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**GEOLOGICAL PALEOOCENOGRAPHY OF FORE-DOBRUDJA SEGMENT OF TETHYS IN DEVONIAN**

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**ГЕОЛОГІЧНА ПАЛЕООКЕАНОГРАФІЯ ПЕРЕДДОБРУДЗЬКОГО СЕГМЕНТУ ТЕТИСА У ДЕВОНСЬКИЙ ЧАС**

Geological-paleoceanographic situations of Devonian sedimentation within Fore-Dobrudja segment of Paleotethys have been considered. It has been shown that subsidence and cold climate caused terrigenous sedimentation predominance in Early Devonian with local progress of organogenic carbonates. Ascendant tectonic movements and aridization of climate in Middle – Late Devonian caused sulphate-carbonate depositions of cyclic structure in half-isolated basins, fixed by changes of relative level of the ocean.  
*Keywords:* Paleotethys, Dobrudja Foredeep, sedimentogenesis, sedimentation environment.

Розглянуті геолого-палеоокеанографічні ситуації девонського осадоагромадження в межах Переддобрудзького сегменту Палеотетиса. Показано, що субсиденція та холодний клімат зумовили переважання у ранньому девоні теригенної седиментації з локальним розвитком органогенних карбонатів. Висхідні тектонічні рухи та аридизація клімату у середньому-пізньому девоні спричинили нагромадження у напівоізованих водоймах сульфатно-карбонатних утворень циклічної будови, що визначалося коливаннями відносного рівня моря.  
*Ключові слова:* Палеотетис, Переддобрудзький прогин, седиментогенез, обстановка седиментації.

**INTRODUCTION**

The nature of sedimentation is determined by the interaction of several factors of different levels: planetary climatic zoning, eustatic changes in sea level, regime of contemporaneous development of regional and local structural units quite clearly displayed within Fore-Dobrudja sedimentary basin. In Devonian the last one was situated in the equatorial zone (0 – 15° north latitude) in the north-eastern edge of Laurasia (Eide, EA (coord.), 2002). There was a part of a relatively narrow channel of north-eastern strike (over 1000 km), which was separated from the Paleo-Tethys Ocean with mountain ranges of folded structures of the West, East Pontides and Rhodope massif (Fig. 1).

**PREVIOUS STUDIES**

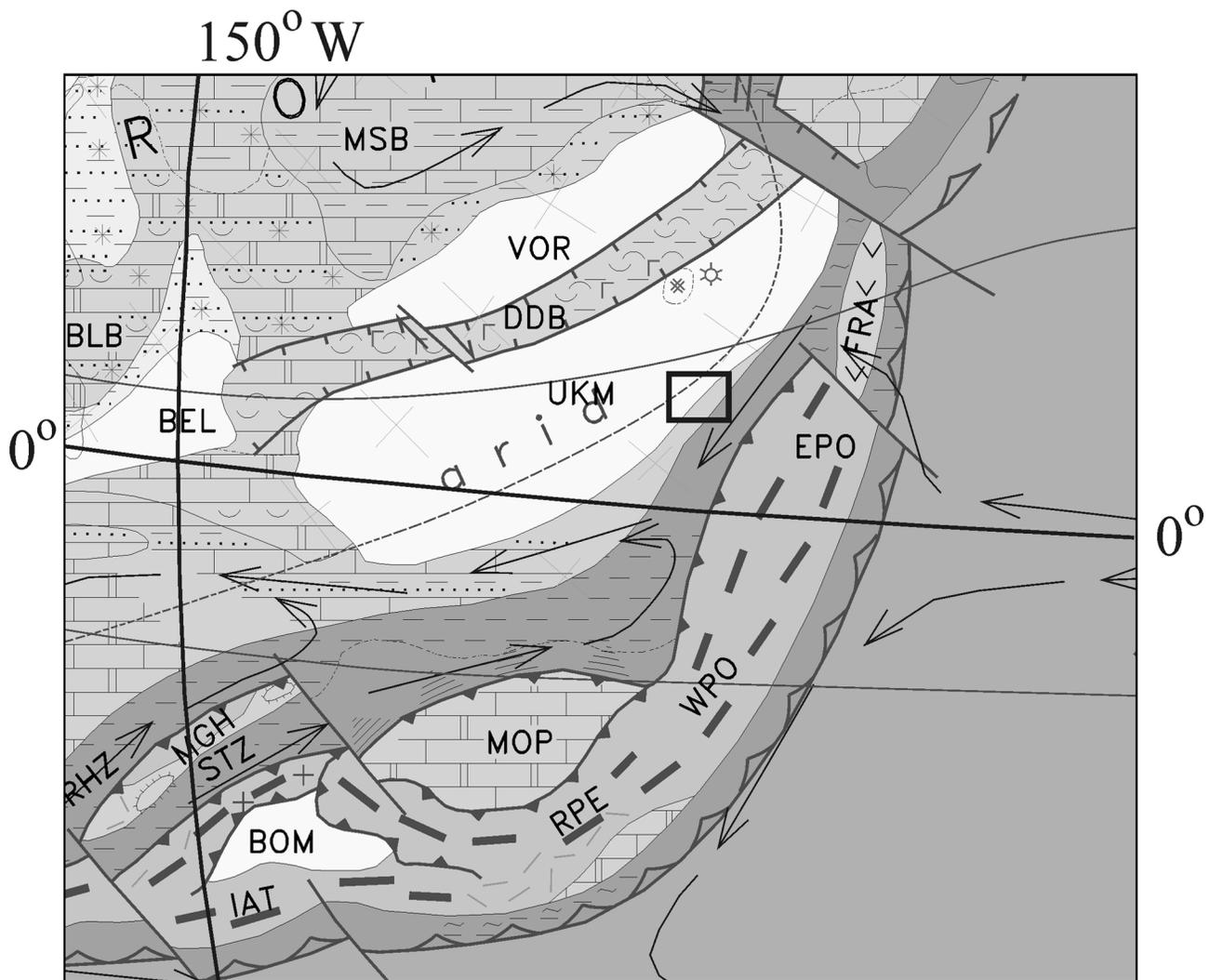
Climatic conditions of Devonian age were generally characterized by warm and arid climate, the existence of small temperature gradients between equatorial and polar zones (Joachimski, 2009). There used to be certain age change of paleo temperature conditions: minimum values inherent in the early Devonian (~ 20° C), they later increased to 30° C (Frasnian-Famennian). The Devonian period was characterized by a general sea level rise from the beginning to the end (Vail, 1977). At the same time against this background there used to be (Fig. 2) medium and small-scale fluctuations as a summing result of interaction of global and regional factors (Haq, 2008). In geodynamic terms, on the bound-

ary of Early and Middle Devonian, within the East European craton, was a change in tectonic regime: Middle-Late Devonian tectonic-sedimentation cycle began with upward movements (Nikishin, 1996).

Actually the factors above identified characteristics of Devonian sedimentation within Fore-Dobrudja basin.

Averaged curve of relative sea-level change within Fore-Dobrudja Devonian basin shows cyclicity (Hnidets et al., 2003). The most expressive moments of high sea level rise – is the middle of Eifelian, Givetian, the beginning and the end of Frasnian. The minimum sea level is observed at the beginning and the end of Eifelian late Givetian and mid Frasnian. It should be noted that these extremes (Fig. 2) coincide with some medium or small-scale fluctuations of global sea level change, indicating that, on the one hand, the dominant role (at certain times) eustatic fluctuations, and, on the other hand – the periodic significant impact of tectonic movements of local rank.

Thus, in general, during Eifel-Givetian sea level the different parts of Fore-Dobrudja basin changed conformably, at the end of Frasnian its differentiation is observed in different parts of the territory, indicating individualization of development of some structures at that time (Hnidets et al., 2003). The structure formed movements is confirmed by traces of Pre-Frasnian break in sedimentation, which is fixed, in particular, with the presence of speckled ironshot argillites and marlstone, breccoid limestones, which



**Fig. 1.** Fragment of paleoceanographic diagram. Middle Devonian. after (V. G. Kasmin, L. M. Natapov, 2000).

MSB – Moscow basin, BEL – Byelorussian high, VOR – Voronezh high, UKM – Ukrainian massif, FRA – Frontal Ridge Caucasus, EPO – East Pontides, WPO – West Pontides, MOP – Moesia Platform, RPE – Rhodopo-Pelagonian Massif, BOM – Bohemian Massif, MGH – Middle Germanys High, STZ – Saxo-Thuringian Zone, RHZ – Rhenohercynian Zone, IAT – Intoalpine Terranes. In rectangle – the territory of exploration.

contain fragments of umbel typical for underlie Frasnian sediments, in a number of holes in the bottom of Famennian sediments.

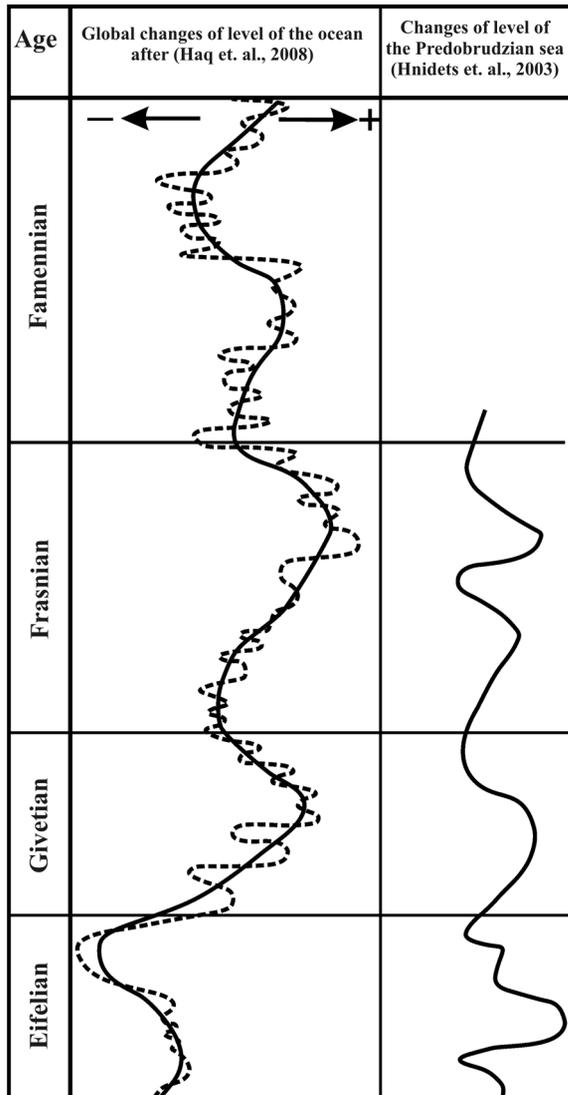
#### RESULTS

The nature of sedimentation of Early Devonian is probably determined, first of all, by global factors (low temperature, the dominance of the descending movements). This led to the formation, within Fore-Dobrudja basin, mainly terrigenous clay layers with the local development of organic carbonate formations on contemporaneous highs (Hnidets et al., 2014).

Warming and the ascendant movements in the beginning of Middle Devonian caused a marked

change in environments of sedimentation in Fore-Dobrudja basin. The same features were marked and for south-western part of the regional strait (eastern France, western Germany), where carbonate platform development is fixed and the inner shelf of carbonate-sulphate deposits formed in isolated lagoons (Garland, 1997).

Eifelian carbonate shelf (Fig. 3) occupied most of the territory of Dobrudja Foredeep and was mainly characterized by small (0-50 m) depth of basin and was divided into two sedimentation basins by narrow, highly elongated Orikhivsky-Suvorivsky-Zmiyina ridge of underwater surface lift. Shallow coastal-marine (inner shelf) environments of sedimentation dominated in the western open sea basin.

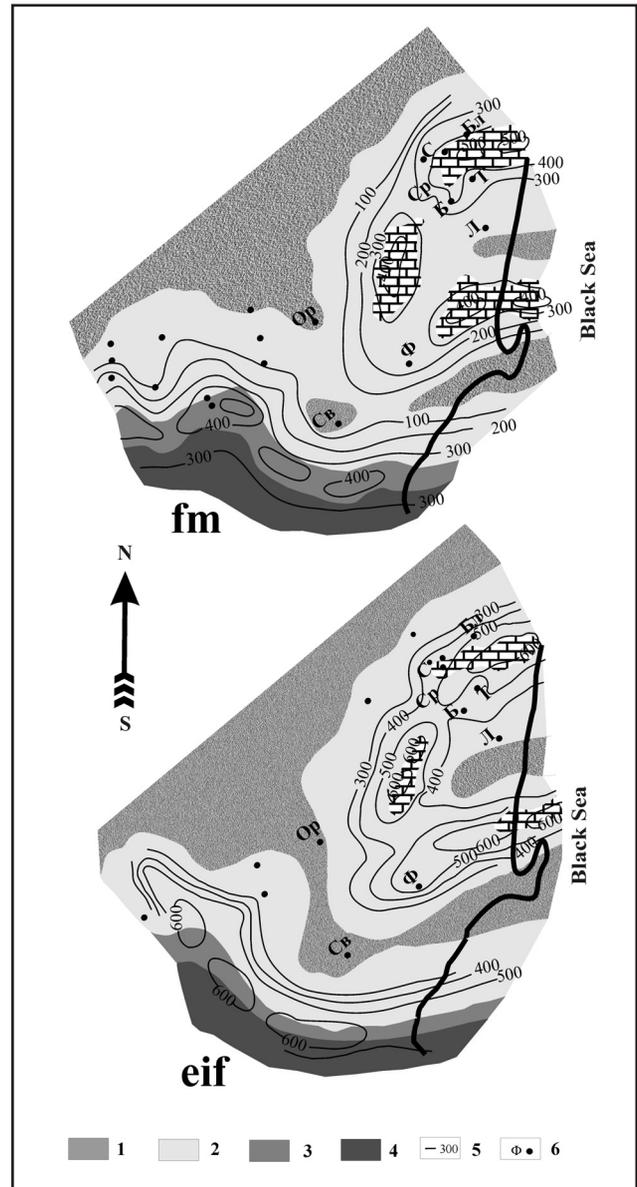


**Fig. 2.** Changes of relative level of the ocean during Middle – Late Devonian.

To the south from the described above facies zone by narrow (sublatitudinal strike) zone, the development of barrier (reef formations up to 600 m (zone Adzhud-Cahul George fault) is prognosticated, that can be considered as a fragment of reef belt along the southern slope of the East European craton, is forecasted.

Zones of foreset slope and outer shelf with depths of basin above 50-100 m within the entire studied area are covered and have prognostic character.

Lagoon environments of sedimentation dominated in the eastern part of depression. Carbonate layered dolomitic silts of tidal flatland and sulfates sabhas were mainly formed here. Taking into account the structural-paleogeomorphic features of this part of the region, the distinguishing of continuous barrier zone is impossible, while some separate sections of development of these

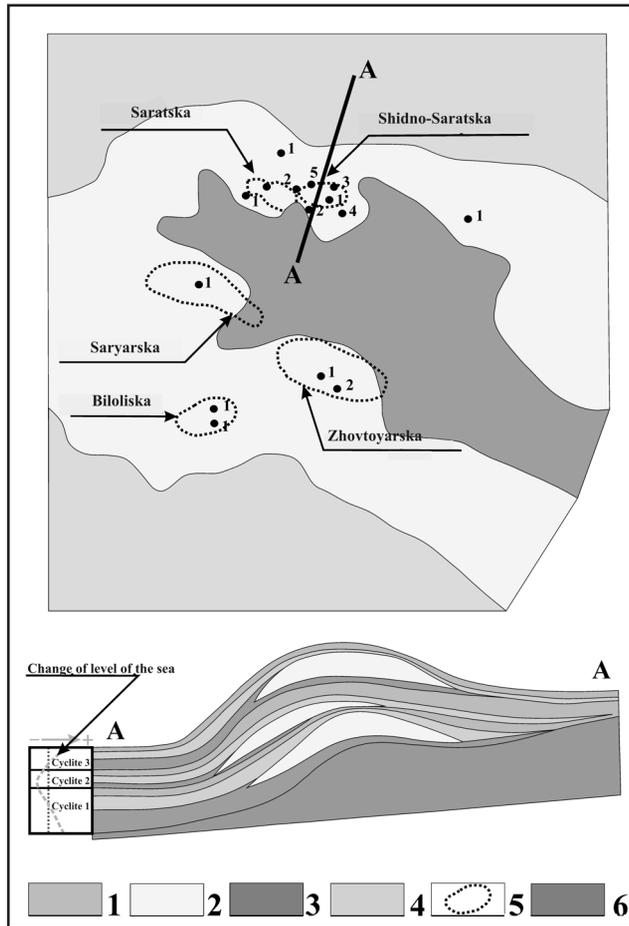


**Fig. 3.** Sedimentation model of carbonate shelf of Predobrudzian depression.

1 – land; facies zones: 2 – inland shelf; 3 – barrier zone; 4 – foreset side and outer shelf; 5 – isopaches; 6 – boreholes of areas: Op – Orikhivska, Ф – Furmanivska, Cp – Saryarska, C – Saratska, Б – Biloliska, Л – Lymanska, Cy – Suvorivska, Бал – Balabanivska, Т – Tuzlivska.

formations have been localizing. Thus, within Furmanivsko-Prymorska depression, the appearance of them is predicted only about 20 km eastward of borehole Furmanivska-1 (near the modern Black Sea coast). This is elongated sublatitudinal stretch field with expected thickness of deposits about 600 m.

A small oval area of barrier development structures is localized in the pre-axial zone of Tatarbunarsky graben.



**Fig. 4.** Model of sedimentation environments and cyclic character of progress of carbonate accumulative bodies. Tuzlivska depression. Middle Devonian.

1 – region of sulfate accumulation (anhydrite element of cyclite); 2 – region of carbonate accumulation (biostrome element of cyclite); 3 – region of clayey (terrigenous) sedimentogenesis; 4 – intermediate element of cyclite; 5 – local structures; 6 – Premiddle Devonian deposits.

The third section of the barrier zone is projected in the axial part of Tuzlivska depression. Evidently, this zone exposed fragmentary on the Shidno-Saratska area (Borehole 1), where, in particular in the intervals 2904-2916, 2992-3001 m, organic detritus limestones of gneissstone type were found. The last one can be interpreted as the formation of the initial stage of biogenic structures growth, so-called stabilization stage. Similar lithotypes were found out in the section of Eifelian deposits opened with borehole Balabanivska-1.

All this and also considerable decrease in sulfate coefficient (content of sulfate rocks in section) from 30-40 to 10-15% towards the inner part of the above-mentioned depressions show a high probability of the existence of barrier zone formations.

As noted above, the Devonian period was characterized by the eustatic level rise of World Ocean from the beginning to the end. In Dobrudja Fore-deep this transgressive trend has led to the deepening of the basin, areas decline of spreading of tidal and sabkhas sedimentation conditions and migration of barrier zone towards the coast.

During the Eifelian age this transgressive trend was realized very clearly: almost everywhere sulfate and carbonate-sulfate sedimentation of early age has changed, at the end of it, only to carbonate sedimentation. Givetian age was characterized by normal water salinity of sedimentation basin. There are organogenic formations with corals in the far west area (in Near-Danube part). Conditions of carbonate sedimentation dominated in Furmanivska area. Perhaps this was due to the breakdown of Suvorivsko-Zmiyina land into separate islands; straits between them helped water circulation and restored normal salinity of basin. At the same time within Tuzlivska depression as before, carbonate-sulfate environments of sedimentation dominated.

During the Frasnian age unstable conditions of sedimentation were formed when marine and lagoon environments of sedimentation alternated. In Furmanivska area carbonate sedimentation changed to sulfate-carbonate in the late Frasnian. Environments of the barrier zone development were extended to the east. In particular, such formations exposed in borehole Saratska 5 (depth 2920, 2868, 2866 m), Zhovtoyarska-1 (3159-3176 m), where gneisstones and wackstones with fragments of ostracodes, crinoideas, brachiopods, corals, blue-green algae were determined.

In Famennian throughout the territory of Dobrudja Foredeep the salinity of the shelf sea was close to normal. However, at the end of this time in Biloliska and Tuzlivska areas, carbonate-sulphate deposits were formed, that could be related to the lifting of some structures in the late Devonian due to the beginning of Breton tectonic phase.

#### DISCUSSION

Thus, in Famennian, within the studied region high salinity isolated basins were absent; water exchange between different areas of the sedimentation basin was more active. Mainly pelittic-morphic carbonate oozes with layers (at the top of the section) of anhydrites, and at the bottom – carbonate sands and sandstone dolomites with total thickness of over 500 m were formed here.

Paleogeomorphology of Famennian basin bed of the region comparing with Eifelian age has changed much. Primarily this is due to dissection

and reduction of Orikhivsko-Suvorivsko-Zmiyina land. There used to be a few isolated, small islands separated by channels. Straits contributed to the water exchange between ocean basins of the western and eastern parts of the region, and continuous flow could result in development of the carbonate clastic sediments within them. The last ones were replaced with organic sediments of barrier zone toward submergence of paleotopography and towards uplifting with sabkhas formations.

Barrier zone, as the zone of inner shelf, in the west of the region, compared with Eifelian age, slightly shifted towards north, and the area of its development increased. It is localized as sublatitudinal belt with the thickness of sediments of about 400-500 m.

Reefoid or biogermal structures, according to (Bondarenko et al., 2001), are recorded in various parts of the region at different stratigraphic levels of Mid-Late Devonian. It should be noted that these formations studied (Hnidets et al., 2003), are not massive organic structures but they are cycle based measures with the presence of «swelling» limestone, which tend to slopes or vaults of contemporaneous lift. As a result, almost entirely biogenic accumulative bodies (the analogue of barrier zones of carbonate shelf) are formed in the section. Their formation is associated with relative sea-level changes that are the result of the interaction of regional eustatic variation and local (zonal) structural movements that, in principle, led to the formation of cyclic lithological structure of the section of Middle-Late Devonian measure.

Fig. 4 shows the model of biostrome forming and sedimentation diagram for the formation of

a particular cyclicity. Carbonate-clay sedimentation dominated in the pre-axial part of Tuzlivska depression, and within distant sides – sulfate accumulation. Definite lateral migration of sedimentation environments is predicted because of changes in sea level. In particular, at the low level- carbonate accumulation bodies belonged to the outer slopes of lift, during transgression – they formed in their pre-arch areas. Besides, in the first case thick anhydrite horizons were formed; and in the second – on the background of a significant reduction of the sulfate accumulation role, the importance of depression carbonate-clay sedimentogenesis increased. This is reflected in the growth of thickness of basal terrigenous clay sequence and also structures of in-between (sulfate-carbonate) element of cyclicity.

## CONCLUSIONS

In early Devonian the peculiarities of sedimentation were mainly determined by global paleoceanographic factors: domination of descending tectonic movements and cool climate. This caused forming of pelite-aleuro-psammitic formations in contemporaneous depressions and organic carbonates – in lifts. Ascending differentiated movements caused periodic isolation of some part of Fore-Dobrudja basin, that together with warming and aridizing resulted in the formation of cyclic sulfate-carbonate sediments of Middle-Late Devonian. Cyclicity in specific cases was determined by fluctuations of relative sea level, which was the total result of interaction eustatic fluctuations and tectonic regime of local structural units.

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