Fault Tectonics of the NE Black Sea Shelf and Its Relevance to Hydrocarbon Potential*

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Abstract

Although faults of the consolidated crust play crucial role in the origin of sedimentary features and hydrocarbon accumulation, the tectonic setting of the NE Black Sea shelf is poorly known. The aim of this work is to compile the most detailed map of faults in the consolidated crust and test comprehensively a linkage between crustal disturbances and potential hydrocarbon features. Understanding such a relationship may be helpful in planning location of exploration boreholes.

For the first time, 3D gravity and magnetic models have been obtained at a scale of 1:200,000 for the NE Black Sea shelf. Based on the analysis of the observed magnetic field and gravity effect of the consolidated crust, the most detailed map has been compiled for tectonic faults of the consolidated crust. The relationship has been derived between the crustal and sedimentary faults. The prospective local anticlinal features have been revealed to be associated with certain systems of tectonic disturbances in the different crustal layers and magnetic inhomogeneity in the crust. The magnetic bodies of the consolidated crust and sedimentary cover can be of common origin due to the influence of hydrocarbons vertically migrating along the deep faults.

An individual block of high density has been delimited by the faults in the consolidated crust where there occur practically all prospective hydrocarbon features. The southern margin of this block is recommended as a new potential area for oil and gas exploration where gas seeps are genetically related to the tectonic disturbances of different orders.

A first model has been derived for thermal evolution of the Kerch-Taman Trough from the pseudo-well method. A total subsidence of its basement can reach 5.0-6.5 km. The present-day temperature vs. depth profiles have been calculated. A thermal and stratigraphic position has been determined for zones of oil and gas origin.

Selected References

Clarke, R.H. and R.W. Cleverly, 1991, Petroleum seepage and post-accumulation migration, *in* W.A. England and A.J. Fleet, (eds.) Petroleum Migration: Geological Society (London) Special Publication, v. 50, p. 265-271.

Clayton, J.L. and I. Konca, 1991, Application of organic geochemistry to petroleum exploration in Bekes Basin, Hungary: AAPG Bulletin, v. 75/3, p. 554.

Shnyukov, E.F., S.A. Kleshchenko, and Y.G. Artemov, 2003, A new field of gas flames in the western Black Sea: Geophysics Journal, v. 2/25, p. 153-160.

Starostenko, V.I., R.I. Kutas, O.V. Legostaeva, 2003, Solution of stationary geothermal forward problems for an inhomogeneous vertical rectangular, arbitrarily truncated prism: Izvestiya Russian Academy of Sciences Physics of the Solid Earth, v. 39/12, p. 1021-1028.

Starostenko, V.I., V. Buryanov, I.B. Makarenko, O. Rusakov, R.A. Stephenson, A. Nikishin, G. Georgiev, M. Gerasimov, R. Dimitriu, O.V. Legostaeva, V. Pchelarov, and C. Sava, 2004, Topography of the crust-mantle boundary beneath the Black Sea basin: Tectonophysics, v. 381/1-4, p. 211-233.

Starostenko, V.I., V.N. Zavoisky, and O.V. Legostaeva, 2005, The forward problem of magnetic survey for 3-D bodies of complex configuration with anisotropic magnetic susceptibility: Izvestiya Russian Academy of Sciences Physics of the Solid Earth, v. 41/7, p. 585-593.

Tugolesov, D.A., A.S. Gorshkov, L.B. Meisner, and V.V. Soloviev, 1985, Tectonics of the Mesozoic-Cenozoic Deposits of the Black Sea Basin: Nedra, Moscow, 215 p. (in Russian).

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FAULT TECTONICS OF THE NE BLACK SEA SHELF AND ITS RELEVANCE TO HYDROCARBON POTENTIAL

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INTRODUCTION

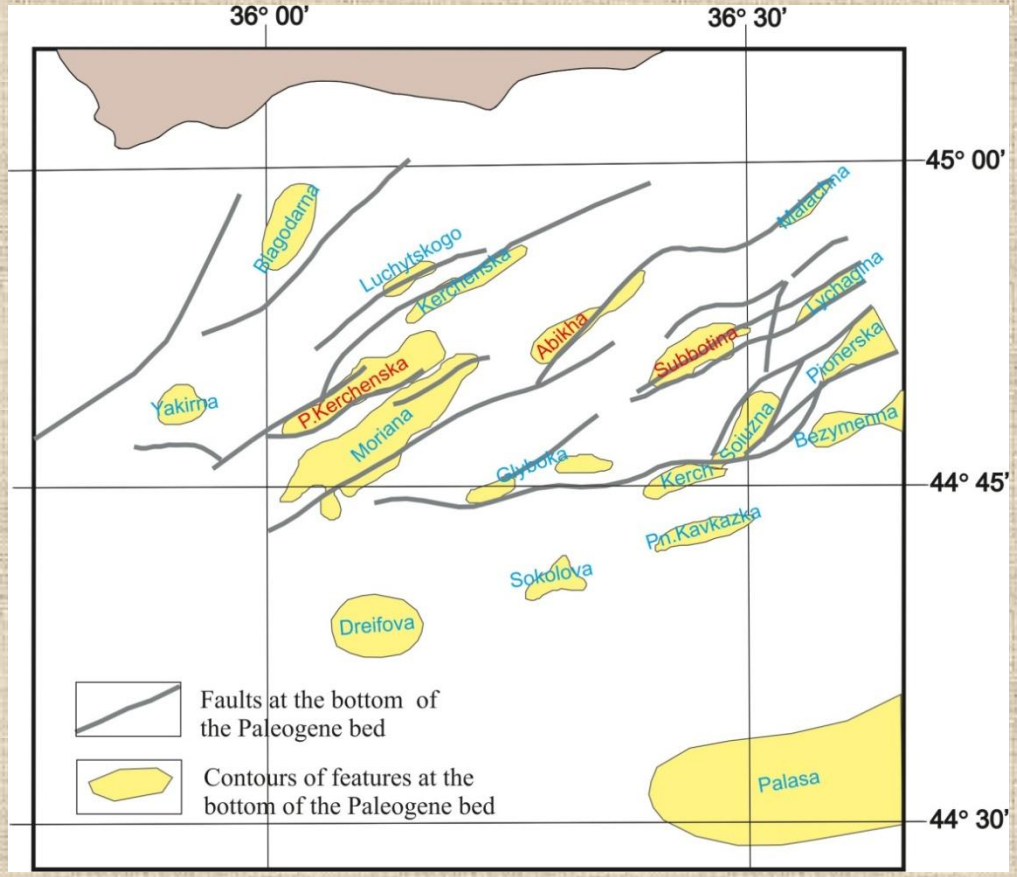
Faults of the consolidated crust play crucial role in the origin of sedimentary features and hydrocarbon accumulation in them. However, their setting is unknown on the NE Black Sea shelf. Therefore, the aim of this study is as follows:

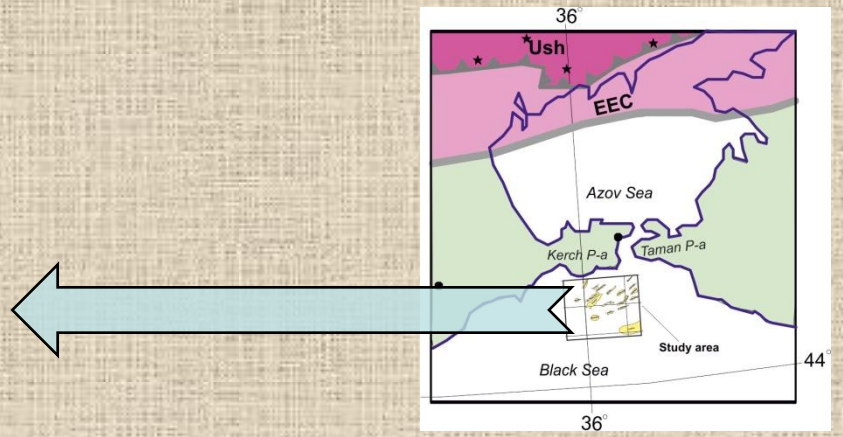
- to first compile a map of faults in the consolidated crust applying an innovative approach to interpreting gravity and magnetic data;
- to analyze influence of crustal faults on the formation of sedimentary features;
- to test a linkage between crustal disturbances and potential hydrocarbon features;
- to examine relationship between gas seeps and fault tectonics;
- to determine the thermal and stratigraphic position for zones of oil and gas origin.

Understanding these factors may be helpful in planning location of exploration holes.

LOCAL UPLIFTS ON THE NORTH-EASTERN SHELF OF THE BLACK SEA

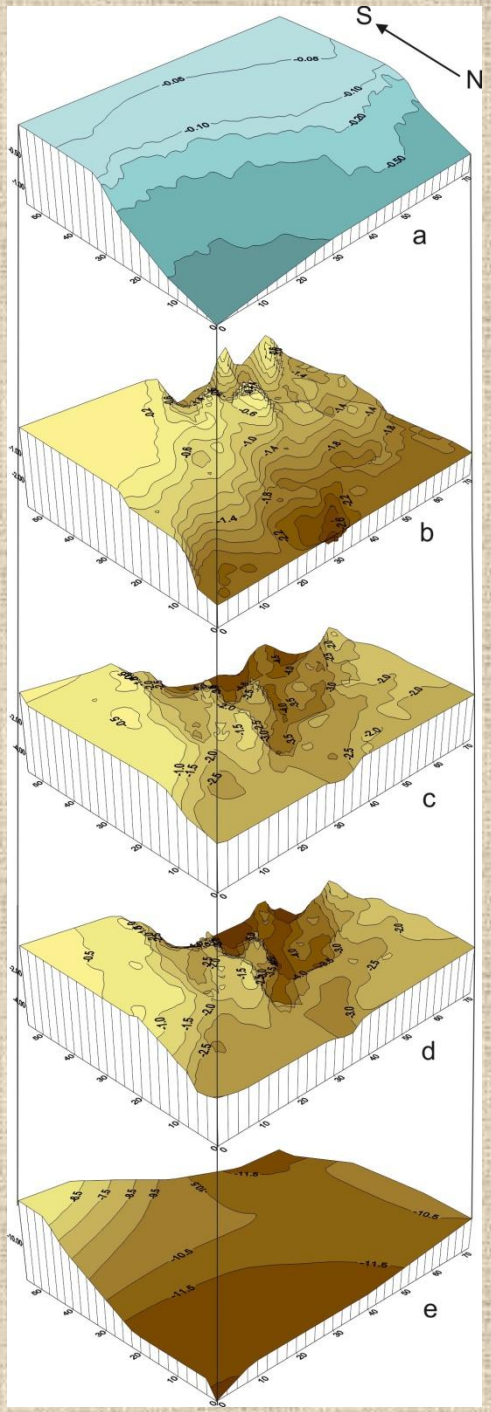
Scale 1:1 200,000





A multi-channel seismic survey resulted in the discovery of about 20 local uplifts in the Paleogene and Neogene oil and gas-bearing sequences of the region (Tsiokha et al., 2003; Komornyi el al., 2004). The Subbotina, Abikha and Pivdennokerchenska features were considered as the most prospective .

Mass media in Ukraine report that the Subbotina feature is an oil field. Drilling of holes is in progress to determine its reserve..



3-D STRUCTURAL MODEL AND LAYERS DENSITY FOR THE SEDIMENTARY COVER

Information for the model is from (Tugolesov et al., 1985 and Tsokha et al., 2003). Depths are in km.

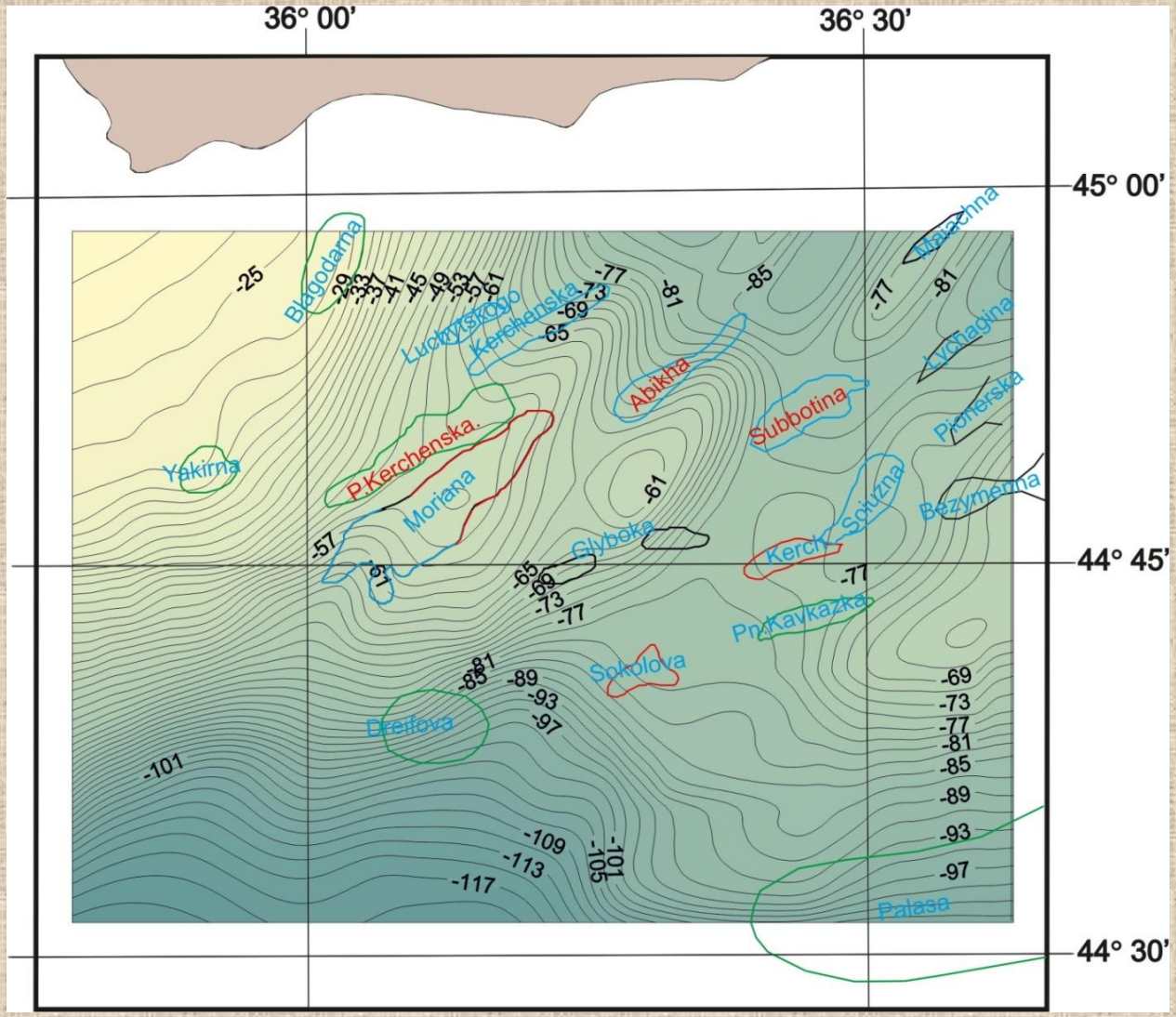
(a) Sea bottom topography
(b) Depth to the top of the Maikop series
(c) Depth to the bottom of the Maikop series
(d) Depth to the top of the Upper Cretaceous layer
(e) Depth to the top of the consolidated crust

Data for density values are from (Starostenko et al., 2003). Density is in g cm^{-3}.

(a) Water (1.03);
(b) Pliocene –Quaternary sediments (1.87-2.17)
(c) Maikop series (2.34);
(d) Eocene-Paleogene (2.57);
(e) Cretaceous (2.64);

Density contrast of each layer was calculated relative to the reference value of 2.68. Our 3-D gravity approach is described in detail in Tectonophysics (Starostenko et al., 2004).

COMBINED GRAVITY EFFECT OF WATER AND SEDIMENTARY LAYERS

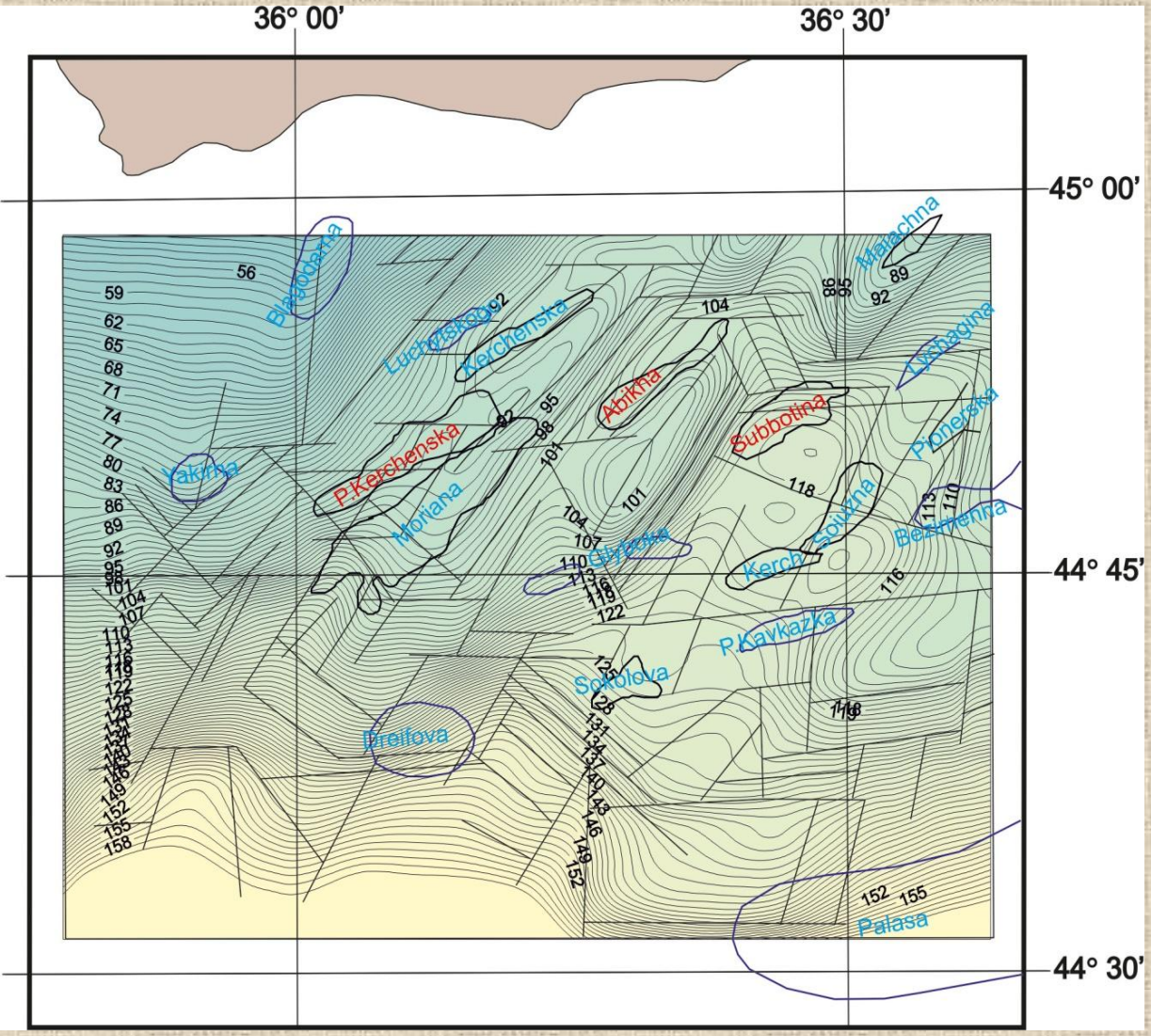


Scale 1:200,000
Contour interval is 2 mGal

A total gravity effect of water, sedimentary cover and mantle was calculated to discriminate the crustal component of the observed field (Starostenko et al., 2004).

Most sedimentary features are marked by negative anomalies (e.g. Subbotina, Moriana, Abikha) or are located in the gradient zones (e.g. Palasa, Dreifova, Yakorna,. The Kerch, Sokolova, NE Moriana features are registered by positive anomalies of low intensity.

RESIDUAL GRAVITY FIELD AND ELEMENTS OF ITS DISTORTIONS IDENTIFIED AS FRAGMENTS OF FAULTS



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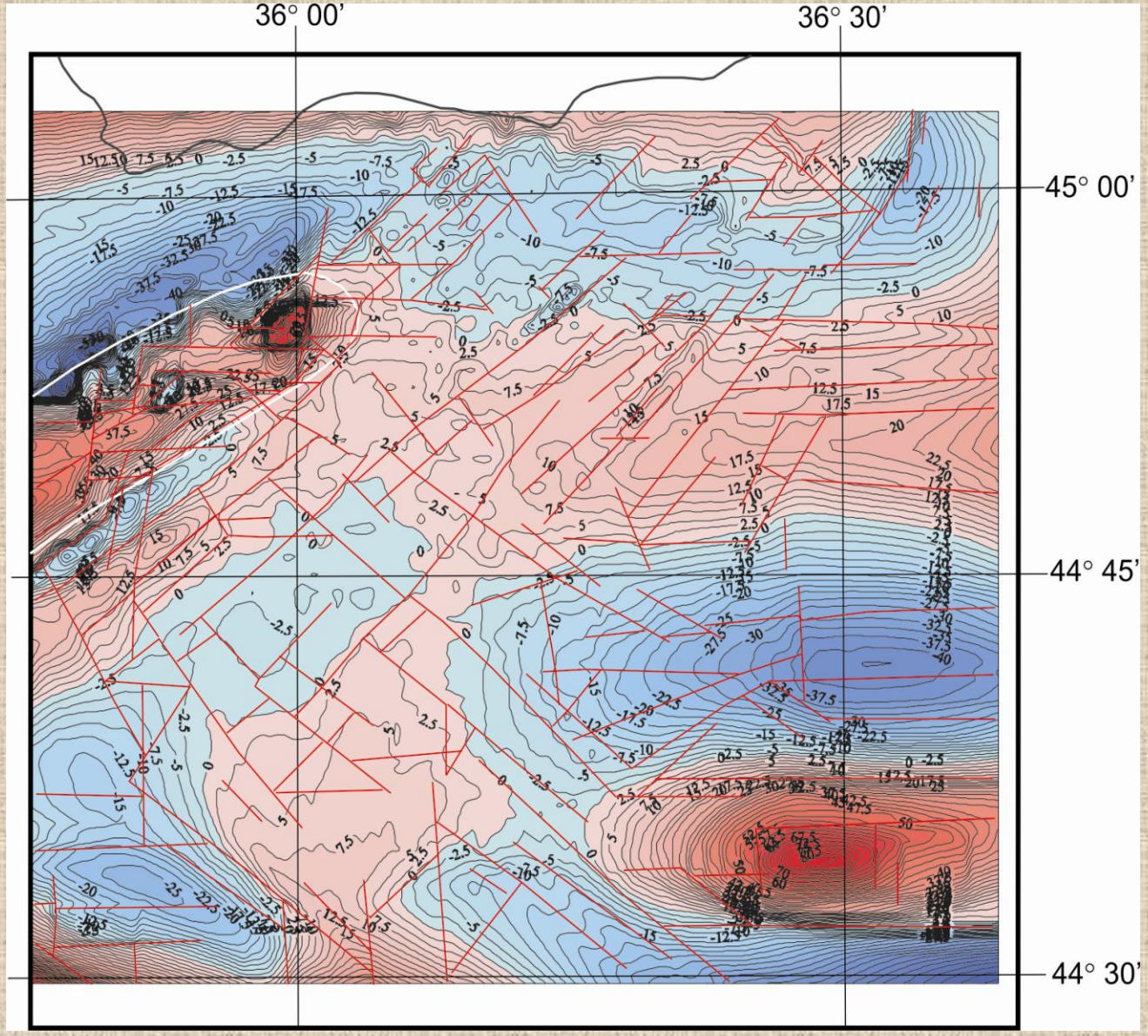
Contour interval is 2 mGal

The residual gravity component of the consolidated crust was obtained by removing the combined gravity effect from the observed field.

The horizontal-gradient method was used to discern steep gradients (e.g. Smith et al., 2002; Starostenko et al, 2005; Aryamanesh, 2009).They are identified as fragments of faults and shown by straight lines in black.

Most sedimentary features are located in the gradient zones (e.g. P. Kavkazka, Dreifova, Blagodarna, Yakirna, Palasa)

LOCAL COMPONENT OF THE GEOMAGNETIC FIELD AND ELEMENTS OF ITS DISTORTIONS IDENTIFIED AS FRAGMENTS OF FAULTS

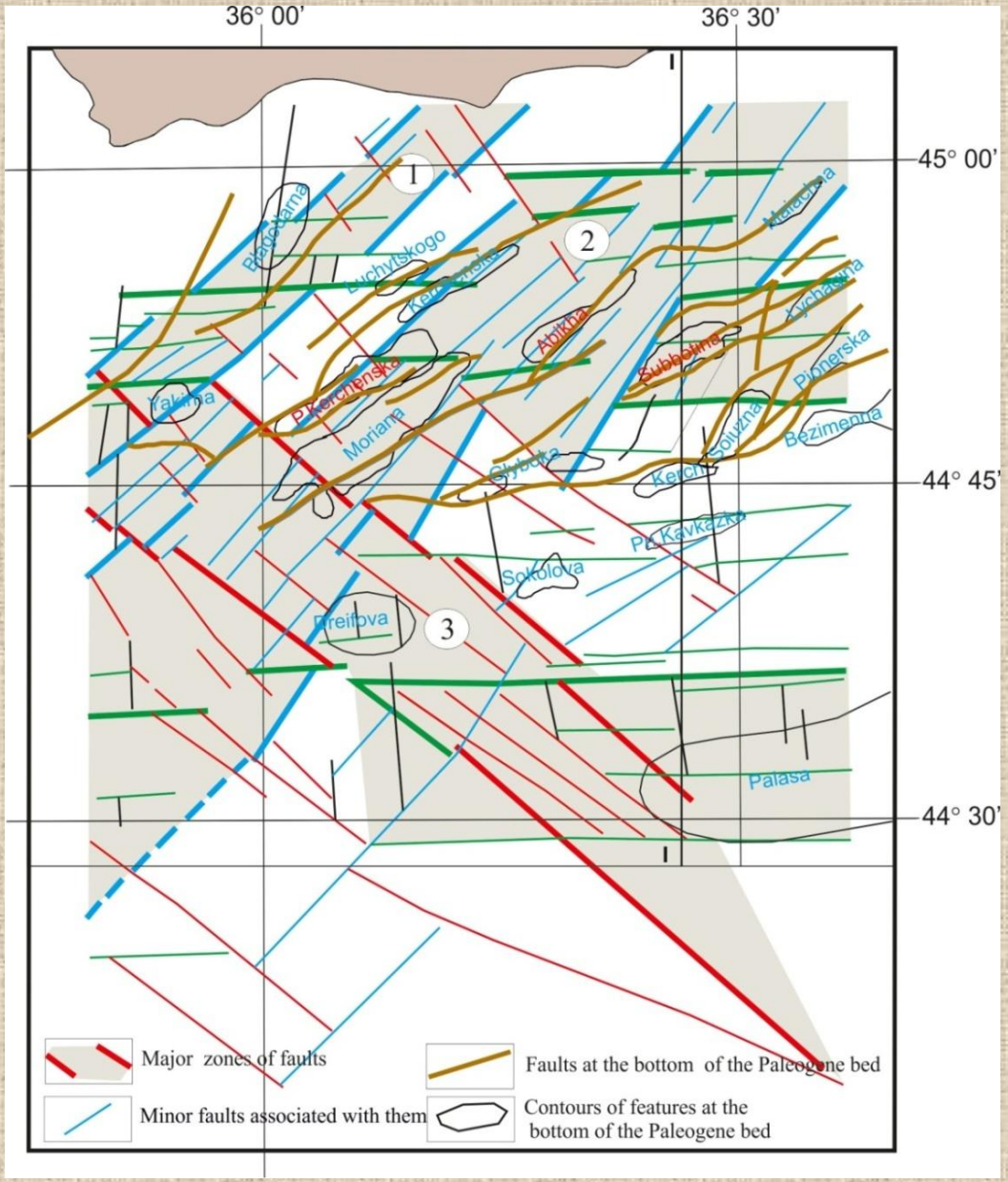


Scale 1:200,000
Contour interval is 2.5 nT

The local component was obtained by removing the regional field from the observed field. The horizontal-gradient method was also used to discern steep gradients.
The steep gradients are identified as the fragments of faults and shown by straight lines in red.

FAULTS OF THE CONSOLIDATED CRUST

Scale 1:200,000



The integrated interpretation of the gravity and magnetic gradients resulted in the diagonal and orthogonal systems of the faults. The faults have mainly NE and NW strike respectively. There are several faults of the latitudinal strike.

Three large zones of the faults are recognized:

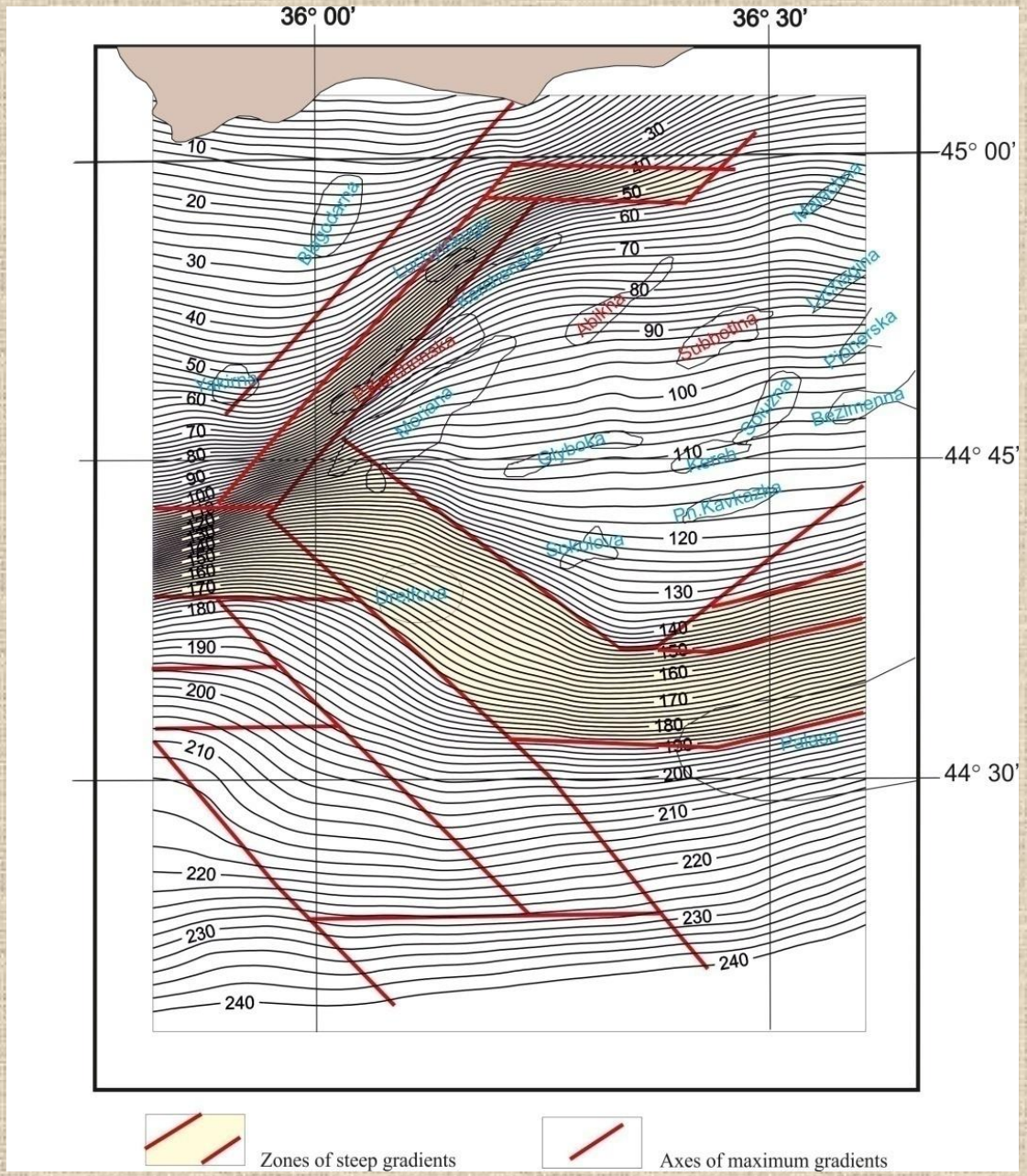
the Uzurlasko- Gornostaivska zone with NE strike has a width of ca.7 km (1);

the Pravdynska zone with NE strike has a width of 10-20 km (2);

the Molbaiska zone with NW strike has a width of 10-15 km (3).

The strike of the faults at the bottom of the Paleogene layer is controlled by the diagonal system. It implies that younger faults inherited the older tectonic pattern.

REGIONAL RESIDUAL GRAVITY FIELD OF THE SEDIMENTARY COVER



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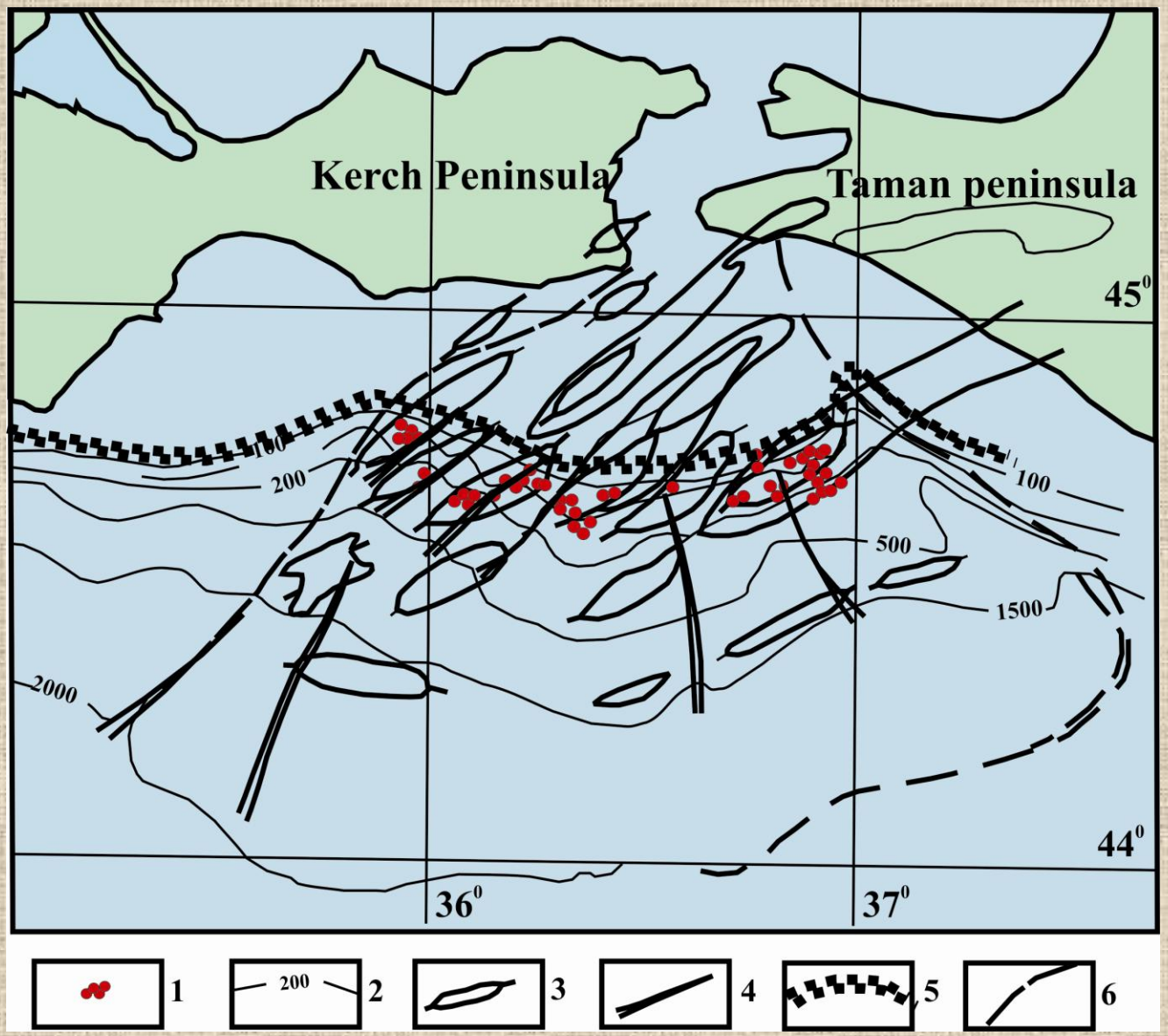
Contour interval is 2 mGal

3-D regional model was obtained to discern the regional peculiarities of the fault tectonics and its relationship with the gradient zones. Only the Blagodarna, Dreifova, Palasa and NW P. Kerchenska features are located in the gradient zones. The rest of the features are undoubtedly situated within the block bounded by the steep gradients of the residual gravity field.

We named it the Mithridates block.

GAS SEEPS AND SUBMARINE CANYONS



Scale 1: 200,000

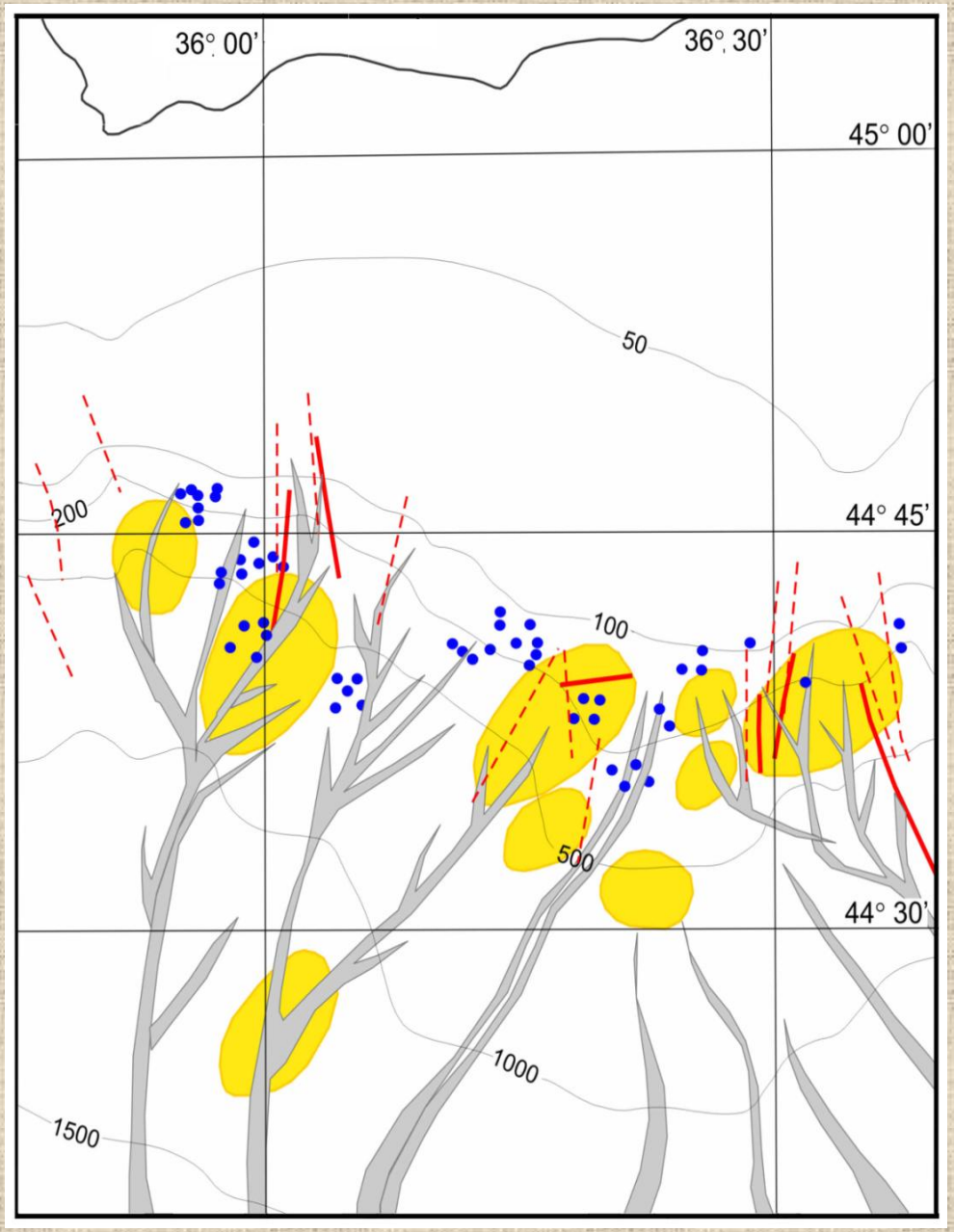
1. gas seeps;
2. isobaths;
3. local uplifts;
4. submarine canyons;
5. shelf-continental slope boundary;
6. area of the buried paleo-Don fan.

Data are from Shiukov et al., 2003.

INFORMATION 1. Over 75% of the world's hydrocarbon basins contain surface seeps *(Clarke & Cleverly, 1990; Clayton et al., 1991).*

INFORMATION 2. The gas reserves in the sediments of the Nile fan are estimated to be 80 trillion m^3 (Melnikov & Rachevskii, 2000)

GAS SEEPS AND AND ABNORMALLY GAS-SATURATED DEPOSITS



Scale 1:200,000

gas seeps;

submarine canyons;

500 isobaths, m;

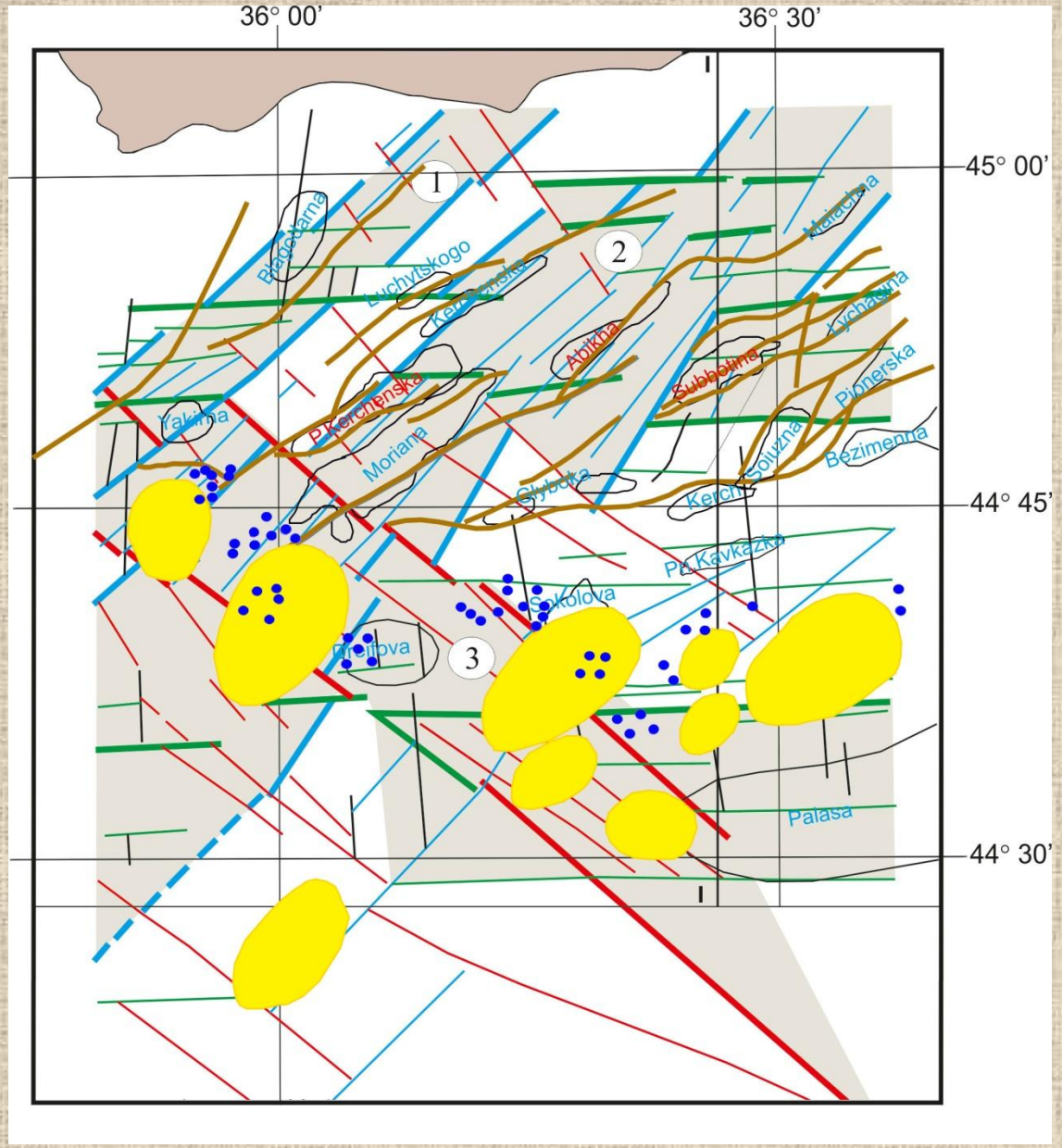
gas (methane) in deposits;

tectonic faults;

neotectonic disruptions

Gas seeps are from Shiukov et al., 2003. Contours of gas-saturated deposits are from Shimcus et .al., 1998. The gas (methane) content is 0.1-1.0 ml per 1 kg of sediment.

CRUSTAL FAULTS, GAS SEEPS AND ABNORMALLY GAS SATURATED DEPOSITS



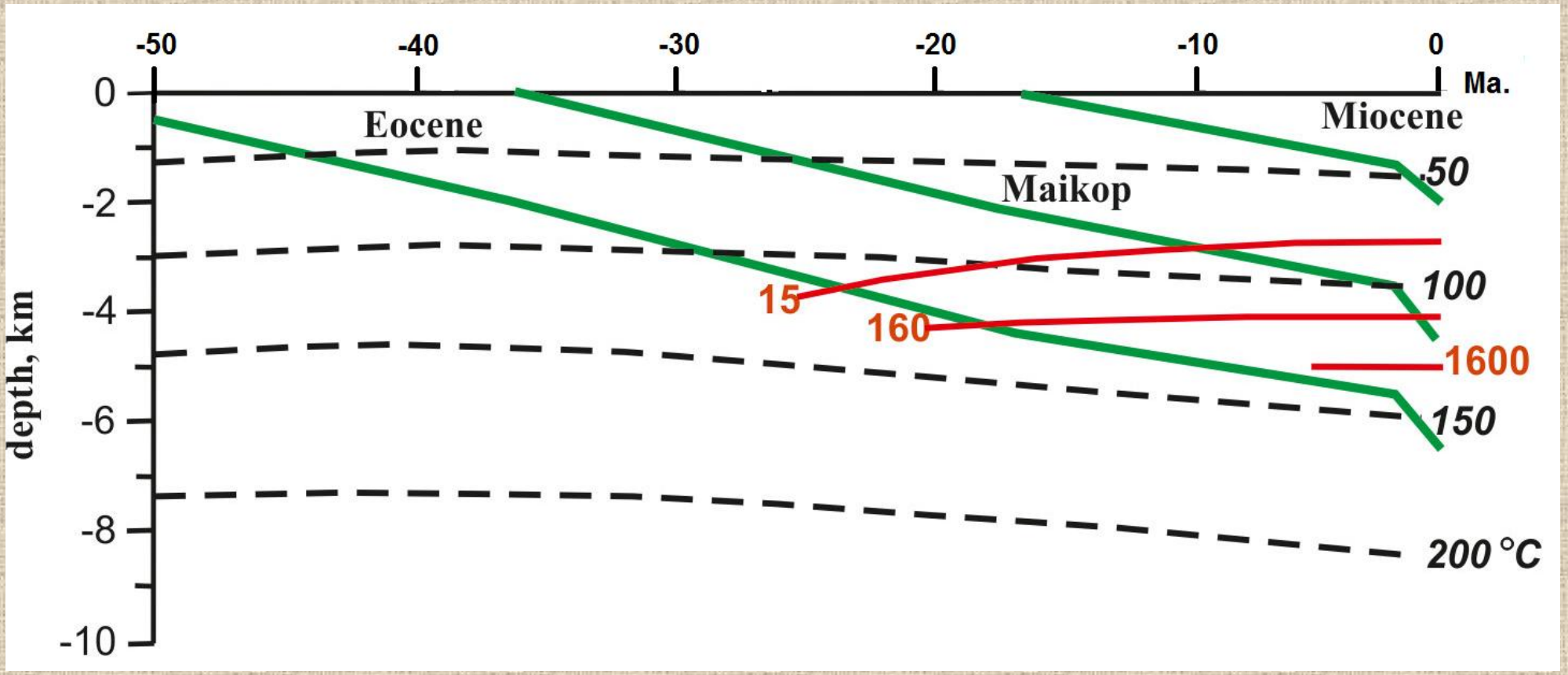
Scale 1:200,000

- Major zones of faults
- Minor faults associated with them
- Faults at the bottom of the Paleogene bed
- Contours of features at the bottom of the Paleogene bed
- Gas seeps
- Gas (methane) in deposits

Gas seeps and abnormally gas saturated deposits are localized in the zones of the deep gradient, crustal faults of NE and the EW strike as well as within the buried Don fan.

Collectively these observations allow us to recommend the belt on the upper continental slope as a new potential hydrocarbon area.

THERMAL EVOLUTION OF THE PALEOGENE AND NEOGENE SEQUENCES



stratigraphy boundaries

isotherms

isolines of TTI (based on the Lopatin's метнод)

Based on the temperature-time indices (TTI) in the Mithridates block, the most favourable conditions for oil generation are in the Upper Eocene and Lower Maikop sequences. These calculations are supported by a presence of oil in core samples of similar age from the Subbotina feature (Gladun et al., 2008). As for gas, it can be mostly generated in the Upper Cretaceous and Eocene sediments.

MAJOR CONCLUSIONS

✓ For the first time there is a map of faults at a scale of 1:200,000 for the consolidated crust on the northeastern shelf of the Black Sea;

✓ tectonic distortions in the sedimentary layers are controlled by the faults in the consolidated crust;

✓all potentially hydrocarbon uplifts are localized within the Mithridates autonomous block at the junctions of the faults of the different orders with the northeastern and sublatitudinal strikes;

✓ the faults serve as channels of vertical-migrating hydrocarbon;

✓ the zone on the uppermost continental slope is recommended as a new large hydrocarbon prospective area;

✓ due to the thermal regime in the Mithridates block, the Upper Eocene and Maikop sequences are favourable for oil generation while the Eocene and the Upper Cretaceous — for gas generation.

THANK YOU FOR ATTENTION