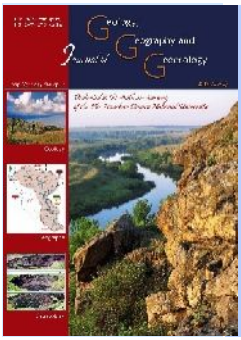

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On the development of geotouristic routes on the objects of the Precambrian Rock Association of the Western Priazovia

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Abstract. The article describes the priorities of the development of a new sphere in tourism – the geological sphere (geotourism). We have developed a complex of necessary measures for increasing the touristic attractiveness of objects of the geological heritage including justification of the touristic value of the objects selected for creating the touristic routes, posting information about the objects on available web-sites, including not only geotouristic routes and objects in the surrounding area, but also any other tourist attractions: geobotanical, landscape, archeological, historical-cultural, sacral, ethnic, etc. The paper justifies the necessity of involving the outcrop of Precambrian rocks of crystalline basement as geotouristic objects of Western Pryazovia. It was determined that almost all the most attractive geotouristic objects are geological relics of nature or geosites, some of which have official status and are included in the Nature-Reserve Lands of Ukraine. The paper describes the most important pages of the ancient history of Pryazovia in general and the Berda river in particular. Three variants of routes have been proposed, each based on the observations of the authors and their colleagues during geological surveys and field geological practice with university students specializing in geology. It was found that the most promising objects for touristic routes are the outcrops of crystalline Precambrian rocks located along the Berda river and surrounding territories. There, one can see a practically full section of outcrops of rock associations of the Osypenkivska Archean seria, which compose the Olzhinska metabasite and Krutobalkivska metasedimental suites; intrusive and ultrametamorphic formations which form the Osypenkivskyi gabbro-diorite, the Shevchenkivskyi plagiogranite-tonalite and the Saltychanskyi granite complexes. Among the geological objects which are exposed to observation in this relatively small territory, there are deposits of gold (Surozhske), rare metals (Kruta Balka), ceramical pegmatite (Mohyla Zelena and Velykyi Tabir Ravinne), iron (Korsak Mohyla). These objects give us a full impression of the structure of the crystalline massif of the Western Pryazovia megastructure of the Ukrainian shield. We have formulated the main recommendations for the preparation and conducting of geotourism routes in Ukraine,which can be the basis for development of both internal and external geotourism.

Key words: geotourism, Precambrian, geological site, geosite, intrusive complexes, ultrametamorphic complexes, Western Azov Sea, Ukrainian shield.

До питання розробки геотуристичних маршрутів по об’єктах докембрійського фундаменту Західного Приазов’я

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Анотація. Розглянуто пріоритетність розвитку нового напрямку в туризмі - геологічного (геотуризму). Розроблено комплекс необхідних заходів для підвищення туристичної привабливості об’єктів геологічної спадщини, серед яких розробка обґрунтування туристичної цінності вибраного для проведення геологічних маршрутів об’єкту, розміщення в інтернет-ресурсах інформації про об’єкт на легкодоступному сайті, включення до маршруту не тільки довколишніх геотуристичних маршрутів і об’єктів, але й будь-яких туристичних атракцій: геоботанічних, ландшафтних, археологічних, історико-культурних, сакральних, етнічних та інше. Обґрунтовано необхідність для Західного Приазов’я залучати у якості геотуристичних об’єктів саме вихід порід докембрійського кристалічного фундаменту. Визначено, що практично всі найбільш привабливі об’єкти геотуризму являють собою геологічні пам’ятки природи або геосайти, частина з яких має офіційний природоохоронний статус і входить до Природно-заповідного фонду України. Наведено важливі сторінки давньої історії Приа-

зов'я в цілому та р. Берди зокрема. Пропонується три варіанти маршрутів, кожен з яких спирається на дослідження авторів та їх колег при проведенні геолого-знімальних робіт та польових навчальних геологічних практик із студентами університетів, що навчаються за напрямом геологія. Установлено, що найбільш перспективними для проведення туристичних маршрутів є відслонення кристалічних порід докембрію вздовж річки Берда і на прилеглих до неї територіях. Тут практично у повному розрізі відслонюються породні асоціації осипенківської серії архею, що складають ольжинську метабазитову і крутобалківську метаосадову світи; інтрузивні і ультраметаморфічні утворення, що складають осипенківський габро-діоритовий, шеченківський плагіограніт-тоналітовий і салтичанський гранітний комплекси. На означеній незначній за площею території розміщуються і доступні для безпосереднього спостереження родовища золота (Сурожське), рідкісних металів (Крута Балка), керамічних пегматитів (Могила Зелена і Балка Великого Табору), заліза (Корсак Могила). Ці об'єкти нададуть повне уявлення про будову кристалічного масиву Західноприазовської мегаструктури Українського щита. Сформульовані основні рекомендації по підготовці і проведенню геотуристичних маршрутів в Україні. Запропоновані і описані найбільш важливі геологічні об'єкти Західного Приазов'я, використання яких може стати основою для розвитку як внутрішнього так і зовнішнього геотуризму.

Ключові слова: геотуризм, докембрій, геологічна пам'ятка, геосайт, інтрузивні комплекси, ультраметаморфічні комплекси, Західне Приазов'я, Український щит.

Introduction. Geological tourism being a developing global trend takes an important place among tours, and to some extent can meet the needs of the most demanding tourists. This type of tourism is new for Ukraine, but not for the world. Internet offers a plenty of links to various geological, paleontological and mineralogical tours and excursions around different geological places of interest and gems and mineral deposits. Ukraine can also add to the list of links, as it is rich in surface geological objects in a number of natural and artificial outcrops aged from the Old Archean (dating back more than 3.4 bn years) to quaternary deposits with a complete geological section rich in various rock types, minerals, and skeletal remnants of fauna. It is necessary only to develop the most interesting routes and create adequate conditions for observation of these geological objects along these routes.

It is clear that for a geological object to become a touristic one, it has to be adequately prepared. According to available Internet resources, it is necessary:

1. To develop the substantiation of touristic attractiveness of the chosen geological routes. To give characteristics of the surrounding landscape.

2. To give short geological insight into geological structure of Ukraine in general and by region of the touristic object, in particular. To give short characteristics of surrounding geotouristic routes and objects.

3. To give detailed geological description of the object or the route, to train guides.

4. To prepare the object for excursions (to clear the rock outcrops, to plot a route with route identifiers, the main and intermediate information stands in two languages about the geological object in general and each main outcrop in particular, to prepare appropriate tools, samples for demonstration and probably, for sale for tourists).

5. To design brochures with the description of the route or geological object, maps and schemes to provide or sell to tourists. The brochure must contain general information (how to get to the object, accommodations available). That is, information must be sufficient for the tourists to orient themselves around the object.

6. To upload information to the Internet about the object in some easily available web-site.

Western Pryazovia is unique for geotourism. It encompasses crystalline massif of the same name megastructure of the Ukrainian Shield (USh), mainly containing thin quaternary deposits, which resulted in the formation of significant visible crystalline rocks outcrops even in shallow river trenches. The outcrops are sometimes continuous or with insignificant turfness: for hundreds of meters, or even first kilometers one can observe various crystalline rock complexes formed within1.4bn years from 3.4 to 2.0bn years.

Gneiss-migmatite-plagiogranite complexes of Early Archean, gneiss-shale metamorphites and intrusive formations of ultramafic, intermediate and acid composition of Middle and Late Archean are available for observation. Granite complexes dating back to Early Proterozoic period are especially diverse. At this, we have an opportunity to observe metamorphic complexes of different level of facial changes – from granulite to greenschist facies. It should also be noted, that there is a possibility of immediate observation of granite pegmatites in natural and artificial outcrops. These unique geological formations are both geological natural objects and minerals, depending on the composition of pegmatite, on ceramic raw materials and rare (lithium, rubidium, cesium, tantalum, niobium, tin, beryllium) and rare earths elements of yttrium group. There is also a rare opportunity to observe rocks of Surozski gold deposit in natural outcrops, ravines and adits.

Below is given a short characteristic of the most attractive geological objects that, from the authors' our point of view deserve to become geotouristic objects.

Substantiation of touristic attractiveness of geological route along the Berda river. The picturesque steppe river Berda has its sources in the

Pryazovia hill ridges, flows through Bilmaksk and Berdiansk districts of Zaporizhia oblast, crosses a small area of Donetsk oblast and flows into the Azov Sea. The old names of the river are Hipakiris, Agara, Agarlibert, Kayala, Kayalibert (Berda (river), 2018). The Turkic name "Berda" means "Given by God". According to our data, berdo means "cliff" (Yanko, 1973). It is presumed that initially the name meant "the river that flows through cliff banks" (Dolgachev, 1989). At any rate, the river bordered by rocky cliffs of crystalline rocks lives up to this presumption. Presumably, in the ancient times, nomads came across a steppe river rich in prey, juicy grass and fish. It is possible that some of them gave this name to the area, and then to the river flowing there. It is likely that Persian king Darius in the summer of 515-512 BC led his innumerous army to “Stone graves of Scythian kings” located on the right bank of the Karatush river, to the Berda river (Azovskoe kazache vojsko, 2018). Before 1770 the banks of the Berda river (Kaiala-Bert, Stony Berda, Great Berda) were the border lines between the countries of Western Nogai (Crimean Steppe – Ogula desert) of the Crimean khanate and the lands of Kalmiusk area of Zaporizhzhia state. For the first time, the Berda river is mentioned in Zaporizhzhian Cossacks’ chronicles in 1575-1576, when Bohdan Mykhailovych Ruzhunsky (? – 1576). Volyn prince, Zaporizhzhia Cossack hetman who was the first hetman acknowledged by Polish authorities, led a military campaign across the Berda river. Starting from this time, the banks of this Pryazovian river from its riverhead to its mouth belonged to Zhaporizhzhia area. In the autumn of 1616 Petro Konashevych-Sahaidachny, "The Hetman of both banks of the Dnipro and the Zaporozhian Cossacks", sailed via the Dnipro to the Black Sea on Chaikas (big boats) with a group of two thousand cossacks, approached the eastern shore of Taurica (the Crimea), where he burned down a trading city Kafa (where currently is Feodosia), and then, after crossing the Black Sea to the south, approached the coasts of Anatolia, where he stormed the Turkish Black Sea ports Trebizond, Sinope, subjected the environs of Stambul to fire and sword, and returned to the Sich via the Kerch Strait, the Azov Sea, the Berda and the Konka (Konka waters) (Azovskoe kazache vojsko, 2018). In the area of the Kalaitanivka village of Berdiansk district of Zaporizhia oblast, the remains of the Zaharivska Fortress can still be seen today. Since that time, the shores of the Pryazovia River Berda from its source to the mouth became property of the Zaporizhians. Along the Berda and Konka in the 1770s , the Dnipro defence line was built, which consisted of seven fortresses located 30 versts one from another: Oleksandrivska, Mykytynska (Velyky Luh floodplain), Hryhorivska, Kyrylivska, Oleksiivska, Zaharivska and Saint Peter (Petrovska, Berdianska) fortresses. The mouth of the river is located in the vicinity of Druga Vershina village (Kuibyshevski region of Zaporizhzhia oblast) on the slopes of Pryazovia hills at the height of 300m above the sea level next to Mohyla Kordonska burial mound. It flows along the territory of Kuibyshev and Berdiansk regions of Zaporizhzhia oblast. The river flows along steppe area. Its banks are characterized by steppe and meadow flora with occasional artificial forest plantations. Sometimes crystalline rocks outcrops can be seen along the river banks (Fig.1).

Fig. 1 Outcrop of crystalline rocks on the right bank of the Berda river

In the interstream area between rivers Berdda and Kalchyk (tributary of the river Kalmius), and along the right bank of the small river Karatysh (left tributary of the Berda river) there is located a natural re-serve “Kamiani Mohyly”, a subsidiary of Ukrainian steppe natural reserve. In the mid-stream of the river, bordering with Donetsk oblast, is located regional landscape park “Polovetska step”. On the Berda river, near Osypenko village, in 1954 was build Berdianske water basin. The water from the basin is used to irrigate and supply water to seven adjacent settlements, including the town of Berdiansk. The range of fish in the river is wide: redfin, crucian carp, pike. 25 km from the mouth, river-valley significantly increases. The floodplain is one-sided up to 100m wide. In the lower areas it is swamped. River fall is 2.1 m/km. The stream is fast. The channel is twisting, 6-10m wide with sparse inundation up to 15-25m. The channel is grassed by a quarter. The floor is sandy, and stony on cripples. It freezes in December, and unfreezes in early March. The ices is unstable. The river is nourished from the show and ground waters. Spring floods are characteristics. It intakes melt-water even in winter during thaw, which results in the increase of the water-level. It doesn’t run dry. It flows into the Azov Sea near Novopetrivka vil. (Berdiansk regiona, Zaporizhzhia oblast). Berdianska sand bar exists thanks to the Berda river. The river length is 125 km.

Description of the main geological objects. The objects that outcrop along the Berda river and its confluents are offered for geological tours, and belong to Western Pryazovia megastructure of the Pryazovian megablock of the Ukrainian Shield. Western Pryazovia megastructure is structurally and historically the oldest plume-structure of the Ukrainian Shield (Early-Mid-Archean). It consists of Vovchansk and Saltychansk granite-gneiss domes and Orihovo-Pavlogradski and Maloyenisolski synclinores located around (Bobrov, Sivoronov, Malyuk and Lisenko, 2002; Isakov, Bobrov, Paranko, Shpilchak & Shurko, 2011; Isakov & Paranko, 2013) (Fig. 2).

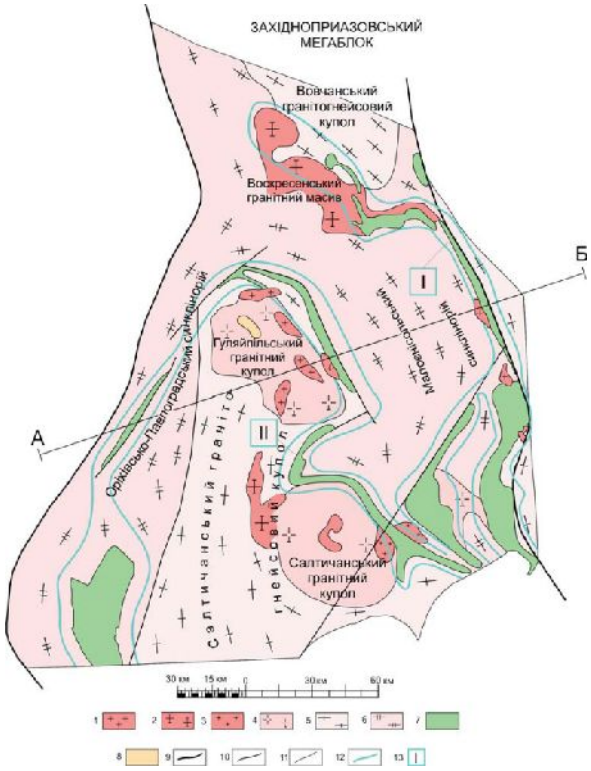

Fig. 2. Geological-structural scheme of Western Pryazovia megablock.
Twofeldspar granites of: 1 – Dobropilsky, 2 – Yanvarsky, 3 – Saltychansky complexes; 4 – plagiogranites, tonalites of Shevchenkivsky complex; 5 - metamorphic Western Pryazovia series and ultrametamorphic Novopavlivsky complex of dome structures; 6 – megamorphic rock masses (Vovchanska and Dragunska) and ultrametamorphic Remivsky complex of suture area; 7 – megamorphized volcanogenic-terrigenic complexes of trough structures of greenstone type (Osypenkivska series and Novogurivska, Ternuvatska, Kosivtsevska rock masses); 8 – terrigenic complexes of fault-line superimposed structure (Guliaipilska suite); 9 – regional abyssal fractures; 10 – other disjunctive dislocations; 11 – geological boundaries; 12 – conventional boundaries of greenstone belts; 13 – greenstone belts: I – Shevchenkivsko-Berestivsky, II – Sorokynsko-Gaichursky

The domes are composed of ul-trametamorphised gneisses and crystalline schist of Western Pryazovia series of the Early Archean, while its central parts are filled with granitoid formations of Mid-Late Archean and Early Proterozoic era. Synclinores are presented by highly-metamorphized metamorphites jammed into narrow linear isocline folds of Vovchanska and Dragunska rock mass of

the Early Archean. In the outline of the domes there are developed specific long narrow trough structures (up to 40km long, mainly 1-2km wide), composed of metavolcanogenic and metaterrigenic formations of different age of green-stone complexes of Mid- and Late Archean.Trough structures form two discrete arch-like belts. South-Western Sorokinsko-Gaichurski belt stretches to more than 300 km and enframes Saltychansky granite-gneiss dome practically along the perimeter in the form of discrete trough structures. North-Eastern Shevchenkivsko-Berestivski belt enframes marginal Eastern and Northern parts of the megablock.

Intrusive magmatic formations of Western Pryazovia megastructure are presented by massifs of Shevchenkivsky plagiogranites of granite magmatic domes such as Yelyseivsky and Guliaipilsky, as well as multiple phase intrusives of Yanvarsky, Dogropilsky and Saltychansky complexes developed along greenstone trough structures (Isakov, Bobrov, Paranko, Shpilchak & Shurko, 2011; Isakov & Paranko, 2013). The establishing of granite domes and massifs resulted in the formation of the basement structures of the level and led to the formation of greenstone troughs(State geological map of Ukraine. Scale 1: 200,000. Series: Central-Ukrainian. Sheets L-37-VIII (Mariupol), L-37-IX (Taganrog).

Object under observation 1. Section of greenstone complex of Sorokinsky structure on the right bank of the Berda river. The route goes across Surozhska area of Sorokinska greenstone structure (GS) (Geology, Radiological Age, Metallogeny of Greenstone Complexes in the Ukrainian Shield, 2008) (Fig. 3). The length of the route is 1.36km. Here in natural outcrops, one can observe in details a practically uninterrupted section of Olzhynska and Krutobalkivska suites of Osypenkivska series dating to Mid- and Late Archean, presented by rock complexes of metacomatiit-tholeiite, metarhyodacite and metaconglomerate-sandstone-clay-schist formations composing Sorokinska structure, metamorphised into greenschist, epidote-amphibolite and amphibolite levels of metamorphism.

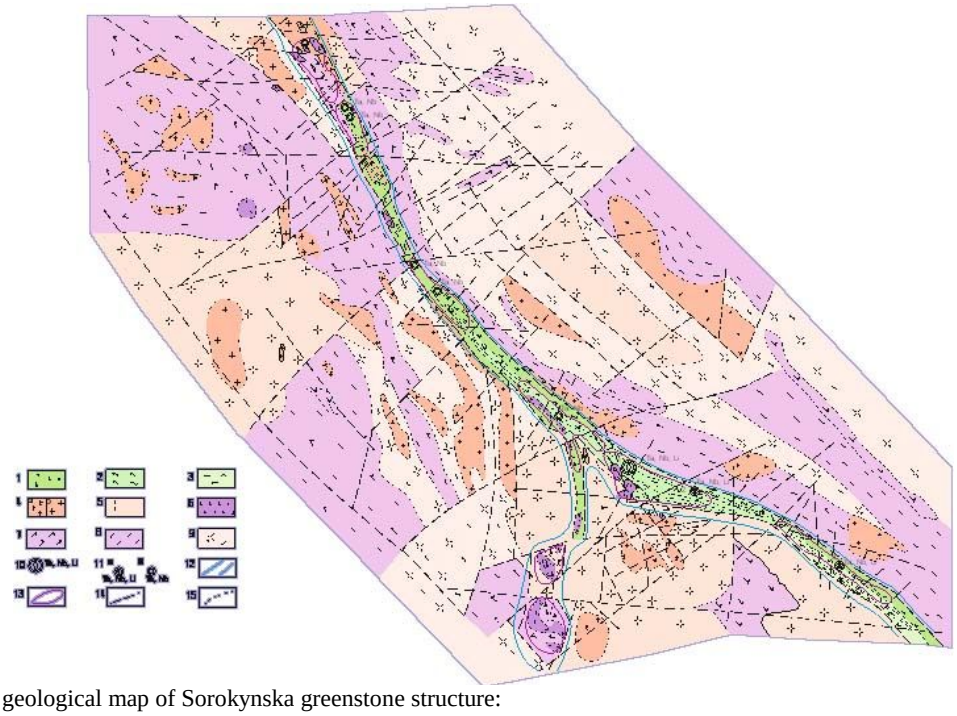

Fig.3 Schematic geological map of Sorokynska greenstone structure:
1 – megavolcanites of Olzhynska suite; 2 – mica-ceous schists of Krutobalkivska suite; 3 – terrigenic-homogenic formations of Sadova suite; 4 – granites: a – muscovite and muscovite-biotite granites of Yanvarsky complex; b – orthite-bearing granites of Saltychanski complex; 5 – plagiogranites of Shevchankivsky complex; 6 – ultrabasite bodies; 7 – amphibole-pyroxene gneisses and schists of Western Pryazovia series; 8 – biotite gneisses of Dragunska rock mass; 9 – plagiomigmatites; 10 – Kruta Balka rare metals deposit; 11 – associated with pegmatites: a – ore occurrence, b – anomalies of rare metals; 12 – development outline of Sorokynske pegmatite field; 13 – intersection of rare-metal pegmatites; 14 - disjunctive dislocations; 15 – geological boundaries.

Within Surozka area, there is a sudden change of North-West direction of strike of the main syncline of Sorokinska GS to East-West direction. Its span reaches 2100m. Southern wing tends northward; angle of dip of the rocks is steep up to near-vertical in Southern direction.

At the beginning of the route one can observe outcrops of metabasites of Olzhynska suite. Metabasites are presented by amphibolites along metabasalts and metabasalt tuffs (tuff-lava) as well as metagabbro-dolerites that are comagmatic to them (Fig. 4).

Fig. 4 Amphibolites along metabasalts and metabasalt tuffs (tuff-lava).

Further along the route, there is an outcrop of acid volcanites. The rock mass is presented by metarhyodacites, metarhyolite with porphyritic structure conditioned by the presence of rather large separations of quartz and plagioclase (oligoclase) at the background of fine-cryptograin kalifeldspath-plagioclase-quartz formation of rock mass (0.06-0.15 mm).

Isochronic age, obtained by isotropic U-Pb ratio of zircon (Artemenko, Tatarinova & Popov, 2001)is 3160±140 mln years.

Further along the route, there are observed metabasites followed by outcrops of significant ultra-basite part of section of Olzhynska suite, they are presented by metacomatiit-dunite-harzburgite volcanic-plutonic association. At the interface with terrigenous rock mass, there are observed iron gold-bearing quarzites (Artemenko, Tatarinova & Popov, 2001).

Further on, there are outcrops of metaterrigenous formations of Krutobalkivska suite (Fig. 5) that form nonconformable boundaries with formations of Olzhynska suite and occur in the core part of Sorokinska GS.

Fig. 5. Outcrops of metaterrigenous formations of Krutobalkynska suite

This assize is presented by paragenesis of coarse-terrigenous deposits (metaconglomerates, metagravelites, sandstone) that are associated with quartz-sillimanite-garnet schists and metasandstone-clay formations of high alumina ratio up to high-aluminous types (andalusite-staurolite-cordierit schist). In the section, there are also various schists: garnet-biotite-feldspar-quartz, biotite-feldspar-quartz, bi-nary mica, turmalin-muskovit-biotite-feldspar-quartz, sometimes with graphite, tourmaline; staurolite-garnet-biotite-feldspar-quartz, sillimanite-garnet-biotite-feldspar-quartz and other types of schist with relict blastopsammitic structures. According to Artemenko G.V. at al. (Artemenko, Tatarinova & Popov, 2001) cluster-forming zircon is dated 3330±40 mln. Years U-Pb. Zircon characterizes the radiogenic age of the source of decomposition that provided the fragmentary material to the basin of the sedimentary formations of the time of Kruta Balka.

Object under observation 2. Outcrops of metavolcanogenic section (Olzhynska suite) of greenstone complex of Sorokynska structure on the left bak of the Berda river. This route is a logical continuation of the previous one. Here one can observe in detail petrographic kinds of basite-ultrabasite rock mass of Olzhynska suite (Geology, Radiological Age, Metallogeny of Greenstone Complexes in the Ukrainian Shield, 2008). The length of the route is 1.1km. In ledge rocks up to 20m high and about 150m long, there are observed essentially ultrabasite and basite part of the section of Olzhynska suite. The lower part is presented by ball-pillow-like lavas of metabasalts, the upper part – by tremolitite and actinolitite developed on metacomatiites. In the latter, there are observed relicts of spinifex-structures conditioned by the development of specific needle-like separations of olivine. The section contains plutonic formations – amphibolites that in their turn form subconformable and transverse dyke and vein bodies. In metabasalts, there are diognozed weakly deformed ellipse-like pillows with dimensions 15-50 by 5-23 cm. Peripheral parts of the balls being guarding areas, are characterized by a darker colour and coarse-grain structure (at the expense of post-genesis recrystallization). Balls and pillows of the basalt lavas have distinctive "tailings" in the lower part, which allows determining the direction of lava flow. The above mentioned rocks are cleaved by a series of pegmatite veins with rare-metal specialization.

Further along the route, there are observed active contacts of Shevchenkivsky plagiogranites with metavolcanites of Olzhynska suite.

Object under observation 3. Surozke gold-ore deposit (within Object under observation 1). The excursionists will have a chance to see a cross-section of one of iron quarzites in an adit and in an outcrop (iron quarzites represent a bedrock outcrop (with the thickness about 5m) of a gold-ore body of the Surozke deposit).

Ledge rock crops out on the slope of a hill to the left edge of mouth part of the Sobacha river. The abandoned adit is located nearby. In the mentioned outcrop and adit, gold-bearing magnetite quarzites crop out (Fig. 6), located adjacent to metabasite rocks of Olzhynska suite with metaterrigenous formations of Krutobalkivska suite. The main ore body is sampled from the surface in bulldozer trenches (available for observation, need clearing) and in many intersections of different level bore holes.

Fig. 6. Gold-bearing iron quartzite (Surozke deposit)

The deposit is 0.7km by 2.5km, coordinated to contact of metabasite rocks of Olzhynska suite with metaterrigenous formations of Krutobalkivska suite. Moreover, the deposit is characterized by localization of intersection node of three complex structured and variously oriented fractures: sublateral – Skifsky, North-West – Stepovy, and North-East – Sichny, which conditions the manifestation of the Ravine in modern relief. The ore bodies are immediately spacially connected with iron quartzite seams that are intensely limonitized to "iron hats". Magnetite quartzites contain iron minerals in the form of magnetite, tiger's eye can be found in this area(fine-fibrous pseudomorphosis of quartz in a mixture with goethite on asbestos-like ribecyte).

By ore composition, the deposits belong to gold-sulphide-quartz type. Free gold occurs in undulosed quartz on the contact with sulphides (50-80%), gold content (5-15%) is found in crystal-jams with sulphides (pyrite, pyrrhotite, chalcopyrite) and magnetite. The rest (10-30%) is located in low-sulphide quartz, in fissures and mineral interstices. The gold is of high rate (926-933). Gold content in ores is between 3-5 g/t and in separate samples reaches 8-15 g/t.

Object under observation 4. Outcrop of Shevchenkivskyi plagiogranites along the Berda riv-

er. Osypenkivskyi plagiogranite massif. The route lies along the right and left banks of water stor-age basins, starting from no-name ravine, and stretching for 1.75km.

Osypenkivsky plagiogranitoid massif is located in the North part of Sorokinsky structure (see Fig. 3), intruding its South-West edges forming along them a continuous line of outcrops of crystalline base from the upper Kruta river to the far South of Sadova area of Sorokinska structure, stretching for about 8-9km. The width differs from 0.5 to 4km. The massif consists of plagiogranitoides of tonalite-plagiogranite formation. It also contains a wide range of ores presented mainly by abyssal and hypabyssal plagiogranitodes: hornblende diorite, quartz diorite; biotite, hornblende-biotite tonalites and plagiogranites, hornblende tonalites.

In tonalite outcrops along the Berda river, elements of texture irregularity are practically everywhere (freckles, stripes) conditioned by alternation of areas with different granularity.

Contacts of plagiogranitoides with country rock are well-marked with frequent overlapping, un-even outlines of contact interface. Thus, in outcrops of the left edge of the water storage basin of the Berda river, there are observed contacts of middle-coarse-grain massive tonalites and weakly gneiss-like tonalites with fine-grain thin-striped metabasalts. The area of contact changes is up to 7m thick and is presented by complete biotitization of metabasalts that are injected with a large number of quartz (quartz-pyrite) veins in the contact area.

Object under observation 5. Outcrop of rare-metal pegmatites (deposit of rare-metal pegmatites of Balka Kruta). Along the route, in separate small ledge rocks, are found outcrops of Shevchenkivsky granites, metabasites of Sorokynsky complex, schists and gneisses of Krutobalkivska suite. Among them, there are observed quartz-albite pegmatites of Balka Kruta deposit (Isakov, 2007; Gurskij, Esipchuk, Kalinin, Kulish, Nechaev, Tretyakov&Shumlyanskyi, 2005.) (Fig. 7).

Fig. 7. Ledge rock of rare-metal pegmatite of Balka Kruta deposit.

Pegmatites of rare-metal deposit of Balka Kruta occur in a small massif of basites of Sorokynsky complex and its junction zone with the biotite schist rock mass. In the deposit, there is a developed system of North-West and sub-lateral fractures, which makes the geological structure of the deposit more complex.

The establishing of pegmatites is connected with magmatic activisation and establishing of massifs of Saltychansky granites. As a result of massif formation, at the finishing stage, there were abruptions of solution-melt, and a system of fissures in granites and schist rock mass and metaultrabasites was formed. Pegmatite bodies are falling and tabular (sometimes mushroom-like) with length-thickness ration of 6:1 and more. Vertical-wise, pegmatites make up a stratified “pie”, within which about a dozen of pegmatite bodies are located.

General direction of vein dip is South-East 140^{o}withangles of 5-25^{o}. Some massive veins dip is directed Eastward under 20-35^{o} angles.

Pegmatites make up: a quartz core (*block quartz zone*); *block microcline* zone (mainly pale-pink and grey microcline). There are also a patch of crystals of pale-green spodumene up to 0.8m in dimension; *quartz - muscovite zone*, consisting of large packets of muscovite crystals of diamond shape; *albite zone* composed of sugary grained albite containing quartz, muscovite and very rarely – apatite with black tourmaline (schorl) (Fig. 8); *quartz-albite-spodumene zone* characterized by mainly consistent composition with quartz, albite and spodumene prevailing, with rarely occurring areas of quartz-spodumene composition; *quartz-albite zone* making up marginal parts of the majority of veins.Pegmatite of Kruta Balka are a small deposit of lithium and tantalum.

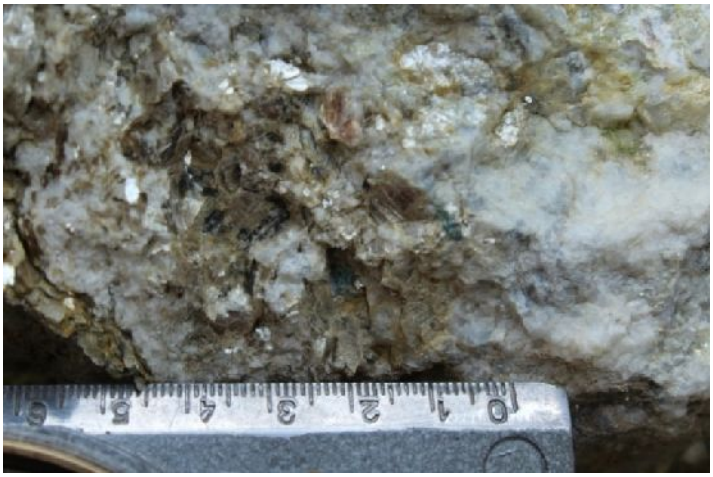

Fig. 8. Pegmatite (albitezone) ofBalkaKrutadeposit. Pegmatites of Kruta Balka are a small deposit of lithium and tantalum.

Object under observation 6. Quartz metasomatites (barren quartzites) across Saltychansky granites in outcrops on the right bank of the Berda river. Quartzite metasomatites form bodies with thickness up to 100m and length of up to 1.5km, usually associated with contacts of Saltychansky granites massifs. The most characteristic are "Donkey's ears" rocks (Fig. 9) that make up a geomorphological and geological geosites. In their vicinity, these rocks partially crop out in a small abandoned quarry, where a zone of fracture can be observed with intensive manifestation of linear weathered layer. Quartzite rocks are composed of ledge rocks along the right bank of the river stretching for 170-200m. Quartzites making up narrow elevated crests are of light-grey to white colour, crevassed, plastic, with fine-scale mica. Quartzite bodies occur among pink and pink-grey biotite and biotite-amphibole middle- and coarse-grain granites of Saltychansky complex.

Fig. 9. Quartziterocks ("Donkey'sears"). Right bank of the Berda river.

Along with the offered geological tours along the Berda river and its tributary Berestova river, there can be observed practically uninterrupted ledge rocks of Pre-Cambrian formations encompassing rock formations of Western Pryazovian and Central Pryazivian series of Archean, as well as Shevchenkivsky Archean and Saltychanskyi Proterozoic complexes. Placed here geological monuments of nature can be a wonderful extension of the route or be subject to a separate independent route.

1. Rock chain along the left shore of the Berestova river. The rocky outcrop of Precambrian crystalline rocks on the left shore of the Berestova river in Karl Marx village are represented by relatively small ledges and separate blocks and boulders formed as a result of ruination of the rocky outcrop by the pro-cesses acting on the slope and weathering. They all belong to the Berestova tectonic zone and are composed of pink-grey biotite and amphibole-biotite average-grained granites and migmatites with xeno-lites of amphibolites. The rocks are characterized by heightened content of sillimanite, graphite found in the biotite gneiss, veins of quartz and quartzites, and veins of aplite-pegmatoid granites, which often occur there (Fig. 10).

Fig.10. The ridge of the rocks along the left bank of the Berestova River

2. Migmatite rocks in Troitske (Karl Marx) village. In the northern part of Karl Marx village, along the right shore of the Berestova river, near the place where a large tributary and a stream fall into the river, and 100 m away from the dam across the Berestova, there is a small group of rock outcrops slightly above the surrounding relief. They descend stepwise to the stream bed of the Berestova and down, along the current. The rocks consist of rocks of the Anadolsky Lower Archean complex which was first distinguished by N. I. Bezborodko in 1935. Macroscopically, these granites and migmatites are pink and grey-pink, leucocratic, biotite and amphibole-biotite, mixed-grained (average- and large grained) massive and unclearly striped, injectional-striped and spotted, at some places enriched with monazite, sillimanite, apatite and garnet, and contain xenolites of gneiss and amphibolites (Fig. 11).

Fig.11. Migmatite rocks in the village Troitske

3. Proterozoicnon-orequartzites. On the right from the road which lies along the water divide on the right slope of the valley of the Berestova river to Karl Marx village, there is an abandoned quarry, where non-ore quartzites were extracted. Quartzites are deposited as rather thick vein-like bodies (in this case, the observed thickness of the body, exposed from the surface by the quarry, is around 200 m) of non-ore quartzites among the granitoids of the Anadolsky complex. In the quarry on the Berestova river, quartzites are mined for road building. They are a fragment of surveyed Troitske deposit, the reserves of which equal 100 thousand tonsand are available for use in the glass industry and making acidic refractories. The quartzite are light grey to white, yellow-greyish, half-transparent, slightly cellular due to leaching, and lie among granitoids of the Anadolsky complex. Thickness of separate quartzitic veins reaches 21 m.

4. High rock above the Berestova. On the right shore of the Berestova river in the central part of Troitske village, on the river bend, a vertical wall of Upper Archean granitoids of the Shevchenkivsky complex closely approaches the river. The rocks are elevated up to 10-20 m and are observed as a narrow chain up the slope of the valley with distinctive

ver-tical faults which divide them into separate narrow blocks and column-like formations. According to the composition, they are mostly pink and pink-grey biotite and amphibole-biotite plagiogranites and migmatites with veins of grey-light-pink aplite-pegma-toid granites with xenolites of amphibolites, with veins of yellowish-grey quartz. Rock outcrops in the area of Troitske village belong to the Berestovska tectonic zone with manifestations of cordierite-sillimanite mineralization, intense silification of the rocks, cataclasis zones (Fig. 12).

Fig. 12. High rock above the Berestova river.

5. NovosoldatskirocksontheBerda. The Novosoldatski rocks are a stripe of separated high rocky outcrops (up to 10 m) on the right shore of the Berda, below the place where it flows into the Berestova. The rocks are erosional buttes of a Precambrian basement, which has an elevated is location, exposed by the river erosion and changes caused by weathering. The rocks are composed of biotite greyish-pink and pink massifs, average-large grained granites, pink aplite and pegmatoid granites and migmatites, often with smoky quartz, with quartzitic veins. Granites belong to the Anadolsky complex (so-called Anatoliiski granites according to M. I. Bezborodko, 1935) of the Lower Proterozoic eon. The formation of this complex is considered to belong to orogenic stage of development of the Pryazovia region. The granites contain xenolites of gneiss and main crystalline schists (Fig. 13).

Fig. 13. Novosoldatski rocks on the Berda River

6. Mykolaivski granite rocks. On the left shore of the Berda, opposite Mykolaivka village, there is a continuous chain of a picturesque group of rocks. The rocks rise above the level of the valley up to 20-25 m, cut by small gullies on the sides with formations of small rapids, with large diversity of forms of weathering and erosional activity of streams. The rocks are composed by different ultrametamorphic, intrusive and metasomatic rocks of Archean and Proterozoic epochs. They include quite common graphite gneiss, overlapped by amphibolites, garnet, sillimate and amphibolite gneiss of the West Pryazovia seria. Also common are granites and migmatites of pink-grey and pink uniformly-grained type, veins of pink aplite-

pegmatoid granites, dikes of serpentinous ultrabasic rocks and diabases.

In a more distant route, the following various geological objects can be offered for observation:

1. *Great Stone Rock, Gusarka vil.* (Bobrov, Sivoronov, Malyuk, Lisenko, 2002), located in the upper Sukha Konka river, between villages Gusarka and Konski Rozdory. Here, mainly on the left slope of the valley, a group of picturesque rocks crop out. Some of them are elevated above the river level (near the mouth of the Chabanka river) up to 25-30m. The rocks are composed by biotite and amphibole-biotite gneiss of the Western Pryazovia series with alternations of amphibolites, mainly intensively migmatized and interrupted by various granites and numerous veins of aplite-pegmatiod and pink porphyroblastic granites, with diabase dykes.

In the vicinity, next to Zrazkove vil., in a small quarry, there are outcrops of Pre-Cambrian monzonite intruding corund-silimanite-dichroite gneisses.

2. *Kamiani Mohyly (Stone Graves) Granite Massif.*The first reports about the geological structure of the region of location of the granite massif are traditionally attributed to Johann Anton Güldenstädt, who in August-September of 1774 traveled through Sloboda and left a detailed description of his surveys and observations. The nearest settlements he reached were Sloviansk and Bahmut, therefore it is no wonder that he failed to mention not only "Kamyana Mohyla" but any outcrops of crystalline rocks (Journey of Academician Gildenstedt in the Slobodsk-Ukrainian province, 1892). In 1787 with a geographical excursion organized by the Russian Academy of Sciences for studying the borderlands of Russia, Pryazovia was visited by Peter Simon Pallas, one of the most famous encyclopaedist scientists. He found outcrops of grey and red granites and gneiss covered by alluvium. It is unclear which outcrops he described, but the Besh-Tash rock massif, as Kamyana Mohyla was known at the time, was not mentioned by Pallas (Manyuk, Vol., Manyuk, Vad.V., 2017).

A bit later, in 1837, A. N. Demidov, a famous Ural oligarch sent a French engineer Frédéric Le Playto the Donbas. On the basis of his investigations, he developed geological maps of 1:265 000 and 1:420 000 scale of the territory, in the northwestern part of which, the Kamyana Mohyla reserve is located. Besides, as A.B. Ivanitsky had done earlier, he described the rocks which would later be called mariupolites.

In 1880, O. V. Gurov for the first time conducted a stratigraphic division of the Priazovia crystalline complex. He classified the rocks which compose the red granite structures (intrusive rocks of "Kamiani Mohyla,, Katerynski granites) as rocks formed after the granite-gneiss rocks which contain them. V. O. Domger, a famous researcher of the southern Ukraine, discoverer of the Nikopol manganese ore deposit, in 1881 published a work devoted to crystalline rocks of south-west Russia.

In 1940, a geological survey on 1:50 000 scale was conducted, guided by experienced geologists N. T. Vadimova and V. N. Gladky, as a result of which, the "Kamyana mohyla" granite massif was for the first time studied in detail and its relatively young age was determined. Due to absence of radiometric dating, the age was determined as Paleosoic-Mesosoic, i.e. significantly younger than the actual age(Manyuk, Vol.V., Manyuk, Vad.V., 2017).

Among the studies conducted in the area later and which involved the massif, we should mention the Mariupol map sheet of 1:200 0000 scale, which was conducted by the geological party of the Priazovia expedition led by G. D. Kravchenko during the geological survey in 1957–1960. The study significantly elaborated the petrologic and mineralogical composition of the rocks of the intrusive massif, for the first time determined the presence of quartz-fluorite veins and veinlets, found such minerals as baryte, cassiterite, zinnwaldite and topaz determined the tectonic relationship between the intrusive rocks and the zone of the Rozivsky fault. The rocks of the Kamyana Mohyla area were determined to have an excessive content of rare soils, tantalum, niobium, molybdenum and tin. The absolute age was for the first time determined using radiometric dating, but due to disadvantages of the argon dating method provided a large range - 700 to 1600 M years. According to modern stratigraphic scale, this corresponds to the Middle and Late Proterozoic eon, but the authors consider the age of the pink granites as Paleozoic-Mesozoic, though this time interval is 542 – 251 M years (Fig.14).

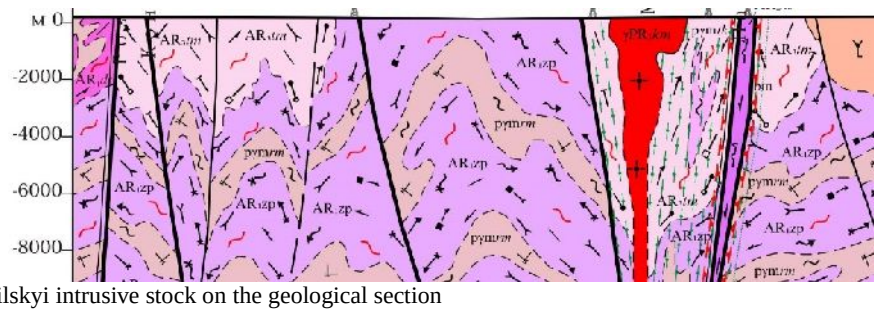

Fig.14. Kamenomogilskyi intrusive stock on the geological section

The first mention of peculiar granites of the Kamyana Mohyla and Katerynivks in Pryazovia in literature was made in the publications of I. G. Sagaidak (1937). As an integrated granite complex Kamyana Mohyla was determined by M. N. Ivantishny in 1960 and the name has remained in use after its initial appearance in the first variant of the unified stratigraphic schemes of the Precambrian Shield of Ukraine . Later, the peculiarities of the geological structure, mineralogy and petrography of the rocks of the complex were studied V. I. Kuzmenko (1946), V. N. Gladky (1958), U. U. Urk (1956, 1964), G. G. Konkov and R. M. Polunovsky (1964), L. F. Lavrynenko (1968), V. F. Razdorozhny (1985, 2004), V. V. Vasilchenko and others.

The granitoids of the complex were described in different levels of detail in a number of monographic publications, particularly "Metasomotites of the Eastern Pryazovia" (Liashkevych Z. M., 1971), "Mineralogy of Pryazovia" (Lazarenko E. K. et al., 1981), "Petrology, geochemistry and ore reserves of the intrusive granitoids of the Ukrainian shield" (Yesypchuk K. E. et al., 1990), "Petrology of the Ukrainian shield" (Scsherbakov I. B., 2005) and others (Esipchuk, Sheremet & Zinchenko, 1990).

Granite rocks of the *Kamiani Mohyly* form two lines with strike azimuth of 310° on the right slope of the Karatysh river. Separate hills are of significant dimensions and tower over the Karatysh river for 100-110m. Kamianomohylsky massif is composed of pink middle- and coarse-grain disseminated biotite granites of Kamianohomylsky complex dating back to Paleo-Proterosoic era (Fig.15). Mineral composition of the granites is: microcline, plagioclase, quartz, biotite, muscovite, fluorite and auxiliary minerals – topaz, xenotime, cassiterite, zircon, sphene, apatite, and often zinwaldite. Among subporphyritic granites, there are a significant number of veins and lenses of pegmatite up to 0.5m thick with cavities occasionally containing automorphic crystals of smoky and milky-white quartz, rock crystal and morion. The majority of granite outcrops, elements of the relief and natural landmark have their own names – Gostra (*Sharp*), Vitiaz (*Knight*), *Beshtash,* Liagushka *(Frog),* Dolyna Masok (*Masks Valley).*

Fig. 15. Granite massif of Stone Graves

The rock formation Kamyana Mohyla belongs to one of the 25 promising objects of geological heritage of Ukraine, suggested for the European list. It is characterized by high level of geodiversity and, according to the criterion, meets most requirements for the contenders for the European network of geoparks.(GeologicalLandmarks (geosites) ofUkraine, 2011; Manyuk, 2005, 2006, 2007).The massif makes the basis for *Kamianomo-*

hylskyi steppe natural reserve (Bobrov, Sivoronov, Malyuk, Lisenko, 2002).

Here, next to Rozivka urban type settlement, in the Northern part of the "Kamiany Mohyly" natural reserve, one can observe a geological significant sight "*Contact of Kamiany Mohyly granite massif with gneiss-migmatite complex rocks"* represented by the contact of pink porphyroblastic granites of Kamianomohylsky complex with the rocks of Western Pryazovia seris of Paleo-Archean era.

3. *Outcrop of ceramic pegmatites of Zelena Mohyla (Green Grave) deposit in an abandoned quarry on the right bank of the Malyi Chokrak river in the vicinity of Yeliseevka vil.*The abandoned quarry is the most picturesque part of the relief and looks nothing like any other areas not only in Priazovia, but in Ukraine as a whole, and is conditioned by peculiarities of the worked out pegmatite veins. The ceramic pegmatite deposit was developed to extract ceramic raw materials in the 50-60s of the 20th c., the majority of the veins are worked out. The remaining pegmatites are well cropped out in three quarries (Fig. 16). It is located within the Obytochnenska syncline in the basin of the Chokrak river and is composed of the Zelena Mohyla, Belyky Tabir Ravine and other deposits. Their location is related to the ancient Chokrak fault orientated towards the north-west. The deposit consists of four large pegmatite veins with apophyses and a range of smaller ones.

Enclosing rocks are mainly migmatites of diorite composition, and in a smaller extent migmatites of granite composition. Migmatites stretch in the North-West direction with the azimuth of 345–360°. The dip is steep 78–86° directed westward, and in the western part of the deposit it is directed eastward. Migmatites are contorted into fine isosynclinal wrinkles that complicate a thick anticline fold. The largest pegmatite bodies are associated with the central part of the anticline. The pegmatites of the deposit stretch from North to South for 0.8-1.0km. They have both matched and transverse contacts, as well as a range of apophyses separating from the main veins in different directions. A small number of lesser veins have sub-lateral strike and gentle northward dip (15–20°). The length of the largest vein ranges between 60-190m being from 5-10m to 80-96m wide. The majority of veins are practically not zonary, the change of one structural feature by another is fixed as frequently irregular by dip and thickness.

Fig. 16. Yelyseyevskyi quarry for extracting pegmatite deposits of Zelena Mohyla (Green Tomb)

At some places there is accessory rare-soil-rare metal mineralization represented by columbite, tantalite, zircon, beryl, monazite and wolframite. The rock structure is mainly pegmatiod and granite, the texture is lens-shaped and striped. By mineral composition, pegmatites are microline-oligoclase, and much rarer – oligoclase-microcline, some bodies are albite-oligoclase-microcline. Mica is presented by biotite and muscovite.

4. *Ceramic pegmatites of the jointing of Balka Velykogo Taboru deposit (of the same-name quarry).* The deposit is located 2.5km to the West of Yeliseivka vil. in the interstream area between this ravine and the Chokrak river. It contains up to 80% of the proven resources of pegmatites in Ukraine. Within this jointing, three veins - #1, 11 and 12 – were explored in the same-name deposit between 1956 and 1958.

By mineral composition, pegmatites of the jointing are presented by plagioclase and plagioclase-microcline types. Among mafic minerals are biotite, muscovite, garnet, occasionally magnetite. Mass content of K_2O in the rock ranges within 1.53–3.74 % (average – 2.08 %), Na_2O – 5.20–7.45 % (average – 6.05 %).K_2O/Na_2O ratio is from 0.01:1 to 2:1. Feldspar along with quartz makes up up to 90% of the rock.

Pegmatite veins of “Balka Velykogo Taboru” deposit are mainly composed of pegmatites of indistinctly graphic (51.1%) and graphic (33%) structure. Pegmatites of pegmatiod, grain and block structure (1.1%) are less significant. Pegmatites of graphic structure, are usually pind and bright-pink rock mainly composed of microcline, and regularly grows in long quartz crystals (“ichthyoglypts”). Plagioclase is less frequent. The most typical composition of graphic pegmatite is: microcline – 50-75%;biotite+muscovite – from 0 to 3%; plagioclase – 3-15%; ore – up to 1%; quartz – 20-35%; minerals – up to 1%. Averagecompositionofpegmatiteofindistinctlygraphicstructureis: microcline - 20-50%; plagioclase - 10-40%; quartz - 20-40%; biotite+muscovite — 3%. Pegmatite of indistinctly graphic structure is mainly the product of recrystallization and albitization of graphic pegmatites.

5. *Outcrops of Obitochnenskyi diorites in an abandoned quarry on the right bank of the Obitochna river.* In ledge rocks on the pit walls, diorites of Obitochnenskyi complex crop out. Diorites are dark-green to dark-grey colour, middle- to coarse-grain, mainly massive. Mineral composition of diorites is: plagioclase - 40-60 %, hornblende-30-50 %, biotite - 1-7 %, quartzup to 3-5 %, clinopyroxene up to 5 %. Hornblende in the diorites has bluish-green colour. In the outcrops along the Obitochna river, the same diorites crop out, further along the route down the river, the diorites are changed by migmatites of Remivsky complex. Among the diorites, occasionally veins of pegmatites and aplites can be observed.

6. *Saltychanski granites on Kamiana Mohyla mount.* The outcrop is located at the extreme point of the mountain in a small quarry of oval shape about 100m in the length and width (Fig. 17). The height of the edge is up to 60m. On the microscopic scale they are light-grey, fine- and medium-grain granites. Mineral composition is the following: the main body is plagioclase (70-80%), quartz (10%), biotite (8%) and orthite (2%). The granites of the quarry are characterized by homogeneity and consistency of the texture and mineral composition. Sometimes, there occur xenolithes of basic rocks, occasionally adding the rock migmatite appearance. There occur thin aplite veins. The minerals surrounding orthite grain have apparently changed colouring because of orthite influence.

Fig. 17. Abandoned quarry on Mount Tomb Korsak.

Fig. 18 Korsak Mohyla geological monument (geosite)

7. *Ferruginous quartzite of Korsak-Mohyla (GeologicalLandmarks (geosites) ofUkraine, 2011; Manyuk, 2005, 2006, 2007).* The relief of Korsak-Mohyla is presented by two parallel belts of island-

mountains stretching in North-West direction and separated by a ravine. The western belt consists of 5 hills, the highest being 138.4m, while the eastern one has one hill 124.3m high, the surface around the hills is elevated at 90.0m. An abandoned quarry is located on top of the hill (Fig. 18), where rich iron ores were extracted at the beginning of the last century.

The belts are composed by rocks of Demianivska suite of Central Pryazovian series. The lower part of the suite is composed by barren indistinctly laminated quartzites with the thickness up to 40m with assises of biotite-pyroxene schists. The middle part is composed of the interchanging pyroxene-magnetite and magnetite quartz with fine-grain quartzites and characteristic bands of biotite-plagioclase and graphit-garnet-biotite-microcline gneisses. The upper part of the suite is composed of light-grey and greenish-grey, scaly, gneisses of different composition. For the whole section, multiple veins of microcline and plagioclase granites as well as general mineralization are characteristic.

8. *Nyziansky and tokmatski granites of Tokmak-Mohyla* in the vicinity of Novopoltavks vil. Tokmak-Mohyla or Synia Gora (*Blue Mount*) (Fig. 19, 20) is an island-mountain composed of granites of Nyzianska association of Late Archean with the ground level of 307.0m. The country rocks are gneisses and migmatites of Western Pryazovia series, charnokites and enderbites of Tokmatski complex. Nyzianski granites are leucocratic microcline granites. They are pink, leucocratic, inequigranular massif or slightly banded rock. Nyzianski granites together with Tokmakski enderbites at the foot of the hill are stripped in the Novopoltavski quarry located nearby.

Fig.19. Tokmak-Tomb or Synia Gora (Blue Mountain)

Fig. 20. Novopoltavsky quarry on the Blue Mountain

Conclusion. Western Pryazovia belongs to one of the most attractive regions for development of geotourism with high concentration of unique objects of geological heritage. it was determined that the most promising place for developing tourist routes is the outcrop of crystalline Precambrian rocks along the Berda river and in the surrounding territories. The outcrops represent a practically full section of rock associations of the Osypenivska Archean seria, which form Olhinska metabasite and steep-bank metasedimental suites; intrusive and ultrametamorphic formations which compose the Osypenivsky gabbro-diorite, the Shevchenkivsky plagiogranite-tonalite and the Saltychansky granite complexes. This small area includes places exposed to direct observation - deposits of gold (Surozke), rare metals (Kruta Balka), ceramic pegmatites (Mohyla Zelena and Velyky Tabir Ravine), iron (Korsak-Mohyla). These objects provide a full image of the structure of the crystalline structure of the West Pryazovia megastructure of the Ukrainian shield. The outcrops of the crystalline Precambrian rocks in Western Pryazovia, suggested as geotouristic objects have been identified and described. A small proportion of these objects are geological relics which have an official protection status and are included in the List of the Nature-Reserve Fund of Ukraine, other are promising geosites, whose inclusion in the list is an important task in the development of this fund and for the preservation of unique geological heritage for the future generations. We have formulated the main recommendations for preparation and activation of geotouristic routes in Ukraine. We have suggested and described the objects of geotourism in Western Pryazovia which can certainly be developed and activated in the near future.

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