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MACEDONIAN GEOLOGICAL SOCIETY SKOPJE 1952

5-ти КОНГРЕС / 5-th CONGRESS
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Geologists of the Republic of North Macedonia

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MORPHOMETRY OF PALEOCHANNELS – THE KEY TO DIAGNOSTICS OF SEDIMENTATION ENVIRONMENTS ON THE EXAMPLE OF PONTIAN SEDIMENTS OF THE PANNONIAN BASIN (SERBIA)

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Key Words: morphometric analysis, sinuosity of channels, clinoform complex, Pannonian basin

Abstract
Based on the identified morphometric patterns of buried paleochannels, a method for quantitative prediction of the morphometric parameters of channel bodies (paleochannels) was developed and patented in 2018. The approach with paleochannel morphometry has been tested and demonstrated using the example of the clinoform complex of the Pannonian Basin. It is shown how to trace the boundaries of areas with different morphology of paleochannels and, on the basis of this, more confidently draw the boundaries of different facies zones. Channel morphology is described for four depositional environments: the upper deltaic plain/lacustrine alluvial plain of the Pannonian paleolake, the lower deltaic plain, the shelf and the lacustrine turbidite zone (fondoform). Parameterization and prediction of channel parameters allow to predict the size of possible lithological traps, make forecasts and recommendations for further study.

INTRODUCTION

Seismic data provide a fairly accurate representation of the stratigraphic architecture in the inter-well space, but the information content in genetic diagnostics is rather low. At the same time, modern approaches, methods and tools of seismic interpretation make it possible to obtain and use quantitative characteristics of various geological bodies and paleochannels, among others. By paleochannel we mean any sedimentary body formed by a flow (unidirectional stable or variable, reversible) in any sedimentation environment and filled with sediment of different granulometric composition. It should be noted that of the large number of classifications of river channels, only some partially use morphometric parameters (Rich J.I., 1923; Friend et al., 1979; Hirst, 1991; Gibling, 2006; Miall, 2006). The morphometric characteristics of channels are formed under the influence of a number of factors: flow speed, flow regime, volume of transported sediments, stability of underlying soils, etc. As a result, a synergistic effect occurs, leading to certain morphometric patterns. The purpose of this paper was to demonstrate the possibility of morphometric analysis for the diagnosis of paleochannels, paleogeographic reconstructions and prediction of lithological traps. The widespread introduction of digital technologies into practice significantly expands the capabilities of morphometric analysis, since many calculation procedures and information transformations can be automated and built into existing software.

EXPERIMENTAL PART

Based on the identified morphometric patterns of buried paleochannels, a method for quantitative prediction of the morphometric parameters of channel bodies (paleochannels) has been developed (Patent, 2018). This approach has been tested in hydrocarbon fields of Western Siberia (Olneva, Zhukovskaya, 2016; Olneva, 2017) and the Pannonian Basin (Olneva, Zhukovskaya, 2017). Buried paleochannels are identified based on seismic facies analysis using an object-oriented approach of seismic interpretation (Olneva, 2017). The elongated bodies of paleochannels were identified using attribute maps, mostly – the results of spectral decomposition in RGB format. Next, the necessary parameters were measured (**Fig. 1**), as well as the shortest distance between the starting and ending points L and the length "along the way" L' (**Fig. 1**) to determine the sinuosity coefficient. Another important characteristic is the type of bends (meanders), which vary depending on the type of meandering. To compare with the main types of river systems, key parameters are given in (Olneva, Zhukovskaya, 2016).

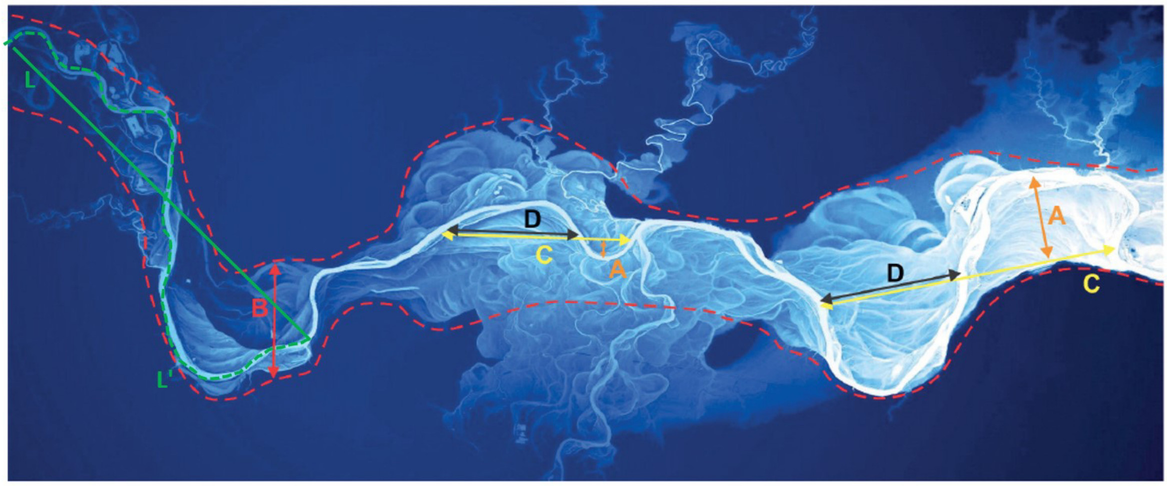


Figure 1. Parameters necessary for diagnosing the morphogenetic type of paleochannel: A – amplitude (height) of the meander; B – width of the channel formation belt; C – period (length) of the meander; D is the half-period (step) of the meander, L is the shortest distance between the boundary points, L' is the distance "along the channel/along the way". Example of a LIDAR (laser scanning) image showing the 1,500-year movement of the Willamette River in Oregon (created by Daniel Coe).

RESULTS AND DISCUSSION

This approach was applied to the Pontic clinoform complex of the Pannonian Basin in the Middle Banat region (Serbia). For the first time for this territory, the surfaces of clinocyclites within the seismic geological clinoform complex were traced. Each clinocyclite includes different-facies sediments that accumulated almost synchronously in the conditions of deltaic plains/coastal plains, shelf, coastal slope and fondoform zone. Attribute maps were performed for all surfaces, and for the purpose of identifying paleochannels, the map of the result of spectral decomposition turned out to be the most informative (**Fig. 2**). Based on specific elongated anomalies, various elongated bodies were identified. Their extent corresponds to the ranks of local and zonal lineaments (Kopylov, 2014).

An assessment of changes in the morphology of each such body made it possible to group them into several classes that are fundamentally different from each other, and to typify these bodies based on the performed morphometric analysis **(Table 1, Fig. 3).** The regular change in the morphology of paleochannels reflects the facies range inherent in each clinoform: from the alluvial plain to sediments at the fondoform zone of the lake basin. In addition, observed differences for individual clinoforms may also indicate a change in the slope of the alluvial profile or basin topography.

The different origins of these bodies were confirmed by the results of core studies. Despite the similar grain size of the channel sediments and the trend towards a decrease in grain size up the section, there are objective criteria for their difference, the main ones of which are given in **Table 2**.

As a result of the analysis, it was possible to trace the boundaries of changes in the morphology of paleochannels and, on the basis of this, more confidently draw the boundaries of different facies zones. Within these facies zones, sedimentary hydrocarbon reservoirs in the form of paleochannels have their own structural and developmental features. Some traps with the lithological boundaries were discovered.

For the upper deltaic plain, channel bodies have signs of both free and incomplete (broken) meandering in the form of various bends/meanders – segmental, omega-shaped, chest. The sinuosity coefficient varies from 1.05 to 2.33, with an average of 1.33, varying slightly in individual clinocyclites. These deposits are difficult to distinguish from river deposits, but the fan-shaped orientation of the channels is more typical of deltaic sedimentation environments.

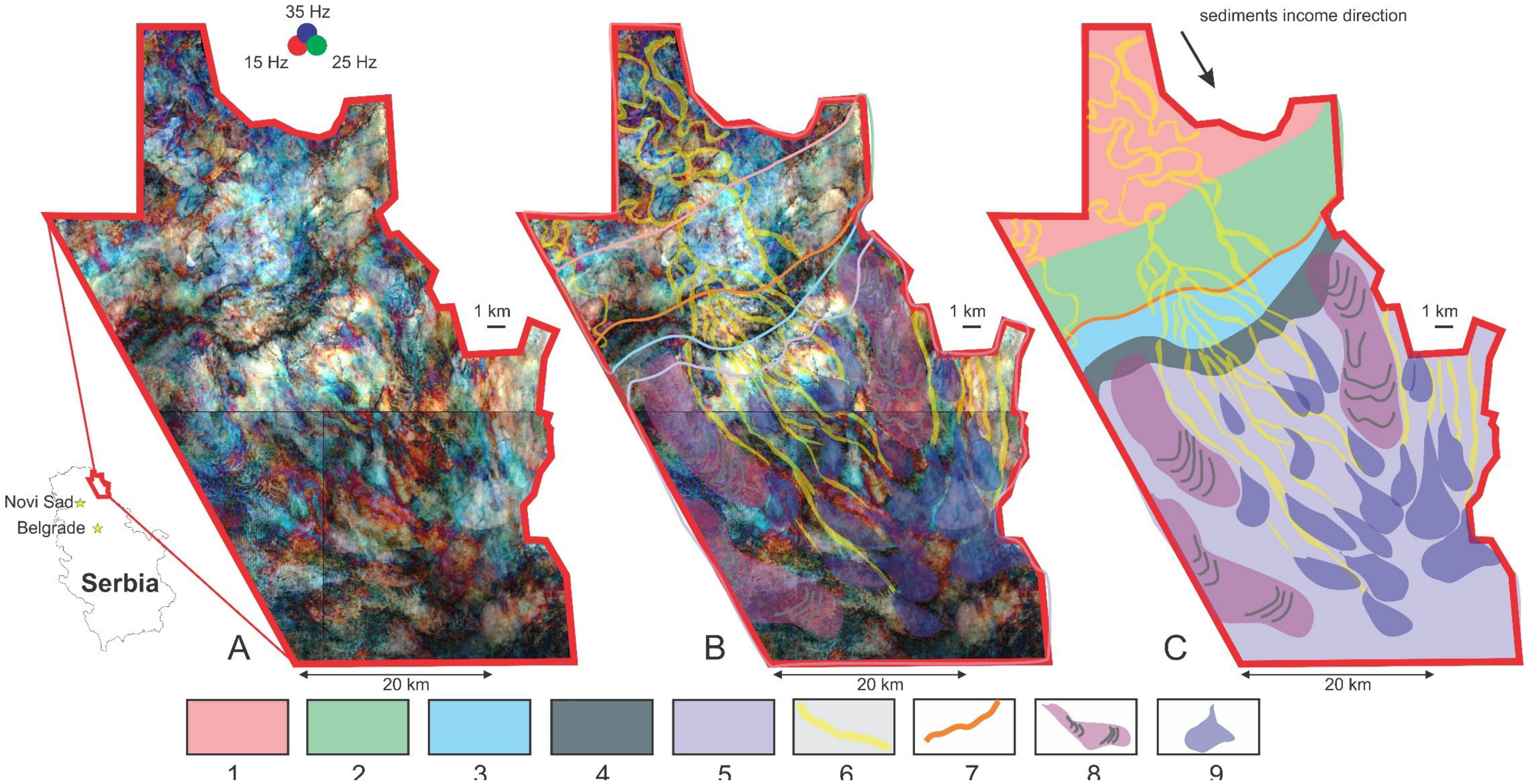


Figure 2. Result of spectral decomposition in cyclite C6 without (A) and with the author's interpretation (B). Resulting facial scheme (C). 1 - Upper deltaic plain / lacustrine-alluvial plain, 2 - Lower deltaic plain, 3 - Shelf, transitional and prefrontal beach zone, 4 – slope, 5 – fondoform, 6 – channels, 7 – paleoshoreline, 8 – mass transport deposits (slumps), 9 – deep-water fans

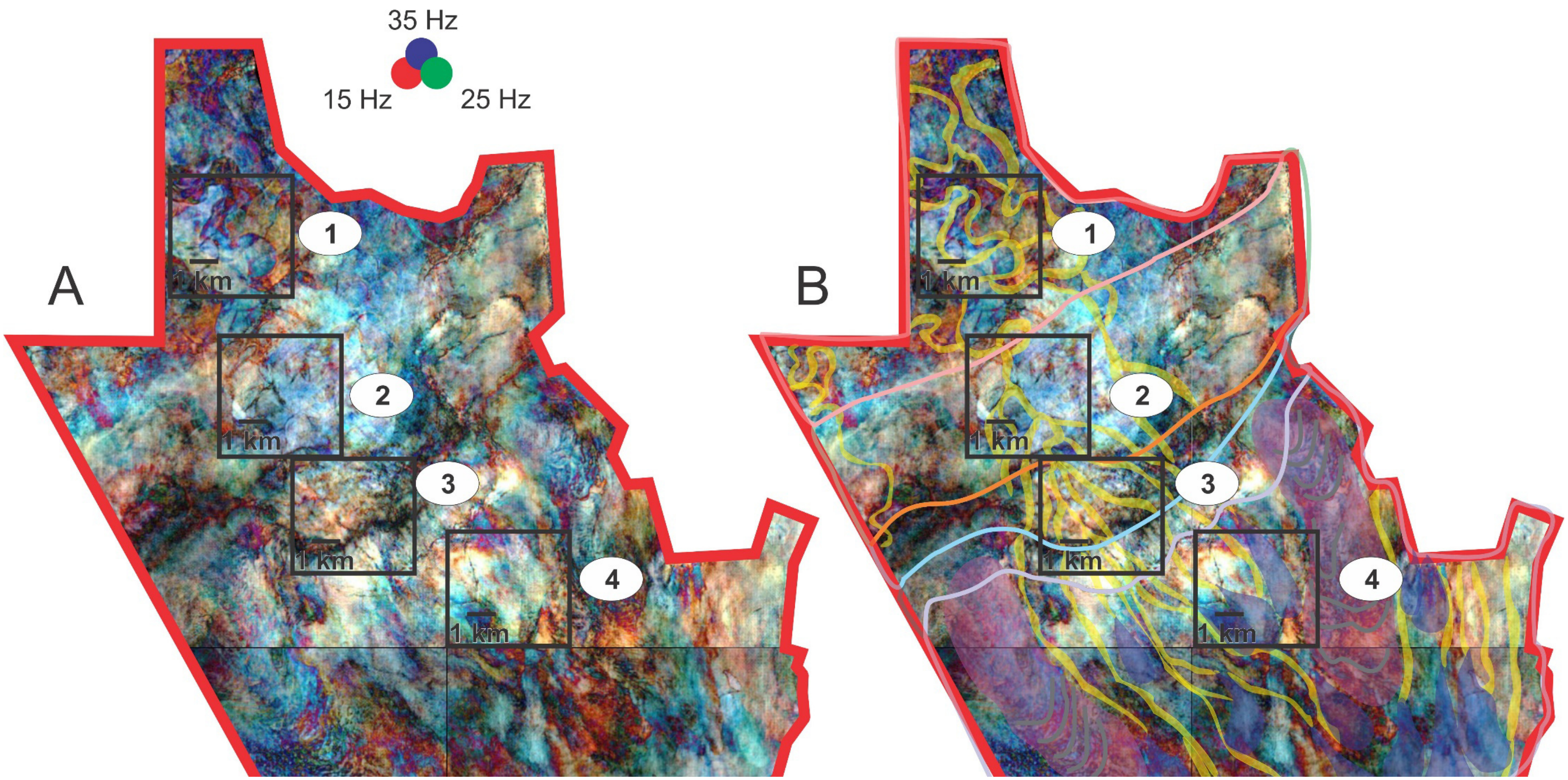


Figure 3. Fragment of fig. 1 in different scale. Result of spectral decomposition in cyclite C6 without (A) and with the author's interpretation (B). 1-4 - the position of the squares from table 2 (Seismic image column) is shown. 1 - river meandering in upper deltaic plain / lacustrine-alluvial plain sedimentation setting, 2 - distributive deltaic channel slightly sinuous with predominantly segmental bends in lower deltaic plain sedimentation setting, 3 - straightened channels in deltaic / shelf sedimentation setting, 4 - turbidite channel

Table 1. Morphological characteristics of paleochannels

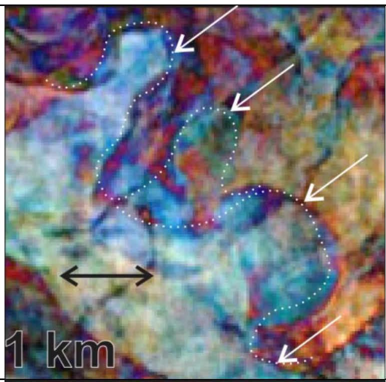
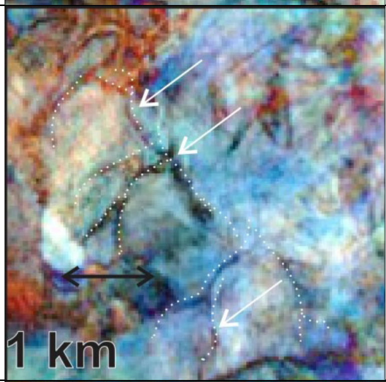
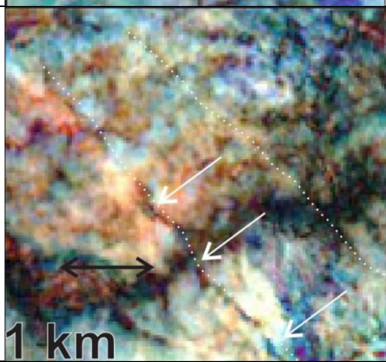
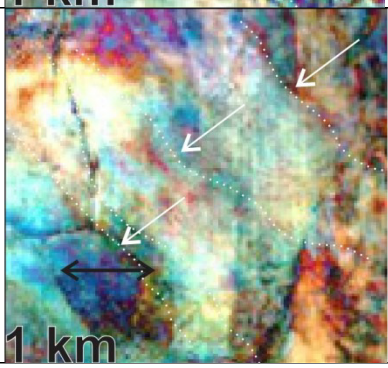
Channel type	Sedimentation setting	Seismic image	Channel morphology	Morphometry for paleochannels in cycle C6
River meandering	Upper deltaic plain / lacustrine-alluvial plain		Sinuous with various shapes of bends	parameters for the meandr: • step 1,11-7,11 km, • period: 2,22-13,33 km, • amplitude 0,1-5,21 km; average sinuosity coefficient 1,33 (1,05-2,33)
Distributive deltaic	Lower deltaic plain		Slightly sinuous channels with predominantly segmental bends	parameters for the meandr: • step 0,89-4,89 km, • period: 1,56-7,56 km, • amplitude 0,22-1,61 km; average sinuosity coefficient 1,23 (1,04-1,78)
Deltaic / shelf	Shelf, transitional and prefrontal beach zone		Straightened channels	parameters for the meander: • step 0,88-7,11 km, • period: 1,77-8,88 km, • amplitude 0,23-1,82 km; average sinuosity coefficient 1,10 (1,04-1,25)
Turbidite channel	Lake turbidites with the influence of hyperpycnal processes (slope and fondoform)		Straightened and weakly sinuous channels	parameters for the meandr: • step 1,48-4,82 km, • period: 3,04-14,78 km, • amplitude 0,36-1,74 km; average sinuosity coefficient 1,09 (1,02-1,31)

Table 2. Lithological characteristics of paleochannels

Channel type	Facies association based on core	Main diagnostic features based on core	Photo of core	Erosion type
River meandering	Channel alluvium, floodplain alluvium oxbow sediments, swamp sediments	Intraformational conglomerates, erosional contact, flow ripples, paleosol horizons, root remains		Lateral
Distributive deltaic	Channel alluvium, floodplain alluvium, lacustrine/lagoonal sediments, mouth bars	Intraclast sandstones in basal parts, small-scale flow ripples, freshwater ichnofossils and macrofauna		Lateral and bottom
Deltaic / shelf	Sublittoral tempestites	Intraclast sandstones in basal parts, small-scale current and wave ripples, brackish ichnofossils, macro- and microfauna		Bottom and lateral
Turbidite channel	Levees, lobe deposits, interlobe space facies, slope deposits, landslide bodies and debris flows	Erosion contact, intraclast and massive sandstones, unidirectional cross-bedding, gradational and plastic deformation textures		Bottom

The lower deltaic plain is replete with distribution channels with less sinuosity (**Table 1**) and with bends of a segmental appearance. The ratio of the period (length) of the amplitude for the distribution channels of the deltaic system with a predominance of river influence is in the average 1:5.5, which is close to the ratios obtained in the Jurassic and Cretaceous sections of the West Siberian Basin from 1:4 to 1:8 on average 1:6.5. Deep gullies on a short shelf (1.8-11.5 km) are transitional objects from the point of view of channel morphology, being a continuation of deltaic distribution channels. They are predominantly developed in the estuarine parts of river systems. They have a straightened morphology, which is inherited further down the slope.

Turbidite channels on the slope and at its foot and fondoform are maximally straightened, they are oriented perpendicular to the line of shelf edge if there are no obstacles in the form of landslide bodies, which the channels go around, moving towards the side parts. It is extremely rare that channels break through the landslides with a flattened surface. The evolution of downslope channels involves some degree of dichotomy or increasing sinuosity.

CONCLUSION

In general, the consistent change in the morphology of paleochannels, confirmed by morphometric analysis, is of a natural nature and consists in straightening the channels in the direction of the basin. Knowing the pitch of the paleochannel bend (in our example, the paleochannel), one can calculate its width (Jacob A. Covaultet al., 2021) and compare it with that measured by seismic to clarify the geometry of the bodies.

Only an integrated approach to the interpretation of geophysical data with the mandatory involvement of core studies and morphometric analysis makes it possible to reliably determine the morphology, size of bodies and predict the distribution of sandstone outside the drilled part of the deposits.

In turn, parameterization of the object and prediction of individual values that are beyond the resolution of the seismic method allow a more realistic assessment of the morphology of the paleochannel, predict the size of possible lithological traps, estimate resources, make forecasts and recommendations for further study. The given example of a numerical assessment of the morphometric parameters of paleochannels clearly demonstrates its advantages for in-depth geological interpretation. In the absence of strict rules for morphometric analysis, we recommend using the experience obtained by the authors at least for the pontic deposits of the Pannonian Basin.

REFERENCES

Patent No. 2672766 C1 Russian Federation, IPC G01V 1/28, G01V 9/00. Method for predicting morphometric parameters of channel bodies (paleochannels): No. 2018104929: application. 02/08/2018: publ. 11/19/2018 / T. V. Olneva, E. A. Zhukovskaya; applicant LLC Gazpromneft STC.

Olneva T.V, Zhukovskaya E.A. (2016). Seismic vision of geological processes and phenomena: channel deposits of continental sedimentation environments. Geophysics, 2. P. 2–9.

Olneva T.V., Zhukovskaya E.A. (2017). Parameterization of the sinusoidality of paleochannels for facies reconstructions and object modeling. Geophysics, pp. 41-46.

Olneva T.V. (2017). Seismic facies analysis. Images of geological processes and phenomena in seismic images. Izhevsk: Institute of Computer Research. 152 p.

Olneva T.V., Zhukovskaya E.A. (2017). Comprehensive study of the thickness of Neogene deposits of the Pannonian basin based on seismostratigraphic approaches with elements of seismic facies analysis. Notes of the Mining Institute, 228, 631. https://doi.org/10.25515/pmi.2017.6.631

Kopylov I.S. (2014). Scientific and methodological foundations of geoecological studies of oil and gas regions and assessment of the geological safety of cities and objects using remote methods. Abstract of PhD dissertation, Perm. 48 p.

Jacob A. Covault, Zoltán Sylvester, Can Ceyhan, and Dallas B. Dunlap. (2021). Giant meandering channel evolution, Campos deep-water salt basin, Brazil. Geosphere, 17(6). Pp. 1869–1889. https://doi.org/10.1130/GES02420.1