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SVISION — A NEW REALITY IN DELINATION OF STRATIGRAPHIC TRAPS

Over the past decade, the global E&P business steadily shifting its exploration efforts toward stratigraphic prospects. At the same time, such traps are regarded as the riskiest exploration targets. Conventional methods often demonstrate weakness in their effective disclosure and subsequent examination. Thus, the demand to resolve this obstacle arises. In the course of searching for an efficient and prompt approach aiming to delineate and assess stratigraphic prospects, new SVision technology allowing direct traps detection in 3D seismic volumes has been applied to the Sakhalin-5 data set. In addition to earlier discoveries, within the studied area, SVision animated models reveal large fan systems all over the Pliocene sediment section. Some of them considered as new targets demonstrate direct hydrocarbon indicators.

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Introduction

The increasing exploration maturity of sedimentary basins drives more attention to stratigraphic traps as remaining exploratory targets. Even so, drilling of such traps is undertaken after all possible structural prospects have been tested. A well-known time delay of stratigraphic trap exploration behind the exploration of structural traps is due to the high risk owing to the difficulty in both accurate trap delineation and in assessing their sealing potential [1–3]. Stratigraphic traps are often found accidentally while drilling toward anticlines [4]. Due to historical emphasis on anticline structures and owing to the difficult seismic imaging of stratigraphic trap components, their exploration was generally restricted to the areas where seismic data allow the direct assessment of the fluid content and evolution of a reservoir. As a result, only 10–15% of the world's giant hydrocarbon fields were found in stratigraphic traps despite their overwhelming numbers over structural traps in many basins [5]. Since 2000, giant oil and gas discoveries in stratigraphic and mixed-type traps rose to nearly 50% as a result of applying 3D seismic surveys that provided better reservoir imaging.

The conventional procedure for locating prospective stratigraphic traps employs all available data from wells, seismic and, in some cases, outcrops [6–9]. The sequence stratigraphic principles provide a framework for the data integration. The method uses seismic sections to identify sequences and systems with depositional environments favorable for stratigraphic trap origination to focusing on further. Then seismic attributes meant to clarify depositional trends are analyzed to detect probable stratigraphic targets [10–15].

However, the sequence stratigraphic models often exhibit changes in depositional environments resulting in significant lateral variations of thickness, angles, and facies even within sequences of simple geometry [16]. This observation evidences against the dependency between specific depositional environments and a certain type of system tract which decreases predictive ability of the sequence stratigraphic models. Aiming to demonstrate multiple opportunities for stratigraphic trap exploration, Dolson depicted possible locations of traps within the context of sequence stratigraphy [5]. According to the researcher and others scientists [17], such traps occur in combination with all types of system tracts and sequence boundaries; hence the necessary requirement for stratigraphic traps to develop is facies changing merely. So, the promising stratigraphic trap may occur in any part of the cross-section, and the only way to detect all stratigraphic prospects is a total screening of sedimentary cover [18–19].

Hereby, despite a noticeable improvement in finding promising stratigraphic traps, their delineation and assessment remains a sophisticated and time-consuming procedure, and the need for enhanced efficiency in the deliberate search for stratigraphic traps is still relevant [20].

In the course of searching for an efficient and fast approach aiming to thoroughly investigate stratigraphic traps, a new technic has been examined. This paper addresses the results of direct detecting of stratigraphic traps from 3D seismic volumes with the SVision method developed ASAP Service LLC.

Global setting

Kaigan-Vasuykansky south block of Sakhalin-5 project is located at the North Sakhalin offshore of the Sea of Okhotsk. Water depths within the studied area range up to 140 m. The area belongs to the west slope of the Deruygin basin (**Fig. 1**).

The sedimentary cover comprises the Cenozoic marine clastic deposits above the Cretaceous basement (**Fig. 2**). Four exploration wells penetrated the Pliocene–Quaternary section of the sedimentary cover within the studied area.

The discovery of a small Kaigan–Vasuykansky gas-oil field proved an active petroleum system of the Deruygin basin with the mature Lower–Middle Miocene source rock and Pliocene reservoirs [21–24].

The observed geological conditions are quite favorable for the development of stratigraphic traps including the presence of a fully charged petroleum system, simple basin architectures and low dips in the accumulation zone.

Material and methods

The geologic information for the investigations involves about 2000 square kilometres of 3D seismic, as well as the data from 4 wells and all technical and geologic reports addressing the studied area, obtained with permission from Russian State Geologic Depository [25].

The analysis of the paleo-depositional environments and the basin's successive evolution restoration was performed using SVision animated models.

In the course of animated modeling, stack seismic is transformed into the Stratigraphic Cube (SC) using SAI automated full-volume seismic interpretation technology (**Fig. 3**). The Stratigraphic Cube is a three dimensional grid where each grid point coincides with relative geologic age [26]. The resolution of the grid corresponds to the input seismic directly.

SC is a continuous stratigraphic model of a sedimentary section and its every equivalent time surface is a horizon. The entire seismic volume is involved in the topologic analysis in the course of SC construction, providing consistency of the model. Thereby, the Stratigraphic Cube is the most detailed and balanced (horizons do not intersect) stratigraphic model obtainable from seismic data [27].

SVision models usually comprise 100–200 isosurfaces coinciding with the most widely spread reflectors selected based on the Majority Chart and extracted from the Stratigraphic Cube.

The animated models delivering as .gif files require no any special software to visualize and work with. It takes not more than 1 or 2 days to obtain a Stratigraphic Cube and construct SVision models, and only few minutes to analyze them [28–29].

Results

The constructed SVision animated models embrace the Upper Miocene to Pliocene section of sedimentary cover. The models reveal stepwise shifting of depositional trends within the studied area from distal marine deep-water environments to proximal shallow-water conditions. Since the beginning of the Pleistocene, the shelf covers the entire studied area.

Fine-grained sedimentation represented by Savitskaya borehole core samples prevailed during the Early Pliocene all over the area with the exception of sporadic coarse-grained mass transport deposition (MTD) in the south part. Three generations of Lower Pliocene gravity flows clearly recognized on SVision snapshots (amplitudes) indicate the changes in direction of material transportation, as well as in the location and morphology of the fan systems (**Fig. 4**). About 100 m of sands with 40% of gravel comprise the Lower Pliocene section of Pela Lache borehole which penetrates all three MTD.

Udachnaya, Yuzno-Vasyukanskaya and Pela Lache boreholes flow hydrocarbons, while Savitskaya is dry.

During the Late Pliocene sedimentation took place under various conditions of the shelf, slope and basin plain. All domains well exposed on SVision snapshots (both isochrones and amplitudes) reflected several prograding/aggrading events in the northwest direction which were not contemporaneous along the shelf line (**Fig. 5**). Commonly, progradation coupled with backstepping and erosion at neighbor parts of the shelf.

SVision model revealed another fan system developed in Late Pliocene (see fig. 4). Its morphology peculiarities point at different source, and very likely at different lithology compared with the older ones.

In the course of shelf progradation, the slope instability caused numerous failures resulted in sliding, slumping and other manifestation of mass transport deposition.

Fig. 1. Overview map of the study area

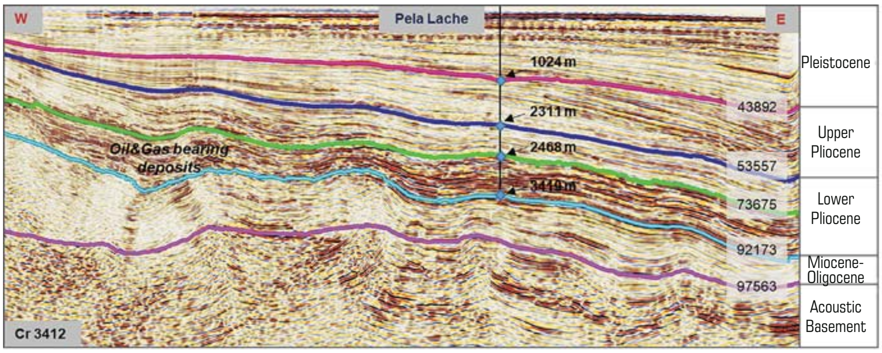

Fig. 2. Simplified geologic structure of the sediment cover showing mostly monocline gently sloping to the East Pliocene–Pleistocene deposits and folded Miocene–Oligocene sediments. The depth of Lower Pliocene oil- and gas-bearing deposits varies from 2000 to 3500 m within the studied area. Numbers at the seismic horizons indicate their relative stratigraphic age

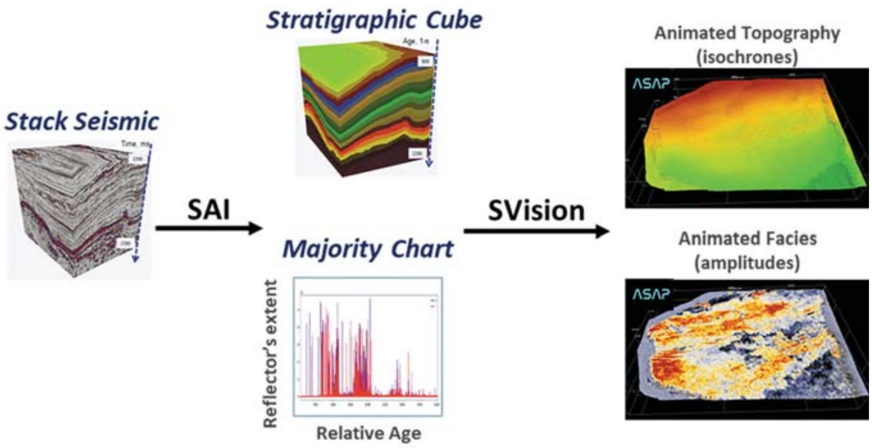

Fig. 3. SVision Workflow

In the course of the investigations, it was also revealed that fan systems developed all over the Pliocene interval with no obvious connection with local sea-level fluctuation.

Besides paleogeographic settings, direct hydrocarbon indicators (fluid contacts) spotted on the Animated Facies (amplitudes) snapshots represent additional essential signs for trap delineation. First noticed and tested at Pela Lache trap (Kaigan–Vasuykansky gas-oil field) with oil-water contact proved by well tests, similar flat spots (amplitudes conformed to structure) were detected in several structural and stratigraphic prospects (**Fig. 6**).

At the same time, some stratigraphic prospects demonstrate no such signs. The spacious Lower Pliocene fan system located to the southeast of the Pela Lache trap is an example that needs further examination charging risks assessment.

Discussion

The results of the Sakhalin-5 case study demonstrate the high effectiveness of SVision technology for the seismic facies analysis and stratigraphic traps revelation.

All issues that sequence stratigraphy (along with seismic attributes) designed to provide via sophisticated workflow could be gained directly from SVision animated models in a few minutes. The models provide a clear understanding of the geologic processes such as progradation, aggradation, slumping, sliding, mass transport deposition, etc., compatible with the logic of the basin evolution.

Besides, SVision facies maps exposing geological features enable direct detection of plausible stratigraphic targets (channels, canyons, fans, etc.), which, in turn, are the results of particular geologic processes. Such consistency of geologic features and processes increase the confidence of prospective targets delineation. The existence of direct hydrocarbon indicators

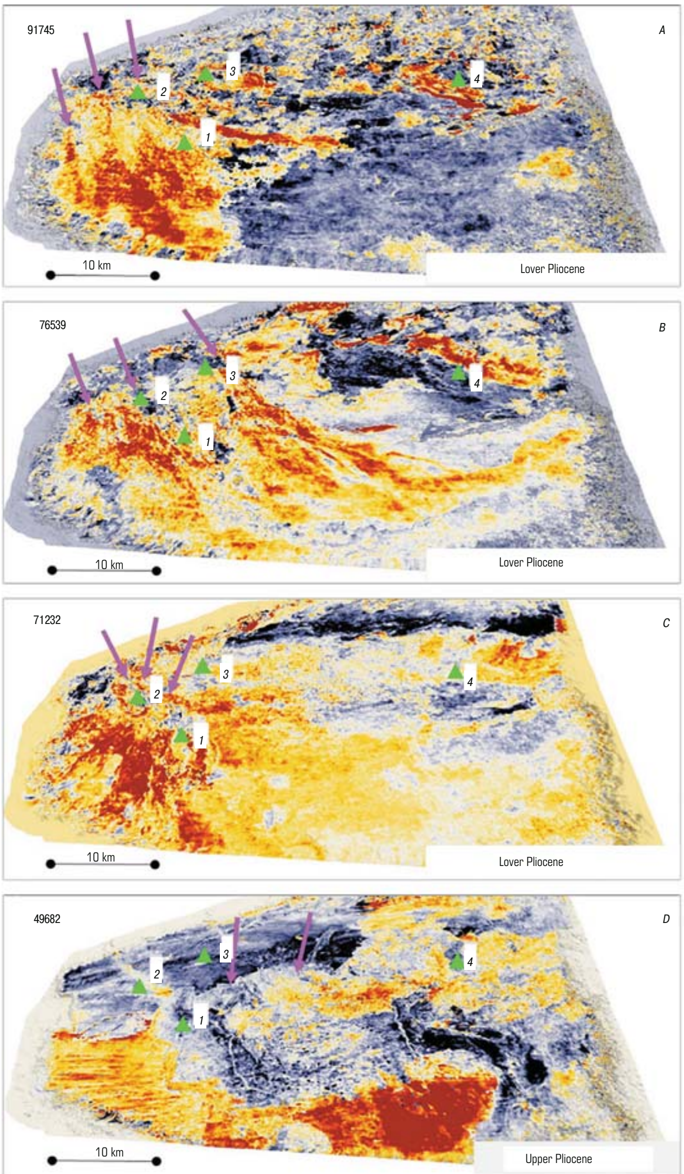

Fig. 4. SVision snapshots (relative stratigraphic age in the upper left) showing several generations of fan systems with different morphology. Arrows indicate changes in direction of material transportation.
Wells: *1* – Pela Lache-1, *2* – Yuzno-Vasyukanskaya, *3* – Udachnaya, *4* – Savitskaya

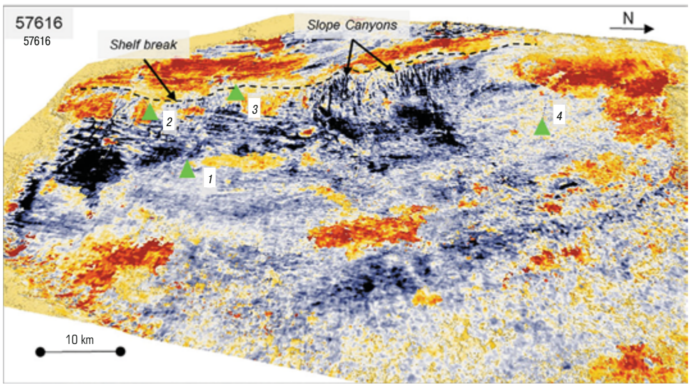

Fig. 5. SVision snapshots (relative stratigraphic age in the upper left) showing Late Pliocene paleobasin domains: shelf, slope, basin plain.
Wells: 1–Pela Lache-1, 2–Yuzno-Vasyukanskaya, 3–Udachnaya, 4–Savitskaya

supporting a trap (fluid contacts) completes the picture and reduces exploration risk significantly.

Lack of direct hydrocarbon indicators compels for deeper investigations of the probable targets. Such risks as seals weakness, migration (trap charging), pay preservation (remigration, destruction) need further consideration [30–31]. In mature basins, it is necessary to involve all available datasets: well logs, tests, hydrocarbon shows, core samples, pressure, etc., to convert seismic facies into lithology and map the reservoir, seal and stratigraphic trap itself. The trap is only determined if the associated tests, shows and pressure data support its geometry. In frontier or lightly drilled basins, numeric geologic modeling (BM&PSM, forward stratigraphic modeling) is essential for upper mentioned risks assessments by generating and testing hypotheses. It will not cost much time and effort since SVision provides sufficient information for basin analysis and Stratigraphic Cube—very detailed basin geometry. Seismic facies maps could be transformed into lithology maps based on simple assumptions, or involving forward stratigraphic modelling, seismic inversion.

In this way, SVision animated models is an efficient tool for screening seismic volumes to detect the most prospective (less risky) traps.

Conclusions

The obtained results prove SVision is an efficient tool for fast screening of 3D seismic volumes for detection and ranking of stratigraphic traps.

The key benefit provided by the animated models is the distinct spatial distribution of facies in the context of geologic processes succession. Due to this advantage, SVision is selected to be the main element to ensure the robustness of the developing technology.

The implemented investigations demonstrate promoting results opening new possibilities in exploration for stratigraphic traps.

Subsequent investigation will use the SVision method in combination with numeric geologic modeling under various geologic settings favorable for origination stratigraphic traps.

Exploration of frontier and mature basins require different workflows. In frontier areas with deficiency of regular drilling, the numerical geologic modeling (BM&PSM, forward stratigraphic modeling) is essential for assessing risks related to seal weakness, trap charging, pay destruction etc., via generating and testing hypotheses.

In mature basins, it is required to involve all available datasets to understand whether the various well tests, hydrocarbon shows and pressure data support the geometry of the prospective trap.

References

1. Allan J. R., Sun S. Q., Trice R. The deliberate search for stratigraphic and subtle combination traps: Where are we now? *Geological Society, London, Special Publications*. 2006. Vol. 254, No. 1. pp 57–103.
2. Allen M. R., Goffey G. P., Morgan R. K., Walker I. M. The deliberate search for the stratigraphic trap: An introduction. *Geological Society, London, Special Publications*. 2006. Vol. 254, No. 1. pp. 1–5.
3. Christopher A., Hutapea O. Stratigraphic traps in the Tertiary rift basins of Indonesia: Case studies and future potential. *Geological Society, London, Special Publications*. 2006. Vol. 254, No. 1. pp. 105–126.
4. Dolson J. C., Bahorich M. S., Tobin R. C., Beaumont E.A., Terlikoski L. J. et al. Exploring for oil and gas traps: Treatise of petroleum geology, handbook of petroleum geology. Tulsa : American Association of Petroleum Geologists, 1999. Vol. 1. pp. 21.2–21.68.
5. Dolson J., He Z., Horn B. W. Advances and Perspectives on Stratigraphic Trap Exploration-Making the Subtle Trap Obvious. *AAPG*. 2018.
6. Imangaliuly I. Possible ways to detect non-structural traps in the central part of the Caspian Sea. *Kazakhstan Journal for Oil & Gas Industry*. 2022. Vol. 4, No. 3. pp. 22–29.
7. Laisheng C., Lin Y., Hong C., Hua L., Xiyan D. et al. Identifying stratigraphic traps in sub sag area. *International Geophysical Conference, Qingdao, China*. 2017. pp. 677–681.

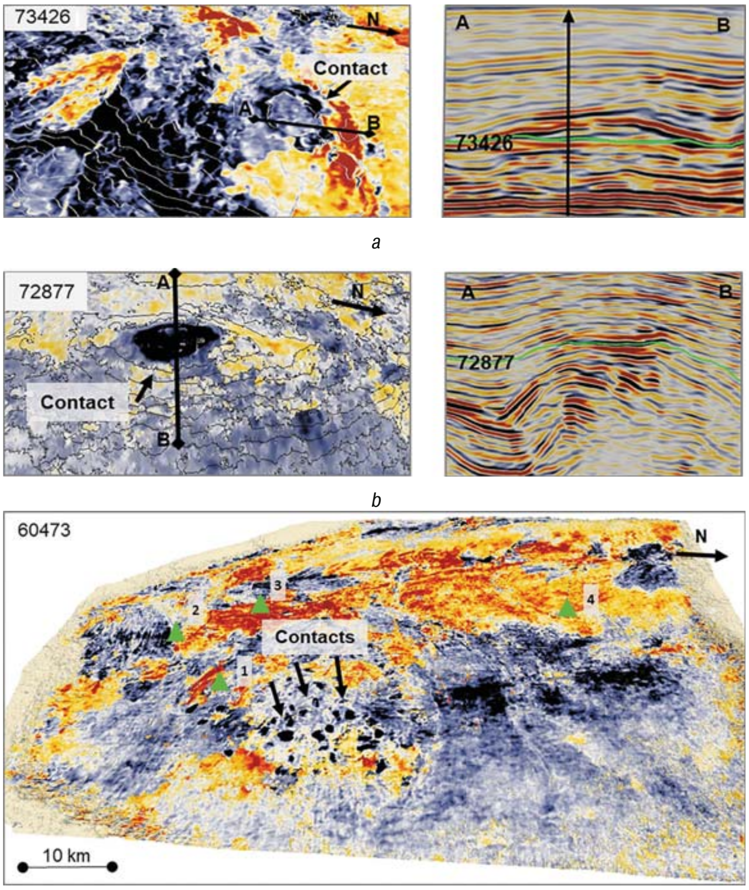

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Fig. 6. Fragment of SVision snapshot and seismic section:

a – Pela Lache well location showing fluid contact of Pela Lache stratigraphic trap; *b* – showing fluid contact of the anticline trap; *c* – SVision snapshot showing numerous fluid contacts of stratigraphic traps within the Lower Pliocene fan system. Wells: *1* – Pela Lache-1, *2* – Yuzhno-Vasyukanskaya, *3* – Udachnaya, *4* – Savitskaya

8. Naseer M. T., Naseem S., Khalid R. H., Sha M. A., Khalid P. Delineation of stratigraphic traps within the basin floor fans of Miocene sedimentary sequences, offshore Indus, Pakistan using inverted acoustic impedance simulations. *Geological Journal*. 2023. Vol. 58, No 2. pp. 722–739.
9. Nikrouz R., Siabeghodsi A., Hassanalizade P. Detection of stratigraphic trap of Sarvak formation using petrophysical logs and seismic attributes in one of the oil fields in the south west of Iran. *Journal of the Earth and Space Physics*. 2017. Vol. 43, No. 1. pp. 53–69.
10. Alsulami S., Ameen M. S. Seismic-based detection of stratigraphic traps and carbonate mounds. *SPE Middle East Oil & Gas Show and Conference, Manama, Kingdom of Bahrain*. 2017.
11. Babasafari A. A., Samadian A. Stratigraphic oil trap detection using seismic attributes and neural network. *Proceedings of the 10th SEGJ International Symposium, Kyoto, Japan*. 2011. DOI: 10.1190/segj102011-001.125
12. Bahmani A. A., Riahi M. A., Ramin N. Detection of stratigraphic traps in the Asmari Formation using seismic attributes, petrophysical logs, and geological data in an oil field in the Zagros basin, Iran. *Journal of Petroleum Science and Engineering*. 2020. Vol. 194. ID. 107517.
13. El-Nikhely A., El-Gendy N. H., Bakr A. M., Zawra M. S., Ondrak R. et al. Decoding of seismic data for complex stratigraphic traps revealing by seismic attributes analogy in Yidma/Alamein concession area Western Desert, Egypt. *Journal of Petroleum Exploration and Production Technology*. 2022. Vol 12. pp. 3325–3338.
14. Haris A., Sari T. W., Lisapaly L., Isniarny N., Riyanto A. et al. Delineating stratigraphic trap reservoir using RGB color blending of spectral decomposition method: Case study in the West Natuna Basin. *AIP Conference Proceedings*. 2017. Vol. 1862, Iss. 1. ID. 030182.
15. Shazia A., Nasir K., Shahid N. Q., Farrukh H., Saeed A. B. Study of a stratigraphic trap of Paleocene/Late Cretaceous Age with the help of seismic Data in Sulaiman Foredeep and Kirthar Foredeep Area (Central & Southern Indus Basin, Pakistan). *International Journal of Geosciences*. 2014. Vol. 5, No. 10. pp. 1049–1061.
16. Dominguez R. F, Catuneanu O., Reijenstein H., Notta R., Posamentier H. Sequence stratigraphy and the three-dimensional distribution of organic rich units in the Vaca Muerta Formation, Neuquén Basin. *ICE&AAPG International Conference and Exhibition*. 2019.
17. Binns P. E. Evaluating subtle stratigraphic traps: Prospect to portfolio publication. *Geological Society, London, Special Publications*. 2006. Vol. 254, No. 1. pp. 7–26.
18. Kerimov V. Y., Osipov A. V., Mustaev R. N., Monakova A. S. Modeling of petroleum systems in regions with complex geological structure. *The 16th Science and Applied Research Conference on Oil and Gas Geological Exploration and Development, Geomodel 2014*. 2014.
19. Lapidus A. L., Kerimov V. Y., Mustaev R. N., Movsumzade E. M., Salikhova I. M., et al. Natural bitumens: Physicochemical properties and production technologies. *Solid Fuel Chemistry*. Vol. 52, No. 6. 2018. pp. 344–355.
20. Citron G. P., MacKay J. A. Appropriate creativity and measurement in the deliberate search for stratigraphic traps. *Geological Society London Special Publications*. 2006. Vol. 254. pp. 27–41.
21. Gladenkov Yu. B., Bazhenova O. K., Grechin V. I., Margulis L. S., Salnikov B. A. Cenozoic rocks of the Sakhalin Island and their petroleum potential. Moscow : GEOS, 2002. 225 p.
22. Kharakhinov V. V. Petroleum geology of the Sakhalin region. Moscow : Nauchnyy mir, 2010. 275 p.
23. Savitskii A. V. Assessment of the oil and gas potential of the North Sakhalin shelf based on basin modeling: Thesis of Dissertation of Candidate of Geologo-Mineralogical Sciences. Moscow, 2005. 143 p.
24. Shein V. S., Ignatova V. A. Geodynamics and prospects of petroleum potential of sedimentary basins of the Far East. Moscow : VNIGRI, 2007. 289 p.
25. Kerimov V. Y., Bondarev A. V., Mustaev R. N., Khoshtaria V. N. Estimation of geological risks in searching and exploration of hydrocarbon deposits. *Oil Industry*. No. 8. 2017. pp. 36–41.
26. Gorbunov A., Lavrenova E. SAI-advanced solution to geologic objectives. 2018. DOI : 10.13140/RG.2.2.30054.47689
27. Guliev I. S., Mustaev R. N., Kerimov V.Y., Yudin M. N. Degassing of the Earth: Scale and implications. *Gornyi Zhurnal*. No. 11. 2018. pp. 38–42.
28. Corcoran J. Application of a sealing surface classification for stratigraphic related traps in the UK Central North Sea. *Geological Society London Special Publications*. 2006. Vol. 254, No. 1. pp. 207–223.
29. Dolson J. Understanding Oil and Gas Shows and Seals in the Search for Hydrocarbons. Switzerland : Springer International Publishing, 2016. 486 p.
30 Kerimov V., Kosyanov V., Lavrenova E., Gorbunov A. Strategic Innovation in hydrocarbon Exploration. *Progress 2019: Exploration as a Business—Oil and Gas International Exploration Conference*. 2019. DOI: 10.3997/2214-4609.201953010
31. Lavrenova E. A., Gorbunov A. A., Kerimov V. Y., Mustaev R. N. Scalable basin modeling—An application for petroleum exploration. *Geomodel 2019– The 21st Conference On Oil and Gas Geological Exploration and Development*. 2019. pp. 1–5. DOI: 10.3997/2214-4609.201950040 EM