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COMPLEX STUDY OF NEOGENOUS DEPOSIT THICKNESS OF PANNON BASIN ON THE BASIS OF SEISMOSTRATIGRAPHIC APPROACHES WITH ELEMENTS OF SEISMOFACIAL ANALYSIS

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From 2011 to 2017, large-scale seismic surveys were carried out by PJSC Gazprom Neft within the Pannonian Basin (territory of Serbia). Currently, the coverage area of seismic surveys in the modification of MOGT 3D is approaching the stage of regional study and is about 5,600 km^2. The obtained data signify a new stage in the geological study of the region and represent a rich material for further understanding of the geological structure of the research area.

The full-scale introduction of seismic prospecting in the modification of the MOGT 3D has made it possible to use modern approaches to interpretation, such as seismostratigraphic and seismic facies analysis. On the one hand, the results obtained contribute to a more successful geological exploration. On the other hand, the adaptation of seismostratigraphic approaches, sequestration techniques and seismic facies analysis techniques to the regional features of the Pannonian basin makes it possible to develop the methods themselves, since the subject of research, in the opinion of many scientists, is in many senses a natural laboratory.

The article describes the main seismostratigraphic complexes, the principles of their isolation, the features of interpretation approaches for seismic facies analysis in each of them, and the results of seismic facies analysis are combined with core studies.

Within this region, more than 500 deposits with total reserves of over 1,400 million tons of conventional oil have been discovered. Despite the small size of the vast majority of deposits, they are profitable and further exploration is of great practical interest.

Key words: Pannonian basin, Neogene, seismostratigraphy, seismostratigraphic complex, interpretation of seismic data, seismic facies analysis, sedimentation model

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Introduction. The current level of technological development of seismic studies combined with favorable seismic and geological conditions makes it possible to obtain sufficiently high-quality seismic images that allow not only to effectively use modern interpretation approaches but also actively develop them.

The introduction of the seismostratigraphic approach and seismic facies analysis into the production chain of interpretation of seismic data at the sites of PJSC Gazprom Neft in the southeastern part of the Pannonian basin (Serbia, Vojvodina) allowed:

• to identify specific regional features of seismic data;

• to propose new methods of interpretation and adapt existing technologies;

• to develop methods for paleogeographic reconstructions through mapping of individual geological events.

The subject of the research are Neogene deposits, filling the Pannonian basin, their thickness in one of the deepest drawdowns reaches 7 km. The pre-enogenous base has a complex structure: sediments of the Paleozoic, Mesozoic and Paleogene ages emerge under the cover of the sedimentary section. The basin features an active tectonic regime, thinning of the earth's crust (22-30 km against 36 km in surrounding areas, 50-60 km in the Carpathians) and an increased heat flux (from 80-100 to 130 mW/m^2) [12].

The first oil field in the region was discovered in 1885 in Croatia. The petroleum potential is proved for the deposits of the Mesozoic, Paleogene, Miocene in Hungary, Romania, Serbia and Croatia. By the beginning of the XXI century more than 500 deposits with total reserves of over 1,400 million tons of conventional oil have been discovered within the region. Despite the small size of the fields, their development is economically viable, and new discoveries in the region are of great practical interest [9].

Formulation of the problem. Seismostratigraphic approaches developed originally by Peter Weil and his colleagues from Exxon Production Research Co. [6, 7], are based on the principle assumption that seismic reflections approximate isochronous geological surfaces originally associated with eustatic fluctuations in the level of the World Ocean. One of the features of the Pannonian basin is the fact that in its history there were different stages of relationships with the World Ocean: in some periods the basin was opened, but most of the time it developed in isolation. Each of the subbasins that make up the Pannonian basin, bears the features of the general history of the geological development of the region and has its own individual characteristics. This causes difficulties in identifying age-old sequences, especially in the submerged parts of the depressions. However, the characteristic drawing of a seismic record and the identification of certain geological events established for specific age intervals allow them to be stratified conventionally, even in the absence of borehole information.

The features of basin bridging process include the existence of multiple sources of ablation, a rapid change in the conditions of sedimentation, and a wide range of facial settings. These factors largely determined the nature of the seismic image: most of the intervals are represented by intermittent coherence axes, there are problems of tracing them along laterals and identifying paleoisochronous events. The listed features have designated «weaknesses» in the standard interpretation approaches of phase correlation, based on tracing extended reflective horizons, which are associated with rather long breaks in sedimentation. For in-depth seismic-geological interpretation, author's object-oriented approaches have been developed and implemented, allowing to take into account all the features of the seismic image, the information content of the conditioned reflecting horizons, the characteristic combinations of local co-phase axes, and so on [3, 20].

Subject of research: the evolution of the Pannonian basin. Modern ideas about the evolution of the Pannonian basin are detailed in the works of scientists who have been studying it for a long time [12-22].

The Pannonian basin was localized within the region of the ***Paratethys*** Sea. In the early Paleogene within the southern margin of the Eurasian continent, there were marginal seas of the Tethys: Alpine-Carpathian and Caucasian-Kopetdag. At the end of the Eocene, as a result of the collision of the Afro-Apulian-Arabian continent with Eurasia (the late Pyrenean phase of the Alpine folding), a continuous mass of land formed, separating these marginal seas from the basins of the ancient Mediterranean, Mesopotamia, and the Indian Ocean.

By the beginning of the Oligocene, the Alpine-Carpathian and the Caucasian-Kopetdag basins were transformed into a system of intercontinental reservoirs, named Paratethys (Laskarev, 1924), with a variable regime of salinity and oxygen exchange. The initial development cycle of Paratethys (the early Oligocene beginning of the late Oligocene) is characterized by a fairly wide connection with the World Ocean. The salinity of the basin at the beginning of the Oligocene was close to normal. At the end of the early Oligocene, the first short-term closure of Paratethys occurred, accompanied by significant desalination, and subsequently the connection with the Ocean was restored, mainly with the Atlantic. In detail, the paleogeography and biogeography of the Paratethys basins in the period from the late Eocene to the Early Miocene inclusive is described in the work of S.V.Popov, M.A.Akhmetev et al. [5].

Over time, the communication between Paratethys and the Ocean became more and more difficult and, presumably, occurred through a complex system of narrow straits [11].

By the beginning of the Miocene Paratethys was divided into the Western and Eastern parts. The eastern part, called the Euxine-Caspian, was more than twice as large as the western, Pannonian part. There is an opinion that the differentiation of Paratethys to the Western and Eastern was not clearly indicated until the middle Miocene [1].

The Pannonian part represented a narrow strait, extending from the Vienna to the Styrian basins in Transcarpathia, with expansion in Transylvania and a branch to the Pre-Carpathian Gulf. The Moldovan strait connected Western Paratethys with the East. The complex history of the interrelationships of the individual parts of Paratethys, their periodic isolation and the subsequent restoration of communication between them predetermined the conditions of sedimentation and complexity in the stratification of the same-aged sequences [10].

The most part of the Pannonian basin is attributed to the Early Miocene, indicating the boundary at 20-21 million years [1]. At its base is a complex set of blocks, which are conditionally grouped into two slabs: ALCAPA and Tissa-Dacia block. The plates are separated by the Mid-Hungarian fault zone, which was formed in the Upper Oligocene-Early Miocene period. There is considerable uncertainty as to the geometry of the blocks, the sequence of their movement, the nature of this displacement, and so on [14].

In the history of the development of the basin, two phases are singled out: the synphrite and post-tritic phases.

Specialists suggest that rifting proceeded according to the asymmetric scheme of B.Vernike, with the formation of semi-grains limited by listric discharges. The rift stage lasted until the middle Miocene inclusive. There is an assumption that the completion of the rift stage does not have a single time boundary, since, according to the latest seismic studies, the rifting processes continued in the eastern part of the basin until the late Miocene [12].

The deposits formed in the initial phase of rifting are usually represented by conglomerates with sandy matrix, coarse, medium- and fine-grained sandstones, siltstones, silty sandstones, clays, less often marls, and the presence of coals.

An outburst of tectonic activity in the Alps, Tibet and other systems of the Alpine-Himalayan complex, called the Styrian phase of orogenesis, was recorded at the turn of the early and middle Miocene. Sedimentation occurred in conditions of disconnected basins, the communication between which was periodically restored. The beginning of Baden was marked by a major transgression, which led to the opening of a corridor of communication with the World Ocean through Slovenia and the north of Croatia. In Baden's time, experts identify several eustatic cycles of the third and fourth orders, but correlation with global sea level changes is not transparent, the influence of regional tectonics is the guiding [13]. Deposits of early Baden are mainly represented by shallow-marine facies, characterized by the presence of both reef-like limestones and coarse clastics. The sediments are more deep-watered within drawdowns. The wide presence of volcanic material is noted. The deposits of middle and upper Baden are more localized.

Deposits of the Sarmatian age also accumulated mainly in shallow-water conditions. The geological events that took place in the Sarmatian time are described in detail in the work of R.Jovanovich [17]. The author identifies three phases: the phase of the area carbonate sedimentation in the early Sarmatian and the subsequent two phases of active tectonic movements in the early and late Sarmatians, which led to the formation of a dismembered relief, subsequently eroded, which explains the local distribution of the Sarmatian deposits in the paleo-submerged sections of the pre-Neogene base.

The completion of the middle Miocene is recorded by the regional erosion boundary of the so-called «Pannonian disagreement». It has been suggested that this disagreement is evidence of the end of the syn-rift phase, but as more detailed interpretation of seismic data in different areas experts came to the conclusion that within the basin the completion of the rift stage does not have a single time boundary.

The isolation of the Pannonian basin dates back to the end of the Sarmatian time (11.6-11.3 million years ago) [12]. The newly formed Pannonian Sea-Lake with a depth of about 1000 m was rapidly desalinated by rivers flowing into it, which brought a huge amount of terrigenous material, forming clinoform thickness of lateral accreation. At the end of the Pontus – the beginning of the Pliocene in the region, active tectonic movements are noted.

Greatly changing in its size Pannonian Lake finally ceased to exist at the turn of the Pleistocene and the Holocene. It is believed that the water from it went along the Danube through the Djerdap gorge – at the point of rapprochement of the mountain systems of the Carpathians and Stara Planina.

Factual information. Seismic studies in the region have been carried out since 1956. The first seismic survey of the MOGT 3D was developed in 1997. The current stage of active seismic surveys in the modification of MOGT 3D began in 2011. To date, the factual material is about 5600 km^2. In general, seismic survey parameters are maintained at all areas: sources – vibrators, distance between excitation points is 40 m, distance between receivers is 40 m, bin is 20×20 m, sampling rate is 2 ms, recording time is 5 s, spread length is up to 3 km. Seismogeological condi-

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tions are generally favorable, and the field material is of good quality. The peculiarity of fieldwork in the territory of the autonomous province of Vojvodina in Serbia is characterized by high population density, a large number of economic entities, roads, lakes, and rivers. These factors have a significant influence on the regular distribution of the geometry of observations and interference.

Processing and interpretation of seismic data is carried out in the Echos software package of Paradigm; interpretation using seismostratigraphic and seismic-facies approaches is done in the software complexes of the company Paradigm and Schlumberger.

Discussion: regional seismostratigraphic complexes (SSC) and their description. In seismic sections of the Pannonian basin, the seismic stratigraphic complexes can be based on different criteria, depending on the completeness of the geological section in one or another part of the basin, so that the number of seismic complexes can vary.

In this paper, five seismostratigraphic complexes are described. For each complex, a description of the features of the seismic image, events corresponding to this period of geological history, the most effective methods of interpretation developed by the authors in the process of working with seismic data are described.

SSC 0. Pre-enogenous base. At the base of the Pannonian Basin there is a heterogeneous and complexly built basement. The thickness of the Neogene deposits covers the rocks of the Paleozoic, Mesozoic and Paleogene ages.

For hydrocarbon deposits discovered in the pre-Neogene base, several types of deposits are characteristic: deposits formed in the near-surface part of the basement; the deposits located in the traps inside the basement; massive reservoirs with a common water-oil contact with the synfritic complex.

On extended regional profiles, in the first approximation, the complex of the pre-Neogene base is well recognized, since the seismic record in the interval of the cut, compared with the pre-Neogene base, differs sharply from the seismic image in the overlying thickness and is characterized by irregular chaotic reflections. Reflection from the surface of the pre-neogenous base in the region, as a rule, is a complex response, variable laterally. With this moment, the problems of interpretation of the reflecting horizons characterizing the distribution of the Lower and Middle Miocene deposits overlapping the pre-Neogene base are related (Fig.1).

Within the designated interval there are no reference reflective horizons. The seismic image does not fully convey the complex internal structure of the base. The separate in-phase or wave train axes are noted fragmentarily, both on the seismic data of the MOGT 2D, and on the seismic data of the MOGT 3D.

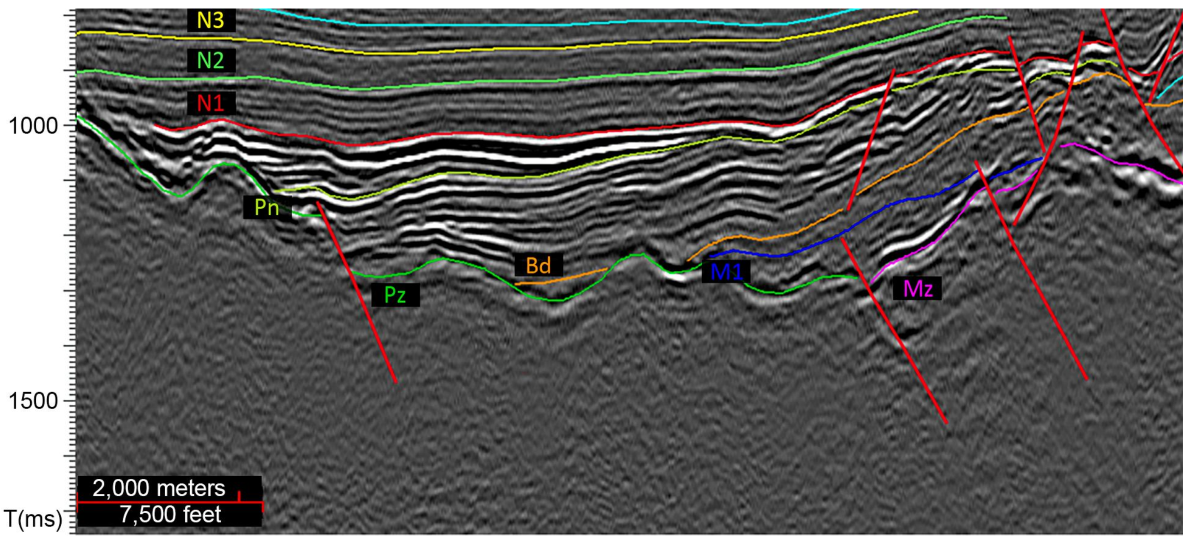

Fig.1. Time cut. SSC 0 corresponds to the interval associated with the Mesozoic and Paleozoic deposits.
The upper boundary of the complex is drawn along the reflecting horizon Pz and the reflecting horizon Mz;
SSC 1 – the interval of development of the Lower Miocene deposits, in the roof of the complex – the reflecting horizon M1;
SSC 2 – the interval, including sediments of the pannon and the lower pontus; the upper boundary corresponds
to the base of the progradation – the reflecting horizon N1

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With borehole information, seismic reflections can be conditionally identified with stratigraphic boundaries, but only within local areas. Wells that open different age ranges within the pre-Neogene base are extremely small in number.

In the literature they give examples of the successful identification of reflections in the basement under conditions of integration with borehole information, for example, in the contiguous Vienna basin where deposits of both oil and gas have been identified in the Jurassic and Triassic deposits [8].

Within the southeastern part of the basin, Paleogene deposits are present locally, represented by continental terrigenous formations. On seismic sections they can be separated into a separate local SSC.

SSC 1. A synrift complex. Lower Miocene deposits. The Lower Miocene deposits within the territory of the Pannonian basin were preserved locally. Despite the fragmentariness of the presence of sediments over the laterals and the remoteness of the surviving sections, the geological record captures similar geological processes. The main conceptual model of the formation of the Lower Miocene sediments is «trails of fractured slopes» [2].

On the territory of Serbia within the studied areas, the lower Miocene, as a rule, is represented by continental terrigenous deposits, folded breccias, conglobes, conglomerates, sandstones with admixture of gravel material, limestones with an admixture of terrigenous deposits of various granulometric composition. Breccias and conglomerates consist of fragments of sandstones, siltstones, limestones, shales, quartzites, granitoids, serpentinites, and diabases.

A number of oil and gas fields in the region are confined to the Lower Miocene sediments. The types of traps are diverse: structural, structural-tectonic, and lithologically screened. There is a significant facial heterogeneity and a sharp differentiation of deposits by area, thickness and properties. For example, within one of the deposits, the total thickness of the reservoir strata varies from 3 to 26 m, the porosity varies from 6.2 to 22.2 %. The oil rates during the test in the column vary from 0.2 to 50 m^3/day.

The seismic stratigraphic complex SSC 1, which is compared with the Lower Miocene deposits, is limited from below by the surface of the pre-Neogene base, from above with a reflecting horizon, stratigraphically identified as the roof of the Lower Miocene sediments (Fig.2).

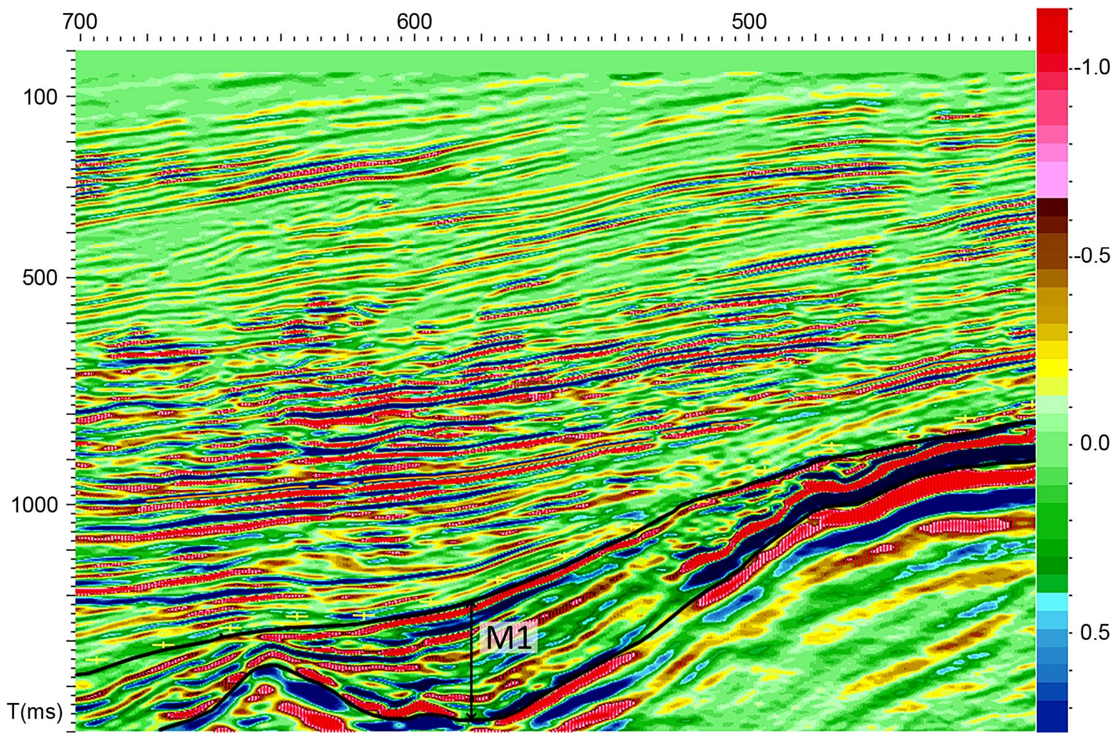

Fig.2. An example of a seismic image typical for SSC 1 on a time scale
Here and in Fig.3-5, the color scale corresponds to the relative intensity of the amplitudes; the numbering of traces is made after 20 m (horizontal scale)

In the section of the SSC 1 cut is characterized by alternation of extended and locally expressed in-phase axes. Some features of the seismic image on sections and slices can be related to the stages of active receipt of material filling the depressions of the paleo relief. It is possible to distinguish stages only conditionally, since the process occurred continuously and intermittently. Each stage includes similar events of more local character or more short-term in duration. Within the individual sections, the figure corresponds to the characteristic mapping of landslide processes. The testing of various interpretation techniques, such as the analysis of sedimentation and horizon cuts of various attributes of the seismic record, the classification of the target interval in the form of a path for the detection of individual events and lithological features, allows us to conclude that seismic data reflects the heterogeneity of the Lower Miocene sequence from the point of view of its formation process.

SSC 2. A synrift complex. Middle Miocene deposits (Baden, Sarmatian). The deposits of the Middle Miocene complex transgressively overlap the rocks of the pre-Neogene base (locally), in drawdowns they have deposits of the Early Miocene age. Depending on this, the lower boundary of the SSC is determined in different ways.

Within the areas characterized by a complete cut of deposits of the Middle Miocene age, intervals with «marine» filling and «continental» can be identified on seismic sections. In the first case, the seismic image is more contrasted and consists of sufficiently extensive bright reflections; in the second case it looks more muffled and chaotic. Most reflections are of an interference nature. The upper boundary is the acoustic boundary at the contact with sediments of the Pannonian age.

For objects under consideration, sometimes a special character of the seismic image is observed, which allows to formulate additional search criteria, for example: a more pronounced phase, local amplitude maxima or minima.

The main difficulties in interpreting the SSC are created by local nature of its distribution, the presence of faults, interference with reflection from the surface of the pre-Neogene base, uncertainty in the identification of stratigraphic breakdowns, and the scarcity of cores for research (see Fig.1).

SSC 3. Post-rift complex. Upper Miocene (pannon, lower pontus). Traditionally within the complex the outstanding and sufficiently well-traced reflections are distinguished. The lower part of the complex, represented by the sediments of the pannon, is characterized by extended high-amplitude reflections. The roof of SSC 3, the ground of the clyneform complex itself within a single area is difficult to track, as the reflection taken as the base for the degradation may turn out to be a deep-water marine deposit part of the previous clino-cyclite. Therefore, it is very important to take into account the regional component in the process of area interpretation (Fig.1).

Depending on the direction of the process and the proximity to the submerged blocks of the base, characteristic for this interval of formation in the style of landslide «streams» are distinguished. They attract attention to the chaotic recording in the section, are well displayed on the horizon slices, they have outlines in plan. They are of our main scientific interest, since they unambiguously indicate the direction of the ablation.

SSC 4. Post-rift complex. Clinoform complex (pontus). A very thick clinoform complex can be considered a visiting card of the typical section of the Pannonian Basin. A complex combination of many factors, such as tectonic processes and climate variations, has attributed to the uniqueness of this complex.

Within the sediments of the Pontic and Pliocene ages, 97 hydrocarbon deposits have been identified by the statistical data on the area of research (the southeastern part of the Pannonian Basin) to date: 46 deposits are found in the Lower Pontus sediments, 33 in the Upper Pontus sediments and 18 in the Pliocene sediments. One-sixth of the reserves and resources are concentrated in the sediments of the Upper Pontus and Pliocene, the rest in the Lower Pontian sediments.

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The seismic stratigraphic complex is very interesting from the point of view of sequential stratigraphy. The seismic section within the interval corresponding to the clinoform complex is characterized by the presence of sigmoidal amplitude-expressed reflections (Fig.3). Specific features of the seismic image of the clinoform complex are the easily distinguished fragments of irregular chaotic reflections, which are identified with the manifestation of gravitational landslide processes (Fig.4). The areal study of such a geological phenomenon is complicated by the fact that in the section there are practically no lateral reflecting horizons, which are paleoisochronous surfaces. Accordingly, there is also no basis from which it is possible to quickly and efficiently «cut» the horizontal and proportional slices in order to identify in the section all the same paleoisochronous surfaces for studying their amplitude texture. Nevertheless, such tools as «placing» the smoothed horizon on a specific maximum or minimum allow you to map the event in detail. The methods of spectral decomposition using RGB-mixing for visualization, work with seismic lifts in the transparency mode proved to be very useful for express analysis. On the sedimentary (horizon) slices within the slope, the blades of the cones of removal are recognized, supplying the channels, despite the small thicknesses of the deposits and the interference pattern as a whole (Fig.5).

The seismic section in the clinoform complex is characterized by the presence of anomalies such as «bright spot». The application of a «bright spot» as a search criterion in the late 1980s was marked by the discovery of a large gas field. Later, several smaller deposits were discovered. However, the results of drilling in recent years show that the nature of the anomalies is different and associated not only with the presence of hydrocarbons, but also with lithological changes.

SSC 5. Post-rift complex. Upper pontus, Pliocene. The clinoform complex is overlapped by deposits of the Upper Pontus and Pliocene formed in the conditions of a vast lacustrine-alluvial plain, which, according to the seismic image, can be definitely separated into a single unified SSC. The interval of the seismic section, comparable to the thickness of the Upper Pontus-Pliocene sediments, is characterized by discontinuous in-phase axes, the presence of local anomalies, and the absence of lateral supporting reflecting horizons. Reflections associated with the boundaries of the lower pontus – the upper pontus and the upper pontus – the Pliocene, as a rule, are interference.

According to the data of seismic facies analysis, deposits of the Pont-Pliocene age of the Pannonian Basin are characterized by the development of paleoreal systems. According to seismic data, the dominant submeridional direction of the channels is determined, which reflects the position of the key geostructural elements. During the Upper Pontus and Pliocene in the region, active tectonic activity continued both in the central part of the basin and on its periphery. Together with global variations in the climate, tectonic processes have affected the feeding of rivers and the density of the river network (especially for mountain areas), erosion processes (with the uplifting of blocks), the morphology of river valleys and their change, the direction of the channels.

The implementation of seismic interpretation and seismic facies analysis set a number of specific problems. As practice has shown, time-tested and traditional methods of interpretation proved to be ineffective. First of all, it is necessary to note the absence of supporting reflecting horizons due to significant lateral and vertical variability of the section. As a result, the correlation is carried out with a very free approximation and the horizons are assigned the status of «conditional». This leads to the problem of identifying single-stage geological events. The presence of three paleosoles on one slice for an inaccurate correlation can be a reflection of the migration of this channel along the lateral, rather than the presence of three separate objects

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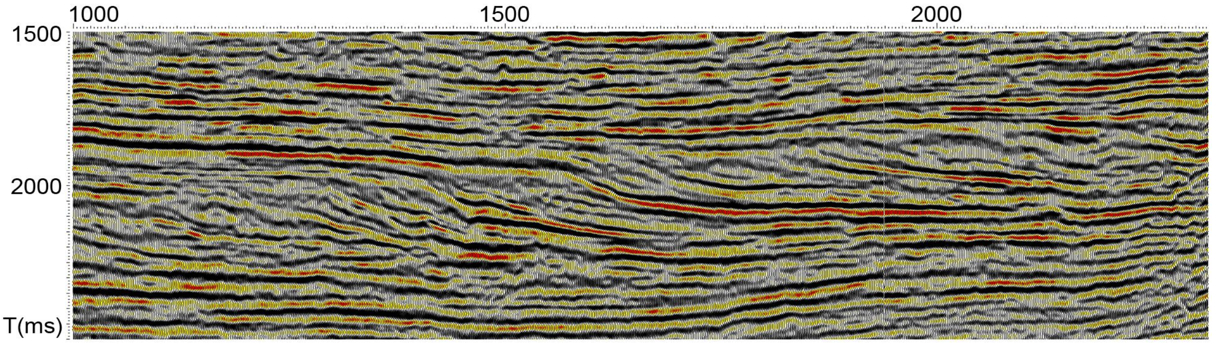

Fig.3. Typical time section of the clinoform complex

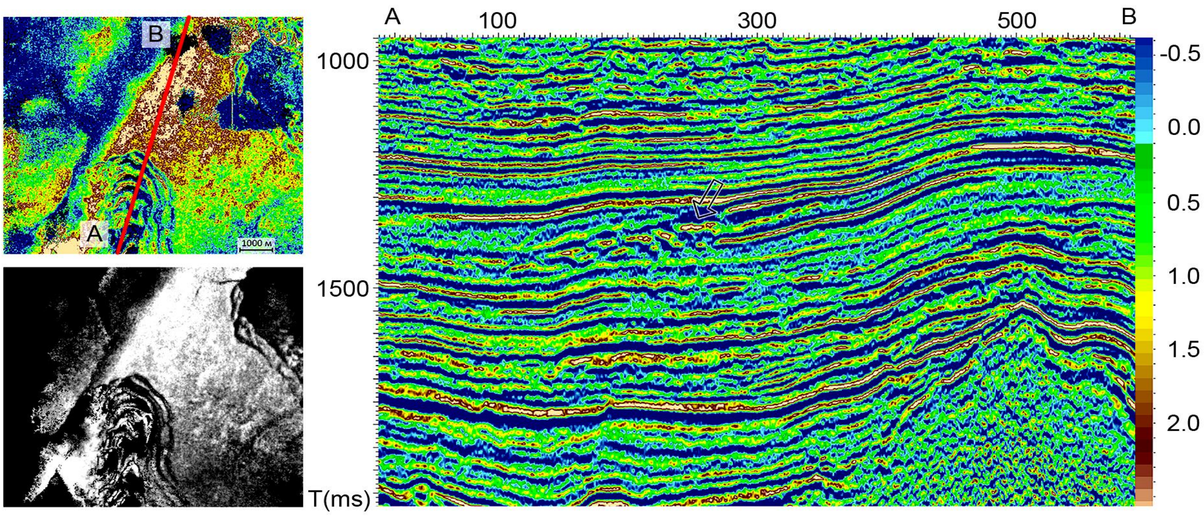

Fig.4. The mapping of landslide formations on the horizon and time sections (SSC 4)

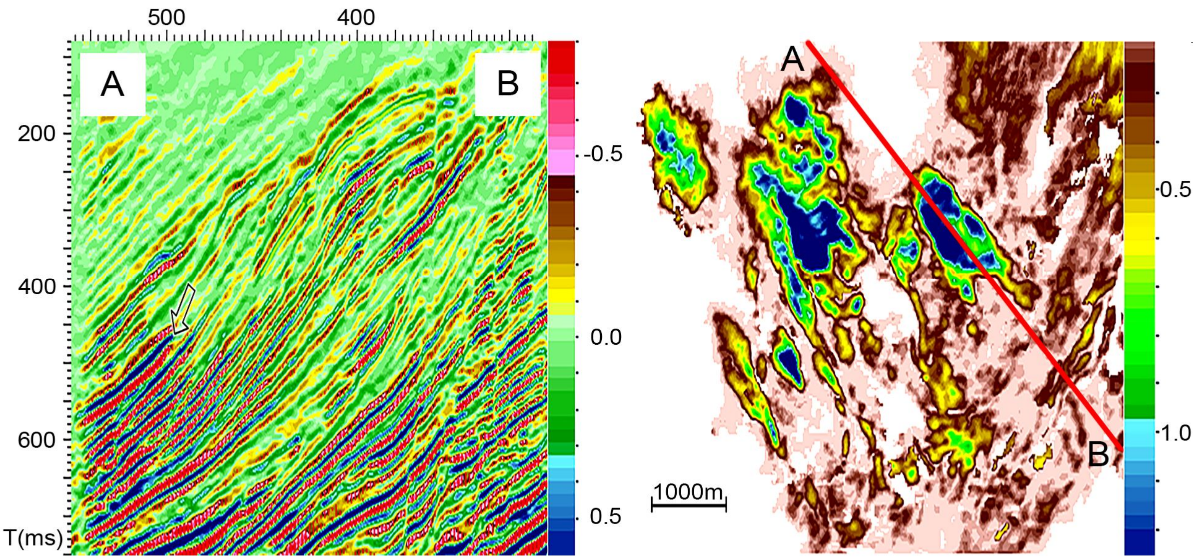

Fig.5. Display of the blades of the ablation cones in the time and horizon sections (SSC 4)

The second problem is that smoothed interpretation options, usually sufficient for structural constructions, are not optimal for seismic facies analysis, since they do not allow to obtain a clear image when amplitude is taken along the horizon and various attributes are calculated in the target interval.

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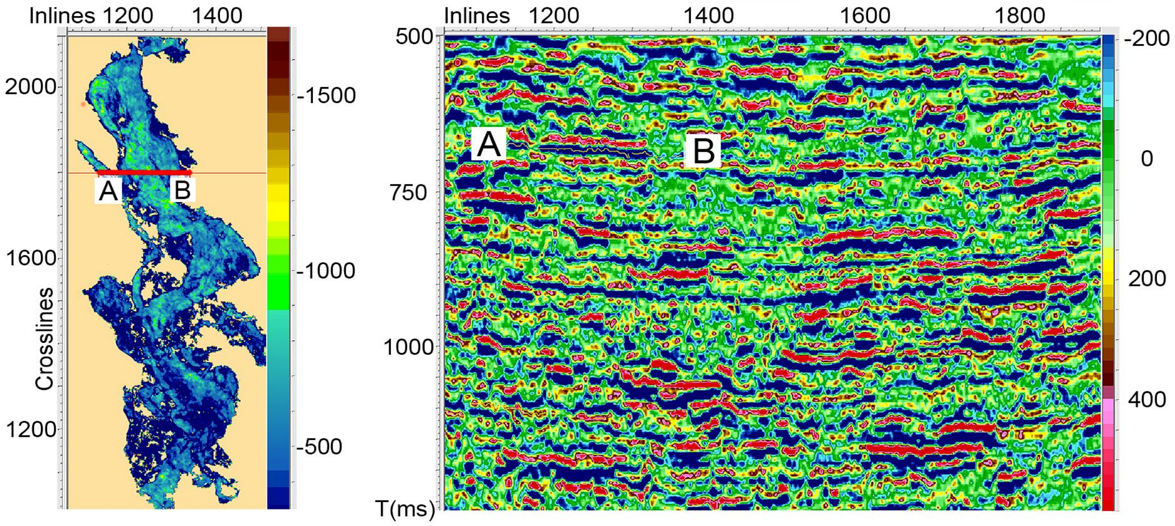

Fig.6. Mapping of paleo-wood with methods of object-oriented interpretation (SSC 5).
Here and in Fig.7, the color scales correspond to the relative intensity of the amplitudes; the numbering of lines and tracks on the section is made after 20 m

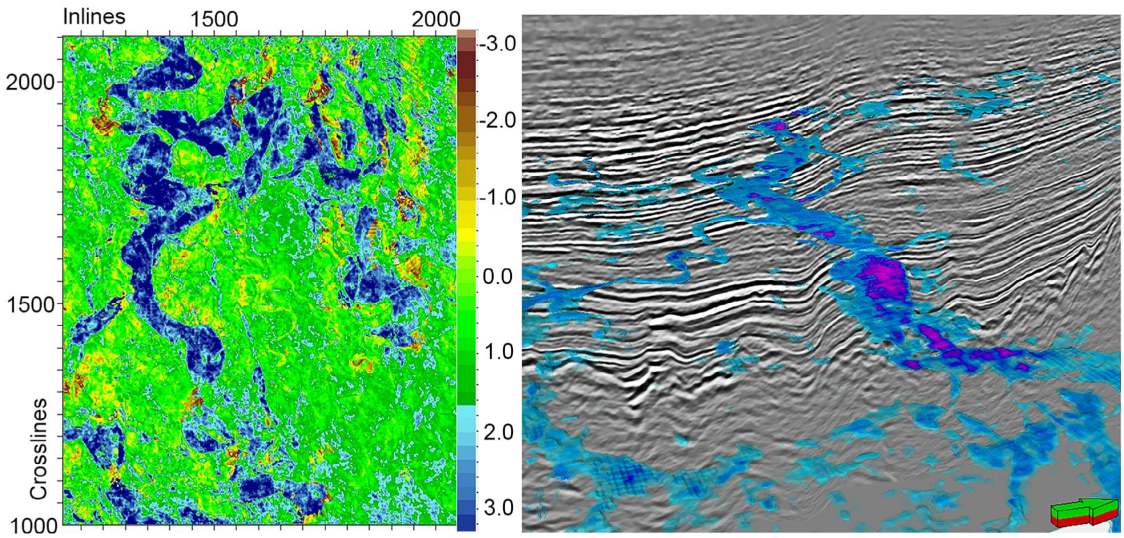

Fig.7. Identification of paleoils in SSC 5 on the section and in the transparency mode

Especially for similar conditions and seismic data on the Pannonian basin, an object-oriented approach to interpretation was developed (Fig.6, 7). The peculiarity of the new methodical approach is that the object-oriented interpretation is based on the already existing conceptual model. Object-oriented approach involves scrupulous work of extracting an object from a general seismic image with multiple iterations to achieve the best result. The effectiveness of the approach is obvious in cases when the geobody tool cannot be used for one or another reason. The tools of this approach are described in the article by T.V.Olnyeva, V.Yu.Ovechkina [3].

Conclusion. The obtained results of the reserach mark a new stage in the regional seismogeological interpretation. A detailed analysis of each seismostratigraphic complex allows us to develop a database of seismic images typical of specific sediments and geological events. Type assignment of fragments of the seismic section leads to a reduction in uncertainty in the process of area correlation. For example, the seismostratigraphic approach allowed the creation of a regional framework for the basin model of the Pannonian basin, despite the large inconsistencies in the stratigraphic correlation of data from Hungary, Romania and Serbia [9]. We continue to work on detailing of the basin model within individual regions. Simulation of facies is carried out on the ba-

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sis of the data of area seismic facies analysis. This approach allows us to determine the potential of lithologic and lithologic stratigraphic traps in a large number of Neogene deposits.

Within individual areas, the features of the geological structure of the Pannonian basin, such as the extremely high degree of lateral lithofacial variability, predetermined the need to search for new seismic-geological interpretation techniques. The most effective to date are object-oriented approaches that allow us to build a correlation with observing the paleoisochronism of the interpreted horizon from a specific geological event to the outside. The indicated approaches, in combination with different-scale geological and geophysical studies, on the developed fields allow us to update the conceptual models and develop new search criteria for the satellite deposits [4].

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REFERENCES

1. Nevesskaya L.A., Voronina A.A., Chepalyga A.L. History of Paratethys. 27-i Mezhdunarodnyi geologicheskii kongress. Paleookeanologiya. Moscow: Nauka. Vol. 3. 1984, p. 91-101 (in Russian).
2. Sedimentation and facies conditions. Ed. by Kh.Reding. Moscow: Mir, 1990, p. 384 (in Russian).
3. Olneva T.V., Ovechkina V.Yu. Object-oriented correlation as a new methodical approach in the process of data preparation for seismic facies analysis. *Geofizika*. 2016. N 4, p. 9-14 (in Russian).
4. Popov A.Yu., Rodionov A.E., Milei E., Bogatyrev I., Gogich A., Vuchkovich B., Olneva T.V. Determination of search criteria for geological exploration in the region on the basis of a comprehensive study of the satellite field (North Banat region, Republic of Serbia). *Neftyanoe khozyaistvo*. 2016. N 1, p. 24-27 (in Russian).
5. Popov S.V., Akhmet'ev M.A., Lopatin A.V., Bugrova E.M., Sychevskaya E.K., Shcherba I.G. Paleogeography and biogeography of the Paratetis basins. Part 1. Late Eocene – Early Miocene. Moscow: Nauchnyi mir, 2009, p. 200 (in Russian).
6. Pozament'er G., Allen Dzh.P. Sequential stratigraphy of terrigenous deposits. Basic principles and application. Izhevsk: Institut komp'yuternykh issledovanii, 2014, p. 436 (in Russian).
7. Veil P.R., Gregori A.P., Mitchem R.M. ml., Sheriff R.E. Seismic stratigraphy. Moscow: Mir, 1982. Part 1. Vol. 1, p. 375 (in Russian).
8. Fenin G.I. Abnormal reservoir pressures in hydrocarbon accumulation zones of oil and gas basins. Elektr. nauch. zhurnal «*Neftegazovaya geologiya. Teoriya i praktika*». 2010. Vol. 5. N 4. http://www.ngtp.ru (in Russian)
9. Dulich I., Bogichevich G., Rodionov A., Olneva T. Abnormal reservoir pressures in hydrocarbon accumulation zones of oil and gas basins. *Geofizika*. 2016. N 4, p. 27-34 (in Russian).
10. Khain V.E., Lomize M.G. Geotectonics with the basics of geodynamics. Moscow: Izd-vo MGU, 1995, p. 480 (in Russian).
11. Shimkus K.M. The processes of sedimentation in the Mediterranean and Black Seas in the Late Cenozoic. Moscow: Nauchnyi mir, 2005, p. 280 (in Russian).
12. Horvath F., Musitz B., Balász A., Végh A., Uhrin A., Nádor A., Koroknai B., Pap N., Tóth T., Warum G. Evolution of the Pannnonian basin and its geothermal resources. *Geothermics*. 2015. 53, p. 328-352.
13. Royeden L.H., Horvath F., Nagymarosy A., Stegena L. Evolution of the Pannonian Basin System: Subsidence and Thermal History. *Tectonics*. 1983. 2, p. 91-137.
14. Lenkey L., Dovenyi P., Horvath F., Cloetingh S. Geothermics of the Pannonian basin and its bearing on the neotectonics. EGU Stephan Mueller Special Publication Series. 2002. 3, p. 29-40.
15. Horvath F. Towards a mechanical model for the formation of the Pannonian basin. *Tectonophysics*. 1993. 226, p. 333-357.
16. Horvath F., Tary G. IBS Pannonian Basin Project: a review of the main results and their bearings on hydrocarbon exploration. The Mediterranean Basins: Tertiary extension within the Alpine Orogen. London: Geol. Soc. Spec. Publ. 156. 1999, p. 195-213.
17. Jovanovich R. Sedimentology, petrography, tectogenesis and lithostratigraphy of reservoir rocks of petroleum deposit Pz+Sm Kikinda-Varoch. Novi Sad. 2011 DIT-Naftagas, p. 122.
18. Kovach M. Badenian evolution of the Central Paratethys Sea: paleogeography, climat and eustatic sea-level changes. *Geologica Carpathica*. December. 2007, p. 579-606.
19. Matenco L., Radivojević D. On the formation and evolution of the Pannonian Basin: Constraints derived from the structure of the junction area between the Carpathians and Dinarides. *Tectonics*. 2012. Vol. 31. NC 6007, p. 31.
20. Olneva T., Zhukovskaya E. Innovative approaches to seismic data interpretation: building reliable depositional models of fluvial systems. 78th EAGE Conferece & Exhibition: Abstract. EAGE, Vienna, 2016.
21. Royeden L.H. Late Cenozoic tectonics of the Pannonian basin system. L.H.Royden & F.Horváth (eds.). The Pannonian basin, a study in basin evolution. American Association of Petroleum Geologists, Memoirs. 1988. 45, p. 27-48.
22. Schmid S., Bernoulli D., Fügenschuh B., Matenco L., Schefer S., Schuster R., Tischler M., Ustaszewski K. The Alpine-Carpathian-Dinaridic orogenic system: correlation and evolution of tectonic units. *Swiss Journal of Geosciences*. 2008. 101, p. 139-183.

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