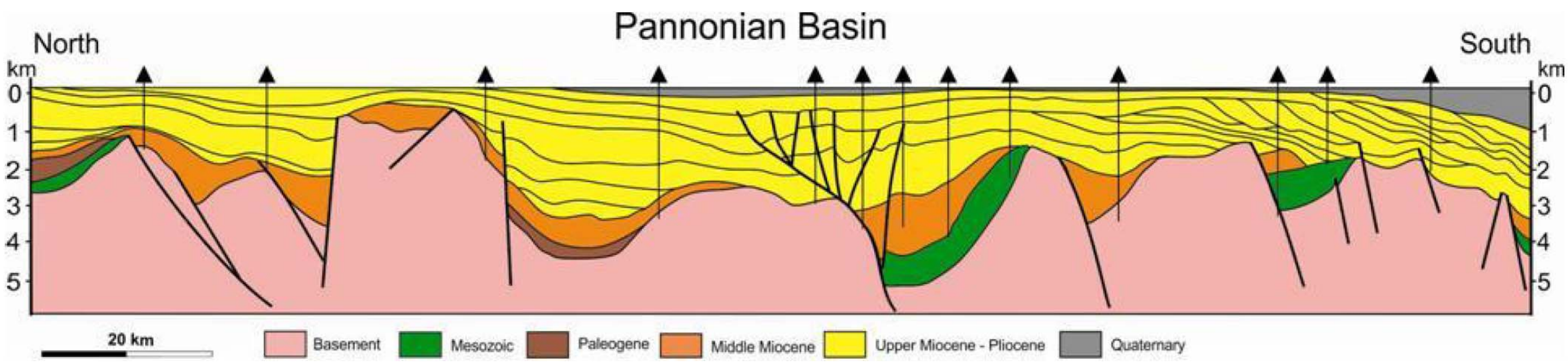


Figure 4. Regional cross-section of the Romanian side of the Pannonian Basin, redrawn based on Răbăgia (2009). Location is in Figure 1.

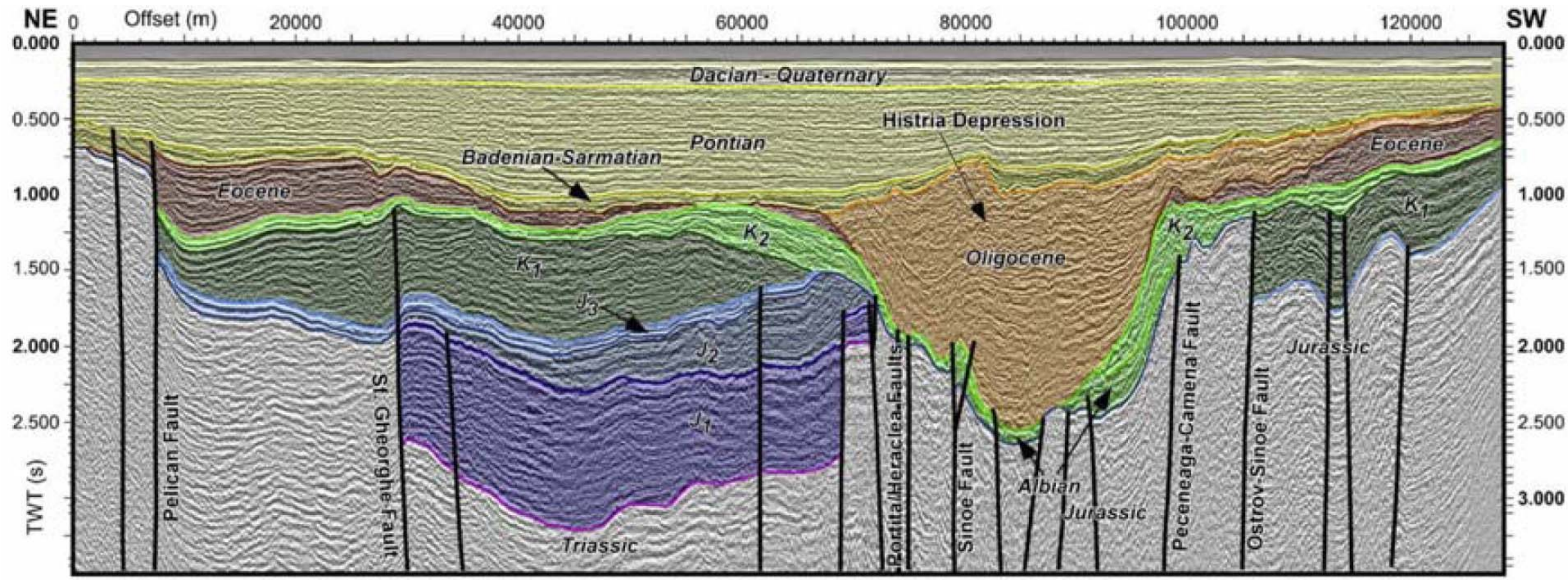


Figure 5. Regional seismic section of the Western Black Sea, adapted from Dinu et al. (2005). Location is on Figure 1.