DEVELOPMENT OF ACHIMOV DEPOSITS SEDIMENTATION MODEL OF ONE OF THE WEST SIBERIAN OIL AND GAS PROVINCE FIELDS

Yury Nefedov[1], Danila Gribanov[1], Emil Gasimov[1], Dmitry Peskov[1], Gao Han[1], Nikita Vostrikov[1], Shafagat Pashayeva[2]

•

[1]St. Petersburg Mining University, Russia.
[2]Azerbaijan State Oil and Industry University
nefedov_yuv@pers.spmi.ru
danila.gribanov@gmail.com
azayli.emil@gmail.com
s190872@stud.spmi.ru
gaohan878989@gmail.com
sh73.73@mail.ru

Abstract

The Geological Process Modelling (GPM) module developed for the Petrel software package enables digital modelling of natural processes of erosion, transportation and deposition of clastic sediments. Modelling of cones of removal was carried out for Achimov strata of the Western Siberia field. The results obtained characterize the expected sediment geometry, lithology distribution due to sea level changes, paleogeography, paleoclimate, tectonics and sediment input rates. The results allow the evaluation of different options and enable us to predict the distribution of prospective oil and gas bearing sediments in areas where no wells have been drilled. As a result, a sedimentation model was obtained, which reflects the formation of the elements of the sedimentation system of the study area. According to the sedimentation model, the main facies zones of the turbidite sediments under consideration are identified.

Keywords: Sediment modelling, Achimov sediments, deep-sea cones of export, unsteady flow algorithms.

I. Introduction

The deep-water cones of Western Siberia have enormous hydrocarbon potential and are a promising area for exploration and development [1, 3]. Successful development depends on well-built conceptual models that reflect the processes of oil and gas reservoir formation [14, 22]. The construction of geological models that realistically reproduce the internal structure of the reservoir ensures the reduction of risks and uncertainties and contributes to increased hydrocarbon production [15, 23, 28].

Achimov deposits are of great interest in the West Siberian oil and gas province. They are widespread throughout the area and have confirmed commercial oil and gas content. This stratum is represented by lenticular sandy-siltstone bodies of discontinuous distribution lying at the base of the neocomposition. Three zones are distinguished in the structure of the clinoform: shelf complex (undaform), slope (orthoform) and bottom formations (fundoform) [12]. The fundoform parts of the clinoforms are bounded by silt-sand sediments of the Achimov Formation.

Achimov sediments are turbiditic in nature, but differ from classical turbidites by a shallower sedimentation depth. The depth of the epicontinental West Siberian basin was, according to various estimates, from 300 to 600 meters [11]. Sedimentary material flowed through "feeding channels" to the "conditional shelf" - a shallow plain with relief bends, the last of which is taken as the "shelf edge". Sediment accumulated on it in the form of bars and was transported down the slope through distribution channels [6]. Sedimentary material entered the basin mainly from the east. The source of material for the formation of the Achimov sand bodies was the shelf of the epicontinental basin, which was an accumulative terrace gently dipping towards the center of the basin [26]. The displacement occurred under the influence of gravitational flows caused by eustatic sea level fluctuations, tectonic processes or climatic changes.

II. Methods

An important step in building a conceptual model is the use of seismofacial analysis based on the calculation of seismic attributes [16, 33, 34]. If the values of seismic attributes change significantly, one can assume a change in elastic properties and, consequently, in facies settings [17].

For the formation under consideration, the most informative is the spectral decomposition algorithm - decomposition of the seismic signal into frequency characteristics [27, 32]. It is based on the assumption that local study of the wavefield spectrum allows to obtain more information about the internal structure of geological objects. The color combination algorithm used for visualization is RGB-mixing [9, 25]. The program input is three amplitude cubes, each of which corresponds to a different frequency and a certain color - green, blue, red. The result is a map, each point of which corresponds to three amplitude values.

The obtained map of spectral decomposition results allows us to divide the formation into undoformed and phondoformed parts (Fig.1).

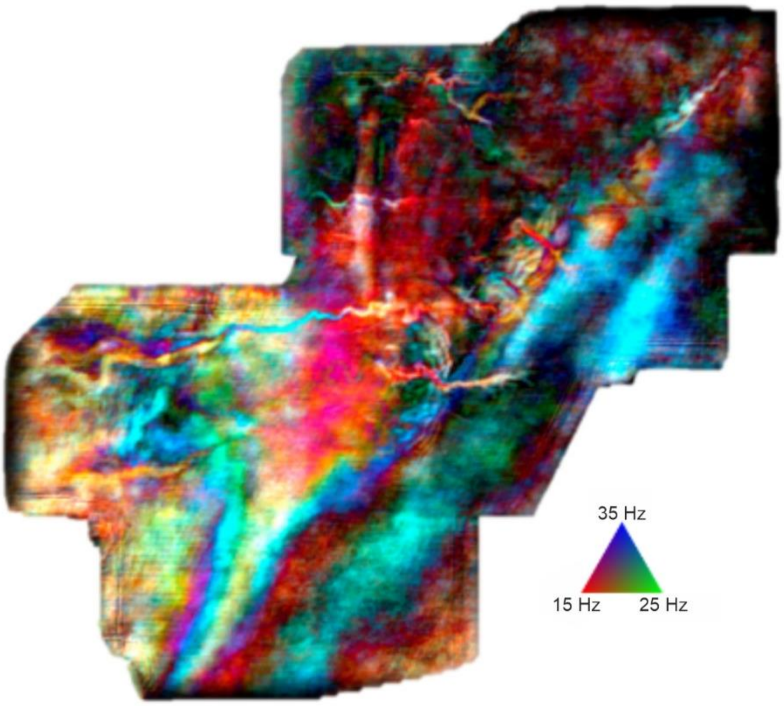

Fig. 1: *RGB-mixing map of the results of spectral decomposition of 15, 25, 35 Hz frequencies for BP_{6-2} - Ach_2 formation*

The predominance of high frequency (blue shade) is characteristic of longshore drifts. Sediments from the shelf area accumulate in the western part, where area cones of export are developed [35]. Also, the material transport paths are clearly distinguished [4].

Not only seismic attributes, but also the wave field itself in the local area, along the seismic horizon, can be used for area zoning. The shape of the reflected wave directly depends on the elastic properties of the acoustic boundary, and the change in the seismic record can be used to judge the change in these properties [29]. This algorithm reduces to a classification problem. Initial cubes of seismic amplitudes are used as input. In a sliding 3D-window, the size of which was defined as 20 ms, the studied territory is divided into classes - areas characterized by a constant signal shape; as a result, a map of class distribution over the territory is obtained [8]. This type of analysis is implemented by various algorithms, among which the most common are Kohonen neural networks and the K-average method.

Based on the results of the classification task, the main facies zones of the area can be distinguished. In the shelf area, longshore ramparts are formed. In the western part, Achimov cones of export are formed.

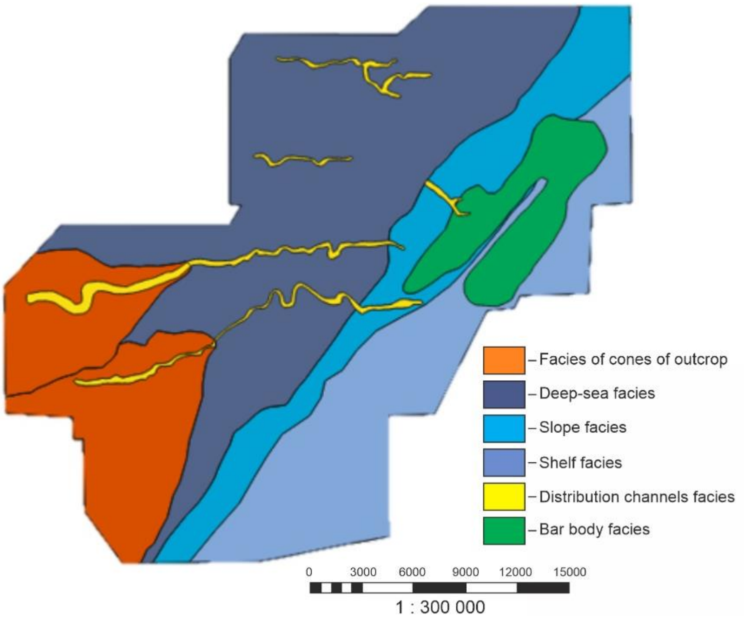

Fig. 2: *Conceptual model of the BP6-2 - Ach2 reservoir*

As a result of facies analysis based on well and seismic data, a conceptual model was constructed (Fig.2), where the shelf part is clearly distinguished, where longshore ramparts were formed, which are characterized predominantly by sandstones and have good reservoir properties. Extended debris transport channels also stand out. Sediments were deposited in the western part, where outcrop cones were formed.

III. Paleosurface reconstruction and identification of demolition sources

The sedimentation model is based on the reconstructed palaeosurface. The paleorelief map (Figure 3) was constructed by subtracting the structural surface of the roof of the Bazhenov Formation (OG B) from the structural surface of the studied horizon. The Bazhenov Formation is assumed to be conventionally flat and horizontal at the time of its formation.

After palaeosurface reconstruction, corrections to the predicted paleobasin depths must be made. The correction was carried out taking into account regional paleogeographic schemes [10].

At the time of the formation of the Achimov deposits, there was a regression of the inland West Siberian Sea from southeast to northwest [2]. During the Berriasian age, the study area was in the deep sea zone. An uncompensated mode of sedimentation prevailed, and clayey-carbonaceous-siliceous sediments of the Bazhenov Formation were formed [7]. In the late Berriasian-early Valanginian, active horizon formation took place on the adjacent land, which was the main cause of avalanche sedimentation and rhythmic filling of the sea basin with sediments from the east and southeast; sandy-siltstone cones of the Achimov Formation were formed at the foot of the slope [5].

Deposits of the Sortym Formation were mainly accumulated in the area of shallow sea. The clayey regional packs were formed as a result of short-term regressions that complicated the general regression. As a result of avalanche sedimentation, slope progradation occurred very rapidly [21]. In the Early Valanginian, the study area occupied a transitional position with increasing slope dip angle, then, in the Late Valanginian, it was in the shallow sea zone, and the slope became more gentle.

From the constructed palaeosurface it is possible to determine the sources of drift. In the GPM module, the drift sources are understood as the areas of matter transport start in the perimeter of the modelled space.

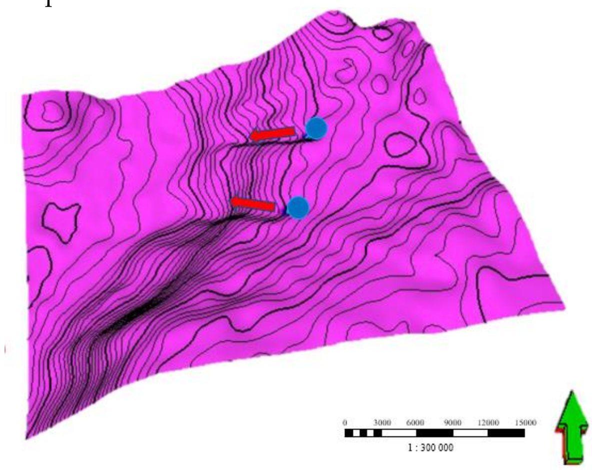

Fig. 3: *Paleo-basis for modelling and diagram of the location of point demolition sources*

The shelf edge was analyzed for the presence of elongated negative landforms and inferred drift sources were identified from the reconstructed palaeosurface.

IV. Construction of sedimentation model

Sedimentation modelling of the Achimov cones was carried out in the Geological Process Modeling (GPM) module of Schlumberger's Petrel software package.

For correct modelling it is necessary to clearly understand the processes of formation of the local object [31]. It is possible to build a sedimentation model based on the conceptual model and prepared input data.

Modelling was carried out using an algorithm for unsteady flow. The mathematics of the process controls the priority filling of depressions in the paleorelief of the near-slope part [20, 30]. Distribution of lithotypes occurs by initial deposition of the coarser fraction on the slope, the finer fraction being carried to the most distant areas [18].

The obtained time slides of the sedimentation model (Fig.4) with two drift sources clearly show the formation of a system of drift cones with debris transported along the slope. Each subsequent modelled flow takes into account current changes in paleorelief and subsequent iterations build up the object with flows. The type of feed sources and the particle size distribution (Fig.5) of the sedimentary mixture determine the morphology of the cones of withdrawal. The body is 18.5 km wide and 15.6 km long.

Sediment modelling in the GPM module offers a new approach to building a dynamic model that can be used to validate and improve the conceptual field model [13, 19]. The use of a geological process simulator allows the creation of a realistic architecture of the turbidite system [24]. As a result of the simulation, a model is obtained that reflects the formation of deep-water cone elements of the Achimov Formation and can be used for further geostatistical modelling of facies and petrophysics. The obtained result is consistent with seismofacies analysis and drilling data.

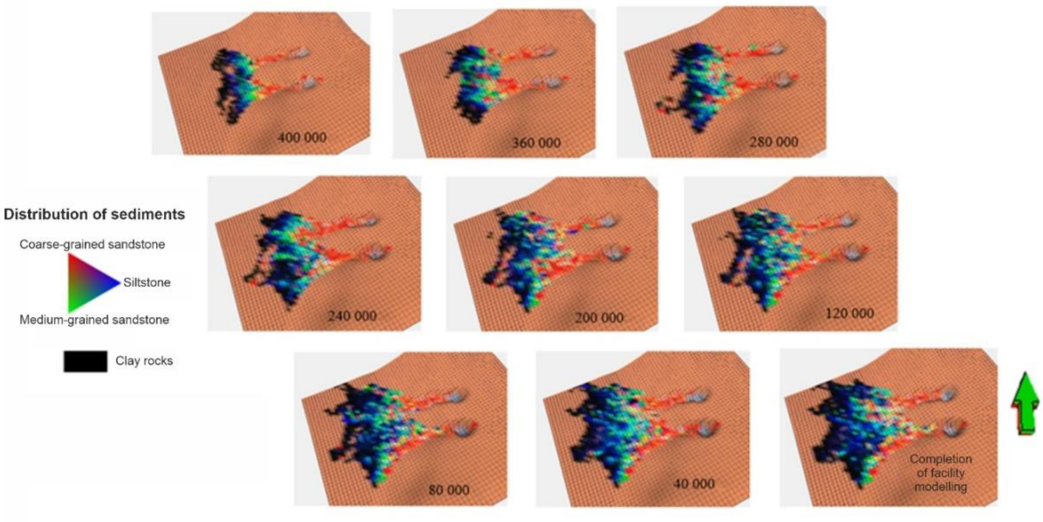

Fig. 4: *Sequential slides of the sedimentation model*

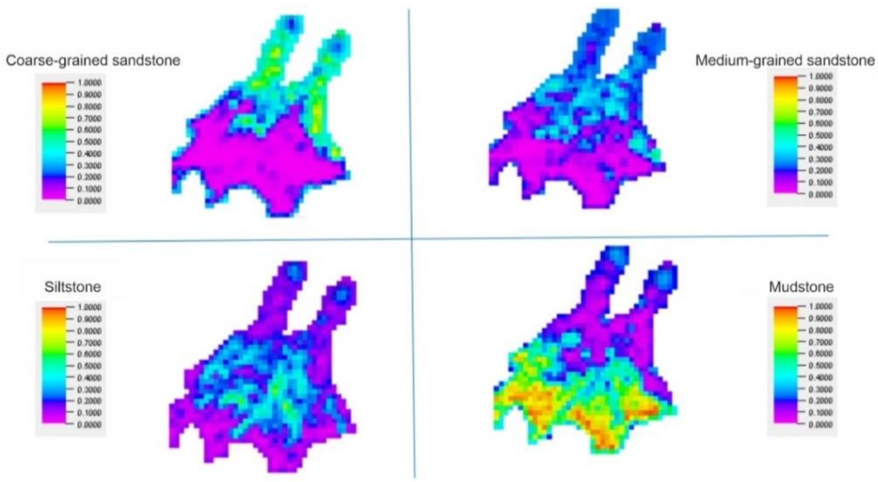

Fig. 5: *Fractional distributions of sediments in the sedimentation model*

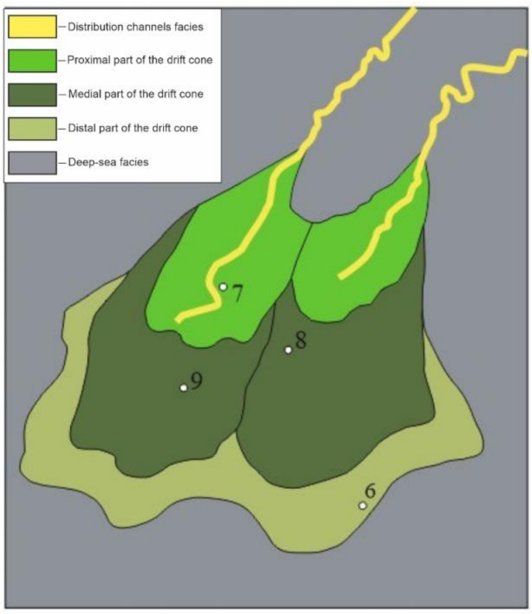

Fig. 6: *Facies model of the Achimov deposits*

According to the constructed sedimentation model and borehole data, it is possible to identify the main facies zones of the turbidite sediments under consideration (Figure 6).

Deposits of the proximal and medial zone are distinguished, which are characterized by good reservoir properties. The distal part is also distinguished, which is characterized by deposits with deteriorated properties.

Conclusion

The resulting sedimentation model reflects the reservoir architecture of the turbidite system. The performed facies analysis, the developed conceptual model, the reconstructed palaeosurface and the identified drift sources allow us to construct the sedimentation model. The dynamic model is consistent with seismic and well data. The results obtained are comparable to the conceptual model and allow to predict the distribution of drift cones. This method opens up positive prospects for more reliable geological modeling.

References

[1] Andreichyk, A., Tsvetkov, P. (2023). Study of the relationship between economic growth and greenhouse gas emissions of the Shanghai cooperation organization countries on the basis of the environmental kuznets curve. *Resources*, 12(7), 80. DOI:10.3390/resources12070080

[2] Borodkin V.N., Kurchikov A.R., Melnikov A.V., Khramtsova, A.V. Formation model and textural features of rocks of the Achimov complex in the north of Western Siberia: textbook. Tyumen, Tyumen NGU, 2011. [in Russian].

[3] Buslaev, G., Lavrik, A., Lavrik, A., Tcvetkov, P. (2023). Hybrid system of hydrogen generation by water electrolysis and methane partial oxidation. *International Journal of Hydrogen Energy*, 48(63), 24166–24179.DOI: 10.1016/j.ijhydene.2023.03.098

[4] Butorin, A.V. (2015). Structure of the productive clinoform formation according to seismic data. *Geophysics* , 1, 10–18. [in Russian].

[5] Ershov, S.V. (2018). Sequence stratigraphy of Berriasian-Lower Aptian sediments of Western Siberia. *Geology and Geophysics*, 59(7), 1106–1123.

[6] Gladysheva, Y.I. (2023). Petroleum potential of Achimov deposits in the north of Western Siberia. *Oil and Gas Studies*, 1, 13–28. [in Russian]. DOI: 10.31660/0445-0108-2023-1-13-28

[7] Gurari, F.G. Structure and conditions of formation of clinoforms of the Neocomian of the West Siberian Plate (history of formation of ideas). Novosibirsk, SNIIGGiIMS, 2003. [in Russian].

[8] Huang, J., Mu, L., Chen, H., Et al. (2013). Preliminary study on a depositional interface-based reservoir modeling method. *Pet Enplor Dev*, 40(5), 591–594. DOI: 10.1016/s1876-3804(13)60083

[9] Kilhams, B., Godfrey, S., Hartley, A., Huuse, M. (2011). An integrated 3D seismic, petrophysical and analogue core study of the Mid-Eocene Grid channel complex in the greater Nelson Field area, UK Central North Sea. *Petroleum Geoscience*, 17(2), 127–142. DOI: 10.1144/1354-079310-022

[10] Kerimov, V.M. (2021). Tectonomagmatic evolution of the Eocene volcanism of the Talysh zone (Azerbaijan). *Proceedings of Tomsk Polytechnic University. Georesources Engineering*, 332(11), 200-211. DOI https://doi.org/10.18799/24131830/2021/11/2878

[11] Kontorovich, A.E., Kontorovich, V.A., Ryzhkova, S.V., Shurygin, B. N., Vakulenko, L. G., Gaideburova, E. A., Danilova, V. P., Kazanenkov, V. A., Kim, N. S., Kostyreva, E. A., Moskvin, V. I., Yan, P. A. (2013). Jurassic paleogeography of the West Siberian sedimentary basin. *Russian Geology and Geophysics*, 54(8), 747–779. DOI: 10.1016/j.rgg.2013.07.002

[12] Kontorovich, A.E. Melenevskii, V.N., Zanin, Y.N., Zamirailova, A.G. Kazanenkov, V.A., Kazarbin, V.V., Makhneva, E.N., Yamkovaya, L.S. (1998). Lithology, organic geochemistry and formation conditions of the main rock types of the Bazhenov Formation (Western Siberia). *Geology and Geophysics*, 39(11), 1477–1491. [in Russian].

[13] Laptey, A., Dolmatova, S. (2016). Anomalous Achimov and Bazhenov sequence's modeling. *SPE Russian Petroleum Technology Conference and Exhibition*. DOI: 10.2118/182138-MS

[14] Litvinova, T., Kashurin, R., Lutskiy, D. (2023). Complex formation of rare-earth elements in carbonate–alkaline media. *Materials*, 16(8), 31-40. DOI: 10.3390/ma16083140

[15] Mardashov, D.V., Limanov, M.N. (2022). Improving the efficiency of oil well killing at the fields of the Volga-Ural oil and gas province with abnormally low reservoir pressure. *Bulletin of the Tomsk Polytechnic University Geo Assets Engineering*, 333(7), 185–194. [in Russian]. DOI: 10.18799/24131830/2022/7/3707

[16] Mityaev, M.Y., Butorin, A.V., Asmandiyarov, R.N. (2017). Geological model matching with seismic data in the case of submarine slide sedimentation environment. *Neftyanoe Khozyaystvo - Oil Industry*, 8, 48–51. DOI: 10.24887/0028-2448-2017-8-48-51

[17] Olneva T.V. Seismofacial analysis. Images of geological processes and phenomena in seismic image. Izhevsk: Institute of Computer Research , 2017. [in Russian].

[18] Olneva T.V., Zhukovskay E.A. Sedimentation modeling in the program complex Petrel. MAI Publishing House, 2022. [in Russian].

[19] Otoo, D., Hodgetts, D. (2019). Geological process simulation in 3-D lithofacies modeling: application in a basin floor fan setting. *Bulletin of Canadian Petroleum Geology*, 67(4), 255–272.

[20] Otoo, D., Hodgetts, D. Applying forward stratigraphic modeling approach to enhance facies characterization and fluid mobility prediction in geological models of basin floor fans. Basin Analysis and Petroleum Geoscience Group, School of Earth and Environmental Sciences, Williams, 2018.

[21] Polyanskov, Y.V., Evseev, A.N., Poroykov, V.A. (2012). Model of sedimentation of solid particles from heterogeneous materials. *Bulletin of Samara State Aerospace University Named after Academician S. P. Korolev (National Research University)*, 33(2), 208–213. [in Russian].

[22] Prischepa, O.M., Kireev, S.B., Nefedov, Y.V., Martynov, A.V., Lutsky, D.S., Krykova, T.N., Sinitsa, N.V., Xu, R. (2023). Theoretical and methodological approaches to identifying deep accumulations of oil and gas in oil and gas basins of the Russian Federation. *Frontiers in Earth Science*, 11. DOI: 10.3389/feart.2023.1192051

[23] Raupov, I., Burkhanov, R., Lutfullin, A., Maksyutin, A., Lebedev, A., Safiullina, E. (2022). Experience in the application of hydrocarbon optical studies in oil field development. *Energies*, 15(10), 3626. https://doi.org/10.3390/en15103626

[24] Reading, H.G., Richards, M. (1994). Turbidite systems in deep-water basin margins classified by grain size and feeder system. *AAPG Bulletin*, 78, 792–822. DOI: 10.1306/A25FE3BF-171B-11D7-8645000102C1865D

[25] Ruizhao, Y., Chao, X., Tian, Z., Yuxin, L., Pengpeng, L. (2017). RGB frequency mixing method based on the residual impedance of seismic inversion. *International Geophysical Conference, Qingdao, China*, 17-20 April 2017, 1036–1039. DOI: 10.1190/IGC2017-264

[26] Saks, V.N. Problems of Paleozoogeography of the Mesozoic of Siberia, Leningrad, Science, 1972. [in Russian].

[27] Schmidt, I., Lacaze, S., Paton, G. (2013). Spectral Decomposition and Geomodel Interpretation - Combining Advanced Technologies to Create New Workflows. *75th EAGE Conference Exhibition Incorporating SPE EUROPEC*, 1–5. DOI: 10.3997/2214-4609.20130567

[28] Tananykhin, D., Grigorev, M., Simonova, E., Korolev, M., Stecyuk, I., Farrakhov, L. (2023). Effect of wire design (profile) on sand retention parameters of wire-wrapped screens for conventional production: prepack sand retention testing results. *Energies*, 24–38.

[29] Tananykhin, D., Struchkov, I., Khormali, A., Roschin, P. (2022). Investigation of the influences of asphaltene deposition on oilfield development using reservoir simulation. *Petroleum Exploration and Development*, 49(5), 1138–1149. DOI: 10.1016/S1876-3804(22)60338-0

[30] Teles, V., Chauveau, B., Joseph, P., Weill, P., Maktouf, F. (2016). CATS – A process-based model for turbulent turbidite systems at the reservoir scale. *Comptes Rendus Geoscience*, 348(7), 489–498. DOI: 10.1016/j.crte.2016.03.002

[31] Tetzlaff, D., Tveiten, J. Salomonsen, P., Christ, A.-B., Athmer, W., G. Borgos, H. Sonneland, L. Martinez, C., Raggio, F. (2014). Geologic process modelling. *Conference: IX Conference of Hydrocarbon Exploration and DevelopmentAt: Mendoza, Argentina*, 1–16.

[32] Torrado, L., Mann, P., Bhattacharya, J. (2014). Application of seismic attributes and spectral decomposition for reservoir characterization of a complex fluvial system: Case study of the Carbonera Formation, Llanos foreland basin, Colombia. *GEOPHYSICS*, 79(5), 221–230. DOI: 10.1190/geo2013-0429.1

[33] Van Hoek, T., Gesbert, S., Pickens, J. (2010). Geometric attributes for seismic stratigraphic interpretation. *The Leading Edge*, 29(9), DOI: 10.1190/1.3485766

[34] Zakrevskii K.E., Nassonova N.V., Soloviev N.N. Geological modeling of clinoforms of the Neocomian of Western Siberia. GERS Publishing House, 2021. [in Russian].

[35] Zhang, L., Manzocchi, T., Pontén, A. (2015). Hierarchical parameterization and modelling of deep-water lobes. *Pet Geostat*. DOI: 10.3997/2214-4609.201413606