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# SEDIMENTARY BASIN ANALYSIS: BLACK SEA–CASPIAN REGION

*The accomplished analysis has found out that the study basins were the parts of the Black Sea–Caspian basin system in the Mesozoic era, partly participated in dislocation tectonics later on, and are the part of the Alpine folding zone from the viewpoint of the modern tectonic zoning. Furthermore, the analysis has set the main stages of the sedimentation cross-section formation with the specified sedimentary depocenters at each stage, which allows reconstructing the sedimentation evolution. The studies of the delineated area reveal four zones of stable downwarping within the period of the plate mantle formation: the Karkinit, Indol–Kuban, Eastern Kuban and Terek–Caspian basins. Each basin features unique evolution in terms of different tectonics modes and sedimentation velocities. These factors govern the geological structures of the basins–different thickness relationships of sedimentary units.*

***Keywords:*** *sedimentation development analysis, Scythian–Turan basin system, oil/gas exploration trends, foredeeps, sedimentary rocks, regression, sedimentation, downwarping diagram*
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## Introduction

According to the concept of the two-level basement of young platforms, the Scythian Platform has two levels: the ancient level (Baikal consolidation) is the crystalline basement itself, and the upper level is an intermediate system formed after varied intensity folding of the pre-platform mantle in the Hercynian and, partly, old Cimmerian ages of tectonogenesis [1–4]. The ancient basement formed in a geosyncline system established in the southern outskirts of an ancient platform at the later Proterozoic (Riphean) time [5–7]. As compared with the basement rocks, the intermediate measures feature moderate and weak dislocation and metamorphism (mostly dynamic metamorphism) which decrease top downward and are more pronounced inside and nearby faulting zones.

The intermediate system includes the middle-to-late Paleozoic measures and the Mesozoic deposits from the Triassic to middle Jurassic period. The stratigraphic interval of the intermediate measures is inconsistent and varies in relation to the tectonic development of individual blocks of the Scythian Platform. The late Mesozoic (J3)–Cenozoic deposits belong to the plate mantle. Starting from that time, the tectonically quiet platform conditions set in the most part of the territory [8–12]. The southern outskirts of the platform experienced later tectonic deformations because of the Caucasian orogeny, while the center and east periphery were dragged in the low-rate uplift processes (1.2 cm/thousand years) [13].

**Figure 1** shows a detailed analysis outline against the tectonic zoning map of the territory. Here, the best part of the area is occupied by the Scythian and Turan Platforms. The rest geological systems are the southern outskirts of the East European Platform, Terek–Caspian foredeep, Crimeann–Caucasian folding system, and the northeast of the Black Sea–South Caspian depressions.

## Research procedure

For the purposes of the basin analysis using all geological and geophysical data available, the sedimentation velocity mapping is carried out for all stratigraphy units in the sedimentary mantle in the Black Sea–Caspian region (**Figs. 2** and **3**).

**Figure 4** describes downwarping in the centers of the four selected basins. The stratigraphy columns on the right of the diagrams illustrate the thickness ratios of the sedimentary levels in the plate mantle. The steepness of the lines of the levels in the diagrams depicts the change in the downwarping velocity of the sedimentation process at different evolution stages of the basins: the steeper line means the higher downwarping velocity.

## Results

The implemented research shows that the plate mantle in the study area represents carbonate and terrigene sedimentary rocks of the Upper Jurassic–Cretaceous period, and the Cenozoic terrigene deposits. The mantle is divided by the main surface of unconformity into seven units: Upper Jurassic, Cretaceous, Paleocene-Eocene, Maykopian, lower Middle Miocene, Upper Miocene–Pliocene and Quaternary.

In the later Jurassic period, within the limits of the Scythian Platform, the plate started to form in the conditions of the unarrested vast regression. In the most part of the area, the terrestrial conditions established and no sedimentaries built up [14–16]. The marine conditions and the main depocenters existed in the southwest of the study area (see Fig. 2).

The Greater Caucasus Basin stands out, as well as some independent basins in the northern periphery: Southern Crimean, Crimean–Kerch, Indol, Western Kuban and Eastern Kuban. In the east, the small-area Terek–Caspian foredeep lies.

Later on, the most of these basins experienced folding and inversion under the impact of orogeny in the Caucasus and in Crimea [17–21]. The Southern Crimean basin totally entered the Crimean orogeny. The Greater Caucasus and Terek–Caspian basins underwent partial inversion. The Crimean–Caucasus folding embraced the Crimean–Kerch, Indol and, partly, the Terek–Caspian basins. Only the Western Kuban and Eastern Kuban depocenters never left the Scythian Platform.

The sedimentation velocity map (see Fig. 3*a*) reflects the dynamics of the later Jurassic downwarping. Within the aquatic area of the central Caspian and the adjacent Eastern Ciscaucasia, the late Jurassic age sedimentation velocity was within the first centimeters per year. At the Jurassic depocenters, these values were higher by an order of magnitude. The maximum velocities of sedimentation were observed in the largest Greater Caucasus Basin.

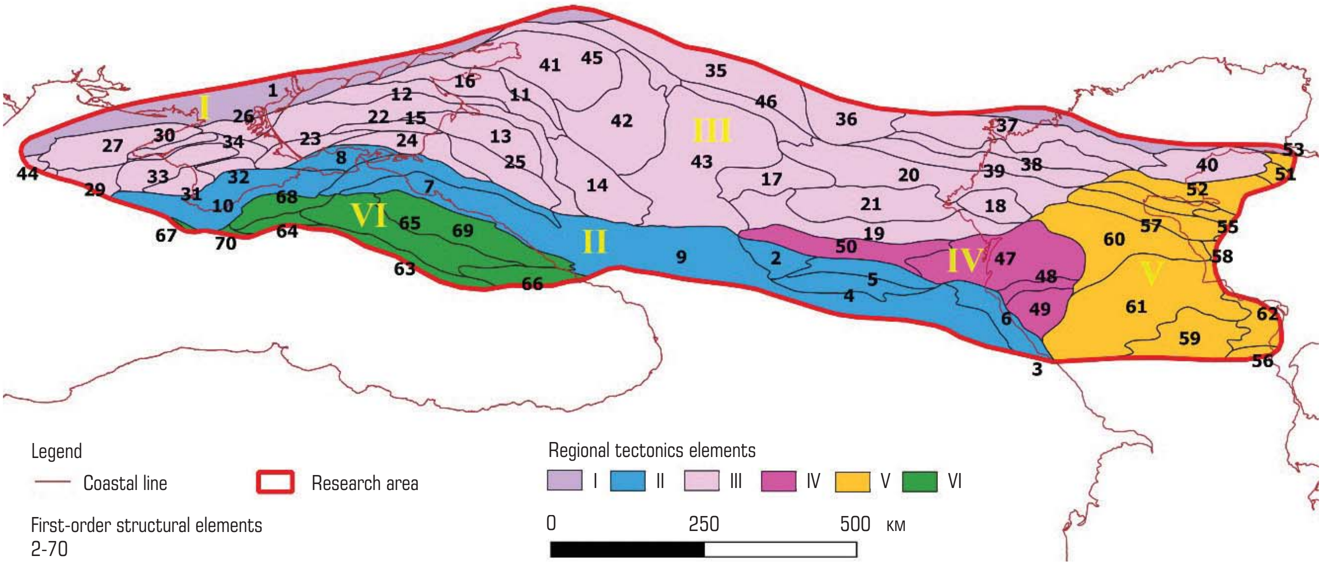


**Fig. 1. Tectonic structure of the Black Sea–Caspian region**

*Legend:* **Regional tectonic elements***: I–East European Platform, II–Crimean–Caucasian orogenic folding, III–Scythian Platform, IV–Terek–Caspian foredeep, V–Turan Platform, VI–Black Sea–South Caspian depressions;* **2nd order structural elements***: 2–Kabardian downwarp, 3–Kusary–Divichi downfold, 4–Terek–Sunzha folding, 5–Ossetian–Chechen downwarping, 6–Dagestan folding, 7–Taman folding and adjacent tertiary folds, 8–North Kerch folding, 9–Greater Caucasus mega anticlinorium, 10–Crimean Mountains mega anticlinorium, 11–Irklievskaya downwarp, 12–North Azov–Beisug downwarping, 13–Timashevsk step, 14–Eastern Kuban downfold, 15–Azov–Maykopian uplifts, 16–Sosyk saddle, 17–Eastern Stavropol step, 18–Nogai step, 19–Chernolesskya downward, 20–Eastern Manych downwarping, 21–Prikumsky–Tyulenevo uplifts, 22–Achuevo step, 23–Eastern Arabat step, 24–Kerch–Temryuk downwarp, 25–Cherbugol step, 26–Sivash foredeep, 27–Shtormovoi (Karkinit) graben, 28–Kraevaya step, 29–Ilichevsk–Tarkhankut uplifts, 30–Tarkhankut swell, 31–Alma downwarp, 32–Simferopol uplift, 33–Kalamita–Novoselovo uplifts, 34–Novotsaritsino uplift (step), 35–Zavetnino step, 36–Buzga block, 37–Promyslovka–Kulaly uplifts, 38–Dzhanai–Zyudeva downwarping, 39–Caspian–Lagan uplifting, 40–Rostov extrusion, 41–Rostov extrusion, 42–Western Stavropol downwarp, 43–Stavropol–Mineralnye Wody uplifting, 44–Dobrudzhi uplifting, 45–Tuzla–Proletarsky foredeep, 46–Manych-Gudilo foredeep, 47–Agrakhan downwarp, 48–Khazry connection, 49–Achisu downwarp, 50–Terek foredeep, 51–Naryn-Tokubay uplifting, 52–South Byzachi foredeep, 53–Beyneus foredeep, 54–Tyub-Karagan swell, 55–Mangustau ridge, 56–Northern Turkmen uplifting (anticlise), 57–Bike–Bashkuduk step, 58–Zhetybay–Uzen step, 59–Kazakh Bay foredeep, 60–Segendyk foredeep, 61–Samur–Peschanomyssk uplifting, 62–Aksu–Kenderli saddle, 63–Crimean–Pontic basin, 64–Tentyaev uplift, 65–Shatsky swell, 66–Western Georgian block mass, 67–Western Black Sea basin, 68–Sorokin foredeep, 69–Tuapse foredeep, 70–Andrusov swell*

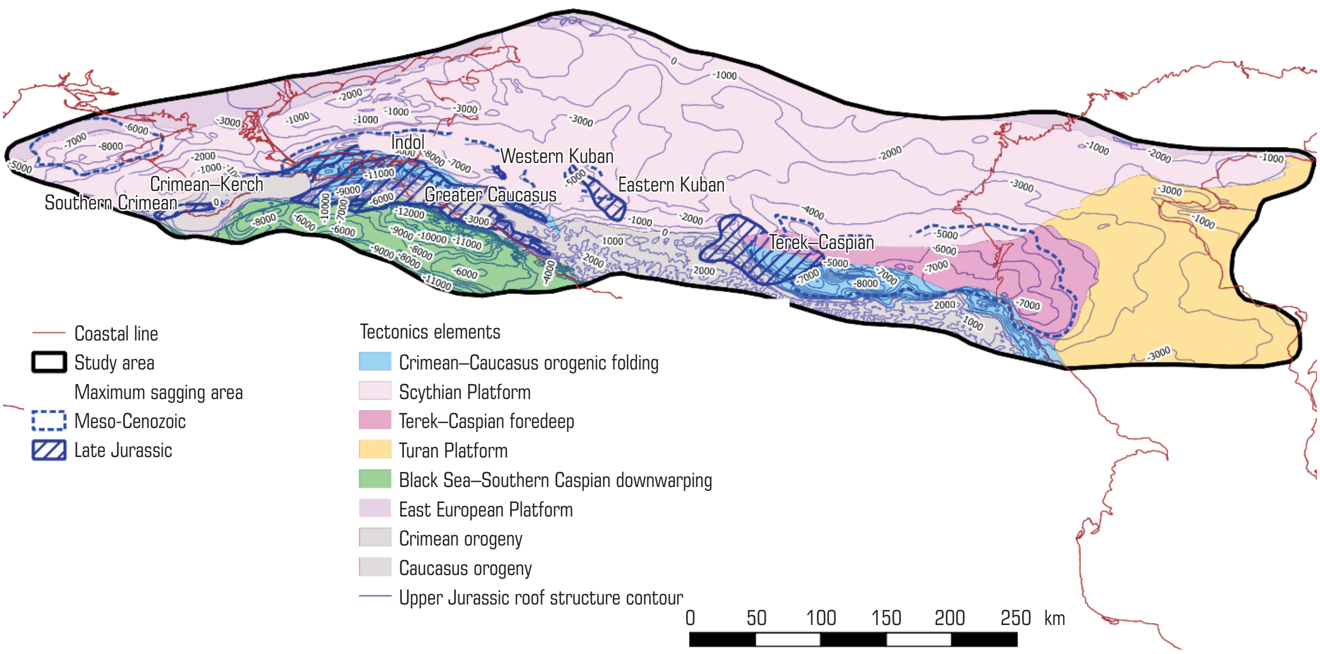


**Fig. 2. Late Jurassic sedimentation map**

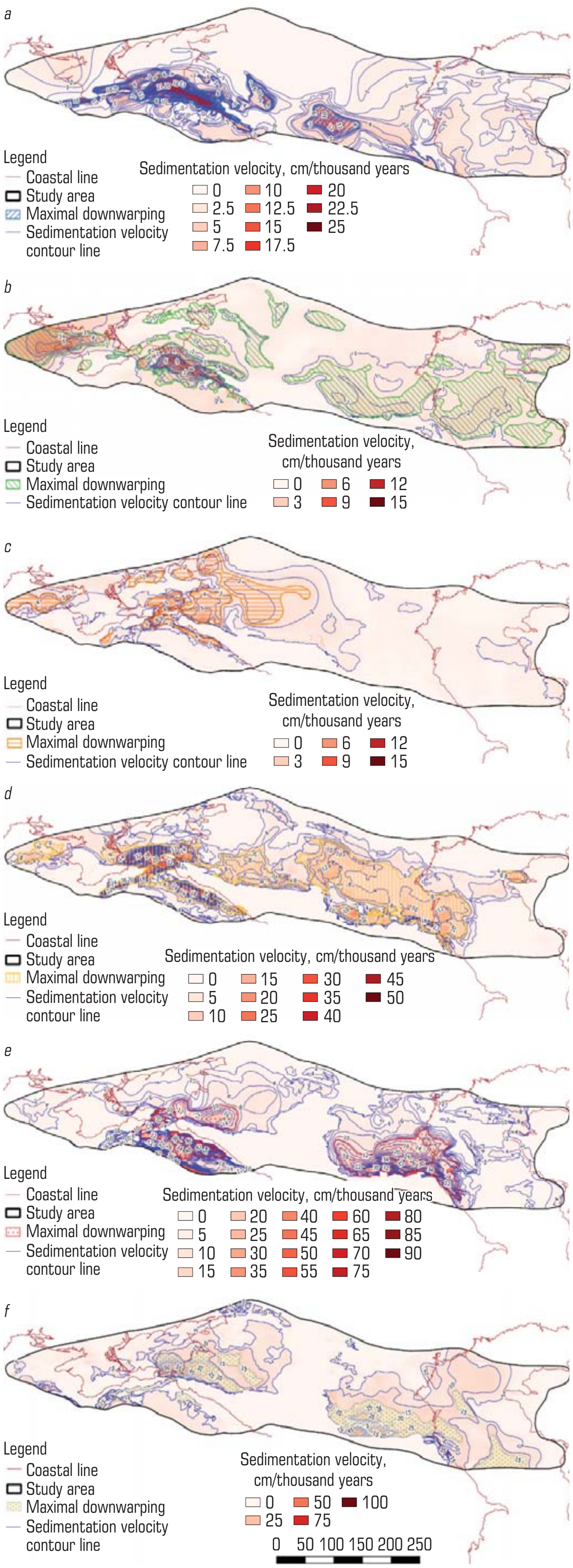


**Fig. 3. Sedimentation velocities in later Jurassic (*a*), Cretaceous (*b*), Paleocene–Eocene (*c*), Maykopian (*d*), Miocene (*e*) and Pliocene (*f*)**

The Cretaceous period sedimentation occurred in the conditions of vast transgression. The marine conditions with numerous depocenters spread across the whole study areas (see Fig. 3*b*).

In the north, along the joint of the Scythian and East European Platforms, a chain of basins established: Karkinit, Northern Azov, Western Stavropol, Gudilo and Ustyurt. In the east, the large Terek–Caspian and Central Caspian basins formed. In the west, the Greater Caucasus, as well as the Western and Eastern Kuban basins expanded larger. The Southern Crimean, Crimean–Kerch and Indol depocenters kept developing.

Like the late Jurassic, the Cretaceous basins in the southern periphery of the Scythian Platform experienced folding and partial inversion (Southern Crimean and Greater Caucasus basins).

The sedimentation velocities in the most of the listed depocenters are low and not higher than 1–2 cm/thousand years (see Fig. 3*b*). Tectonic downwarping only proceeds in the Karkinit and Greater Caucasus basins, which follows from the relatively high sedimentation velocities of 6 and 9 cm/thousand years, respectively.

During Paleogene, the tectonic downwarping totally terminated in the east of the study area. The sedimentary basins of Karkinit–Sivash, Berda, Northern Azov and Western and Eastern Kuban lied exclusively in the west. The Eastern Kuban basin expanded more as against the Cretaceous period, including the Stavropol dome which held its uplift within the whole Meso-Cenozoic evolution era [22–27]. Southward of the Crimean and Caucasus orogeny, the Tuapse, Taman and Sorokin foredeeps (basins) originated.

The sedimentation velocities went on decreasing in the Paleocene–Miocene and reached 10 cm/thousand years in none of the listed depocenters (see Fig. 3*c*).

The Maykopian time features transgression with simultaneous expansion of the marine conditions of sedimentation and with deepening of the basins. The latter, according to [13], takes place under the impact of closure of the Tethys Ocean southward of the study area. Deepwater sedimentation took place in the large depocenters of Eastern Ciscaucasia, Indol, Eastern Kuban Tuapse and Kerch–Taman (see Fig. 3*d*).

The sedimentation velocities grew because of dynamic tectonic downwarping and the resultant expansion of accommodation space. However, the listed basins differentiate substantially in terms of the sedimentation velocities. In the most of the depocenters (Ustyurt, Eastern Ciscaucasia, Western Kuban and Karkinit), the sedimentation velocities are never higher than 10 cm/thousand years. Against this background, the depocenters subjected to the impact of the Caucasus and Crimean orogeny, namely, the Tuapse, Indol–Kuban (west) and Kerch–Taman, feature two–three times higher velocities of sedimentation.

In the Miocene, downwarping only proceeds in the basins influenced by the active orogeny in the Caucasus. These are the large depocenters of Terek–Caspian, Indol–Kuban (east) and Tuapse, and the small depocenters of Sorokin, Anapa and Kerch–Taman. In the

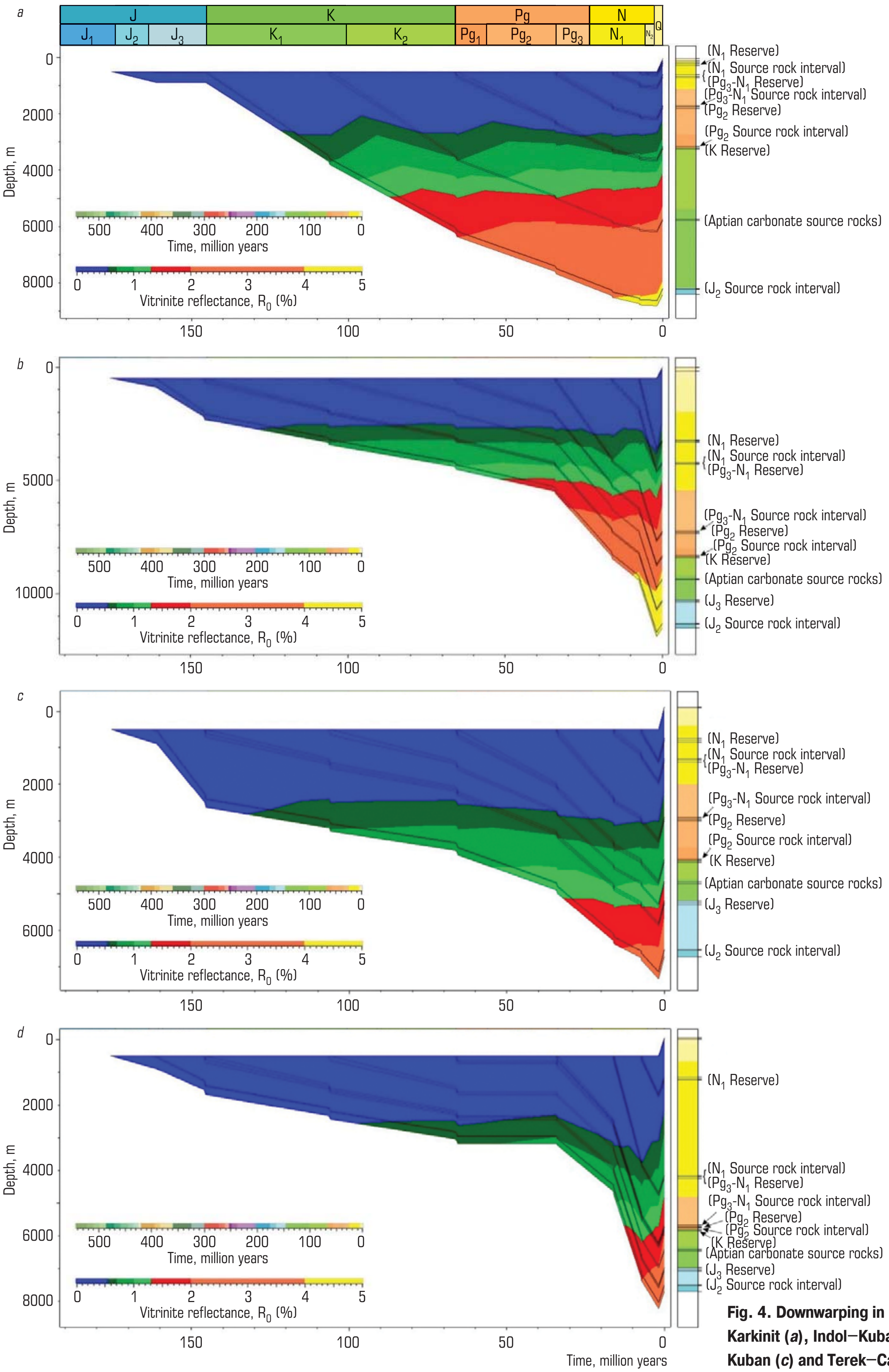


**Fig. 4. Downwarping in basins of Karkinit (*a*), Indol–Kuban (*b*), Eastern Kuban (*c*) and Terek–Caspian (*d*)**

rest area, the accommodation space of the Maykopian basin fills out [28–33]. In the Crimean and within the limits of the Stavropol dome, no sedimentary accumulates. The maximum sedimentation velocities (from 20 to 40 cm/thousand years) are observed in the Terek–Caspian and Tuapse foredeeps (see Fig. 3*e*).

In the Pliocene, downwarping activates in the Eastern Kuban basin. The Terek–Caspian and Western Kuban depocenters keep developing. In the northeast of the aquatic area of the Black Sea, vice versa, downwarping decelerates and the basins split into a few small depressions. The highest velocities of sedimentation are in the Terek–Caspian and Indol–Kuban basins. In the latter basin, the sedimentation velocities reach 50 cm/thousand years. These are the maximum values over the whole test period in the study area (Fig. 3*f*).

It seems to be interesting to compare two largest and most stable basins of Indol–Kuban and Terek–Caspian. The former basin formed within the modern outlines in the Paleocene–Eocene, and the latter—in the late Maykopian–Miocene [13]. The intensity of downwarping changes asynchronously in these basins. The maximum velocities were observed in the Indol–Kuban basin in the Maykopian period, in the Terek–Caspian basin in the Miocene and in the Indol–Kuban basin again in the Pliocene. Both basins are conventionally assumed to be the frontal foredeeps ahead of the Caucasus orogeny front, which is considered as a key control factor for the genesis and evolution of the basins [33–38]. The accomplished analysis shows that a potential complimentary factor to control tectonic downwarping of the Indol–Kuban basin at some stages of its development is the indirect influence of rifting in the Eastern Black Sea depression, via a system of shear-induced dislocations.

Figure 4 describes downwarping in the center areas of the four listed basins. The dominant sedimentary systems are the Cretaceous deposits in the Karkinit basin, Neogene–Quaternary deposits in the Terek–Caspian basin and the Cenozoic strata at the parity of the Paleogene and Neocene in the Indol–Kuban basin. The Eastern Kuban basin features an equitable relationship of the main sedimentary units.

In the Karkinit basin, the highest velocities are typical of the Cretaceous and Paleogene periods. Downwarping shows a sharp drop in velocity since the middle Miocene. The center and the north wall of the basin have the same behavior of downwarping, while the lower velocities are characteristic of the south wall of the basin.

The comparatively gentle lines in the Indol–Kuban basin mean quiet sagging of the sedimentary rocks in the Mesozoic and Paleogene periods. The pattern sharply changes in the Maykopian time: the basin starts to go down very quickly. Such behavior is specifically typical of the center and the north wall of the downwarp. In the Miocene, the south wall downwarping stops and restarts only in the Pliocene.

## Conclusions

The accomplished analysis has identified the main stages in the sedimentation cross-section and the sedimentary depocenters per each stage, which allows the sedimentation evolution reconstruction.

The research delineates four areas of stable downwarping (basins) in the study area within the period of the plate mantle formation: Karkinit, Indol–Kuban, Eastern Kuban and Terek–Caspian basins.

Each basins features unique evolution which shows in different tectonics modes and sedimentation velocities. This governs the specifics of the structural geology of the basins—different thickness relations of the main sedimentary units.

The downwarping velocities are the highest in the Late Jurassic in the Eastern Kuban basin. Downwarping gets slower in the Cretaceous time and then shows an upward velocity trend till the modern time.

For the Terek–Caspian basin, downwarping typically has slow velocities at the early stages of the sedimentary mantle, in the Mesozoic time, and terminates in the first half of the Paleogene. The sharp change in the tectonic mode in the Maykopian period results in the acute dip of the basin up to the Pliocene. The orogeny of the Caucasus caused inversion of the south walls of the basin.

On the whole, the behavior of all basins implies the favorable conditions for the hydrocarbon reservoirs. Gradual downwarping of sedimentary units ensures maturation of the organic matter of the reservoir rocks, on the one hand, and, on the other hand, it as if structures continuous flow of hydrocarbons toward the walls of the basins and to adjacent areas which hold their uplifting for the whole time of development of the basins. Inversion in the south walls of the Terek–Caspian foredeep might cause redistribution of hydrocarbon flows from this part of the basin toward the Caucasus, and the risk of transformation of the deposits. Yet, the inversion had no influence on migration of the north wall of the basin.

Variation of the velocities of downwarping in the basins at different times has had a critical effect on the materialization of oil and gas generation potential in the source rocks.

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