B030

New Seismic Data on the South and North Chukchi Sedimentary Basins and the Wrangel Arch and Their Significance for the Geology of Chukchi Sea Shelf (R

V. Verzhbitsky* (TGS-NOPEC Geophysical Company Moscow), E.M. Frantzen (TGS-NOPEC Geophysical Company ASA), K. Trommestad (TGS-NOPEC Geophysical Company ASA), T. Savostina (TGS-NOPEC Geophysical Company Moscow), A. Little (TGS Geological Products and Services), S.D. Sokolov (Geological Institute, Russian Academy of Sciences), M.I. Tuchkova (Geological Institute, Russian Academy of Sciences), T. Travis (TGS-NOPEC Geophysical Company (UK) Limited), O. Martyntsiva (TGS-NOPEC Geophysical Company (UK) Limited) & M. Ullnaess (TGS-NOPEC Geophysical Company ASA)

SUMMARY

During the summer of 2006 TGS-NOPEC conjointly with Geophysical Solutions Integrator acquired new seismic data in the Russian part of the Chukchi Sea. The area of the Chukchi Sea studied includes (from S to N): South Chukchi sedimentary basin (1), Wrangel Late Kimmerian Arch (2), North Chukchi sedimentary basin (3). Due to the absence of offshore wells in the Russian sector of Chukchi Sea, the interpretation of acquired seismic data and definition of probable hydrocarbon potential must be based on the comparison with the US sector of the Chukchi Sea and the Alaska North Slope, as well as on the geology of Northern Chukotka and Wrangel Island. In the northern part of the Wrangel Arch most of the thrust faults are N-vergent, but double-vergent transpressional structures also occur. To the North of the Wrangel Arch, a clearly recognizable angular unconformity in the upper parts of the North Chukchi basin may correspond to the Lower/Upper Brookian (~Cretaceous/Tertiary) boundary, although it may be as old as Early Cretaceous (pre-Aptian) in age. The maximum Pz-Mz-Cz sediment thickness of the North Chukchi basin exceeds 16 km. In the South Chukchi basin the thickness of sediments (Late Cretaceous?-Cenozoic) mostly doesn t exceed 3-4 km, but in some places reaches 5-6 km. The geometry of the faults indicates an extensional/transtensional setting of the South Chukchi rift basin development. The changes in phase or polarity in upper parts of the sedimentary cover, listric fault planes in the pre-rift sequences, associated with areas of reduced reflectivity in the upper sediments may point to a gas presence. The syn-orogenic (pre-rift) Upper Jurassic-Lower Cretaceous organic-rich terrigenous sequence (containing visible plant remnants), which is exposed onshore in Northern Central Chukotka and is probably present in the Chukchi Sea, may represent regional gas source rocks.

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The studied area of Chukchi Sea includes several regional tectonic subdivisions (from South to North): Chukotka fold belt area, South-Chukchi sedimentary basin, Wrangel (Wrangel-Herald) Arch, North-Chukchi sedimentary basin (fig. 1, 2).

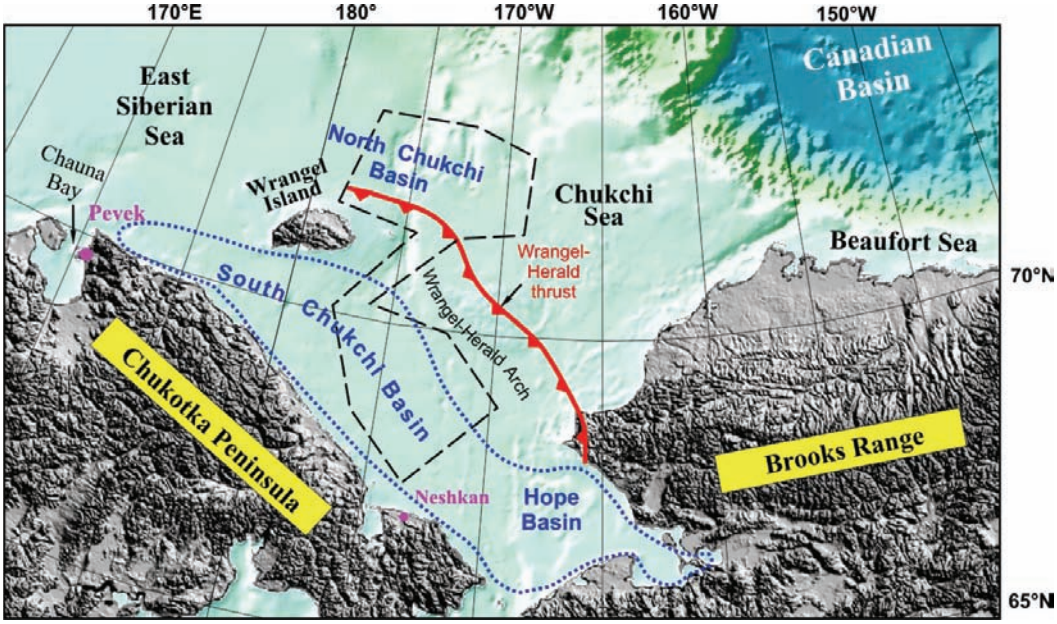

Figure 1. Relief, main geographical names and features of the Eastern Arctic tectonic structure (based on the map of A.O.Mazarovich and S.Yu.Sokolov, 2003). Topographic base – IBCAO (2001, http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/arctic.html). Black dotted line delineates the area of seismic profiling, carried out by TGS-NOPEC in 2006.

Southernmost area, nearest to Chukotka Peninsula, is a part of Late Kimmerian New Siberian-Chukotka fold-thrust fault belt, formed in Neocomian (pre-Aptian/Albian) as a result of closure of South-Anyui paleooceanic basin, subsequent collision between Eurasia and New Siberian-Chukotka microplate and the formation of narrow, highly deformed South-Anyui suture zone [e.g. *Bondarenko, 2004; Sokolov et al., 2001, 2002*] (fig. 2).

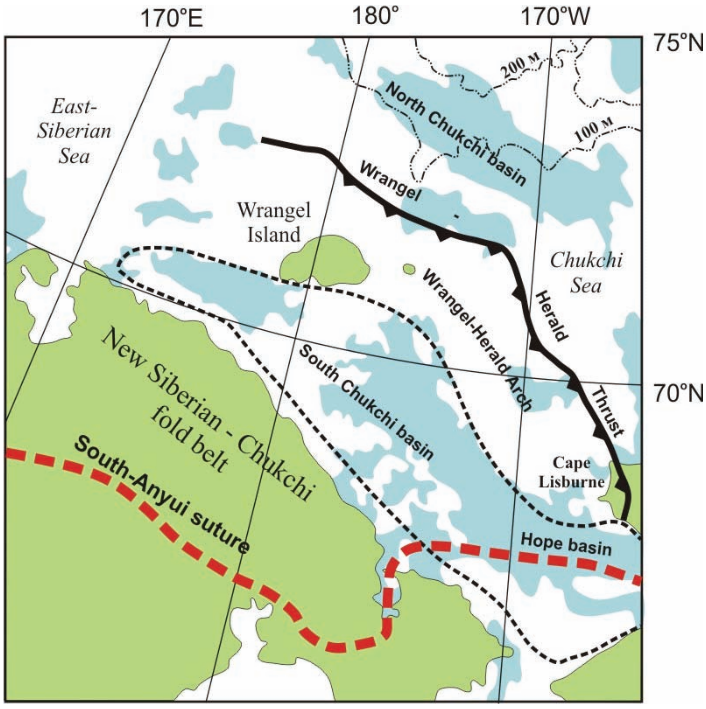

Figure 2. Main tectonic elements of Chukchi Sea region. Compiled after [*Mazarovich., Sokolov, 2003; Khain, 2001; Sokolov et al,, 2001, 2002; Miller et al., 2002*]. Blue color corresponds to the simplified distribution of free air gravity anomalies.

More to the North, between Chukotka and Late Kimmerian Wrangel-Herald arch, the South Chukchi sedimentary basin was outlined by several researchers [e.g. *Shipilov et al., 1989; Mazarovich and Sokolov, 2003*]. The time of its formation is unclear, but as it is superimposed on Late Kimmerian fold belt, the age of its sediment filling must be not earlier, than Aptian-Albian (?)-Late Cretaceous. According to the drilled cores in US part of Chukchi Sea, on the proposed E-SE continuation of the South Chukchi basin – Hope basin, its age is Cenozoic [*Tolson, 1987*]. The geometry of the faults indicates an extensional/transtensional setting of the South Chukchi rift basin development, similar with the Hope basin in US part of Chukchi Sea [*Tolson, 1987*].

The prominent strong reflectivity linear zone, dipping to the South, was found in the basement of southernmost part of studied area, near Chukotka Peninsula (fig. 3). This zone divides the basement in two units with different structural style – “Southern” and “Northern”. “Southern” unit is almost acoustically transparent, but, at the same time, “Northern” has some elements of “stratification”. It is likely, that this boundary may represents basement tectonic fault zone. Obvious Z-asymmetric folds of the reflectors within it point to the North-vergent thrust sense of proposed displacement (fig. 3, incut). One of the possible explanations is, that this zone represents the tectonic contact between two different terranes (sub-terranes), widely distributed in the Mesozoic fold belts of NE Eurasia [e.g. *Parfenov et al., 1993; Sokolov et al., 1997*]. From the other hand, it also may corresponds to the low-angle overthrusting of very intensively deformed Chukotkian Paleozoic-Triassic rocks on the much less deformed syn-collisional Late Jurassic-Early Cretaceous sediments and so, served main elements of stratification. According this interpretation, the horizontal amplitude of thrust displacement my exceed 20-30 km.

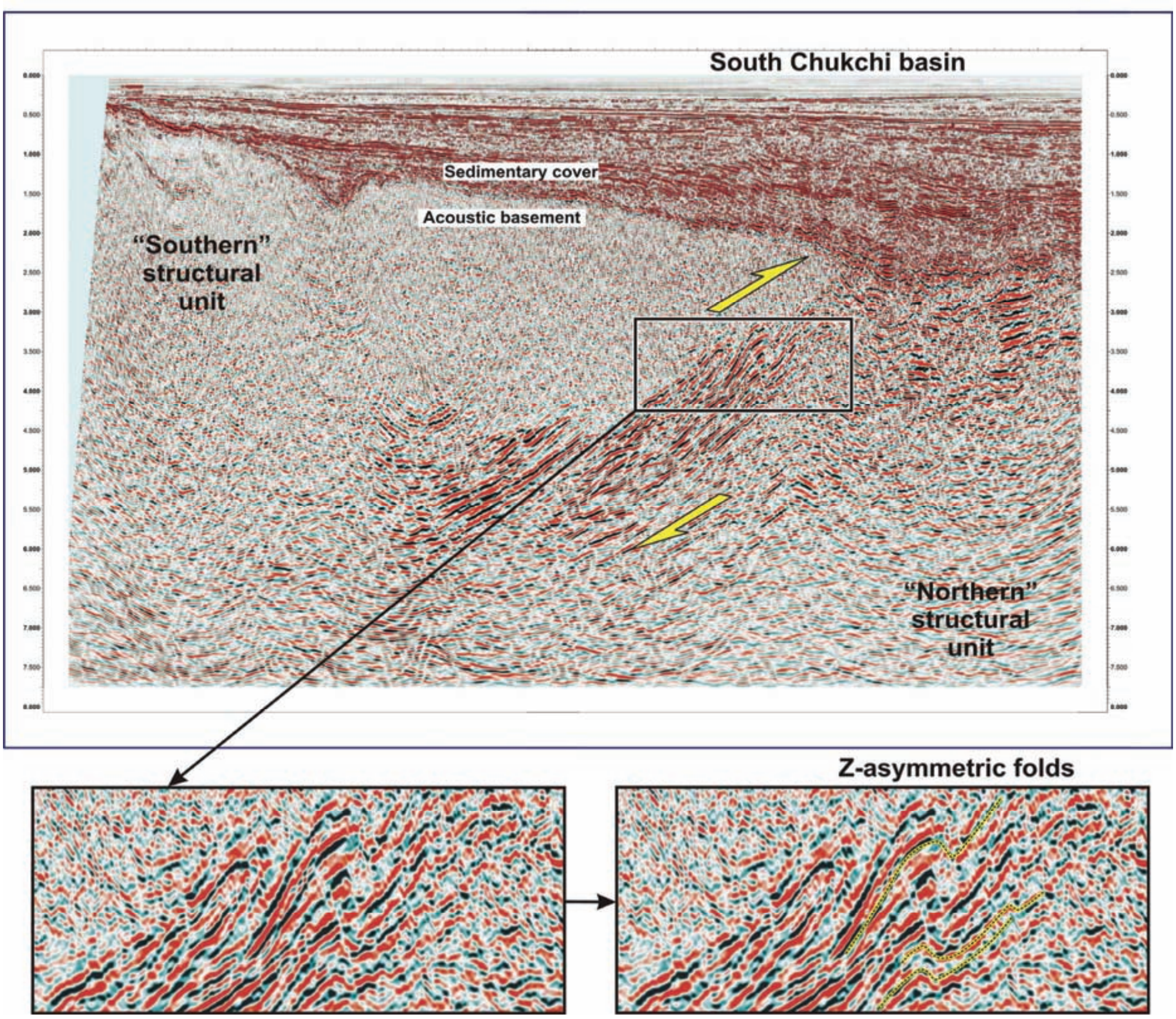

Figure 3. Seismic section across the South Chukchi basin with some elements of interpretation.

The South Chukchi rifted sedimentary basin is superimposed on the mentioned above basement fault zone and have asymmetric structure – gentle southern and steeper northern flank. This observations lead to suggestion, that South Chukchi basin inherited this significant pre-existing Kimmerian zone of displacements and was formed during Late Cretaceous (?) -Cenozoic as the result of the change of regional tectonic setting – from compression to extension. In the South Chukchi basin the thickness of sediments mostly doesn't exceed 3-4 km, but in some places reaches 5-6 km. The changes in phase or polarity in upper parts of the sedimentary cover, listric fault planes in the pre-rift sequences, associated with areas of reduced reflectivity in the upper sediments may point to a gas presence. The syn-orogenic (pre-rift) Upper Jurassic-Lower Cretaceous organic-rich terrigenous sequence (containing visible plant remnants), which is exposed onshore in Northern Central Chukotka and is probably present in the Chukchi Sea, may represent regional gas source rocks.

It is commonly believed, that Wrangel arch represents the NW continuation of Herald thrust - Cape Lisburne and Brooks Range fold-thrust fault structure. The time of arch formation may corresponds also to the Late Kimmerian (or, probably, younger) time. The structures of

Wrangel arch are overthrusted on the North-Chukchi sedimentary basin, which is underlain by Mid-Palaeozoic (Ellesmerian) basement [*Grantz et al., 1990; Khain, 2001*]. It is proposed, that the lowest part of the sedimentary cover must contain Upper Devonian (?)-Carboniferous sediments. The maximum Pz-Mz-Cz sediment thickness of the North Chukchi basin exceeds 16 km.

In the Northern part of Wrangel Arch, close to its junction with North Chukchi basin, the double (both North- and South-vergent) “positive flower” and “push-up” structures are widely distributed in the basement (earlier) and upper part of sedimentary cover (latest) with vertical offset up to the several hundreds of meters (fig. 4). This structural pattern point to the combined compressional/strike-slip (transpressional) kinematics of the Wrangel arch front. The observation is in a good agreement with previous result, obtained for the NW part of East Siberian Sea: *Drachev et al.* [2001] also pointed to the transpressional structural pattern of the Late Kimmerian fold-thrust fault northern front with Hyperborean (epi-Ellesmerian?) massif.

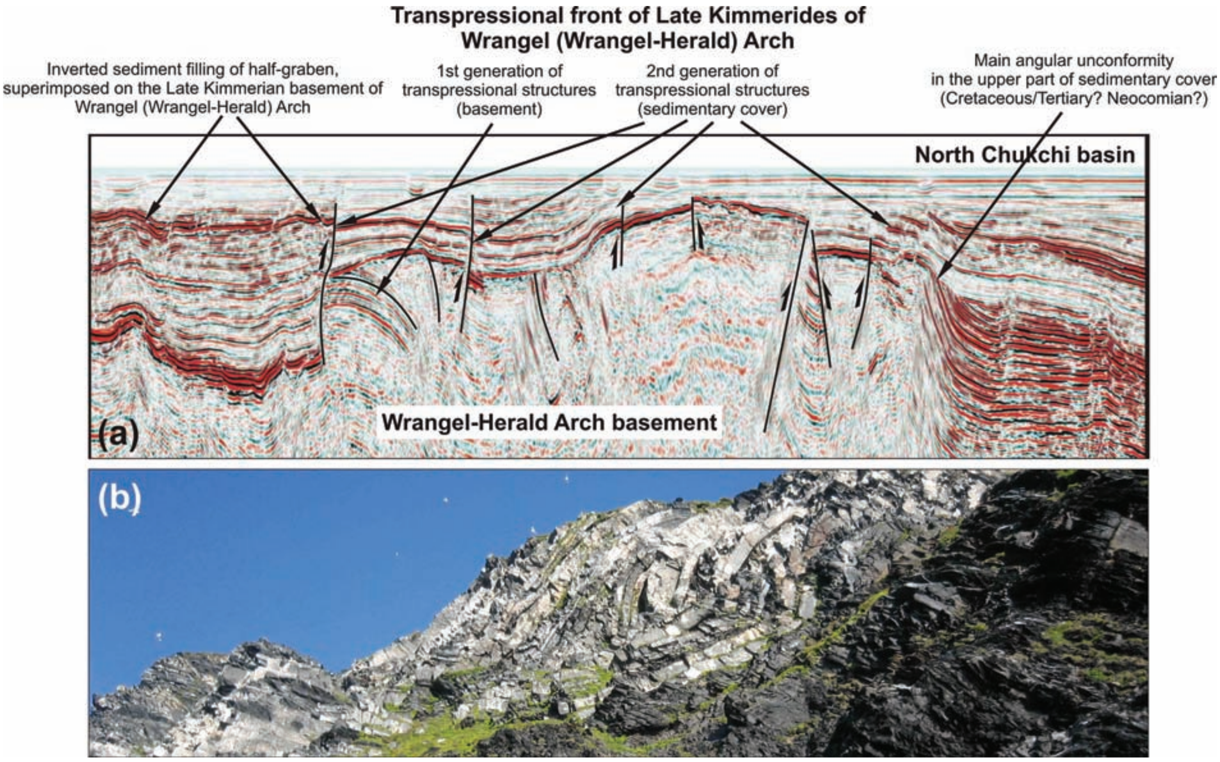

Figure 4. Examples of compressional deformation (faults and folds), occurring within the Wrangel Arch: a – seismic cross-section of the upper Earth crust, located to the NE of Wrangel Island and illustrating the deformations of Wrangel Arch folded basement and sedimentary cover. The length of profile is approximately 100 km; b – Triassic rocks outcrop on the Western coast of Wrangel Island (folded basement of Wrangel Arch). The length of exposure is approximately 150 m. Photo by V.E.Verzhbitsky, S.D.Sokolov, M.I.Tuchkova.

The rather uniform fold-thrust fault-nappe structure of Wrangel arch, gently dipping to the south, is well-documented in on-land outcrops of Precambrian-Paleozoic-Triassic rocks of Wrangel Island [e.g. *Kos’ko et al., 1993*]. If so, transpressional structural pattern of northern front of Late Kimmerides, visible on the obtained seismic profiles, may reflect the latest stages of compressional collision-related deformation, occurred in basement (1st) and in upper part of overlying sediments (2nd). So, at least two or three main compressional events occurred during the formation of Wrangel arch structure. It is interesting to note, that within the South-Anyui suture zone two main stages of collisional deformation were recognized: first – compressional, formed the North-vergent fold and thrust fault fabric, and, second – right-lateral transpressional, formed subvertical and double vergent (both North and South) structural pattern, superimposed on the earlier structure. Both these stages were occurred before the Albian time [*Sokolov et al., 2001, 2002; Bondarenko, 2004*]. From the other (South-Eastern) side of Wrangel-Herald arch, in Brooks Range and North Slope area two main stages of compression were recognized –Jurassic–Early Cretaceous (1) and Late Cretaceous/Early Cenozoic (2) with intermediate Mid-Cretaceous extensional stage [*Miller and Hudson, 1991*]. Slightly inverted small half-grabens, superimposed on the Wrangel arch basement, also may point to the intermediate stage of extension between two compressional/transpressional events. Although the time of compressional/transpressional/extensional stages in studied area are controversial, their existence provide us a good opportunity to correlate the established structure in Eastern Chukchi Sea region with NE East Siberian Sea, Northern Chukotka and, probably, Brooks Range areas.

To the North from the mentioned above frontal part of the Wrangel Arch, the obvious angular unconformity in the upper parts of North Chukchi basin divides compressively faulted and folded sediments (below) from upper much less deformed/undeformed succession. It is likely, that this unconformity corresponds to the Lower/Upper Brookian (MBU, Cretaceous/Tertiary) sedimentary successions boundary, postulated by [*Grantz et al., 1990*]. From the other hand, this unconformity may corresponds to the final stage of Wrangel Arch (Island) collisional compressional deformation. Unfortunately, the definite age of the Wrangel Island Kimmerian deformation is still unclear, but according to the last precise U-Pb (SHRIMP) dating of postcollisional plutons in the Northern Chukotka (made in Stanford University, CA, USA), the oldest granites are as old as Late Early Cretaceous (Aptian - 117 Ma) [*Katkov et al., 2007*], giving us the upper time limit for the age of collisional deformation, related to the of South-Anyui paleooceanic basin closure. If this age is also correct for the Wrangel Arch, the described above unconformity may (hypothetically) be as old as Late Neocomian (pre-Aptian) as well.

References

1. *Bondarenko G.Ye.* Tectonics and Geodynamic Evolution of the Mesozoides of Northern frame of Pacific Ocean // PhD (Doctor thesis) Summary. Moscow State University, Geological Department. 2004. 46 p. (in Russian).
2. *Drachev S.S., Elistratov A.V., and Savostin L.A.* Structure and Seismostratigraphy of the East Siberian Sea Shelf along the Indigirka Bay–Jannetta Island Seismic Profile // Transactions (Doklady) of the Russian Academy of Sciences/Earth Science Section. 2001. Vol. 377A, No. 3, P. 293-297.
3. *Grantz A., Johnson L., and Sweeney J.F. (editors).* The Geology of North America, vol. L, The Arctic Ocean Region // Geol. Soc. of Am., Boulder, Colo. 1990. 644 p.
4. *Katkov S.M., Strickland A., Miller E.L., Toro J.* Ages of granite batholiths from Anyui-Chukotka Foldbelt // Transactions (Doklady) of the Russian Academy of Sciences/Earth Science Section. 2007. Vol. 414, No. 4. P. 515-518.
5. *Khain V.E.* Tectonics of Continents and Oceans. Moscow: Scientific World. 2001. 604 p. (in Russian).
6. *Kos'ko M.K., Cecile M.P., Harrison J.C., et al.* Geology of Wrangel Island, between Chukchi and Siberian Seas, Northeastern Russia // Geological Surway of Canada Bulletin. 461. 1993, 102 p.
7. *Mazarovich A.O., Sokolov S. Yu.* Tectonic subdivision of the Chukchi and East Siberian Seas // Russian Journal of Earth Sciences, 2003, Vol. 5, No. 3, P.185–202.

8. *Miller E.L., Grantz A., Klemperer S. (eds).* Tectonic evolution of the Bering Shelf-Chukchi Sea-Arctic Margin and Adjacent Landmasses // GSA Special Paper 360. Boulder, CA, USA. 2002. 387 p.
9. *Miller E.L., Hudson T.L.* Mid-Cretaceous extensional fragmentation of a Jurassic-Early Cretaceos compressional orogen, Alaska // Tectonics, 1991, vol. 10., № 4., p. 781-796.
10. *Parfenov L.M., Natapov L.M., Sokolov S.D., Tsukanov N.V.* Terrane analyses and accretion in Northeastern Asia // Island Arc, 1993, v. 2, 35-54.
11. *Pease V., Miller E., Sokolov S., Tuchkova M., Verzhbitsky V., Kirkland C., Peel J., Frykman P., Ineson J., Stemmerik L.* The development of the Arctic Ocean // In: Rickberg S. (ed.) Polarforskningssekretariatets Arsbook (Swedish Polar Research Secretariat Yearbook) 2006. Stochholm: Polarforskningssekretariatet. 2007. P. 78-84.
12. *Shipilov E.V., Senin B.V., Yunov A.Yu.* Sedimentary Cover and Basement of Chukchi Sea from Seismic Data // Geotectonics. 1989. Vol. 23. No 5, p. 456-463.
13. *Sokolov S.D., Bondarenko G.Ye, Morozov O.L. et al.* Nappe-type tectonics of South-Anyui suture in the Western Chukotka peninsula // Transactions (Doklady) of the Russian Academy of Sciences/Earth Science Section. 2001. Vol. 376, No. 1. P. 7-11.
14. *Sokolov S.D., Bondarenko G.Ye, Morozov O.L. et al.* Souyh Anyui suture, northeast Arctic Russia: Facts and problems // in *Miller E.L., Grantz A, and Klemperer S.L. (eds)*, Tectonic evolution of the Bering Shelf-Chukchi Sea-Arctic Margin and Ajacent Landmasses: Boulder, Colorado, GSA Special Paper 360. 2002. p.209-224.
15. *Sokolov S.D., Didenko A.N., Grigoriev V.N. et al.* Paleotectonic reconstructions for Northeastern Russia: problems and uncertainties // Geotectonics. 1997. Vol. 31, No 6, p. 498-515.
16. *Sokolov S.D., Tuchkova M.I., Verzhbitsky V.E.* Wrangel Island: a natural geology reserve // *in A.R.Gruzdev (ed.)*, The Nature of Wrangel Island: contemporary researches. SPb. 2007. P. 254-266.
17. *Tolson R.B.* Structure and stratigraphy of the Hope Basin, southern Chukchi Seas, Alaska // in Scholl, D.W., Grantz, A. and Vedder, J.G., eds.,Geology and resource potential of the continental margin of western North America and adjacent ocean basins: Beaufort Sea to Baja California: Houston, Texas, Circum-Pacific Council for Energy and Mineral Resources, Earth Science Series. 1987. V. 6, p. 59-71.
18. *Verzhbitsky V.; Miller E.* Structural studies in the Pevek region, Russia: Possible implications for the evolution of the East Siberian Shelf and Makarov Basin of the Arctic Ocean // European Geosciences Union General Assembly Geophysical Research Abstracts, Vol. 9, 05773, 2007.