Geodynamics of lithosphere as one of the crucial factors of mineral deposits formation of Ukraine

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Comprehensive studies of the lithosphere structure of Ukraine have been performed lately at the Institute of Geophysics NASU in connection with solving the problems of metallogeny, diamond-, gas- and oil-bearing [Starostenko et al., 2007]. These studies included: thourough analysis of geological-geophysical data on tectonics and deep structure of the Earth's crust and upper mantle; plotting the comprehensive three-dimensional geophysical and geodynamic model of lithosphere; generalization of global experience in application of geophysical, including tectonophysical, methods for the search and prospecting of different kinds of mineral deposits. The results of studies allow drawing some conclusions on the character of geodynamic processes, having an influence on formation and distribution of deposits on the territory of Ukraine.

It has been shown by the examples of the Ukrainian Shield, the Dnieper-Donets, the Carpathian and Azov-Black Sea oil-gas-bearing provinces that the regularities of formation, redistribution and concentration of mineral deposits are determined in many cases by special features of tectonosphere evolution arising from the mechanisms of global and regional movements of lithosphere plates.

The Ukrainian Shield (USh). Practically all large fault zones of the USh are *zones of shift with* acute predominance of horizontal component of banks displacements [Gintov, 2005]. They were arised in Neo-Archean and Early Proterozoic as right and left shifts, strike-slip and upthrow faults with amplitude of displacement as kilometers and tens of kilometers and transcending far beyond the limits of the Shield. Their roots according to different geophysical characteristics are relaited to in the mantle up to the depth of 100—200 km and more [Gintov, Pashkevich, 2010]. Existence of such ancient extensive zones of shift may be only explained by convective movements in the mantle, which took place as early as in Neo-Archean and Early Proterozoic. In Proterozoic numerous fault zones were also formed as listric ones or gently sloping overthrust.

According to the results of tectonophysical and paleomagnetic studies of dynamics of lithosphere of the USh a conclusion has been drawn that the Shield as a consolidated structure has existed since the boundary of 1.8—1.6 Ga. According to paleomagnetic data [Elming et al., 1998], it existed before and moved autonomously and even earlier, according to tectonophysical data [Gintov, Pashkevich, 2010], it was divided into several megablocks, which had their own trajectories of movements.

Joint analysis of kinematic and three-dimensional geophysical model of the Shield as well as of V_P tomographic model of the mantle up to the depth of 850 km [Geyko et al., 2006], allows to correlate the results of metallogenic studies of fault zones of the USh with materials of geodynamic reconstructions. Within the limits of the USh more than 75 percent of known metallogenic zones, ore areas and ore fields belong to well studied large fault zones. These are mainly the areas of development of mineralization and deposits of non-ferrous, rare, noble metals, uranium, rare earths et al. [Starostenko et al., 2007].

Dnieper-Donets oil-gas province (DDOGP). Numerous oil-gas deposits within non-anticline, the so-called "non-traditional" traps — on monoclines, half-anticlines, sub-thrust zones, within crystalline basement etc. have been discovered here lately. The majority of such deposits are related to the fractures of fault-, shift and upthrow (shear) fault types. These considerations brought a lot of scientists to the idea of great perspectives of anorganic hypothesis of oil origin and of important role of tangential forces and horizontal movements of lithosphere in formation of traps for hydrocarbons.

Numerical modeling of the process of the Dnieper-Donets aulacogene (DDA) formation by the back-stripping method within the limits of continental lithosphere stretching concept of D. McKenzie testifies the possibility of its formation in the Late

Devonian by the type of rift basins with formation of sub-oceanic crust [Stifenson et al., 1997]. Important role has been proved of shifting processes in formation of contemporary structure of DDOGP and of many types of oil-gas deposits. The system of faults of the DDA manifested during Alpine time as the largest right shift, which is the result of super-regional sub-longitudinal contraction, which covered during Meso-Cenozoic time the territories of the south and south-west of the East-European Platform (EEP). The explanation can be found in the known plate tectonic reconstructions: the pressure on the EEP from the south as a result of movements of the African and Arabian plates is passed through West-Black Sea and East Black Sea micro-plates [Nikishin et al., 2001; Patalaha et al., 2003; Kazmin et al., 2004].

The suture zone of the Donets Folded Structure (DFS) with the south slope of the Voronezh crystalline massif (Starobelsk-Millerov monocline) can be considered as an example of the influence of the processes of compression and shifting upon formation of hydrocarbon deposits. The suture zone is revealed by the series of over-thrusts of Carboniferous-Cretaceous deposits of the DFS upon the monocline — Krasnopopovskiy, Severodonetskiy, Marievskiy, Almaznyi, Iliychevskiy and other ones. Here, within the stripe not less than 50 km wide, a whole set of non-anticline type deposits within the limits of the monocline itself, in Krasnorechensk and Lisichansk gas-bearing areas have been discovered [Gintov, 2005; Starostenko et al., 2009].

The Carpathian Meso-Cenozoic Oil-Gas Province (COGP) is characterized by over-thrust structure of the Meso-Cenozoic strata, doubled and tripled cross-section of the Cretaceous, Paleogene and Neogene, is considered by the majority of geologists and geophysicists from the positions of plate tectonics.

According to the data of seismic tomography high-velocity lithosphere of EEP sinks under relatively low-velocity mantle of the Volyno-Podolian plate and the Carpathians from the depth of 50 to 250—300 km [Geyko et al., 2006].

It has been found by geothermic studies [Kutas, 2005] that for deposits and the areas of oil-gas accumulation, concentrated within the limits of Pre-Carpathian depression (in this case within the External zone of depression gas and gas-condensate deposits predominate, and within Internal one — oil deposits), increased temperature and heat flows are specific. Deposits form two stripes, narrow enough in zones of Carpatian direction Pre-Carpathian and Scole faults which are at a distance of 20—30 km from each other.

In the periphery of EEP accumulation of hydrocarbons in the deposits of accretion wedge could occur as early as Cretaceous and Paleogene. During collision stage redistribution of hydrocarbon potential occurred. Migration processes influenced essentially on hydrodynamic conditions, thermal regime, physical parameters of sedimentary strata. These parameters can be used for determination of the ways of migration and zoning of oil-gas areas.

With the help of numerical tectonophysical modeling the connection of formation and distribution of oil-gas deposits COGP with plate-tectonic mechanism of region formation has been analyzed [Gonchar, 2007]. Palinspastic sections of the frontal part of the Flish Carpathians and Pre-Carpathian depression have been complited. They reconstruct the process of formation of deposits under conditions of lateral accretion and formation of covers in case of obduction-subduction mechanism and explain zoning in distribution of oil and gas deposits within Pre-Carpathian depression.

Application of modern geodynamic concepts of the Carpathian region formation allows considerable widening of its perspectives of oil- and gas-bearing. North-western part of the External zone of Pre-Carpathian depression (Krukenitskaya sub-zone), autokhtonous deposits of Folded Carpathians, platform Meso-Cenozoic deposits of south-eastern part of External zone under the over-thrust of the Folded Carpathians, Trans-Carpathian depression are worth to be paid special attention.

Azov-Black Sea Oil-Gas Province (ABSOGP). A considerable part of the Province is located within the water areas. Therefore analysis of geodynamic processes in it is possible only on the background of geodynamic development of the whole Black Sea-Caucasian segment of the Alpine belt.

ABSOGP and COGP have got some common geophysical peculiarities. It allows treating them from similar geodynamic positions. ABSOGP adjoins to the southern tectonic border of EEP and here, as well as in the COGP, according to the data of seismic tomography [Geyko et al., 2006] submergence can be observed of relatively high-velocity lithosphere of the Craton under relatively low-velocity mantle of Dobrogea, Scythian plate, the Black Sea. The studies of geothermal regime of the region shows that oil-gas deposits are localized within the areas of increased heat flows, forming in this case two sub-parallel stripes: gas deposits are located within the zones of high heat flows and the oil ones — in their periphery. The important role is played by tectono-thermal activization in case of shift displacements of micro-plates [Kutas et al., 2002; 2007].

For the studies of ABSOGP conditions of formation the main interest belongs to Oligocene-Quaternary stage, which began 35—40 million years ago. The results of geothermal studies in the region show that for this period there is strong enough correlation between location of oil-gas deposits and anomalies of heat flow [Kutas et al., 2002; 2007]. At this stage the Black Sea — Caucasian region develops in the indentor regime under the action of Arabian, Pannonian and Adriatic plates [Patalaha et al., 2003]. In addition, the movement of the Black Sea plate within northern points of compass was of reverse character that is indicated by tectonophysical data on the Crimean peninsula: the phases of sub-longitudinal contraction was interrupted by shorter phases of even stretching [Gintov, 2005].

For promising areas of ABSOGP — north-western shelf of the Black Sea and the Kerch-Tamanian depression the detailed schemes of fault tectonics of consolidated crust have been compile [An integrated …, 2006]. They emphasize the leading role of shift deformations during formation of fault and fold structures of the Meso-Cenozoic cover, to which (especially to the knots of fault crossing) hydrocarbon deposits are related. It has also been found by marine geophysical studies that zones of deep faults and neo-tectonic disturbances connected with them are the channels of migration of gas-fluid flows [Kobolev, Kutas, 1999].

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Deep structure and geodynamics of the Kirovograd ore district (Ukranian Shield): correlation of geological and seismic data

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The central part of the Ukrainian shield, where the Kirovograd ore district is located, has been the subject of prolonged investigation of the Institute of Geophysics in cooperation with another research Institutions. Around 20 years ago, A. V. Chekunov et al. (1989) proposed a geodynamic model of this territory, derived from geophysical and geological data. The model is illustrated by the geotraverse VIII Odessa — Krivoy Rog, which intersects the Kirovograd (now Ingulets) lithospheric block and adjacent protogeosynclines (Fig. 1). The Kirovograd block is distinguished from them in seismic velocities in crust and at the Moho discontinuity and in thickness of the crust (35—38 km against 54—58 km). The block is cut by steep faults and gentle tectonic zones which extend into upper mantle. The suggested model explained these phenomena by the continuous development of a mantle plume or a protoasthenolite, which originated at the beginning of Early Proterozoic, influenced the deposition of the ingulo-ingulets series and caused the emplacement of granites, anorthosites and rapakivi granites in crust at the mature stage.

The current study of deep structure of the Kirovograd ore district [Starostenko et al., 2010], is based on the correlation of geological and seismic data, using modern technologies, and accounts for new isotopic dating [Shcherbak et al., 2008]. The study proceeds from a broad interpretation of space boundaries of the Kirovograd polymetal ore district and the incorporation of uranium, lithium, gold and titanium deposits in these boundaries (Fig. 2).

The study indicates that in the Kirovograd ore district, the Paleoproterozoic magmatism started after deposition of the ingulo-ingulets series and developed in two short-lived (30—40 Ma) stages. During the first stage (2.06—2.02 Ga), the crustal Novoukrainsk-Kirovograd granitoid massif formed. During the second stage (1.75—1.72 Ga), the mantle-derived Korsun'-Novomirgorod rapakivi-anorthosite massif originated. In conjunction, they constitute the Novoukrainsk-Korsun'-Novomirgorod pluton which defines the surface structural pattern of the ore district.

Lithium, uranium and gold deposits are located in the Novoukrainsk-Kirovograd granitoid massif and the connected Kirovograd and Zvenigorod fault zones [Bakarzhiev et al., 2005]. Lithium deposits are close in age (2.0 Ga) to the Novoukrainsk-Kirovograd massif and associated with local granite-migmatite domes. Uranium deposits are dated at 1.8 Ga, overprinted on the massif and controlled by its rejuvenated structural elements. Gold deposit's age is unclear. In combination, the deposits outline a wide