

Conturites Are a New Object for Searching for Non-Structural Hydrocarbon Traps in the Lower Cretaceous Sediments of Western Siberia

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Abstract. Based on the results of 3D seismic exploration in the section of the Lower Cretaceous clinoform complex of Western Siberia, elongated bedform (sedimentary waves, ripples, ridge, conturite drifts) oriented along the underwater slope perpendicular to the direction of turbidite channels and lobes have been established. On spectral decomposition and amplitude maps, they resemble Aeolian relief shapes, the ridges can be either straight or sinuous with bifurcation. In seismic sections, conturites are diagnosed by the rugged and discontinuous shape of the recording with a variable amplitude of reflections or represent a “traveling wave”. It was found that in the Lower Cretaceous relatively deep-sea marine basin, high-intensity contour currents were constant, acting with different intensity (flow velocity) in different parts of the marine basin. They eroded and redeposited sedimentary sediments of turbidite genesis, thereby affecting the final morphology of the deep-sea fans of outflow.

Under the influence of bottom currents, both mixed tidalite-conturite-turbidite systems and individual conturite drifts of various lithological composition were formed. The processing of sediments by bottom currents is indicated by characteristic sedimentary structures: double layers, bidirectional and unidirectional crossbedding, horizontal lamination, flaser and lenticular bedding, climbing-ripples cross-bedding, normal and reverse grading, as well as in places the intensive development of bioturbation processing of sediments, which are not typical for turbidite deposits. Sandy conturite drifts can serve as new objects for the extraction of non-structural hydrocarbon traps in the deep-sea marine basin of the Western Siberian megabasin.

Keywords: conturites, contour currents, internal waves and tides, turbidites, Achimov formation, Western Siberia, deep-water fans, bottom-current reworked sands

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Introduction

Currently, due to the development of major structural targets of Western Siberia, an urgent task is to identify potential hydrocarbon traps of non-structural and combined types. One of such important targets in the Western Siberian megabasin are the deposits of the Achimov Formation (sandstone lenses with

interlayers of argillite-like clays) (Decision of the 5th Interdepartmental Stratigraphic Meeting..., 1991), occurring at the bottom of the Lower Cretaceous clinoform complex, in the fondoform part of clinoforms (Gurari, 2003; Nezhdanov et al., 2000; Grishkevich, 2005), on clayey deposits of the under-Achimov sequence or on siliceous-clayey deposits of the Bazhenov Formation and its analogues (Yanovstan, Golchikha, etc.). According to the approved regional scheme of the Lower Cretaceous deposits of Western Siberia, the Achimov Formation (Valanginian – Barremian age) is part of seven suites (Fig. 1): Kulomzinskaya,

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Megionskaya, Shuratovskaya, Nizhnekhetskaya – in the east, Sortymenskaya – in the central part, Akhskaia and Frolovskaya – in the west (Decision of the 5th Interdepartmental Stratigraphic Meeting..., 1991), the area of its distribution is about 1.0 million square kilometers. The Achimov reservoirs are part of 16 regional clinoforms, the names of which correspond to the marker horizons – regional clay caprocks (Labazny, Priozerny, Tagrinsky, Khalmernpayutinsky, Samotlorsky, Uryevsky, Samburgsky, Savuisky, Cheuskinsky, Sarmanovsky, Teplovsky, Pimsky, Enyakhinsky,

Priobsky, Yamburgsky, Bystrinsky), proposed in 2005 by V.F. Grishkevich (Grishkevich, 2005).

The Achimov sequence was formed in a relatively deep-water marine basin as a result of uncompensated lateral filling from the east and southeast (Kontorovich et al., 2014; Shimansky et al., 2023; Syngaevsky et al., 2015) by gravity flows that supplied detrital material to the base of the under-water slope and formed deep-water fans that were reworked by bottom currents (Syngaevsky et al., 2015; Nezhdanov et al., 2000). Recent comprehensive research results show that bottom

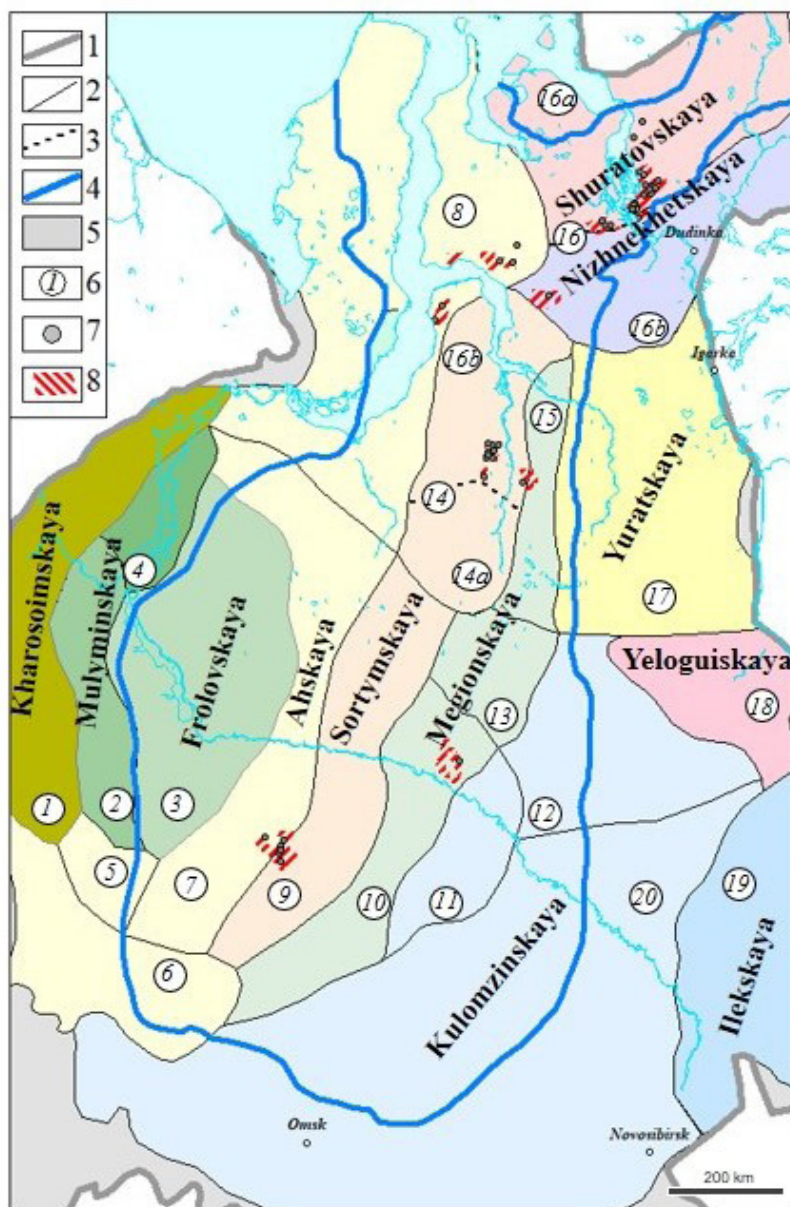


Fig. 1. Study areas on the zonation map by cross-section types of the Berriasian-Aptian deposits of Western Siberia (Decision of the 5th Interdepartmental Stratigraphic Meeting..., 1991). Boundaries: 1 – Western Siberian Plate; 2 – structural-facies regions; 3 – subregions; 4 – distribution of the Achimov Formation; 5 – deposition break zone; 6 – name of the structural-facies regions and subregions: 1 – Polar and Subpolar Trans-Urals; 2 – Igrim-Shaim; 3 – Berezov; 4 – Frolov; 5 – Karabash; 6 – Tyumen; 7 – Tobolsk-Nadym; 8 – Poluistko-Yamal; 9 – Surgut; 10 – Nizhnevartovsk; 11 – Aleksandrov; 12 – Laryak; 13 – Vengapur; 14 – Purpe-Urengoy; 14a – Purpe, 14b – Urengoy; 15 – Tazovsky; 16 – Ust-Yenisey; 16a – Pritaymyr, 16b – Malokhetsk; 17 – Turukhansky; 18 – Eloguysky; 19 – Chulyum-Yenisey; 20 – Ryavkino-Vasyugansky. 7 – cored wells; 8 – areas covered by 3D seismic exploration data used in the study.

currents of thermohaline –induced bottom currents, as well as those associated with internal tides and waves, could form ripple marks on the bottom of the marine basin, reworked turbidites and hemipelagites, and exerted both erosive and accumulative activity. Contourites are sediments affected by alongslope bottom currents (Stow, Lovell, 1979; *Sedimentary Environments and Facies*, 1990; Rebesco, Camerlenghi, 2008) and are found on the bottom of many modern and ancient oceans, deep seas and lakes and have been described in many studies (Saraev et al., 1986; Stow, 2002; Rebesco, 2004; Roslyakov et al., 2009; Miramontes et al., 2021; Rodrigues et al., 2022; Ryabchuk et al., 2023). In the Western Siberian Lower Cretaceous clinoform complex, structural and textural diagnostic features of contourites, their reflections on seismic sections and spectral decomposition and amplitude maps are presented for the first time.

As a result of the analysis of 3D seismic data carried out in many areas of Western Siberia (Fig. 1), in the interval of the Lower Cretaceous clinoform complex, bottom forms similar to Aeolian dunes and barchans were interpreted, which have varying intensity on the maps of seismic attributes and seismic sections, the formation of which reflects the activity of unidirectional bottom currents not associated with turbidite flows.

The main objective of this paper was to study contourites and mixed contourite-turbidite systems, establish their diagnostic features and lithological composition, the effect of bottom currents on sediment formation and reworking, and the morphology of deep-water fans to improve the accuracy of net-reservoir rock prediction.

The formation of contour currents in the Western Siberian semi-enclosed Lower Cretaceous basin was caused by the influx of cold, dense Arctic waters through the northern straits. These waters, sinking to the bottom of the deep-sea basin, were deflected to the right by the Coriolis force and circulated along the under-water slope. Many researchers classify contour

currents as bottom currents, as they can be caused by winds, thermohaline circulation, internal waves and tides (Davis, Dalrymple, 2012; Shanmugam et al., 1993), cascade and geostrophic currents, and tsunamis (Stow, Smillie, 2020; Shanmugam, 2021). The main currents circulating in the Lower Cretaceous marine basin of Western Siberia are shown in Figure 2.

The paleodepth of the semi-enclosed Western Siberian asymmetric deep-sea basin during the Valanginian and Hauterivian ages did not exceed 370–500 m (Ershov, 2016), which corresponds to the lower part of the neritic zone or the bathyal and pseudo-abyssal zones (Krashenninnikov, 1971).

Modern analogues of the semi-enclosed and closed deep-sea basin include the Caspian, the Mediterranean, and the Black Seas, as well as Lake Baikal, on the bottom of which benthic forms (contourites) of various lithological compositions have also been identified (Saraev et al., 1986; Roslyakov et al., 2009; Ryabchuk et al., 2023).

Data and Methods

To establish the mechanisms of sediment formation and their facies affiliation, cores from 52 wells in Western Siberia (the total core meterage was ~3,300 m) (Fig. 1), well logging data, and 3D seismic data (amplitude maps, seismic facies maps, spectral decomposition maps, seismic cross-sections) from 18 sites were used. The subdivision of the Lower Cretaceous clinoform complex was carried out using the methods of sequence stratigraphy (Catuneanu, 2006), biostratigraphy, lithofacies analysis (Alekseev, 2002) and well logging; regional reflectors confined to marker clayey units – maximum flooding surfaces – were traditionally identified. Within the clinoforms (third-order sequences), seismic data were used to further identify unconformity and correlative conformity surfaces, a basal forced regression surface, and a transgressive surface to refine the clinoform complex and identify finer-order sequences (Lebedev et al., 2023). The names of the clinoforms and

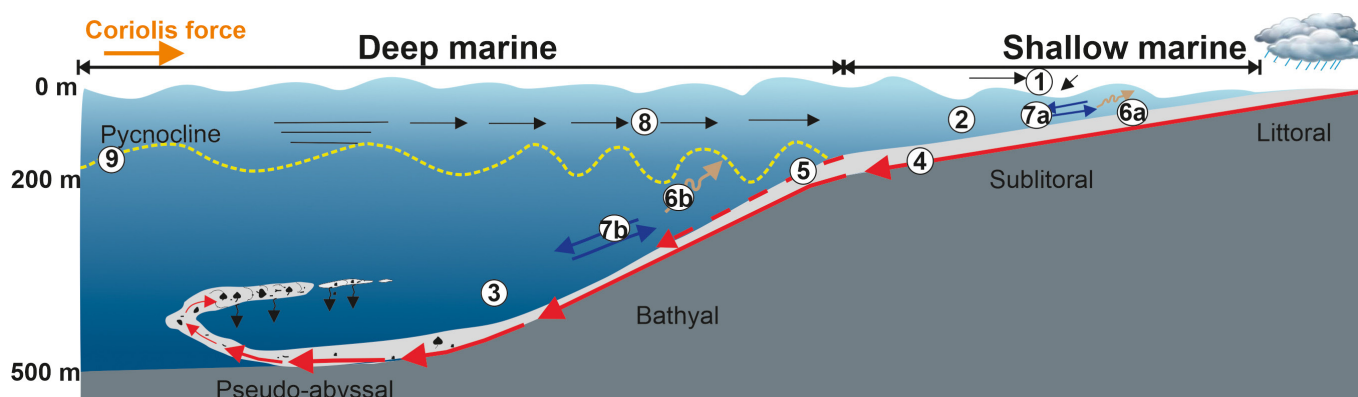


Fig. 2. The main currents circulating in the Lower Cretaceous Western Siberian marine basin: 1 – wind; 2 – alongshore geostrophic; 3 – contour; 4 – hyperpycnal; 5 – gravity/density (classical); 6 – wave: coastal (a) and deep (b); 7 – tides: coastal (a) and deep (b); 8 – internal waves and tides; 9 – pycnocline surface. Compiled by A.V. Khramtsova

systems tracts correspond to the names of the regional marker horizons (Labazny (lb), Tagrinsky (tg), etc.).

Using spectral decomposition and amplitude maps generated across the Lower Cretaceous clinoform complex at different stratigraphic levels (from the Labazny to Bystrinsky marker horizons), turbidite channels and lobes of varying morphology, contourite drifts, and slumps were interpreted. Reflectors and anomalies in the seismic record were analyzed using seismic sections built across the submarine slope.

When describing the core, lithological rock types (lithotypes) were identified based on structural and textural features (Reynek, Singh, 1981; Alekseev, 2002; Facies models, 2017; Einsele, 2000; Stow, Mayall, 2000; Stow, Smillie, 2020). If bioturbation structures were present, ichnofossils, ichnofacies, bioturbation index (BI), ethology and tiering were established (Buatois, Mangano, 2011; Knaust, 2012). The lithotypes of the Achimov sequence were grouped according to genetic features into the following facies: turbidite channels, turbidite lobes, submarine crevasse channels and splays, natural levee, mass-transport complex, basin floor, contourite drifts. Each facies includes subfacies and consists of several lithotypes. Traditionally, the main facies to which reservoir rocks are confined include turbidite channels and lobes, which include: hybrid layers, debrites and sediments reworked by bottom currents (thermohaline, wind, contour currents, deep tides, and waves). To establish the mechanisms of sediment formation, known sedimentary structures of sequences developed for turbidites (Lovie, 1982; Bouma, 1962; Stow, 1990), contourites (Stow, Faugères, 2008; Stow, Smillie, 2020), hybrid layers (Houghton et al., 2009), and hyperpycnites (Zavala et al., 2011; Khramtsova et al., 2024) were used.

Identification of contourites in the cross-section of the Lower Cretaceous clinoform complex of Western Siberia is based on a detailed analysis of the sedimentary structures of rocks (Rebesco, Camerlenghi, 2008; Stow, Smillie, 2020; Shanmugan, 2021) and seismic and morphological analysis of sedimentary bodies based on 3D seismic data (Faugères et al., 1999; Rebesco, Stow, 2001; Faugères, Mulder, 2011; Stow, Mayall, 2000; Rebesco et al., 2014; Fonnese et al., 2020).

Contourites (contourite drifts or ripples, sedimentary waves) affected by bottom currents have a variety of facies: gravel, silts, sand, clays, and mixed (Stow, Smillie, 2020), and can be biogenic, chemogenic, volcanoclastic, or mixed (Rebesco et al., 2014). In the Western Siberian Lower Cretaceous deep marine basin, they have clayey, sandy, and mixed contourites.

Weak bottom currents create capping sediments, predominantly of clayey contourites; during periods of increased current flow, sandy layers can be formed. Sufficiently strong bottom currents can cause erosion,

forming contourite channels, terraces, furrows, eroding turbidite lobes and channels, and redepositing sedimentary material over significant distances. According to morphology, contourite drifts are divided into confined, sheeted, mixed, channel-related and elongated, which include separated and plastered drifts (Rebesco et al., 2014; Miramontes et al., 2021; Rodrigues et al., 2022).

Results

In the cross-section of the Neocomian clinoform complex of Western Siberia, based on the 3D seismic data analysis, contourite drifts were identified. The shape of sedimentary waves elongated parallel to each other, oriented along the underwater slope, across the strike of turbidite channels and lobes (Fig. 3a, 3b, 3d). The crests of the sedimentary waves are wavy with bifurcations (see Figs. 3a, 3c) and straightened (Fig. 3d). Furthermore, isolated drifts of varying intensity, resembling aeolian dunes and barchans, can be interpreted on seismic spectral decomposition maps. The authors classify the series of continuous sedimentary waves and isolated megaripple marks as contourites formed by the action of constant bottom currents.

In Figure 3a, the contourites are of wavy shape, with ripple migration observed toward the underwater slope. At the channel mouths, lobes are not apparent, which suggests the development of mixed turbidite-contourite systems in this area, formed by the combined action of high-velocity bottom currents and turbidite flows.

Contourites on the seismic cross-section along line A-A' (Fig. 3b) are interpreted by the broken and discontinuous signature with variable reflection amplitude of the *smb_2* reflector. A prominent positive seismic anomaly associated with the contourites may indirectly indicate their sandy composition.

Note that high-velocity contour currents were episodic, and therefore large contourite drifts are not observed in all clinoforms. It is known that contour current velocity could be increased due to seafloor morphology, as well as by the Coriolis force (Mizens, 2005). It could be seasonal or periodic; reversals of bottom current direction are also common (Sedimentary Environments and Facies, 1990).

In the northern part of the spectral decomposition map (Fig. 3c), a turbidite channel shift is observed due to contourite drift bending to the left toward the turbidite flow. In this case, we can assume that the turbidite channel shift was caused by its bending around a previously formed contourite drift (Fig. 4a). The displacement of turbidite channels may also be associated with the development of left-sided asymmetry of a submarine fan (Fig. 4b), caused by the asymmetric growth of the submarine levees of the feeding turbidite channel under the effect of constant contour currents and

the Coriolis force. Left-sided asymmetry of deep-water fans of the Achimov Formation is observed in many areas of Western Siberia (Zverev, Khramtsova, 2022).

Schematic diagrams of variations of sedimentary bodies in the deep-sea basin of the Achimov Formation in Western Siberia, depending on the interaction of bottom and turbidite currents, are shown in Figure 4.

Figure 3d shows large, straightened, elongated contourite drifts. In the northern part of the spectral decomposition map, turbidite channels are more severely eroded by contour currents than in the southern part. When contour currents and turbidite flows interact, turbidite channels can be eroded to varying degrees (Fig. 3d, Fig. 4d, 4f). As bottom currents intensify, turbidite channels can migrate to the left of the main channel, changing the morphology of the deep-water fan (Fig. 3c, Fig. 4b, Fig. 5).

Spectral decomposition (Fig. 5a) and amplitude (Fig. 5b) maps of the Teplovsky clinoform complex within a

Western Siberian area show a deep-water fan with an asymmetric form. Contourite drifts of varying severity are identified along the submarine slope, suggesting the effect of bottom currents on the morphology of deep-water channels and lobes. Bottom currents of varying velocities could have continuously circulated along the submarine slope, as evidenced by elongated, poorly defined sedimentary bodies in the form of grooves or lineaments, as well as sedimentary waves and large contourite drifts observed on spectral decomposition and amplitude maps in many areas of Western Siberia (Khramtsova, Kislyak, 2024) in the cross-section of the Lower Cretaceous clinoform complex (Figs. 3–6).

Low-velocity bottom currents formed covers of silt-clay contourites, which are displayed on seismic attribute maps as lineaments extending parallel to each other along the submarine slope (Figs. 4–6). On seismic cross-sections, contourites are identified by an intermittent or wavy signature of reflectors (Fig. 6e, Fig. 6f).

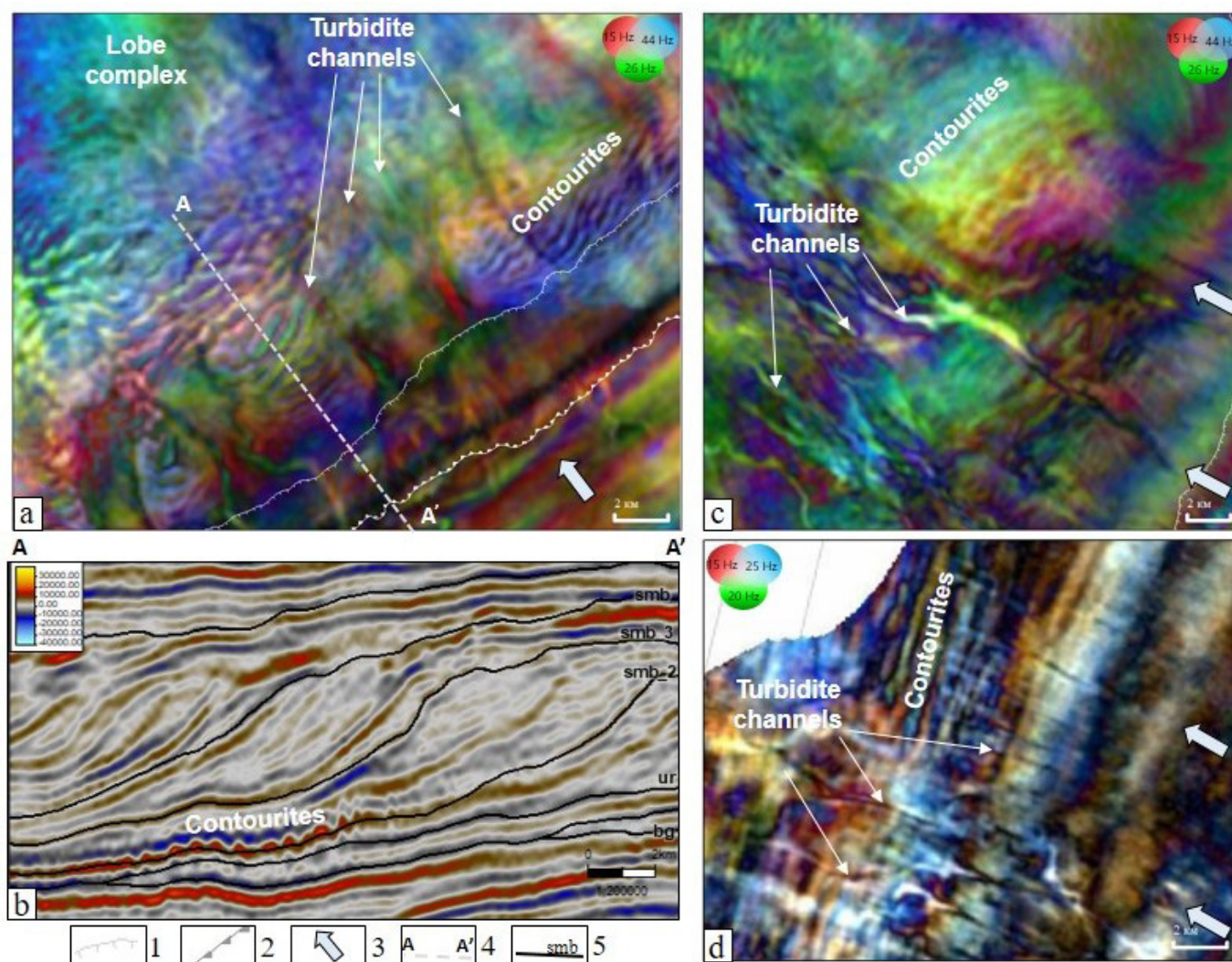


Fig. 3. Contourites of the Lower Cretaceous clinoform complex in the north of Western Siberia on spectral decomposition maps (a, c, d) and on the seismic section (b): 1 – foot of the submarine slope; 2 – shelf edge; 3 – direction of turbidite flow; 4 – seismic section line; 5 – regional seismic reflectors and their names: smb – Samburg (smb_2, smb_3 – smaller order sequences within the Samburg complex), ur – Uryevsky; bg – Bazhenov

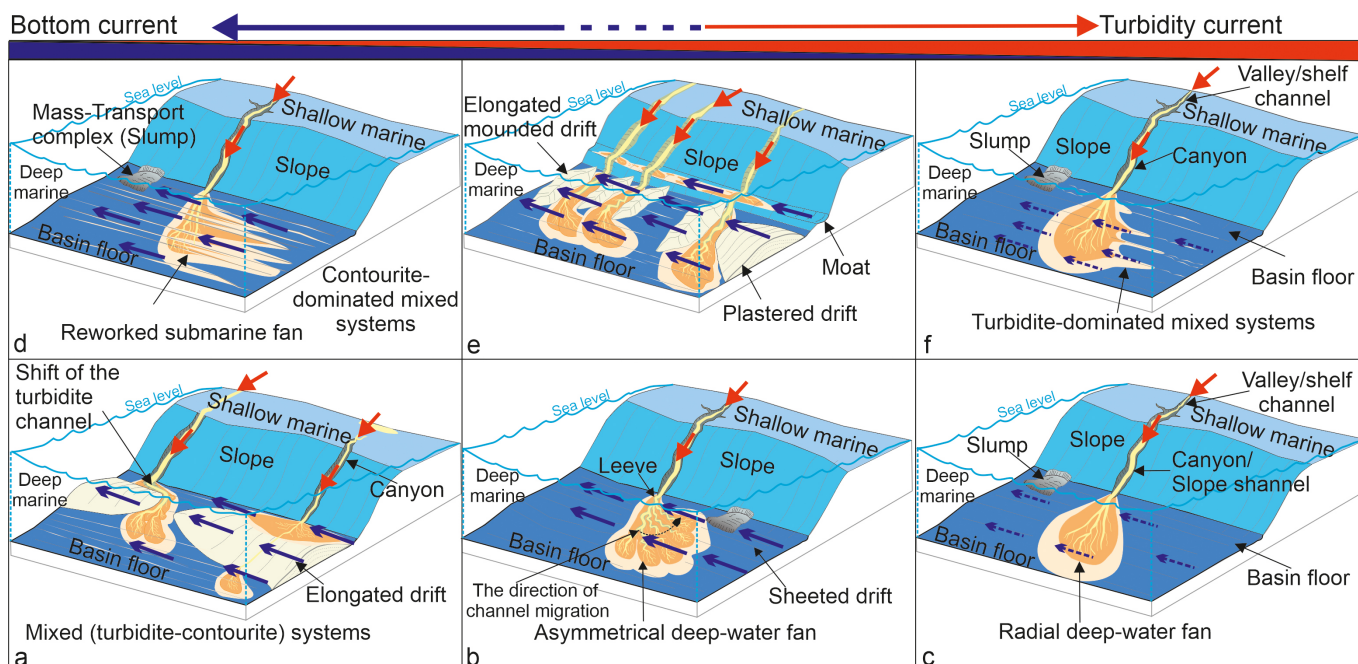


Fig. 4. Diagrams of various sedimentary bodies in the deep-sea basin of the Achimov Formation in Western Siberia, depending on the interaction of bottom and turbidity currents. Compiled by A.V. Khramtsova

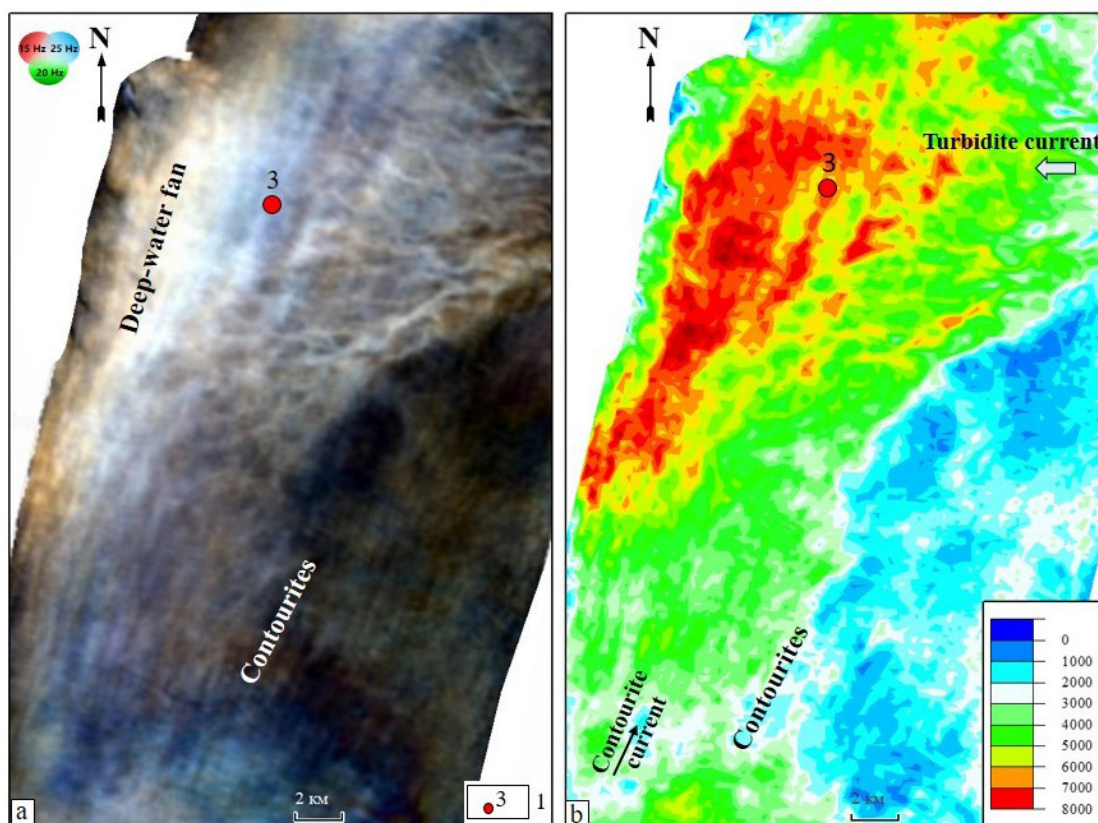


Fig. 5. Left-sided asymmetry of the deep-water fan on the spectral decomposition map (a) and average amplitude values (b): 1 – cored well

Based on core and well logging data from Well 1 (Fig. 6), it was established that the subtle waves (contourites) located between the channels are composed of fine-grained, clayey siltstones with thin sandstone laminae. Sandstones reworked by bottom currents are identified near the channels and lobes (Well 3, Fig. 5; Well 2, Fig. 6) (Figs. 7a–7c).

Textural features of the rocks indicate reworking of the turbidite channel and lobe sediments by bottom currents: bioturbation of the sediment; multidirectional, cross, and horizontal bedding, established based on cores from many wells (Fig. 7). Sandstone interbeds with fine cross-bedding and double laminae (Figs. 7a, 7i) are an important diagnostic feature of deep tides (Shanmugam et al., 1993; Rebesco, Camerlenghi, 2008; Davis, Dalrymple, 2012; Shanmugam, 2021). Double clay laminae (DM) indicate two periods of water standing between the flood and ebb tides, during which clay suspended sediment was deposited. An increase in the number and thickness of sand laminations in rhythmites (Fig. 7h) is caused by spring tides (ST), and their thinning and narrowing are caused by neap tides (NT). The authors agree with G. Shanmugam (2006, 2021), who suggests that sandstones with fine multidirectional cross-bedding, with double laminations, lenses, and interbeds of sandstones with fine cross-bedding due to current and wave ripples (Figs. 7d–7i) should be classified not as turbidites (Tc, Te interval according to

Bouma), but as bottom-current-reworked sandstones (BCRS). Such layers can be found in contourite drifts and mixed tidalite-contourite-turbidite systems.

One of the main diagnostic features of sandy and clayey contourites is bioturbation structures (Figs. 7a, 7g, 7h). According to many researchers (Faugeres, Stow, 1984; Buatois, Mangano, 2011; Rebesco, Camerlenghi, 2008; Rebesco et al., 2014), bioturbation structures are typical of contourites, since bottom currents can supply an additional portion of oxygen and feed material. Low-velocity bottom currents (up to 10–30 cm/s on average) usually contribute to the formation of clayey contourites with high and moderate bioturbation (Sedimentary Environments and Facies, 1990; Shanmugam, 2021). Fine-grained and very-fine-grained, poorly bioturbated sandstones *Teichichnus* (Te), *Asterosoma* (As), *Ophiomorpha rudis* (Op), (Fig. 7a, 7f) are found in the deposits of the Achimov Formation and can serve as one of the signs of bottom reworking of sediments.

In the deposits of the Achimov sequence, the interlayers of coarse-fine-grained siltstones and fine-grained clayey siltstones are most often bioturbated by *Phycosiphon* (Ph), *Nereites* (Ne), *Zoophycos* (Zo), *Helminthopsis* (He), less often by *Chondrites* (Ch), *Scolicia* (Sc), *Planolites* (Pl), the bioturbation index varies from 2 to 3–4 (Fig. 7g, 7h).

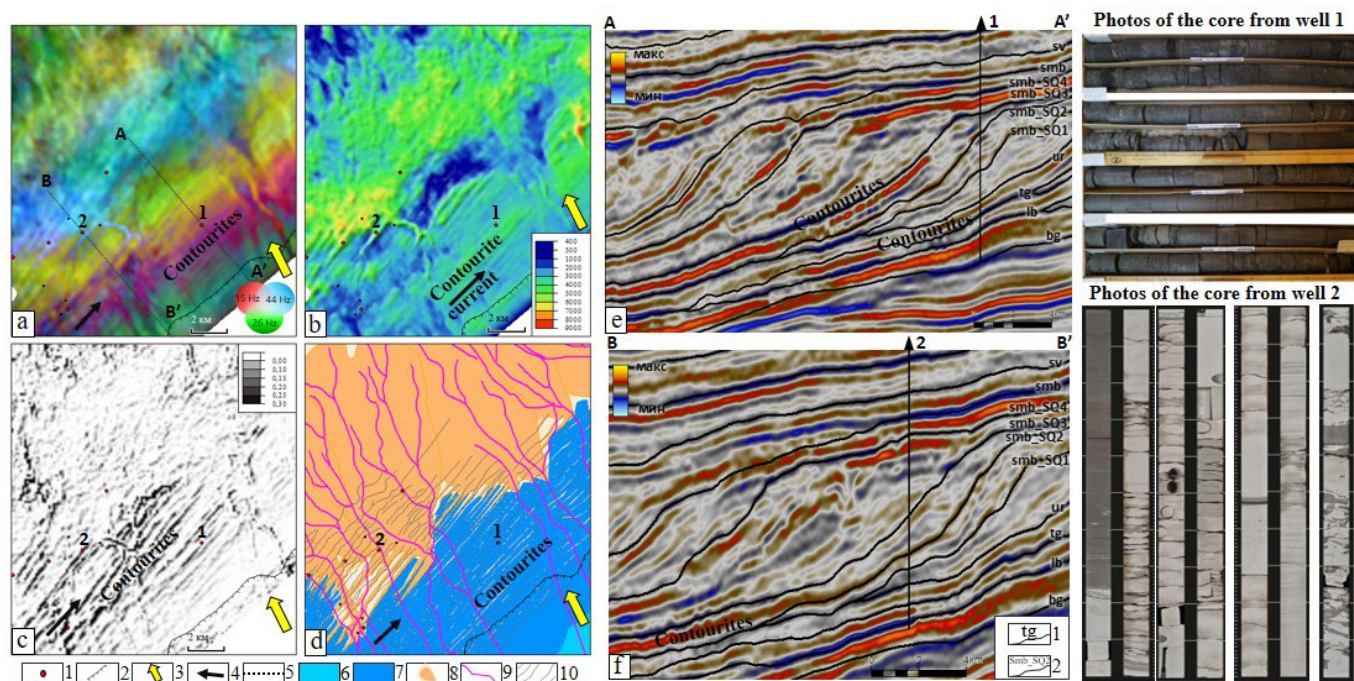


Fig. 6. Contourites on maps of seismic attributes (spectral decomposition (a), amplitudes (b), Variance (c)), facies (d) and on seismic cross-sections (e, f). Tagrinsky clinoform complex of Western Siberia: 1 – cored wells; 2 – foot of underwater slope at the end of Tagrinsky complex formation; 3 – direction of turbidite current; 4 – direction of contour current; 5 – seismic line. Facies: 6 – underwater slope; 7 – Basin plain; 8 – deep-water fans (proximal and distal parts); 9 – turbidite channel; 10 – contourites. On seismic cross-sections (Fig. 6e, 6f): 1 – marker reflectors and their names: Bazhenov (bg), Tagrinsky (tg), Uryevsky (ur), Sambursky (smb), Savuisky (sv); 2 – additional reflectors of the Sambursky complex (smb_SQ1, smb_SQ2, smb_SQ3). See the descriptions and interpretations of core samples from wells 1 and 2 in the text.

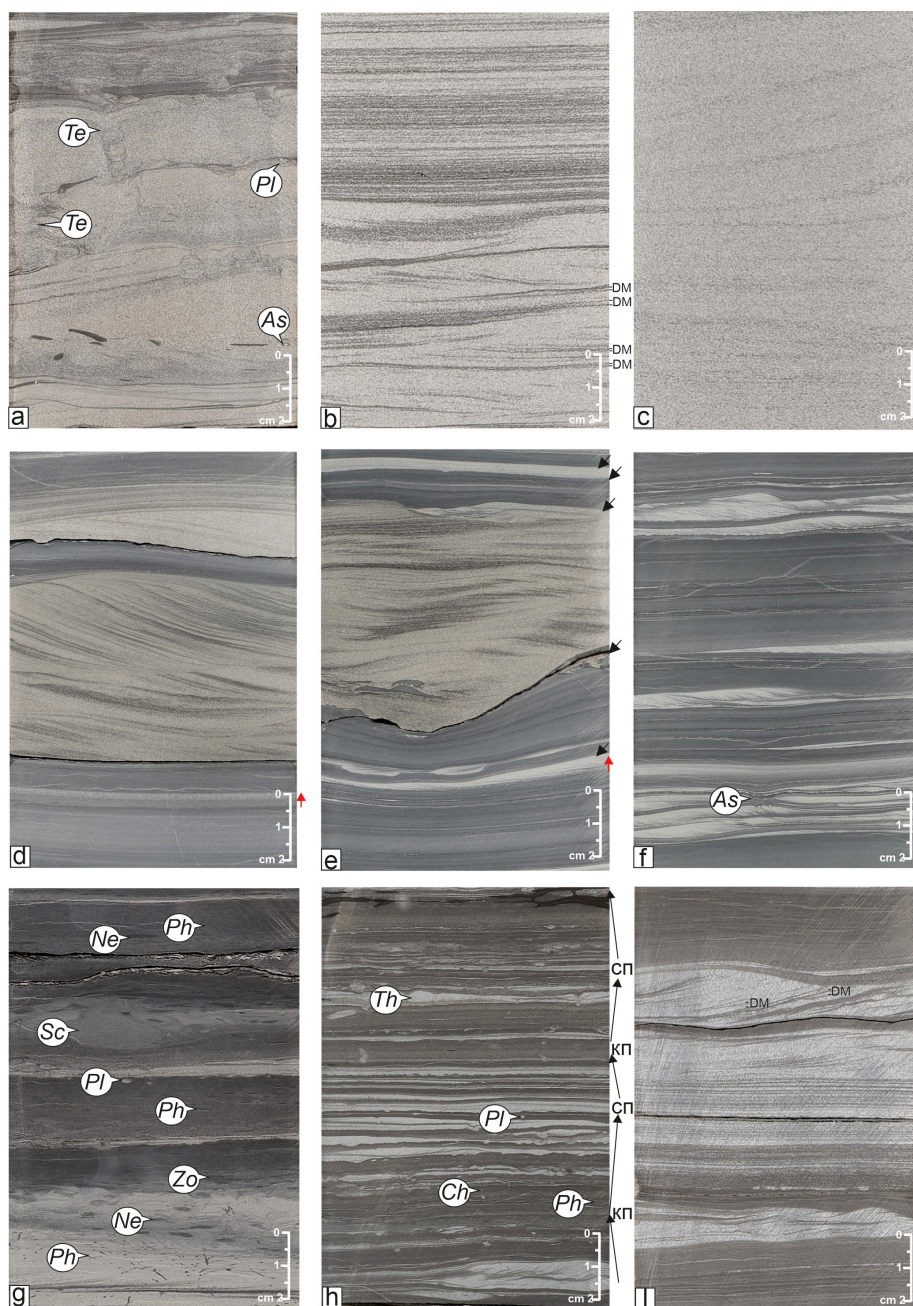


Fig. 7. Contourites and tidalites of the Achimov formation in Western Siberia: a) fine-grained sandstone with mildly wavy cross bedding with double laminae, disrupted by burrows of *Teichichnus* (*Te*), *Planolites* (*Pl*), *Asterosoma* (*As*), in the lower part of the plug there are small clayey intraclasts; b) fine-/very-fine-grained sandstone with fine multidirectional cross bedding with double laminae (DM) (plug bottom) and horizontal bedding (plug top); c) fine-grained sandstone with mild horizontal bedding (plug bottom) and with coarse cross (trough) unidirectional bedding in the upper part of the plug; d) clayey siltstone with interlayers of fine-to-very-fine-grained sandstone with flow ripples, in the upper part of the plug turning into horizontal bedding; in the middle part of the plug the sandstone interlayer with flow ripples has a sharp bottom and top; in the lower part of the sample there is an interlayer of sandy siltstone with reverse gradational bedding and a sharp top (shown by a red arrow); e) fine-grained clayey siltstone with interlayers of fine-grained sandstones. Sandstones with fine cross-bedding (flow ripples), with clayey intraclasts at the bottom of the layer (central part of the plug), contacts between the layers are sharp (shown by black arrows); in the lower part of the plug there are small sand rolls and a thin interlayer of sandstone with flow ripples, with a sharp gradational top (shown by a red arrow); f) fine-grained siltstone, clayey, with thin lenses and interlayers of fine-grained sandstone with fine cross-bedding of current ripples, with a sharp bottom (black arrows) and top, with single burrows of *Asterosoma* (*As*), in the siltstone the reverse gradational bedding is shown by a red arrow; g) fine-grained siltstone, clayey, mildly bioturbated (*Phycosiphon* (*Ph*), *Planolites* (*Pl*), *Scolicia* (*Sc*), *Zoophycos* (*Zo*)) with thin interlayers of very-fine-grained sandstone with current ripples, burrows of *Nereites* (*Ne*) *Phycosiphon* (*Ph*), bioturbation index BI=2-3; h) rhythmic alternation of clayey siltstones and fine-grained sandstones (tidalites), mildly disturbed by sediment bioturbation (*Planolites* (*Pl*), *Phycosiphon* (*Ph*), *Chondrites* (*Ch*)). Changes in the number and thickness of sand laminae are controlled by cyclic changes in the rate of deep tides; an increase in the number and thickness of sand laminae is associated with spring tides (ST) and their thinning and decrease – with neap tides (ST); i) interlayers of very-fine-grained sandstones with horizontal and fine cross-bedding with double clay laminae (DM)

To a greater extent, in the clayey deposits of the Achimov sequence, there are burrows of *Zoophycos* and *Nereites*, which are related to traces of feeding (*Fodinichnia*), locomotion traces (*Repichnia*) and dwelling (*Dominichnia*).

Clayey and thin-bedded contourites are often interbedded with hemipelagites, which can also be bioturbated (Knaust, 2012), which can complicate their identification. Bioturbated structures can be found not only in contourites, but also in clayey-silty deposits of overbank-levee, distal parts of deep-water fans, basin floor, and in sandstones of turbidite channels, but they are more common in clayey deposits (Buatois, Mangano, 2011; Knaust, 2012). The presence and diversity of ichnofossils are influenced by many factors, such as bathymetry, the supply of freshwater (enriched with feed material and oxygen) by hyperpycnal currents, the frequency of turbidite currents, the velocity of bottom currents, and the size of sediments. Bioturbation structures are relatively rare in Achimov deposits; their presence can serve as a diagnostic criterion for sandy and clayey contourites. Contourites are also characterized by inverse gradational structures (Figs. 7e, 7f), horizontal, fine to coarse, unidirectional cross-bedding (Fig. 7c), lenticular bedding, and a sharp upper cap of sandy laminae (Figs. 7e, f, h, i).

Contourites are often confused with slump, but they differ from slump in their structural features, morphology, and formation conditions. A slump is caused by the downslope displacement of semi-consolidated sedimentary masses (MTD – mass transport deposits) under the action of gravity. Their formation usually takes a short time, and even a slight slope facilitates their formation (Sedimentary Environments and Facies, 1990). Submarine slumps are locally distributed and are characterized by syn-sedimentary deformation structures (convolute, slumping, contorted bedding, injection structures), often with preservation of primary bedding (Figs. 8a, 8b). The thickness of slump bodies in the Achimov sequence can range from several tens of centimeters to hundreds of meters. On seismic attribute maps, slump often have the shape of a “tongue” with concentric arcs of compressional folds (Fig. 8c), slump cirques, and have a limited area of distribution. On seismic sections, slump may have features similar to contourites (intermittent reflector signature), but most often they are identified by a chaotic signature of the internal structure (Catuneanu, 2006; Nikishin et al., 2012), as well as the presence of local sedimentary faults and compressional ridges (Fig. 8d).

For the correct diagnosis of sedimentary bodies in the Lower Cretaceous clinoform complex of Western Siberia,

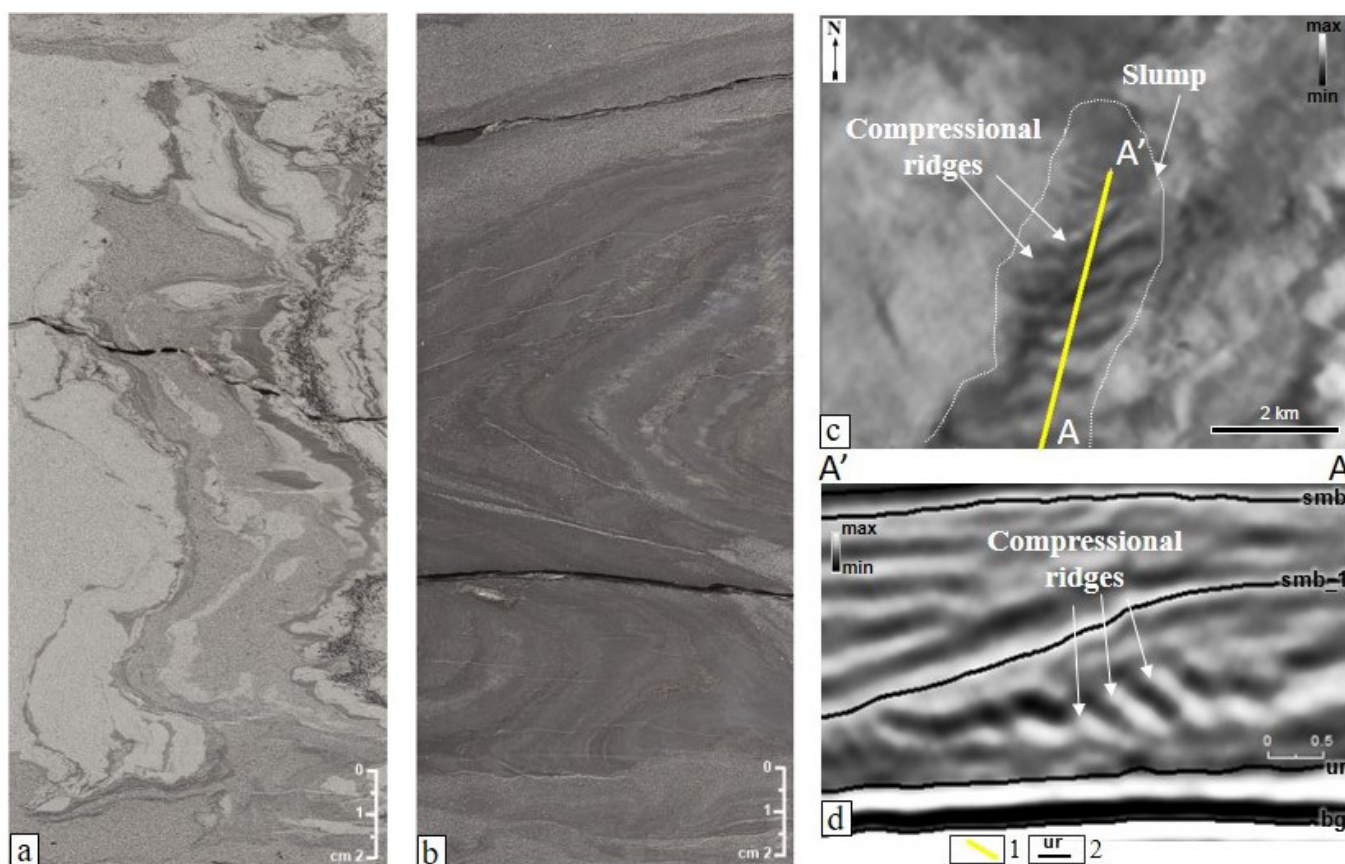


Fig. 8. Convolute lamination in sandstones (a) and dark gray coarse-to-fine-grained siltstones (b) and a slump body on the amplitude map (c) and on the seismic cross-section (d): 1 – seismic line A-A'; 2 – reflecting markers and their names (bg – Bazhenov, ur – Uryevsky, smb – Sambursky, smb_1 – Sambursky additional). Achimov Formation of Western Siberia

based on published materials (Shanmugam, 2006, 2021; Davis, Dalrymple, 2012; Stow, Mayall, 2000, etc.) and our own observations (based on core material and 3D seismic data), a table of diagnostic features of turbidites, contourites, tidalites, and slump (Table 1) was compiled, which differ in structure features, morphology, and formation conditions (Khramtsova, Melnikov, 2025).

Understanding the mechanisms of sediment formation improves reservoir rock prediction and explains the morphology of deep-sea fans and channels, which is crucial for identifying non-structural hydrocarbon traps.

Conclusion

In many areas of Western Siberia, within the Achimov Formation interval of the Lower Cretaceous clinoform complex, 3D seismic data helped to identify bottom – current bedforms (sedimentary waves, contourite drifts, erosive features) oriented along the foot of the submarine slope and across the strike of turbidite channels and lobes. Sedimentary waves of varying sizes and shapes reflect the velocity of bottom currents, the degree of reworking, erosion, and accumulation of sedimentary material.

Contourites differ from submarine slides and turbidites by a characteristic set of sedimentary structures (bioturbation, double laminae, cross-, horizontal, and reverse gradational bedding), as well as by the morphology of sedimentary bodies and formation environments.

It has been established that large contourite drifts (sedimentary ridges) near deep-sea fans can be sandy, while small lineaments composed predominantly of clay and silt material represent mixed contourite covers or clay contourites.

Bottom currents were one of the main causes of the asymmetric structure of deep-sea fans, influencing the formation of mixed tidalite-contourite-turbidite systems and individual contourite drifts of varying lithological composition. High-intensity bottom currents could form sandy contourites and also cause erosion and wash-outs of deep-sea fans and channels.

Sandy and mixed contourites may represent a new target for the search for non-structural traps in Lower Cretaceous deposits of Western Siberia.

To identify contourites, it is recommended to use the results of 2D+3D seismic exploration in combination with core material and well logging data.

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Rock	Turbidites (extrabasinal and intrabasinal)	Tidalites	Contourites	Slides (Slumps)
1	2	3	4	5
Sedimentary textures	Medium-to-fine-grained sandstones to siltstones	Fine-grained sandstones to siltstones	Fine-grained sandstones to fine-grained clayey siltstones	Interlayering of sandstones and coarse-to-fine-grained clayey siltstones
Sedimentary structures	Massive, fluidal, current ripples, normal grading, convolutes, horizontal bedding	Cross-bedding with double laminae, lenticular, wavy lamination	Horizontal, cross-lamination, lenticular, bioturbated, grading (from reverse to normal)	Slump and pillow structures, convolute lamination
Inclusions	Clay intraclasts, mica	-	Clay intraclasts, pyrite	-
Ichnofossils and bioturbation intensity (BI)	<i>Chondrites</i> , <i>Phycosiphon</i> , <i>Helminthopsis</i> , BI=0-2	Absent to low intensity	<i>Chondrites</i> , <i>Nereites</i> , <i>Phycosiphon</i> , <i>Zoophycos</i> , etc., BI=2-4	Rarely
Fauna and flora	Large wood fragments, carbonaceous detritus, rare bivalves (allochthonous), ammonites	Carbonaceous detritus, rare bivalves	Rare bivalves	Carbonaceous detritus, rare bivalves (allochthonous)
Contacts and transitions	Gradational at top, erosive to sharp at bases	Gradational to erosive at bases, gradational top contact	Gradational (from reverse to direct), sharp upper contact	The top and bottom can be sharp
Rheology and flow regime	High and low density turbulent flow	Laminar to turbulent	Turbulent	Plastic
Flow behavior and direction	A long-running, unidirectional flow with unstable velocity. The flow is directed down the underwater slope toward the basin	Increasing, decreasing, reversing, and multidirectional. Flow along a slope channel and canyon or at various angles to the underwater slope	Constant, increasing, then decreasing, unidirectional. Contour currents are directed along the underwater slope or at different angles to the underwater slope	Downslope sliding of semi-consolidated masses
Time of existence	Hours to several weeks, temporary	Hours in each direction	Tens of thousands of years, permanent, semi-permanent	Hours
Source of supply	Slope collapse or flood river waters with a density of more than 3,500 kg/cm ³	Recycling of previously accumulated sediments	Recycling and redeposition of bottom sediments	Submarine slope and shelf edge deposits
Seismic image	U, V - shaped channels; hilly, lenticular - lobes	Vertically: parallel, lenticular	Elongated bottom features (waves, furrows, ripples, drifts) oriented along the base of the slope. Vertically: "traveling wave," wavy, intermittent recording of reflectors	Areally: concentric arcs, landslide cirques, compression ridges. Vertically: chaotic internal structure, presence of faults
Publications	Stow, Mayall, 2000; Mizens, 2006; Zavala et al., 2011	Davis, Dalrymple, 2012; Shanmugam et al., 1993; Shanmugam, 2006, 2021	Faugères et al., 1999; Rebesco, Stow, 2001; Stow et al., 2002; Rebesco, 2008; Rebesco et al., 2014	Depositional Environments..., 1990; Einsele, 2000; Cotuneanu, 2006

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Контуриты – новый объект для поисков неструктурных ловушек углеводородов в нижнемеловых отложениях Западной Сибири

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По результатам 3D-сейсморазведки в разрезе нижнемелового клиноформного комплекса Западной Сибири установлены донные формы (осадочные волны, рифели, рябь, гряды, контуритовые дрифты), ориентированные вдоль простирания подводного склона, перпендикулярно направлению турбидитовых каналов и лопастей. На картах спектральной декомпозиции и амплитуд они напоминают эоловые формы рельефа, гребни могут быть как прямые, так и извилистые с бифуркацией. На сейсмических разрезах контуриты диагностируются по изрезанной и прерывистой форме записи с переменной амплитудой отражений или представляют собой «бегущую волну». Установлено, что в нижнемеловом относительно глубоководном морском бассейне контурные течения были постоянными, но имели разную интенсивность (скорость течения) в разных частях морского бассейна. Они размывали и переотлагали осадочные наносы турбидитового генезиса, тем самым влияя на окончательную морфологию глубоководных конусов выноса. Под влиянием донных течений формировались как смешанные тидалито-контурито-турбидитовые системы, так и отдельные контуритовые дрифты (наносы) различного литоло-

гического состава. На переработку отложений донными течениями указывают характерные текстурные признаки: сдвоенные слои, разнонаправленная и однонаправленная косая слоистость, флазерная, горизонтальная, градационная (прямая до обратной), линзовидная слоистость, а также местами интенсивное развитие биотурбационной переработки осадков, которое не характерно для турбидитовых отложений.

Песчаные контуритовые дрифты могут служить новыми объектами для выделения ловушек углеводородов неструктурного типа в глубоководном морском бассейне Западно-Сибирского мегабассейна.

Ключевые слова: контуриты, контурные течения, глубинные приливы и волны, турбидиты, ачимовская толща, Западная Сибирь, подводные конусы выноса, песчаники, переработанные донными течениями

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