ля. Выявить изменения минерала в зоне локализации золото-свинцово-цинкового оруденения.

Методика. Для исследования хлорита использованы микроскопический, электронно-зондовый и рентгеноструктурный методы.

Результаты. Определено, что хлориты рудопроявлений Bania и Shute принадлежат, главным образом, к группе пикнохлорит-брунсвигит, частично – диабантиту и рипидолиту. В направлении локализации оруденения обнаружено изменение химического состава хлорита – уменьшение содержания *Fe* и увеличение – *Si, Al, Mg, Mn.* Определена температура формирования хлоритов 180– 280°C.

Научная новизна. Впервые исследован состав и некоторые свойства хлоритов метасоматических пород на рудопроявлениях золота в пределах Вышковского рудного поля, установлено изменение их химического состава в направлении локализации оруденения и температуру формирования.

Практическая значимость. Состав хлоритов является поисковым признаком, который можно использовать при поисках скрытого золото-свинцово-цинкового оруденения. Полученные результаты могут быть использованы для сравнения с другими районами, где распространена или возможна золото-свинцово-цинковая минерализация.

Ключевые слова: *хлорит, хлоритизация, метасоматические породы, температура формирования, Вышковское рудное поле, Закарпатье*

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ACTIVATION PERIODS OF KIROVOHRAD PROTOPLATFORM BLOCK (UKRAINIAN SHIELD) AND FORMATION OF DIAMOND-BEARING ROCKS

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ЕПОХИ АКТИВІЗАЦІЇ ПРОТОПЛАТФОРМНОГО КІРОВОГРАДСЬКОГО БЛОКА УКРАЇНСЬКОГО ЩИТА ТА ФОРМУВАННЯ АЛМАЗОНОСНИХ ФОРМАЦІЙ

Purpose. Reconstruction of the endogenous diamond-bearing formation stages in the geologic history of the Kirovohrad block (Ukrainian shield) protoplatform structure development for determination of possible diamonds sedimentary reservoirs geological age.

Methodology. Deep geological and geophysical studies of the lithosphere, the structural-tectonic analysis of the Precambrian basement, complex structural-formational division of geological bodies.

Findings. The Kirovohrad block of the Ukrainian shield refers to promising protoplatform diamond blocks due to localization of diamond structures and formations. It has been established that the geological and structural-tectonic preconditions of endogenous diamond-bearing rocks formation were laid in the Early Precambrian at the stage of protoplatform regime. They appeared on the stages of activation, which occurred from Middle Proterozoic till Paleocene in the Kirovohrad block. It is evidenced with lithological, structural and formational features, and age characteristics of rocks which are associated with diamond formations. Alluvial diamond concentration associated with young and modern Phanerozoic sedimentary formations have been caused by the destruction of ancient endogenous sources.

Originality. Geological, structural and epoch conditions of the Kirovohrad block diamond-bearing rocks formation have been considered through the general background of direct evolution development of the Earth crust in the Precambrian and Phanerozoic. Special attention is paid to the Precambrian period, because of favorable geological and structural-tectonic conditions for diamond-bearing rocks formations.

Practical value. Allocation of activation and diamond-bearing rocks formation epochs allows orienting forecast metallogenic studies and applying a number of important control factors during the search and exploration of this type of mineralization: geological-structural, geochronological, stratigraphic, lithological, paleogeographic. Taking into account space-time regular position of diamond-bearing formations while analyzing protoplatform structures it is possible to estimate the probability of diamonds presence on their territory and also to predict the diamond-bearingness of territory.

Keywords: *activation, Kirovohrad block, protoplatform, diamond bearing formation, mantle*

Statement of the problem. The term “activation”, accepted by geologists since the mid-twentieth century, means the processes of epiplatform recovery or intensive strengthening of tectono-magmatic activity in regions that have completed their development. Activation expressed in Germany-type structural-tectonic rearrangement of rigid consolidated structures (development of deep faults regional zones, near-fault troughs, superimposed depressions, arch-block displacements) and large-scale multiple magmatism. Stable regions, in which such new tectono-magmatic processes held after a long period of tectonic quiescence, belong to areas (zones) of tectono-magmatic activation (TMA).

Analysis of recent researches. Independent determination of the TMA areas as the third (except platforms and geosynclines) type of the Earth tectonic structures first made by V.A. Obruchev in the early twentieth century and developed by G.F. Mirchink in 1940. Further the problem of TMA was developed by such scientists as V.V. Bilousov, K.V. Boholyepov, Chen Goda, V.Yu. Hain, M.P. Heraskov, K.D. Karpova, V.L. Masaitis, M.S. Nahibina, M.I. Nikolayev, Ye.V. Pavlovskyi, Yu.M. Pushcharovskyi, S.S. Schultz, M.S. Shatskyi, Yu.M. Sheinman, O.L. Yanshyn et al. Metallogeny of TMA areas is described in the scientific works of T.V. Bilibina, D.Yo. Horshevskyi, P.M. Hrenov, M.I. Itsykson, V.I. Kazanskyi, Yu.V. Komarov, V.M. Kozerenko, K.O. Radkevych, O.D. Shchehlov et al. In Ukraine, the problem of TMA and allocation of intensive mineralization periods has been developed by Ya.M. Byelyevtsev, O.O. Hoizhevskyi, H.I. Kalyayev, V.V. Naumenko, M.P. Semenenko, V.O. Shumlyanskyi, V.I. Skarzhynskyi, I.S. Usenko et al. The basis of most of these concepts is the idea of the direction and irreversibility of the lithosphere development.

Unsolved part of the problem and state the goal. Nowadays exist single and different informative geological and tectonic data about the existence of uneven TMA processes and related with it diamond bearingness overall in the Ukrainian shield (USH) and in the Kirovohrad block. That is why it is necessary to use historical and geological approach in order to analyze relationships between tectonic and magmatic structures, deposition, endo- and exogenous diamond formation. We consider on geological-structural conditions and the age of diamond-bearing formations in the Kirovohrad block on the general background of direct evolution development of the Earth crust in the Precambrian and the Phanerozoic [1]. Special attention is paid to the Precambrian time, because there were favorable geological and structural-tectonic conditions for the diamond-bearing rocks formation.

The main material. According to the views of Ye.V.Pavlovskyi, initially there was a kind of the lithosphere tectonic regime which was different from that in geosynclines and platforms. The scientist identified that there were two stages of ancient platforms sialic shell formation in the Early Precambrian. The first one was the Archean, that was nuclear due to the long and powerful outflows of spilite lava and the subsequent accumulation of greywacke in sedimentation basins. Later, isolated centres of intensive processes of metamorphism, migmatization and basalt crust granitization were formed there. The Archean metamorphic rocks of the lower structural stage of the Kirovohrad block is the example of the nuclear complex. The upper age limit of this stage is Archean and Proterozoic boundary – 2600±100 m yrs.

On the second Early Proterozoic stage, after granitization of nuclear complex, the relatively thin sialic shell acquired ri-gidity and was cracked by deep faults. Its intense depression in the Early Proterozoic led to the accumulation of thick (5–7 km) effusive-sedimentary clastic deposits – the products of granitizated nuclear complex and basic volcanic rocks erosion. Consolidation of protoplatform regime in the rigid parts of the USH crust occurred about 2.0 billion years ago.

Protoplatform structures differ from typical platforms by relatively low rigidity, high permeability and development of large isolated granitoid massifs of 2100–2000 m yrs. old (Novoukrainskyi, etc.) which deformed weakly metamorphosed protocover. All these specific features of epi-Archean "stable structures" give reason to attribute them to protoplatforms. Their development began in the Archean–Early Proterozoic and continued till the Middle Proterozoic (1800±100 m yrs). Examples of such structure of protocover are Inhulo-Inguletska (Kirovohrad block) and Teterivska (Volynskyi block) series.

At the beginning of the Middle Proterozoic (1900±100 m yrs) platform conditions dominated. However, on the boundary of 1800–1700 m yrs., qualitatively new development of protoplatform began with the formation of structures of such protoactivation areas. V.A. Kryuchenko distinguished (on geological and geophysical data) large-size region of protoactivation in the central part of the Kirovohrad block. In deep structure it is expressed as latitudinal zone (width of more than 100 km) of crustal thickening (up to 44–46 km) with intensive block structure. This is the regional structure of the deep-laid (formed during Middle Proterozoic), transverse to the strike of folded forms. Lengthy and repeated tectonomagmatic processes happened in it, they were accompanied with fault-block tectonics, volume fracture without appreciable displacement, intense hydrothermal-metasomatic activities and dyke formation.

Latitudinal structural transverse zone of protoactivation with abnormal structure of the crust is probably corresponds to transverse ore-concentrated Central-Ukrainian megazone of activation that was allocated by L.S. Haletskyi [2].

V.O. Krupennikov allocated such concordant zone. According to geological and geophysical data, Kanivsko-Novouktainska deep protozone forms meridional tract width of 80–120 km and length of over 300 km; it crosses the Ukrainian shield from the North to the South and is traced further under deposits of the sedimentary cover. Protozone is controlled by Korsun-Novomyrhorodskyi and Novoukrainskyi granite massifs, bodies of gabbro-pyroxenites, regional longitudinal faults and tectonic seams systems (Fig. 1). The deep structure of the zone is expressed by thickening of the Earth crust (up to 40–45 km), sharp increased thickness (15–18 km), a high degree of stratification and vertical crushing of granite layer, as well as some variations in the depth of the Moho surface (3–5 km). Protozone is characterized by significant duration of development (more than 2.0 billion years), multiple stages of tectono-magmatic processes of mantle genesis, evolution of endogenous activity and considerable variety of ore formations. That is why these facts allow V.A. Krupennikov consider Kanivsko-Novouktainska protozone of activation as the ore-concentrated structure of the transcontinental lineament Baltic shield–East Africa fragment.

Regions (zones) of activation have been developing during all the Phanerozoic and actively influenced on the structure and ore-bearingness of younger tectonic, magmatic and sedimentary formations of the Late Proterozoic, the

Paleozoic, and the Mesozoic-Cenozoic age. In the Middle Proterozoic there were structures of stretching and decompression of the mantle and crust. Due to thinning Earth crust and consequently lowering the density, in comparison with neighboring areas, isostatical balance of seal was broken. This led to compensatory uplift of the Moho surface; lifting of the asthenospheric layer surface in the form of protoasthenolith and formation of deep faults; income of great mass of pyrolith from the mantle; generation of intermediate chambers of the basic-ultrabasic composition at different crust levels and intense heat flow (30–40 mWt/m^2). All this has led to increased mantle permeability of protoplatform and therefore the formation of endogenous diamond-bearing rocks.

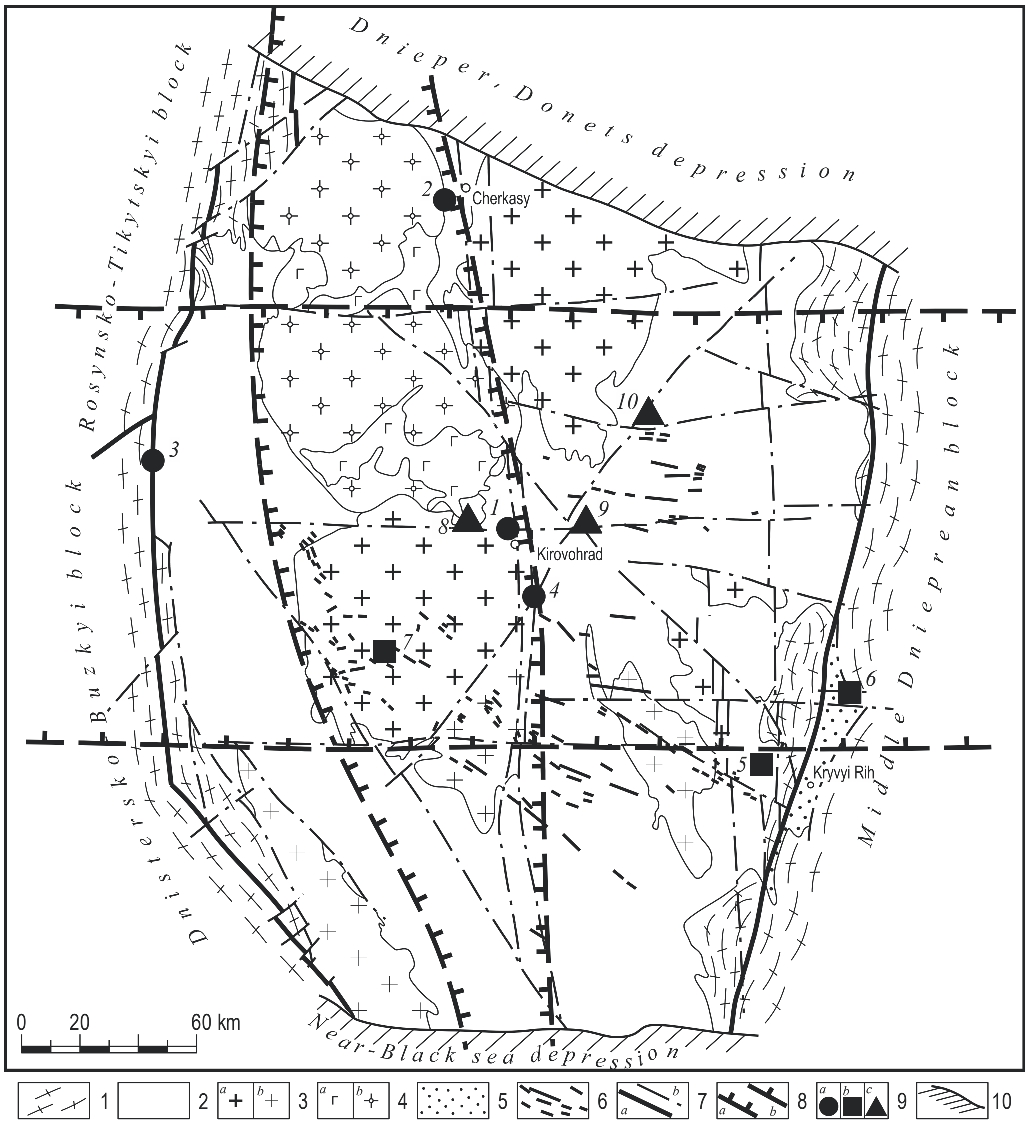

Fig. 1. Zones of TMA and uneven-aged existences of endogenous diamond-bearing formations in the structure of protoplatform Kirovohrad block (Ukrainian shield):1 – blocks of Archean protobasement in the protoplatform marginal parts; 2 – Lower Proterozoic stratified gneiss complexes of protocover (Inhulo-Inhuletska series); 3 – granite massifs of Novoukrainskyi (a) and Kirovohradskyi (b) complexes; 4 – gabbro-anorthosites (a) and rapakivi-granites (b) of Korsun-Novomyrhorodskyi massif; 5 – inter-blocks Kryvorizkyi trough of Lower Proterozoic age; 6 – belts and fields of basic and ultrabasic dykes; 7 – inter-blocks (a) and in-blocks (b) faults; 8 – the ratio of structural-longitudinal Kanivsko-Novoukrainska (a) and structural-cross (b) zones of Proterozoic activation; 9 – uneven-aged existences of endogenous diamond-bearing formations which have been formed within three eras of TMA: a – $PR_{2–3}$ (1 – Lelekivskyi and Shchorsivskyi, 2 – Ruskopolyanskyi, 3 – Pavlivskyi, 4 – Klyntsivskyi), b – $PZ_{2–3}$ (5 – Rodionivskyi, 6 – Ternivskyi, 7 – Rivnenskyi), c – MZ–KZ (8 – Hruzkyi, Lisovyi and Osytnyazkyi, 9 – Subottsivskyi, 10 – Zelenohajskyi); 10 – northern and southern contours of Kirovohradskyi block

According to Yu. Fedoryshyn [3], such powerful manifestations of the upper mantle activation under the protoplatform indicate the completeness of the lithosphere development; they characterize the high degree of maturity (the potassium content) and are the important petrologic prerequisite of its potential endogenous diamond-bearingness. This expresses in significant thickness (≥180–250 km) and depletion of lithosphere and in leucocratic composition of the Kirovohrad block Earth's crust.

The formation of these areas is associated with the medium – Late Proterozoic activation epoch that is manifested as a single logical overlay displays tectonics and magmatism and covered the period of time from 1900±100 to 1650± ±50 m yrs. However, it often continued till the Late Proterozoic (1370–1000 m yrs) due to the considerably stretched in time repeated updates of jointing and due to basic and ultrabasic dikes intrusion.

During the Middle-Proterozoic epoch, the nuclear basement was broken up by faults, the blocks moved in it. All these were accompanied with the intrusions of ultrabasic, basic, alkaline and acid rocks, by the deposition of powerful terrigenous deposits in terms of contrasting dissected topography and by multiple polyfacial progressive and regressive dislocation metamorphism (green schist to amphibolite facies) with local manifestations of rheomorphism and palingenesis. This situation is typical for areas of TMA, so appropriately this epoch in the protoplatform development is characterized (after V.I. Kazansky) as the epoch of protoactivation.

In the Kirovohrad protoplatform the protoactivation is reflected by the introduction of gabbro-anorthosites (with iron-titanium-apatite mineralization) and rapakivi granites (*Li, Rb, Cs, Be, Re, Sc, Y, TR, Fe, F*) of Korsun-Novomyrhorodskyi pluton (1750±5 m yrs), also the powerful tectono-metasomatic zones with microbreccia, diaphtoric rocks, blastomilonites, cataclasites and U-bearing albitites (1900–1800 m yrs) formation. In such dynamic environment of protoplatform activation, some of the oldest dykes of non-diamond-bearing kimberlites, Lelekivska and Shchorsivska, intruded (1900–1850 m yrs) as well as probably other fracture intrusions of Kirovohrad volcanic centre at the junction of deep faults [4]. Together with them, there are explosive breccias of moderately alkaline composition with mantle material admixture. They compose the dikes and stock-like bodies, that complicate the wings of granite-gneiss domes – Krynychevatskyi, Lypnyazkyi, etc. Breccias are expressionless, as are shaded with dynamometamorphism, foliation and metasomatism. Concordant lenticular bodies of diamondiferous eclogite-like rocks (Pavlovskyi and Klyntsivskyi manifestations) have been also discovered in separate places of deep faults. The high-temperature *Fe-Ca-Mg* metasomatism together with dynamometamorphism participated in their formation.

Protoplatform magmatism ended during Late Proterozoic epoch, which means the transition to platform regime of geo-lo-gical development. It is marked by the intensification of the north-west and latitudinal faults, in which powerful echelons of basic and ultrabasic dikes intruded (Znamyansko-Ustynivske field). Dykes of the Kirovohrad block occur in tectonic zones in the form of extended belts or fields, that intersect the Precambrian basement. They are represented by diabases, diabase porphyrites, picrites, micaceous picrites, lamprophyres and sill-like bodies of pseudoleucitic lamproite (1370–1330 m yrs) in endocontact of Korsun-Novomyrhorodskyi pluton. They did not suffer orogenic deformations and regional metamorphism. Explosive volcanic rocks of similar composition are associated with jointy intrusions; this confirmed by their morphological features in the form of bulges and by the presence of isometric geophysical anomalies over them. Sometimes the dyke rocks are of cenotypal mode, but the majority of them have suffered of local post-magmatic hydrothermal alterations (propylitization). Due to geological and isotopic data, L.G. Bernadska and others distinguish three stages of dyke intrusion: 1) older than 1700 m yrs; 2) 1500–1200 m yrs; 3) younger than 1200 m yrs. The youngest are the dikes of diabase porphyrite and veins of quartz por-phyry (1130–1100 m yrs). Late Proterozoic TMA was noticeable in the peripheral parts of the Ukrainian shield (Sushchano-Perzhanska zone, etc.).

Display of the Lower Precambrian endogenous diamond-bearing formations is very rare, due to erosional truncation and burial under overlaping sediments, although there are data about their formation at the stage of the ancient platforms basement formation. Such assumptions are based on known diamonds placers in terrigenic collectors of Lower Precambrian formations Witwatersrand and Tarkwa in Africa (2200 m yrs) and Birim in Ghana (over 2000 m yrs). This includes also metaconglomerate-sandstone-shale formation (Skeliuvatska suite) in Kryvorizkyi with gold, uranium and diamonds (probably redeposited). In the Lower Proterozoic deposits of Kryvorizka series apovolcanogenic rocks of linear type (metabasites of Novokryvorizka suite) are known as well as dyke- and layer-like bodies of talc-carbonate altered rocks, talc and talc-actinolite composition.

Nowadays it is known such poorly diamondiferous igneous rocks in the world, such as: Upper Archean (2.67 billion years) calc-alkali lamprophyres in the Wawa subprovince (Canada), Lower Proterozoic (2.1 billion years) metakomatiite breccias in the greenstone belt Dacin (Guyana), kimberlites and ultramafic lamprophyres (> 2.050 billion years) in kraton Yilgarn in Western Australia, lamproites of Mriya-pipe in the West Peri-Azov region (1950±40 m yrs) and Kostomuksha in Karelia (1230±5 m yrs). There are also single industrial diamondiferous kimberlite and lamproite pipes: Premier in South Africa (1750±100 m yrs), Argyle in Australia (1147–1100) and Maghavan in India (1067 m yrs).

The Kirovohrad block, like the rest of USH, since the end of the Late Proterozoic and during the Paleozoic, targeted mainly from epeirogenic movements and periodically shallow sedimentary strata in the form of the platform cover overlap. The crystalline basement was slowly descending, and weak low-amplitude block displacements along faults were offset with deposits of different thickness. Sometimes, however, the tectonic regime on the shield changed dramatically, and the shield moved to a qualitatively new position due to TMA.

The Medium-Late Palaeozoic epoch of activation is associated with Hercynic tectogenesis; and covers the time from 406±2 till 250±10 m yrs. It could be compared with Hercynides of Dobrogea and poor orogenesis and magmatism in Donbas. Activation has been connected with the resumption of faults due to lifting of the shield and the formation of the Dnieper-Donets basin. A.I. Vorobey mapped in the central part of the Kirovohrad block the porphyric complex of Devonian-Early Permian stage, represented with dikes of syenite-porphyry, vogesite, minetta, quartz porphyry, rhyodacite breccia that cut the granites of Novoukrainskyi massif. According to F.Yo. Kotlovska, the absolute age of microdiabases is 340–300 m yrs, of syenite-porphyry – 300–270 m yrs. Hypabyssal rocks are propylitized, often contain impregnations of native copper, cassiterite, fluorite, barite, cinnabar, etc. Diamond-bearing minetta, which belongs to a group of alkaline lamprophyres, forms cross cutting dykes, small stocks and pipe-like body near the village of Rivne. The absolute age of this minetta is 406–260 m yrs.

The most interesting, from the point of view of explosive structures formation and probable genetic relationship with diamond content, is Western-Ingulets zone [5]. Dykes and pipes of kimberlite-like rocks are controlled here by deep faults: submeridional Western-Ingulets, Kryvorizko-Kremenchutskyi and sublatitudinal Devladivskyi. Eruptive breccias of ultrabasic composition and kimberlite-like rocks near Kryvyi Rih formed Ternivska pipes and dykes at the intersection of Devladivskyi and Kryvorizko-Kremenchutskyi deep faults. Breccias intensively altered by hydrothermal processes, such as: silicification, carbonatization, serpentinization, chloritization, sericitization, opacitization, hisingeritization. The absolute age of the volcanic rocks is 400–250 m yrs. that corresponds to Devonian–Permian epoch. Potentially diamond-bearing pipe bodies and dykes have been mapped in Rodionivskyi display near Karachunivske reservoir; they also are marked by the geophysical data in Zlatopilska and Myrolyubivska areas. Same age of Ternivska pipe and volcanic rocks in Eastern Azov region allows you to connect the TMA in the Western-Ingulets zone with Late Paleozoic epoch of Dnieper-Donets depression development. Hercynian epoch of TMA has been manifested mainly on the slopes of the Ukrainian shield, in Southern Donbas and Dnieper-Donets depression. It involves the introduction of diamondiferous kimberlites in the Arkhangelsk region of Russia, Zhlobynske field in Belarus and the most productive kimberlitic magmatism in Yakutia.

In the Mesozoic-Cenozoic, when the continental coal-bearing strata deposited in the central part of USH, block movements of the Earth crust and rather peculiar magmatism updated once again. They were accompanied with a strict tectonic reorganization, the occurrence of new faults and reactivation of the ancient ones. In this regard, the large area of the central type Alpine volcanism in the Eastern exocontact of Korsun-Novomyrhorodskyi pluton (northern and central parts of the Kirovohrad block, the basin of the Tyasmyn-river) was formed; it is one of the special forms of a young platform activation. According to A.Ya. Radzivil et al., a modern area of Alpine volcanism covers an area of 8 thousand square kilometres, but its preliminary area could reach 15–16 thousand square kilometres (due to post-Paleogenic erosion).

During Mesozoic-Cenozoic epoch of activation, tectonics and magmatism were synchronous to the Cimmerian (Early Alpine) phase in the Caucasus-Crimean region. A.Ya. Radzivil and Yu.A. Kudelya mark that alpine structure of the first order is the Middle Dnieper tectono-magmatic structure with a diameter of about 130 km in the north part of the block.

During the Jurassic-Early Cretaceous epoch special ring subsidence structures have been formed which were filled with acid volcanites: amygdaloidal lavas, injections of tuffizites, eruptive breccias. Lavas and clastolavas have been found at the bottom of the Bovtyska and Rotmystrivska volcano-tectonic depressions sections in the form of the first, Pre-Cenomanian phase of volcanism. Lavas by composition belong to quartz dacite, rhyodacite, rhyolite, tracydacite, trachyandesite, quartz trachyte and felsite. The absolute age of the rocks is 177–75 m yrs. Effusive rocks deposited under the Low-Cretaceous sediments, they suffered from low-temperature hydrothermal alterations with which dispersed sulphide mineralization (chalcopyrite, sphalerite, galena, etc.) associates. The duration of volcanic and associated ore process, according to the radiological data, overall varies from 178 to 54 m yrs.

During the second, Late Cretaceous-Early Paleocene epoch, volcanogenic-sedimentary deposits (clay-fine-clastic breccia with layers of tuffs and tuffites) of coastal and shallow marine facies (Raihorodska suite) have been formed synchronously with explosive-clastic vent funnel bodies which are mapped in the Middle Dnieper ring structure. Raihorodski breccias we interpret as products of planar maar volcanism. Vent funnels were formed as the result of basement blocks subsidence due to explosions of alkali-ultrabasic magma during the final phase of the Mesozoic-Cenozoic TMA. They are close to isometric structures ranging in size from 150 m to 1.5 km; they display in the relief of crystalline basement as depressions of pipe-like form. The pipes are composed of boulders and blocks of crystalline rocks and autolithic tuff breccia of alkaline-ultrabasic composition with clay cement. Cenomanian and Danian-Paleocene microfauna of foraminifer and pelecypod have been identified in marine sediments of the Rotmystrivska depression upper section. Pipe-like bodies are localized in the south-eastern endocontact of Korsun-Novomyrhorodskyi pluton, they are controlled by fault zones. This is shown, for example, in chain distribution of the pipes (Gruzka, Lisova, Osytnyazka) along Zakharivskyi fault of the north-east strike. The position of separate bodies could point faults intersection.

Numerous kimberlite pipes of the Fort á la Corne (Saskatchewan, Canada) are the example of such kimberlite-lamproite volcanism [6]. Kimberlite pipes are spread here on the area of 1350 km^2 (45×30 km, one tube at ~ 32 km^2). Crater parts of the most tubes have been weakly eroded; their size on the plan is 500–1300 m. They were formed as the result of explosions and subsequent deposition of only a small number of volcanoclastic material, the rest of material is scattered outside of crater zone. The craters contain lapilli, ash, crystalloclasts of olivine, as well as boulders and blocks of host Precambrian basement rocks. Cementing groundmass including volcanic glass is intensively altered (clay + serpentine + carbonate + iron hydroxides). The eruptions occurred on the continent, but later the craters were filled with water.

During Mesozoic-Cenozoic the formation of Konsko-Yalynska superimposed depression in Peri-Azov region and intrusive magmatism in the Crimea were connected with the activation of faults and block movements. Obolonska depression of the Jurassic age is known in the northern near-slope part of the Kirovohrad block as well as Bovtyska and Rotmystrivska depressions of Lower Cretaceous age. The most of diamondiferous pipes in Africa are of Cretaceous age (younger than 90 m yrs), kimberlites of the central part of the Slave block in Canada are Cretaceous-Palaeogene (74.0–47.0 m yrs). Junior endogenous sources of diamonds in Kirovohrad block are still unknown, although there is the youngest in the world (Miocene) lamproitic pipe Ellendale (18 m yrs) in Western Australia.

The conclusions. The author identified three epochs of TMA and connected formation of diamond bearing rocks (Table 1): Middle-Late Proterozoic (1900–1000 m yrs), Middle-Late Paleozoic (406–250) and the Mesozoic-Cenozoic (178–54 m yrs). They are most noticeable in transverse latitudinal and longitudinal submeridional (in respect to structures plan) zones of activation and in marginal parts of the Kirovohrad block. Precambrian stages are endemic for central part in the areas of ptorozones intersection, Paleozoic stages are endemic for the central and marginal eastern parts (Western-Ingulets zone), and the Mesozoic-Cenozoic is endemic for the central and northern parts of Raihorodska suite volcanogenic-sedimentary deposits distribution. During Proterozoic and Mesozoic-Cenozoic epochs, the processes of activation were independent; the Palaeozoic epoch, probably, is associated with the formation of the border Dnieper-Donets depression (according to A.D. Shcheglov).

Associated with TMA endogenous processes not only contributed to the development of diverse mineralization in the crystalline basement, but also influenced on the redistribution of their initial concentrations in the sedimentary cover. As a result, soluble and mobile compounds accumulated in zones of hypergenesis and sedimentogenesis and sustainable minerals in placers. Therefore, space-time evolution development of the Kirovohrad block was accompanied with the processes of crust formation and the formation of placers, especially in connection with the formation of the shield sedimentary cover during Mesozoic-Cenozoic. The placers of ilmenite, apatite, zircon, monazite, gold and diamonds have been formed in terms of regressive coastal marine and continental phases of paleogeographic rhythms. Such placers, especially diamondiferous and potentially diamondiferous, in the Kirovohrad block cover were intensively formed during the Mid-Jurassic, Early Cretaceous, Middle Eocene, Oligocene, Miocene, Pliocene, and Quaternary stages (Table 2, Fig. 2). They are associated with clastic and psephytic deposits of local accumulation basins, which have been formed due to the difference of the blocks displacement amplitudes during the TMA.

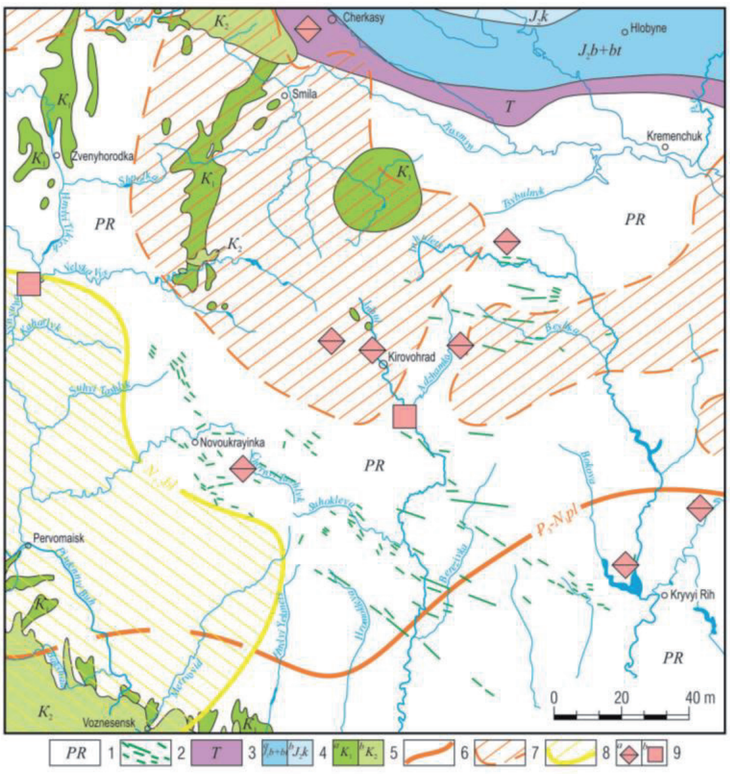

Fig. 2. Age lithologic-structural elements of diamond-bearing placers localization in the central part of the Ukrainian shield. Lower structural stage (Precambrian crystalline basement): 1 – Proterozoic (Inhulo-Inhuletskyi) complex of metamorphic rocks (gneisses, crystalline schists, granite-gneisses, granites; 2 – belts and fields of basic and ultrabasic dykes. Upper structural stage (Mesozoic-Cenozoic sedimentary cover): 3 – speckled clays and quartz sands (T); 4 – Jurassic deposits: a – clays, limestones, inequigranular coaly sands, sandstones, conglomerates (J_2b+bt), b – clays, marls, limestones with siderite intercalation (J_2k); 5 – Cretaceous deposits: a – gravelly sands, coaly clays, conglomerates (K_1); b – glauconitic sands, tripoli, opoka, organogenous limestones, marls (K_2); 6 – the limits of Poltavski deposits spread (P_3–N_1pl) – fine-grained quartz sands with intercalations of coaly clays, sandstones and secondary kaolin; 7 – regions of diamond-bearing placers localization in Poltavskyi sands; 8 – the limits of Baltski deposits spread ($N_{1\text{-}2}$bl) – clays without carbonates and with intercalations of close-grained quartz sands, shingles, sandstones; 9 – endogenous diamond-bearing formations according to the author – magmatic (a) and metamorphogenetic (b)

Table 1

Stages of Endogenous Diamond-Bearing Formations Development in Connection with TMA of Kirovohradskyi Block

Activation era	Stages of Diamond-Bearing Formations Development	Types of Diamond-Bearing Formations	Character, Age and Specific Places of Diamond Bearingness	Connection with Activation Processes of Related Structures	Display of Associated Magmatism	Geochemical Features of Associated Mineralization
Mesozoic–Cenozoic (Alpine)	Late Cretaceous–Palaeocene K_2–P_1^1 (178–54 million years)	Lamproitic	Pipe-like bodies of lamproite-like rocks of Hruzskyi, Lisovyi, Osytnyazkyi, Zelenohajskyi, Subottsivskyi and other manifestations	Konksko-Yalynska depression (Azov region), Bovtyska and Rotmystrivska volcano-tectonic depressions (central part of the Ukrainian shield)	Volcanites of andesite-dacite and dacite composition, trachydacites of Bovtyska and Rotmystrivska depressions (178–54 million years)	Solid bitumen (anthraxolite)
Middle–Late Palaeozoic (Herсynic)	Devonian–Permian *D–P* (406–250 million years)	Lamprophyric Kimberlitic	Dykes, stocks and pipe of minettes of Rivnenskyi manifestation (406–260 million years); pipes of kimberlite-like rocks of Rodionivskyi and Ternivskyi (400–250 million years) manifestations	Dnieper-Donets depression, Donbas, Dobrudzha, Scythian platform, Illinetska volcano-tectonic depression (Middle Buh region)	Porphyric dyke complex of syenite-porphyry, quartz-porphyry, vogesite, minetta, rhyolite-dacite breccia of the Kirovohrad block central part (340–270 million years), dykes and pipe-like bodies of West-Inhuletska zone and others	*W, Mo, Li, Be, Sn*
Proterozoic	Middle–Late Proterozoic PR_{2-3} (1 900–1 100 million years)	Lamproitic Kimberlitic Metamorphic of eclogite-like rocks	Lamproitic sills of Ruskopolyanskyi manifestation (1370–1330 million years); kimberlitic dykes of Lelekivskyi and Shchorsivskyi manifestations (1900–1850 million years); lenticular bodies of Pavlivskyi and Klyntsivskyi manifestations of metamorphogenic diamonds	Superposed Ovrutska depression and Sushchano-Perzhanska fractured zone (Volynski block), linear tectono-metasomatic zones of Kirovohradski block	Dykes of diabases, lamprophyres, picrites of Znamyansko-Ustynivske field (1900–1100 million years), gabbro, anorthosites and rapakivi granites of Korsyn-Novomyrhorodskyi pluton (1750±5 million years), trachytoid granites of Novoukrainskyi massif and porphyry granites of Kirovohradskyi, Voznesenskyi, Chyhyrynskyi and other massifs	Piezoquartz, *Ti, Cu, W, Mo, Li, Be, Sn, TR*, CaF_2

Table 2

Age lithologic-structural features of exogenous diamond-bearing formations in connection with TMA of the Kirovohradskyi block

Stages of diamond-bearing formations development	Geological-structural and paleogeographical conditions of localization	Sedimentary diamond-bearing formation	The type of diamond-bearing formation	Lithologic features of diamond-bearing rocks composition	Associations of accompanying minerals	Areas of diamond placer concentrations distribution
1	2	3	4	5	6	7
N_2^2–Q	Valleys and interfluves of modern rivers covered by blanket of heterofacial Quaternary deposits	Continental sandy-clay	Terrigenous alluvial	Inequigranular sands, silts with lenses and interbeds of clays, in lower part – shingles, sometimes sands with quartz and chert gravel	Ilmenite, zircon, monazite etc.	Basins of rivers Inhul, Inhulets, Ros, Tyasmyn, Synyuha

Table 2 (continuatuon)

1	2	3	4	5	6	7
Stages of diamond-bearing formations development	Geological-structural and paleogeographical conditions of localization	Sedimentary diamond-bearing formation	The type of diamond-bearing formation	Lithologic features of diamond-bearing rocks composition	Associations of accompanying minerals	Areas of diamond placer concentrations distribution
N_2^2–Q	Valleys and interfluves of modern rivers covered by blanket of heterofacial Quaternary deposits	Continental sandy-clay	Terrigenous alluvial	Inequigranular sands, silts with lenses and interbeds of clays, in lower part – shingles, sometimes sands with quartz and chert gravel	Ilmenite, zircon, monazite etc.	Basins of rivers Inhul, Inhulets, Ros, Tyasmyn, Synyuha
$N_{1-2}bl$	Erosional depressions in the south-western part of the block southern slope and in adjacent western part, filled with a complex of various facies type ancient deltaic deposits – alluvial (channel and floodplain), fluvio-marsh, coastal, lagoon and coastal dunes	Shallow sandy-clayey-limestone	Terrigenous deltaic	Gritstones, shingles, poorly sorted coarse-, medium- and fine-grained sands, silts, clays	Ilmenite, rutile, zircon, monazite, pyrope	Basin of Synyuha-river (Middle Buh region)
₽$_3$–N_1pl	Accumulative lowlands in the north and north-eastern near-slope parts of the block, composed of coastal and lagoon sediments	Pelagic sandy	Terrigenous coastal	Fine- and medium-grained quartz sands; fine-grained kaolinite sands, secondary sandy kaolin	Ilmenite, rutile, zircon, kyanite, sillimanite, staurolite	Basins of Tyasmyn-river and of Inhulets-river head (Middle Dnieper region)
₽$_2b\check{c}$	Paleovalleys and accumulative depressions of the block, its related near-slope parts, filled by alluvial (fluvial and floodplain) terrigenous sediments	Continental coal-bearing terrigenous	Terrigenous alluvial	Inequigranular sands with pebbles, gravel and boulders; silts, sandy clays, secondary kaolin	Ilmenite, rutile, zircon, monazite, pyrope etc.	Kaniv-Zvenyhorodskyi region of Hnylyj Tashlyk-river basin, Inhul-river head
K_1a–al $(sm+vr)$	Paleovalleys and depressions in the central and also in the north-western and south-western near-slope parts and in the slopes of the block, filled by (fluvial and floodplain) terrigenous sediments	Continental bauxite- and coal-bearing terrigenous	Terrigenous alluvial	Gritstone, shingles, gravelly, coarse- and inequigranular poorly sorted and kaolinizated sands; secondary kaolin, bauxite-like rocks and bauxites	Ilmenite, zircon, apatite, cassiterite, monazite, bauxites and bauxitic rocks	Kaniv-Zvenyhorodskyi region of Ros-river basin, Smilyanskyi region of Tyasmyn-river basin, interfluve of South Buh and Inhulets
J_2b+bt	Paleovalleys in the north-eastern slope and in near-slope part of the block, filled by alluvial (fluvial and floodplain) terrigenous sediments	Continental coal-bearing terrigenous	Terrigenous alluvial	Boulder-pebble rocks, gravel-pebble conglomerates and breccias, shingles, gritstones, gravelly, coarse- and inequigranular sands; secondary kaolin, sandy clays	Ilmenite, pyrope, Cr-spinellids, zircon, rutile, gold	Kaniv-Zvenyhorodskyi region of the Ros-river basin, basins of rivers Zolotonosha and Sula, downstream of Psel-river

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Мета. Реконструкція етапів формування ендогенних алмазоносних формацій упродовж геологічної історії розвитку протоплатформної структури Кіровоградського блока Українського щита для визначення геологічного віку вірогідних осадових колекторів алмазів.

Методика. Глибинні геолого-геофізичні дослідження літосфери, структурно-тектонічний аналіз докембрійського фундаменту, комплексне структурно-формаційне розчленування геологічних тіл.

Результати. Кіровоградський блок Українського щита за локалізацією алмазоносних структур і формацій належить до перспективних на розшуки алмазів протоплатформних блоків. Визначено, що геологічні та структурно-тектонічні передумови для формування ендогенних алмазоносних формацій були закладені в ранньому докембрії на етапі становлення протоплатформного режиму. Вони виникали на етапах активізації, що в Кіровоградському блоці відбувалися від середнього протерозою до палеоцену. Про це свідчать літологічні, структурно-формаційні та вікові особливості утворень, до яких приурочені алмазоносні формації.

Наукова новизна. Геолого-структурні умови й епохи утворення алмазоносних формацій Кіровоградського блока розглянуті на загальному тлі спрямованого еволюційного розвитку земної кори в докембрії та фанерозої. Особливу увагу привертає докембрійський відрізок часу, оскільки тоді були закладені сприятливі геологічні та структурно-тектонічні передумови для формування алмазоносних формацій.

Практична значимість. Виділення епох активізації й формування алмазоносних формацій дає змогу по-новому зорієнтувати прогнозно-металогенічні дослідження та застосувати під час розшуків і розвідки цього типу зруденіння низку важливих чинників контролю – геолого-формаційний, геохронологічний, стратиграфічний, літологічний, палеогеографічний. З урахуванням закономірностей просторово-часового положення алмазоносних формацій, під час аналізу геологічної будови протоплатформних структур можна оцінити вірогідність наявності на їх теренах алмазів і, відповідно, прогнозувати алмазоносність території.

Ключові слова: *активізація, Кіровоградський блок, протоплатформа, алмазоносна формація, мантія*

Цель. Реконструкция этапов формирования эндогенных алмазоносных формаций на протяжении геологической истории развития протоплатформенной структуры Кировоградского блока Украинского щита для определения геологического возраста возможных осадочных коллекторов алмазов.

Методика. Глубинные геолого-геофизические исследования литосферы, структурно-тектонический анализ докембрийского фундамента, комплексное структурно-формационное расчленение геологических тел.

Результаты. Кировоградский блок Украинского щита по локализации алмазоносных структур и формаций принадлежит к перспективным на поиски алмазов протоплатформенным блокам. Установлено, что геологические и структурно-тектонические предпосылки для формирования эндогенных алмазоносных формаций были заложены в раннем докембрии на этапе становления протоплатформного режима. Они возникали на этапах активизации, которые в Кировоградском блоке происходили от среднего протерозоя до палеоцена. Об этом свидетельствуют литологические, структурно-формационные и возрастные особенности образований, к которым приурочены алмазоносные формации. Россыпные концентрации алмаза, связанные с молодыми фанерозойскими (и современными) осадочными формациями, обусловлены разрушением древних эндогенных его источников.

Научная новизна. Геолого-структурные условия и эпохи образования алмазоносных формаций Кировоградского блока рассмотрены на общем фоне направленного эволюционного развития земной коры в докембрии и фанерозое. Особенное внимание привлекает докембрийский отрезок времени, поскольку тогда были заложены благоприятные геологические и структурно-текто-

нические предпосылки для формирования алмазоносных формаций.

Практическая значимость. Выделение эпох активизации и формирования алмазоносных формаций даст возможность по-новому сориентировать прогнозно-металлогенические исследования и применить при поисках и разведке этого типа оруденения ряд важных контролирующих факторов – геолого-формационный, геохронологический, стратиграфический, литологический, палеогеографический. С учетом закономерностей пространственно-временного положения алмазоносных формаций, при анализе геологического строения протоплатформенных структур можно оценить вероятность наличия на их территории алмазов и, соответственно, прогнозировать алмазоносность территории.

Ключевые слова: *активизация, Кировоградский блок, протоплатформа, алмазоносная формация, мантия*

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GEOPHYSICAL RESEARCH OF AREAS WITH INCREASED GAS CONTENT OF COAL SEAMS

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ГЕОФІЗИЧНІ ДОСЛІДЖЕННЯ ЗОН ПІДВИЩЕНОЇ ГАЗОНОСНОСТІ ВУГІЛЬНИХ ПЛАСТІВ

Purpose. To establish links between the main parameters of geophysical methods of mineral prospecting (electrical resistance, scattering intensity of gamma radiation, rate of elastic waves, etc.) and the gas content of coal seams as well as to give practical recommendations on the economic efficiency of industrial methane extraction from the unrelieved coal seams.

Methodology. The research employed the statistical methods of non-equilibrium thermodynamics, which allow us to determine the response function of the areas with increased gas recovery on the impact of geophysical fields.

Originality. The theoretical explanation of a number of effects, such as the dependence of specific electrical resistivity, scattered gamma radiation and velocity of elastic waves on the thermodynamic parameters of the investigated medium have been obtained.

Practical Value. The thermodynamic approach to the solution of geophysical problems allows us to give a theoretical explanation to a number of effects, such as the dependence of specific resistivity, scattered gamma radiation, and elastic wave velocities on the methane content in coal seams. The solution of these problems results into the technological chain of methane production, detection of high gas content areas, gas production and utilization.

Keywords: *methane, electrical resistivity, secondary gamma radiation, speed of elastic waves, gassing, thermodynamic parameters, method of analogy, well*

Formulation of the problem. Methods of methane extraction for industrial purposes have been applied relatively recently due to the growing interest of scientists in renewable and alternative energy sources. The difficulty of solving this problem is connected with the diverse structure of geological and petrophysical characteristics as well as with the mechanical and reservoir properties of coal seams. Today, one of the main directions of methane extraction is the intensification of the process of methane emissions from coal seams which is primarily connected with their low gas permeability.

The aforementioned complexities are typical for the Karaganda coal basin too. At the basin's mines, the average methane-bearing capacity constitutes 25 m^3/t, at a number of mines it reaches 60–80 m^3/t, and at some mines with high methane content it exceeds these values 1.5–2 times. A small amount of methane extracted by means of degassing (20–30% of the total volume), is characterized by low permeability of coal seams (0.05–0.07 mDA). Cost-effective production of methane from the surface isn't feasible on the entire area of the coal seams. It is possible only on the local areas with high gas content, which should be identified prior to drilling of exploratory or industrial wells.