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Geodynamic Processes of the Southern Margin of the Eastern European Platform in the Phanerozoic

Kostiantyn Andriiovych Bezruchko[1]*, Ludmyla Ivanivna Pymonenko[1], Nataliia Victorivna Vergelska[2], Andriy Anatoliiovych Karhapolov[1]

[1]*Poliakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine, Dnipro, Ukraine*
[2]*State Institution «Scientific Center of Mining Geology, Geoecology and Infrastructure Development» of the National Academy of Sciences of Ukraine, Ukraine*

INFORMATION

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Contact
*Kostiantyn Andriiovych Bezruchko
bkaigtm@gmail.com

ABSTRACT

Geodynamic processes occurring during the formation and transformation of geological structures significantly determine their tectonic structure, characterize the presence and spatial distribution of mineral deposits. In this regard, the features of the geodynamic processes of the southern margin of the East European Platform (EEP) in the Phanerozoic are of scientific and practical interest. The analysis of the lithological and stratigraphic conditions for the formation of the main geological structures in the southern part of the EEP – Dobrogea, Caucasus, Crimea, and Donbas was carried out. The analysis is based on the mobilist concept of global tectonics. Comparison of the main stages in the development, geodynamic processes, and the mechanism of formation of the main structures of the EEP (Dobrogea, Crimea, Caucasus, Donbas) in the Phanerozoic attested to the general patterns in the formation and development of these structures. A characteristic feature in the structure of the considered structures is the shift of the axis of young basins to the northeast. The formation of such structures is possible only as a result of the periodic action of horizontal compressive forces with a significant shearing component. The well-known mechanism for the formation of back-arc marginal basins formed on the active margins of lithospheric plates as a result of subduction corresponds to the established regularities in the formation of structures. The periodic underthrusting of the oceanic plate led to a restructuring of the structural plans and a change in the temperature conditions of the researched regions. This has affected the features of the spatial distribution of oil-and-gas-promising areas. The data obtained will allow expanding the area and optimizing the search process for such areas.

1. Introduction

The formation, accumulation, and subsequent distribution of minerals in the Earth's interior are inextricably linked with the geodynamic evolution of the geological environment. Geodynamic processes occurring during the formation and transformation of geological structures significantly determine their tectonic structure, characterizing the presence and spatial distribution of mineral deposits. In this regard, the features of geodynamic processes of the southern margin of the EEP in the Phanerozoic are of scientific and practical interest.

The lithofacies conditions of sedimentation and tectonic features of various structures of the southern margin of the EEP are described in sufficient detail. But, despite extensive geological research of this region, there is practically no exact correlation of tectonic movements within its boundaries.

Issues of the generality of geodynamic processes and the time of their occurrence during the formation of individual structures are discussed, for example, a possible connection between the tectonics of the Donbas and the geodynamics of the Mediterranean region. So, Sborshchikov (1988) associates the activation of subduction processes in the region with the Old Cimmerian, New Cimmerian, and Laramian phases; Shengor (1993) – Saale, Old Cimmerian, and

Laramian; according to Zakharchuk (1990), the most significant role in the formation of the region was played by the Austrian, Subhercynian, Styrian, and Don phases. The main obstacle to determining the time of activation of tectonic processes in various structures is the insufficiency and spatial unevenness of geological information.

The purpose of the paper is to analyze the geological structure and conditions for the formation of structures located in the south of the EEP in the Phanerozoic.

2. Methodology

Analysis of the lithological and stratigraphic conditions for the formation of the main geological structures on the southern margin of the EEP – Dobrogea, the Caucasus, the Crimea, and the Donbas. Comparative analysis of the main stages of their development, sedimentation conditions, magmatic processes and the time of formation of these structures in the Phanerozoic.

3. Geology and Structural Setting of Study Area

In our opinion, at present, the model of the formation of this region, proposed in the work of Stupka (1986) and based on the mobilist concept is the most reasonable.

According to Stupka (1986), in the Paleozoic-Mesozoic, the southern margin of the EEP was the continental slope of the Tethys Ocean, broken up into separate blocks by long-lived submeridional faults. Due to movements along faults, basins were formed in which marine, coastal, and lagoonal-continental deposits accumulated. The convergent processes that took place in the Tethys caused uneven pressure on the basement blocks in space and time resulting in the features of the structures of the southern margin (Fig. 1).

Fig. 1. Scheme of the structures on the southern margin of the Tethys

Dobrogea is the only structure in which the Caledonian (Baikalian), Variscian (Hercynian), Cimmerian, and Alpine tectogenesis manifested itself (Vergelska at al., 2020). In the Crimean region, the movements of Alpine tectogenesis were most fully exercised. Separate data on the manifestations of the Hercynian and Cimmerian tectogenesis are noted in the structures of the Crimea, the Caucasus, and the Peri-Caspian Depression. Analysis of data on lithology, stratigraphy, and tectonics of these structures will allow clarifying the time, direction, and nature of the forces acting in the region, and establishing their connection with the tectonics of Donbas.

The Dobrogea folded structure is located southwest of the EEP (Trofimenko and Gerasimov, 1991; Larchenkov, 1991). The Baikalian, Hercynian, and Cimmerian tectogenesis manifested themselves in this area. At the same time, traces of each tectonic stage appeared in certain zones (from south to north):

- Baikalian–Mysian massif;
- Hercynian–lower (Machin) and upper (carapelite) subzones;
- Cimmerian–lower (Tulcha), middle (Nalband flysch trough) and upper (Pre-Dobrogea trough) subzones.

The Mysian massif in tectonic terms is a horst bounded from the south and north by regional long-lived, steeply dipping reverse thrusts. The tectonics of the basement is very complex: in the northwestern part, the greenschist strata are crumpled into a system of steep (sometimes overturned) fan-shaped diverging northwest-trending folds with dip angles of 60 – 80°, complicated by folds of higher orders. In the southeastern part, the axes of the folds have an east-northeast strike, and the inclination of their limbs decreases, which is explained by their immersion in the east direction, where the periclinal closure of the folded structure was located.

The rocks of the Hercynian stage of folding are exposed within the Machin subzone, which is divided into the northwestern, where the Paleozoic basement is exposed, and the southeastern (Babadag), reflecting the structure of the Cretaceous cover. The general strike of the folded structure is northwest (310 – 320°). It has the form of a fan-shaped anticlinorium and is characterized by narrow, linearly elongated folds torn by longitudinal ruptures. The folds are inclined to the Northeast at an angle of 80°. This indicates the preservation of the direction of action of horizontal forces in the Paleozoic, but smaller in absolute value.

To the north is the PreDobrogea trough, which is a graben limited by faults and having a southeast strike. The trough is made up of sediments from the Upper Proterozoic (Vendian) to the Neogene inclusive, the thickness of which exceeds 5000 m. In tectonic terms, it represents a structure thrust over the EEP along an arcuate zone (Larchenkov, 1991). The trough is asymmetric: the southern wing is steeper, the northern one is flatter. The Pre-Jurassic basement of the depression is a “bath” with a flat bottom, judging by geophysical data.

The Jurassic deposits filling this bath were folded into gentle brachifolds elongated in a southeasterly direction in the late Cimmerian phase. The deposits of the PreDobrogea trough are broken by faults of various orders and directions: northwestern (310 – 320°), submeridional, and sublatitudinal prevail. The available data indicate active displacement movements along the faults that occurred during the formation of the region (Stupka, 1986). Within the formed horsts and grabens, the deposits are strongly dislocated: narrow, sometimes overturned, folds of the longitudinal type are elongated in the northwest direction (310 – 320°) and are disturbed by breaks and folds of smaller orders.

The identified structures differ in the type of sediments and their thickness, but common features can be noted in their structure:

- direction of strike (310 – 320°) of folds,
- the nature of folding – systems of steep (sometimes overturned) fan-shaped diverging folds of the longitudinal type with dip angles of 60 – 80°, complicated by folds of higher orders,
- displacement of axes of younger troughs to the northeast,
- fault planes of regional faults of the northwest strike, separating individual structures, dip to the southwest and
- intensity of folding of younger deposits decreases to the northeast.

4. Results and Discussions

The analysis of lithological and tectonic data made it possible to establish the relationship between the formation of the structures in the region, which manifests itself during the strongest tectonic phases:

- the Breton (D_3/C_1) - underthrusting of the Moesian Plate under the southwestern part of the EEP led to the fact that during the rise of the southern part of the Machin zone, the deposits accumulated in it were brought to the surface, simultaneously, in the northeastern part of the region, the rate in accumulation of sedimentary deposits increases – Suite "Karapelit";
- Sudeten phase (C_1/C_2) – uplift and erosion of deposits of the Mysian horst → folding (Machin anticlinorium) → laying of a trough in the Tulchi subzone → change in sedimentation conditions (marine conditions changed to continental ones) in the Pre-Dobrogea trough;
- Donetsk (J_1/J_2) – uplift and erosion of sediments in the Machin zone → folding in the Tulcea subzone → laying of Pre-Dobrogea trough.

This relationship indicates a single mechanism for the formation of troughs. Such a mechanism is characteristic of back-arc marginal basins formed on the active margins of lithospheric plates as a result of subduction (Isacks at al., 1968; Malkin and Shemenda, 1989; Zonenshain and Kovaleva, 1974). Theoretically (Lyashkevich 2000), this process is accompanied by magmatic phenomena of felsic composition in the south and intermediate in the north, which is consistent with the available data.

The established common features indicate the formation of the tectonics of the region as a result of the periodic action of compressive forces directed from the southwest to the northeast (Fig. 2).

By analogy with Dobrogea, the following tectonic cycles of the formation of the Crimean Peninsula are identified:

- Tauride trough – accumulation of sediments ($P_2?+T_{2+3}+J_1$) → beginning of rise (T_3 / J_1) → folding (J_1 / J_2);

– Jurassic trough - accumulation of sediments (J_{2+3}) → beginning of rise (J_3) → folding (J_3 (Tithon));
– Cretaceous trough – accumulation of sediments (J_3 (Tithon) + K_{1+2}) → beginning of rise (K_2) → folding (K_1/₽).

According to the nature of sedimentation, the same tectonic cycle can be distinguished in the formation of Donbass as for Dobrogea and Crimea – Paleozoic basin – accumulation of sediments (D+C+P_1) → beginning of rise (C_3 / P_1) → folding (P_1 / P_2) – (Fig. 3), which indicates the unity of the external global forces that caused them.

Based on the lithological-stratigraphic and tectonic conditions of Dobrogea and the Crimean Peninsula, the following general patterns of these structures are established (Lukinov and Pymonenko, 2008):

– sedimentary deposits in the Paleozoic troughs are crumpled into steep isoclinal (often overturned) folds of the northwest strike; in the Mesozoic, the folds are simpler and larger, but their strike is preserved (the exception is the folds on the southern coast of Crimea), which indicates the preservation of the direction and nature of the acting forces;
– at the base of the accumulated sediments there are conglomerates, gravelstones, coarse-grained arkosic sandstones, igneous rocks, and above – limestones, which characterizes the general pattern of sedimentation for these regions; the accumulation of coarse-grained rocks indicates a rapid – "failed" – immersion;
– folded processes were mainly accompanied by magmatic phenomena;
– the laying of each subsequent trough occurs in the same tectonic phase as the folding of the previous one; the troughs are subparallel, they strike northwest, and the axes of the younger ones are shifted to the northeast (in the direction opposite to the direction of the acting forces);
– similar tectonic cycles have the following stages: sediment accumulation → uplift → folding (Table 1).

Comparing the time in the formation of the troughs in the Dobrogea and Crimea indicates the simultaneity of the main Mesozoic regional stages. Therefore, by analogy, it can be assumed that the Paleozoic stages identified in Dobrogea are also characteristic of other structures located on the southern margin of the EEP in the Phanerozoic (Table 1).

According to the conditions of sedimentation, the same tectonic cycle was identified in the formation of Donbas as for the Dobrogea and Crimea – the Paleozoic basin – sediment accumulation (D+C+P_1) → inversion of the tectonic regime (C_3/P_1) folding (Saale phase) → initiation of the Mesoic trough (Pfalzian phase).

The Donbas has the same structure: according to geophysical data, the axis of the Riphean graben is shifted to the southwest from the axis of the Paleozoic, the Mesozoic - to the northeast (Mesozoic trough). The deflection axes are subparallel (Lukinov and Pymonenko, 2008).

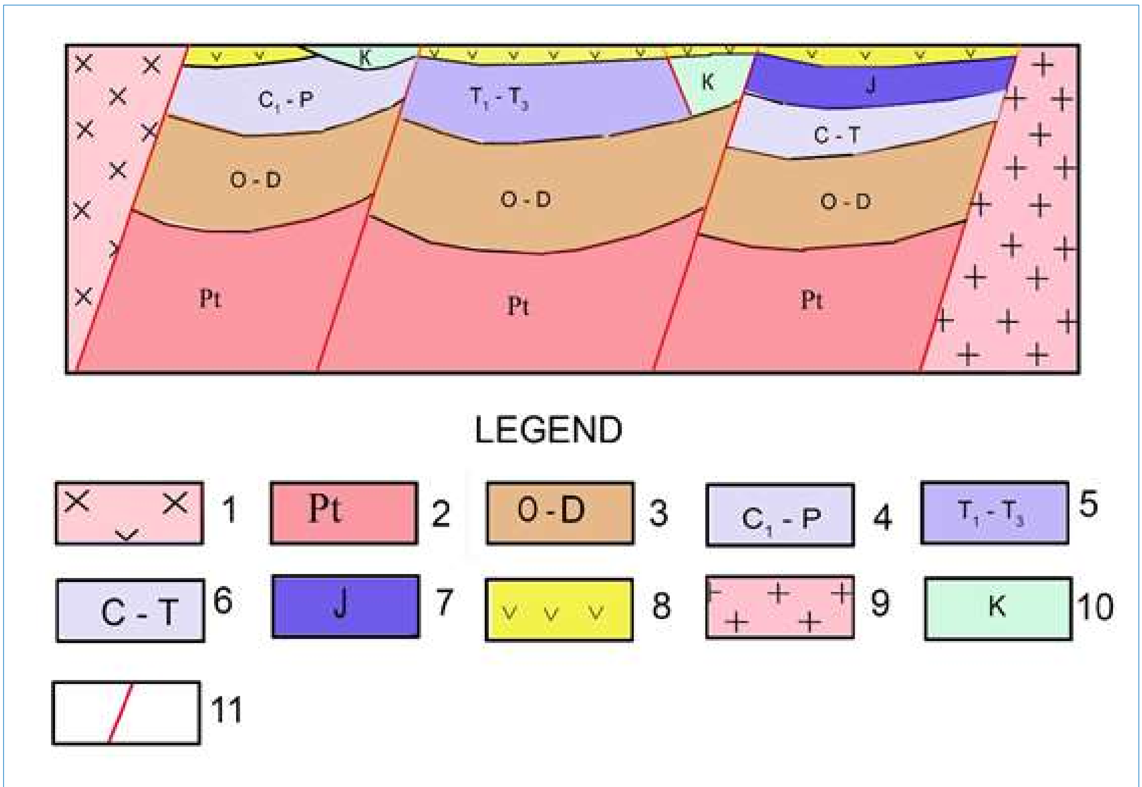

Fig. 2. Schematic diagram of the formation of Dobrogea: 1 – Mysian massif; 2 – crystalline foundation; 3 – Paleozoic deposits; 4 – "karapelite" deposits; 5 – Triassic deposits; 6 – deposits of the Upper Paleozoic; 7 – Jurassic deposits; 8 – Neogene deposits; 9 – EEP; 10 – Paleogene deposits; 11 – discontinuous dislocations

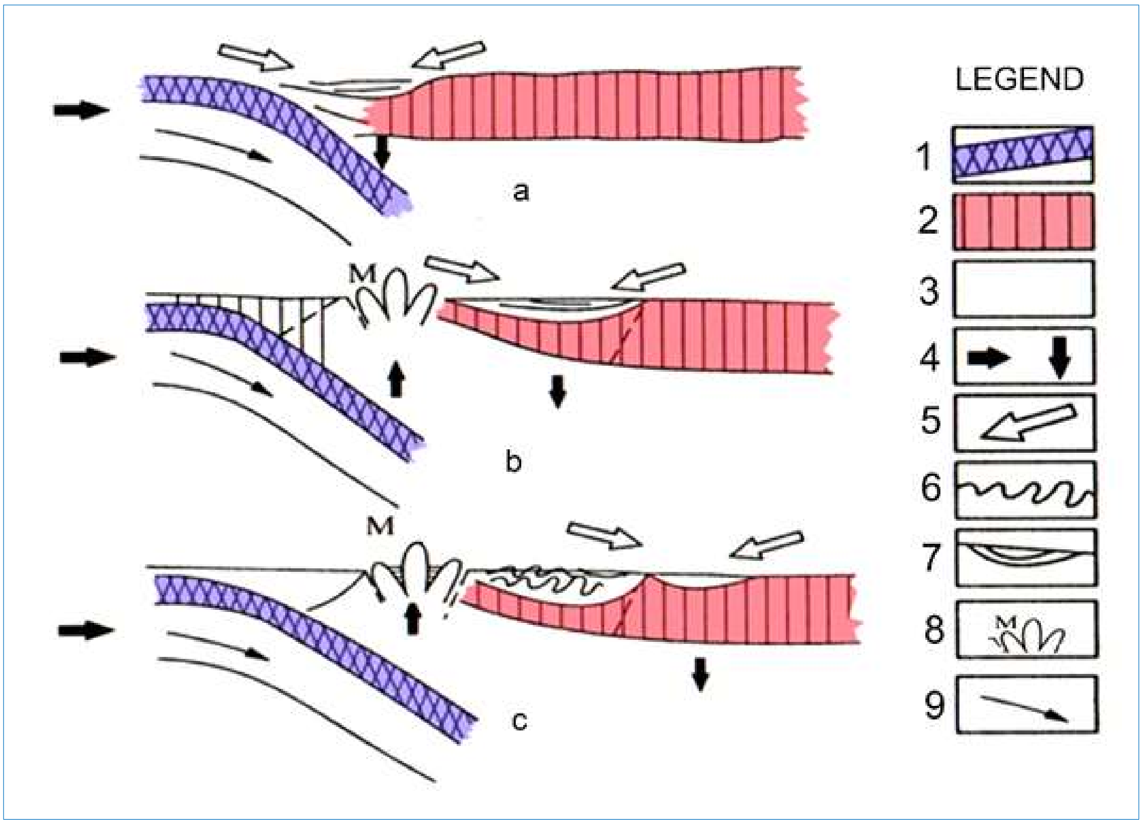

Fig. 3. Stages in the formation of the Dobrogea structure: *a* – accumulation of sediments in the Machin subzone; *b* – accumulation of "karapelite" deposits; *c* – accumulation of Jurassic deposits; 1 – oceanic crust; 2 – continental crust; 3 – mantle; 4 – the direction of movement of foundation blocks; 5 – direction of sediment drift; 6 – discontinuous and folded dislocations; 7 – sedimentary basin, 8 – Mysian massif; 9 – the direction of movement of lithospheric plate

Table 1. The main phases of the folding of structures in the south of the EEP

Tectonic phases	Dobrogea	Crimea	Caucasus
Sudeten (C_1/C_2)	Machin Zone - steep folds formation in NW strike, volcanism	No information available	Greater Caucasus - folding, charriage with the shearing component, volcanism; Svanetian anticlinorium - formation of steep sublatitudinal folds
Saale (P_1/P_2)	Karapelite trough - formation of steep folds of northwest strike, volcanism	Alma window - formation of steep folds of north-western strike	Ciscaucasia - intense folding, Dagestan - formation of folds of sublatitudinal strike; change in strike azimuths of fault planes of ruptures (96° на 139°)
Pfalzian (P_2/T_1)	Laying of the Triassic trough, activation of movements along submeridional faults, volcanism	No Lower Triassic deposits	Inversion in the Eastern Ciscaucasia (Karpinsky swell), intense folding
Ancient Cimmerian (T_3/I_1)	Folding in the Nalband graben, volcanism	Tectonic unconformity	Uplift and denudation of pre-Jurassic deposits
Donetsk (I_1/I_2)	Tulchinsky trough - folding, volcanism	Tauride trough - folding (in the west - northwest strike, in the south - northeast), volcanism	From west to east, a decrease in thickness (from 1000 m to 100 m) and sediment type
New-Cimmerian (I_3/K_1)	Pre-Dobrogea trough - formation of folds of northwestern strike	Jurassic trough - formation of NE-trending folds, volcanism, strike-slip movements	Western Ciscaucasia, - folding; Dagestan - folding (Adyghe phase)
Laramide (K_2/₽)	Babadag trough - folding	Cretaceous trough – folds formation of northwest strike	Adyghe ledge - slight folding, inversion

5. Conclusions

Comparison of the main stages of development, tectonics, sedimentation conditions, magmatic processes, and the mechanism in the formation of the main structures of the EEP (Dobrogea, Crimea, Caucasus, Donbas) in the Phanerozoic showed the general patterns in the formation and development of these structures. The same mechanism and time of formation of these structures, the same type of folding and its parameters reflect the global nature and similarity of the geodynamic processes that took place in the Phanerozoic in the Tethys.

A characteristic feature of the structure of the considered structures is the shift of the axis of young basins to the northeast. The formation of such structures is possible only as a result of the periodic action of horizontal compressive forces with a significant shearing component. The established regularities in the formation of structures correspond to the well-known mechanism for the formation of back-arc marginal basins formed on the active margins of lithospheric plates as a result of subduction.

The periodic underthrusting of the oceanic plate led to a restructuring of the structural plans and a change in the temperature conditions of the researched regions. This has affected the features of the spatial distribution of oil-and-gas promising areas. The data obtained will allow expanding the area and optimizing the search process for such areas.

Conflicts of Interest

The authors hereby state that they do not have any conflict of interest.

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