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Formation of spreading zones on the ocean floor (by the example of hydrocarbon deposits formation in the Sakhalin Island)

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Studies of fluid migration in the oceanic rift zones, where the ocean floor spreading results in ascending of deep materials to the surface and generation of a new oceanic crust, represent a most important field in the marine geology at the turn of centuries.

Transform plate boundaries representing wide zones of deep faults along which shifting of lithospheric plates occurs, are just such structures in the ocean. The Queen Charlotte fault extending along the Canadian coast and the western part of the Aleutian Trench between Bering Island and Kamchatka may serve as examples of such plate boundaries in the Pacific.

These structures are characterized by an apparent shift component with formation of extension zone like a backarc basin at the inner (continental) side of the transform plate boundary. The similarity is rather morphological, but not genetic. In this case, widespread deformations take place along the transform fault instead of the backarc spreading, and the shift with compression (transpression) occurs in one part of the fault, whereas shift with extension (transtension) is observed at the opposite end. Because of this, it is reasonable to call the basins of such genesis, filled with sufficiently thick sediments, as extensional sedimentary basins. These basins, in which the crust is thinned and cut by numerous deep faults, are most prospective for formation of hydrocarbon accumulations belonging to the type under consideration. Therefore, let us to examine the entire transform boundary area including adjacent extension zones.

We can consider here a model of hydrocarbon deposits formation on the example of

Sakhalin hydrocarbon deposits, in conditions of oceanic crust extension (transform fault zone), in the thermal convection regime, and with serpentinite layer as a contributing factor.

Attention of many foreign companies and investors is focused on exploitation and development of oil deposits on the Sakhalin shelf today. The projects “Sakhalin-1” and “Sakhalin-2” are considered by the World community as examples of a successful capital investment in Russia, and are supported by governments of both Russia and USA. The amount of investments into these projects may reach up to 12 billion USD. When the commercial exploitation within these projects commences, bonuses of 100 million USD will be transferred to the Foundation for development of the Sakhalin District during 5 years. The Russian company “Sakhalinneftegaz” performed prospecting and exploration works on the Sakhalin Island shelf since 1958. The exploration included 30 000 km of seismic survey and drilling of 25 boreholes with the total depth 58 836 m. Three oil and gas condensate deposits are discovered in the north-western part of the Sakhalin shelf during the period from 1976 to 1989: Odoptu, Chaivo, and Arkun-Dagi.

Let us consider in more detail possibilities of hydrocarbon deposits formation in similar geodynamic situation on the Sakhalin Island, in the adjacent area of the Sea of Okhotsk, and in the Aleutian islands region. The geological situations comparable with the conditions of hydrocarbon deposits formation along shift plate boundaries may also appear within the tectonic microplate boundaries. For instance, a similar situation is observed at the western boundary of the Sea of Okhotsk plate formed by a dextral shift which was active for a rather long time. So, a considerable dextral displacement occurred in the focus of the Neftegorsk earthquake. In general, the zone of the Sakhalin tectonic boundary is characterized by a weak shallow-focus seismic activity. The crust of the Sea of Okhotsk plate consists of two layers: lower basaltic and upper granitic. The granitic layer is thinned to 2-3 km beneath depressions extending along the boundary between the Sea of Okhotsk and Sakhalin-Hokkaido microplates, and is characterized here by an anisotropy of its physical properties typical for the fractured media. The depression extending along the western coast of the Sakhalin represents a comb-shaped structure which is controlled by fracture zones of meridional strike accompanied by branching faults of north-western and south-eastern directions, with both lateral and vertical dislocation of crustal blocks. The depression is mainly filled with Neogene sediments, 9-10 km thick. This basin is formed owing to Paleogene-Early Miocene rifting destruction. Deep faults extending along the microplates boundary dislocate not only the crustal blocks, but also upper mantle rocks resulting in their intense serpentinization. High heat flow values ranging from 23 up to 380 mW/m^2 are evidence of intense hydrothermal activity in the deep faults. Serpentinite bodies exposed on the north-eastern Sakhalin coast support this suggestion. A possibility to recover serpentinite bodies increases in characteristic structures and features fixed in seismic profiles. Serpentinites may present in thrust blocks and detached masses, as well as in nuclei of chariages composed of low-density serpentinites. These chariages are overlain by oil and gas bearing deposits of the Pilski complex, and are underlain by Nizhnenutovsk rocks. Traps of the serpentinization zone are characterized by the massive reservoir type, porous-fissure and cavernous-fissure collector types. The complex of low-density serpentinites is prospective throughout the north-eastern Sakhalin shelf from the Shmidt sector in the north to the Pogranichnyi sector in the south. However, the potential is the highest in traps within the Trehbratsk and East Odoptinsk anticlinal zones characterized by a favorable combination of conditions of the oil and gas formation and hydrocarbon accumulation.

All large hydrocarbon deposits are related to the North Sakhalin depression. Serpentinites of the overthrusted nap are overlain and underlain by rocks of the Pilsk complex. This increases conciderably the possibilities of hydrocarbon acccumulation in the fractured zones of the massif. North Kaigansk and East Odoptinsk structures, where structural pattern of the Pilsk complex coincides with the local magnetic maxima, represent the first-priority objects for prospecting and exploration. An evaluation of possible hydrocarbon reserves in the East Odoptinsk structure shows that a large oil and gas condensate deposit may be discovered here, with geological reserves of hydrocarbons (sum of oil, gas, and gas condensate) about 300 million tons. Their undoubted relationship to tectonic displacements along the microplates boundary is revealed. Gas hydrate accumulations are found directly in the fracture zones on the Sakhalin slope.