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State Geological and Subsurface Survey of Ukraine

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FIELD TRIP GUIDEBOOK

2nd General Workshop and Field Trip

Kyiv – Dnipropetrovsk, Ukraine

May 19-25, 2013

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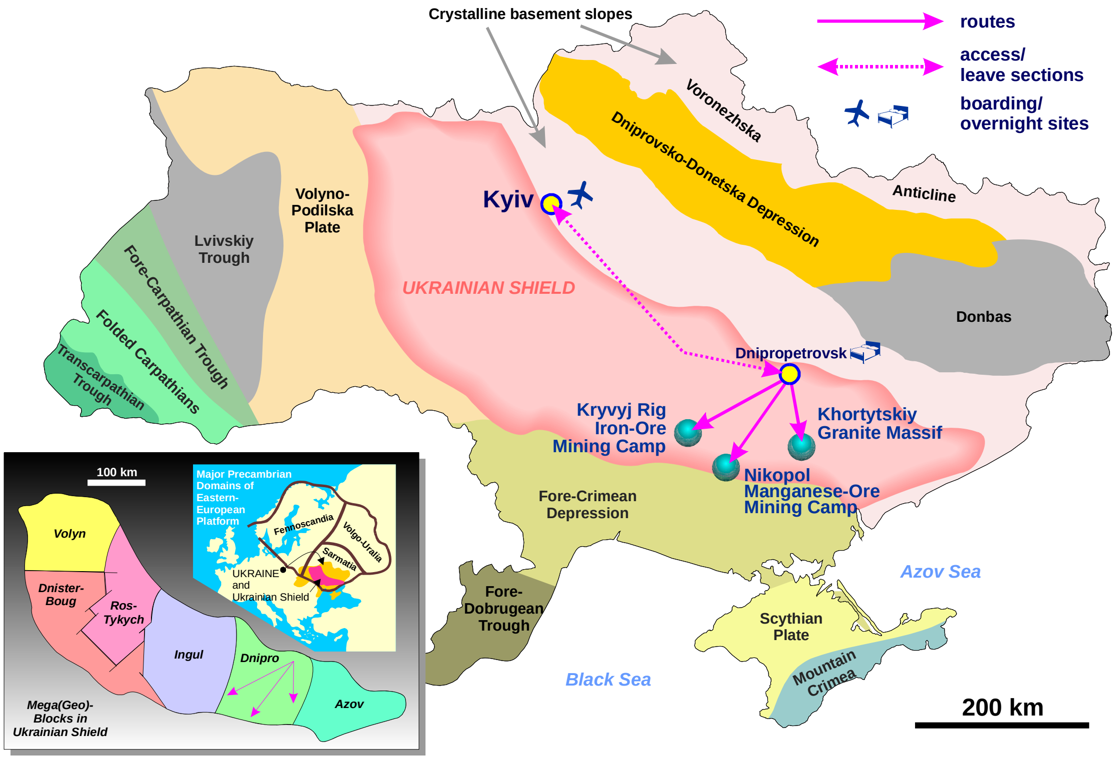
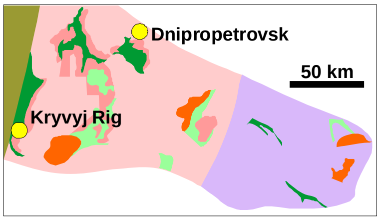
Location sketch



Geology and layout

Administrative sketch

Day 2, Tuesday, May 21, 2013



Object A. Kryvyj Rig Iron-Ore Mining Camp

Rough distance 300 km, estimated duration 9 hours.

Kryvyj Rig iron-ore mining camp is located in the central part of Ukrainian Shield. It is confined to Kryvorizka structure extended over 80 km in the longitudinal direction and developed at the boundary between two mega-blocks: Ingulskiy in the west and Middle-Dniprean in the east. These mega-blocks are separated by deep-seated Kryvorizko-Kremenchutskiy fault extended in the area from south-south-west to north-north-east.

Ingulskiy mega-block is composed of Paleo-Proterozoic rocks whereas Middle-Dniprean mega-block includes Paleo-Archean granitoids with superimposed Meso-Archean greenstone belts.

Kryvorizka structure comprises complex geological unit including Meso-Archean and Paleo-Proterozoic metavolcanogenic-sedimentary rocks as well as Cenozoic sediments. Stratified rocks are hosted by Paleo- and Meso-Archean granitoids (Fig. A.1, A.2).

Structure emerged in Meso-Archean due to Paleo-Archean proto-crust breaking by deep-seated faults and development of rifts separated by granite-gneiss domes (Fig. A.3).

Complex history of the area had caused complicated geology and various minerals associated. Most prominent feature is the **iron-ore mineralization** with a range of large deposits supplying operating mining-beneficiation plants. To date, 16 deposits with explored iron-ore reserves are in production (Fig. A.4).

In term of stratigraphy, the iron-ore deposits are confined to Saksaganska Suite of Kryvorizka Series. High-grade iron-ore bodies as well as ferruginous quartzite layers are also known in the lower part of Gdantsivska Suite.

Kryvyj Rig iron ores belong to metamorphogenic mineral type. Two classes are distinguished by iron content:

- low-grade iron ores with iron content from 15-20 to 46% which are commonly called "ferruginous quartzites";
- high-grade iron ores where iron content varies from 46 to 70%.

The **low-grade iron ores** by mineral composition and forming conditions are divided in two sub-classes: magnetite quartzites and hematite quartzites.

Magnetite quartzites are developed in the sheeted bodies within Saksaganska Suite ironiferous horizons of Kryvorizka Series. They are normally being exploited by open-cast method and processed by beneficiating units at five Kryvyj Rig mining-beneficiation plants supplying magnetite concentrate, agglomerate and pellets. About 30 mineral sub-types of these products are distinguished: magnetite, hematite-magnetite, carbonate-magnetite, carbonate-chlorite-magnetite, cummingtonite-magnetite, riebeckite-magnetite, etc.

Hematite quartzites are the products of magnetite quartzite supergene alteration where magnetite is replaced by martite, the iron carbonates and silicates – by disperse hematite ("hydro-hematite"), and quartz is preserved as the relic mineral. Hematite quartzites are developed in the upper (up to 20-100 m by depth) ironiferous horizons of Saksaganska Suite at the contact with Cenozoic sediments. These ores are not involved in mining operations so far and are considered to be the raw materials for Kryvorizkiy mining-beneficiation plant for oxidized ores (KMBPOO) under construction.

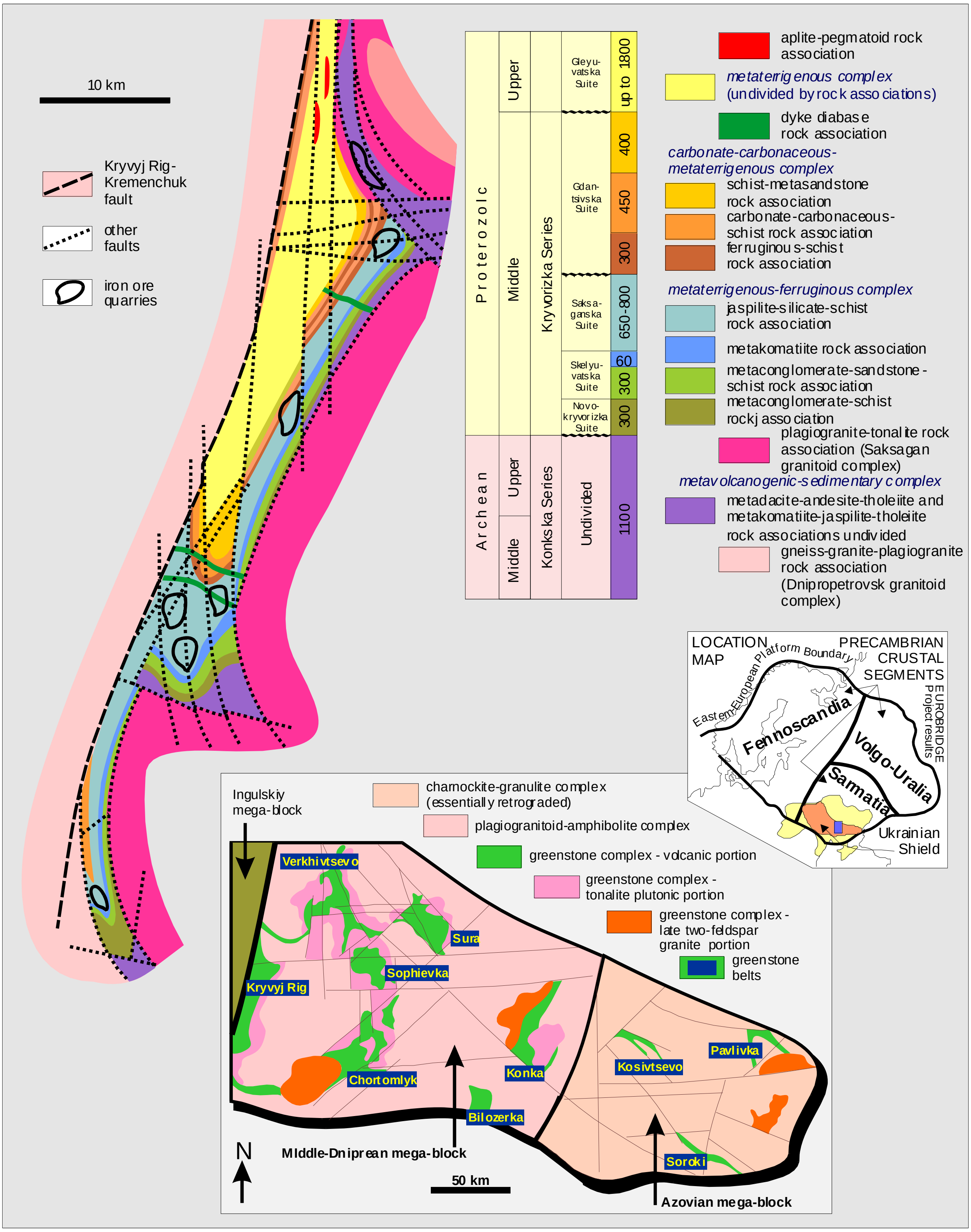


Fig. A.1. Main geological features of Kryvyj Rig structure and regional geology.

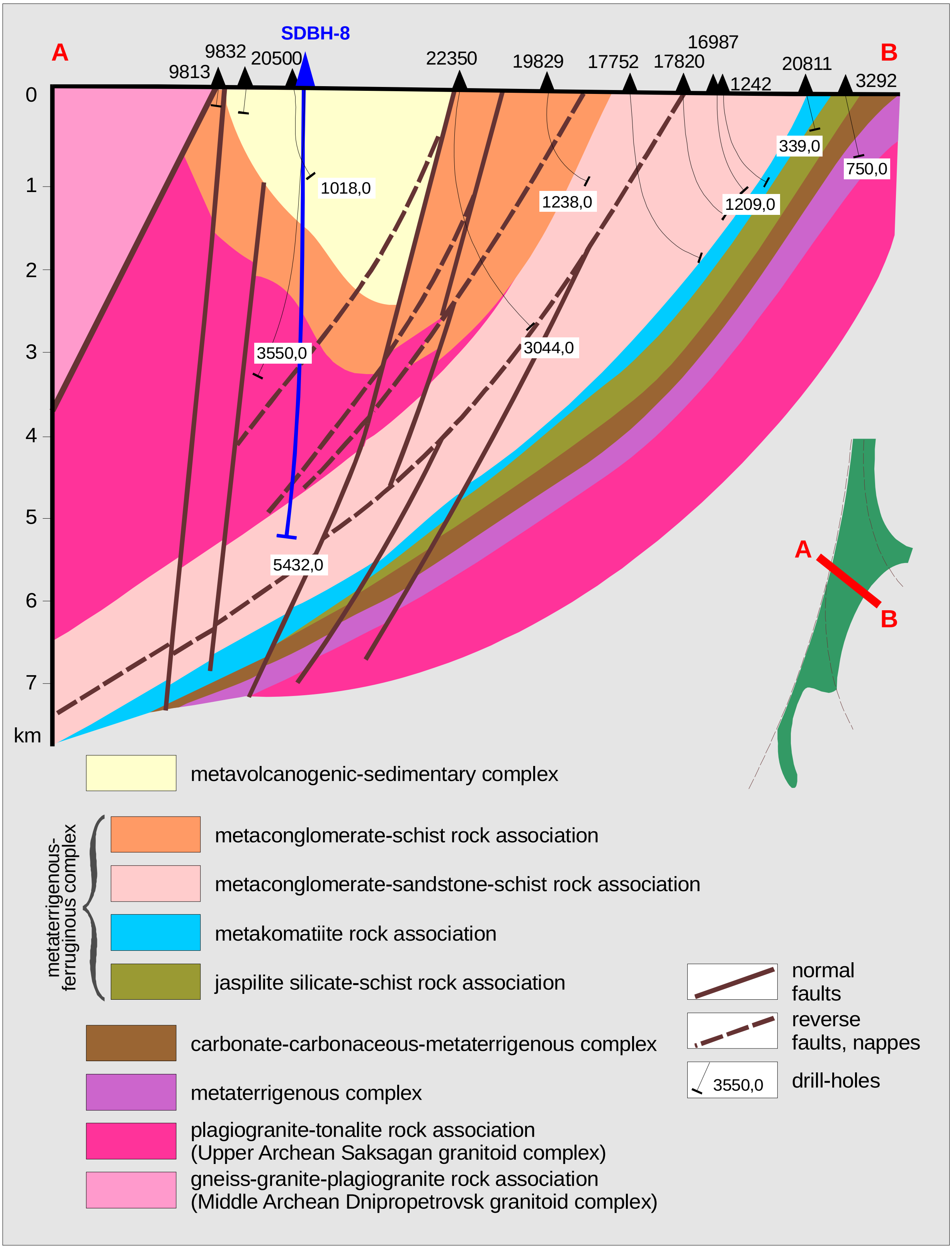


Fig. A.2. Geological cross-section across Kryvyj Rig structure.
SDBH-8 – Kryvyj Rig super-deep borehole.

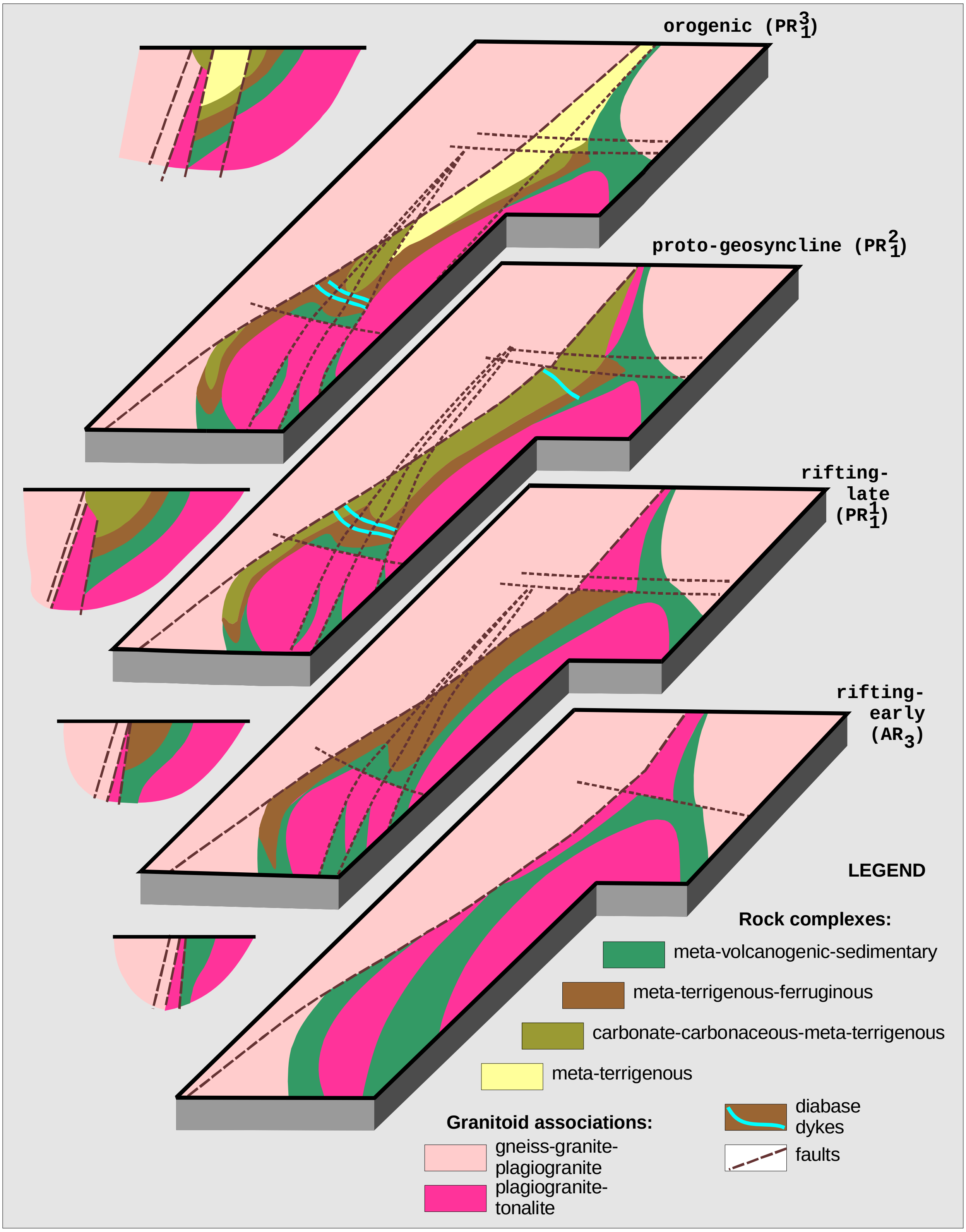


Fig. A.3. Apparent geodynamics of Kryvyj Rig structure (after I.Paranko, 2002).

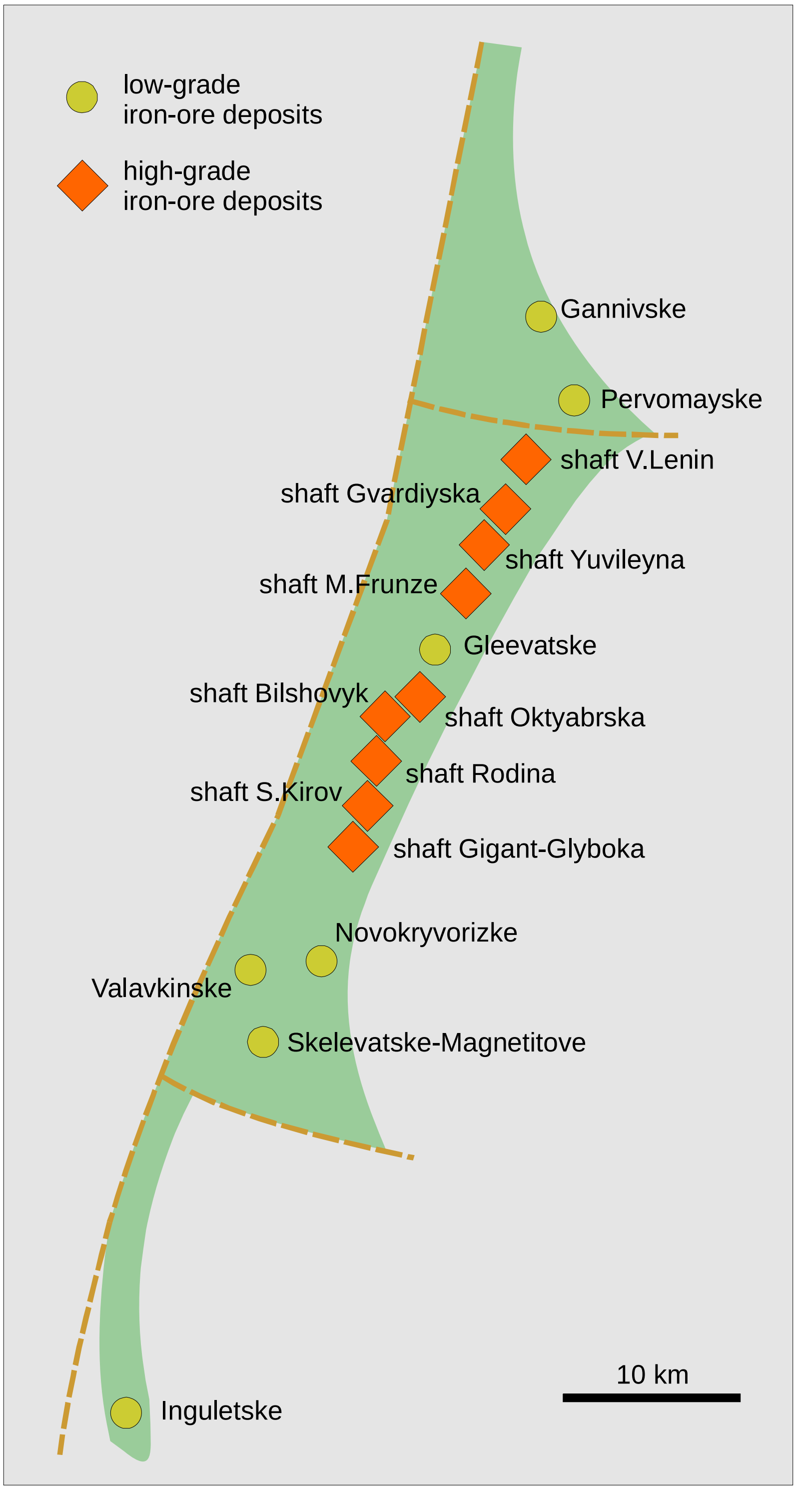


Fig. A.4. Kryvyj Rig iron-ore deposits.

The **high-grade iron ores** are most studied in the area. By mineral composition and forming conditions they are divided into three sub-classes:

- hydrogoethite-hematite (brown iron stones);
- essentially magnetite with silicates and carbonates;
- hematite.

High-grade iron ore reserves are estimated to the depth 1500 m to 1.6 billion tons, and low-grade magnetite ores – 32.0 billion tons.

Besides the iron-ore mineralization described above, the sedimentary rocks of Kryvorizkiy column and alteration products are associated with a range of concomitant minerals. Of metals these include scandium, vanadium, germanium, gold, zirconium, yttrium, REE, beryllium, lithium, platinum and PMG, tungsten, molybdenum, copper, titanium, nickel.

Major industrial and construction materials include talc, garnet, chlorite schist, muscovite, marble, granite, migmatite, amphibolite, diabase, low-grade ferruginous quartzites, feldspar, quartz, pyrite, pyrrhotite, sand, kaoline, clay, loam, limestone, mineral pigment, diverse varieties of gemstone, as well as radon and mineral waters.

In addition, the beneficiation plant wastes comprise valuable technogenic secondary raw materials.

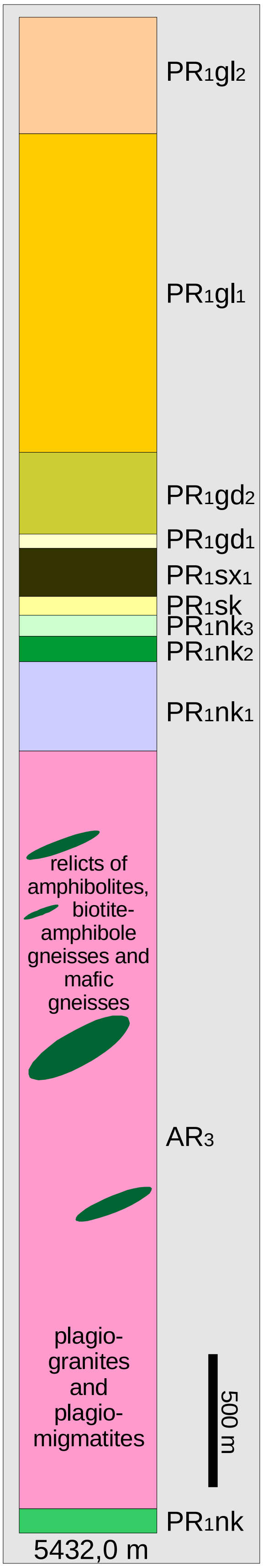


Fig. A.5. Generalized section of SDBH-8.

Kryvyj Rig area is also outstanding with regard to the super-deep bore-hole (SDBH-8, see Fig. A.2) which was drilled in the eastern part of Annivska syncline of the Kryvyj Rig Belt according to joint decision of the State Committee on Science and Technology, Ministry of Geology, and Academy of Sciences of the former Soviet Union in 1981 in the framework of Program 0.50.01 – "Studies of the Earth Interior and Super-Deep Drilling".

This is the deepest borehole in Ukrainian Shield and the third world drill-hole where Precambrian rocks encountered at great depth.

The purposes of the SDBH-8 were defined as follows:

- Receiving of additional and important data on Proterozoic and Archean iron-ore formations;
- Study of the deep structure of Kryvyj Rig – Kremenchuk suture zone and its relationships with surrounding granitoid and metamorphic complexes;
- Study of metamorphic zonation and metasomatism in relation to ore-forming processes;
- Establishing the nature of the seismic boundaries and complex rock properties;
- Solutions of regional problems of stratigraphy, tectonics and ore formation.

Assumed project depth of SDBH-8 was put as 12 km. In 1989 by decision of Ministry of Geology of USSR this amount was put down to 7 km. Actual attained depth is 5432 m and by decision of Ministry of Geology of Ukraine the drilling was stopped. Deviation angle at noted depth is about 8°, azimuth - 214°, temperature – 90°C; core yield during drilling – 85.9%, total length of obtained core – 3107.6 m, exact linear core fraction per drilled meter – 66.6%.

As a result of SDBH-8 activity it was established the complete intersection of symmetric Annivska syncline of Kryvyj Rig belt (see Fig. A.1-A.2), and cutting granitoid-migmatite complex of the Middle-Dniprean granite-greenstone terrain basement rocks. At the bottom SDDH-8 had entered the rocks of Novokryvorizka Suite (Fig. A.5) that mark the pinch of Saksaganska syncline which western limb is cut by the Tarapakivskiy and Saksaganskiy reverse faults.

In the Annivska syncline the section mainly represents Kryvorizka Series that starts with *Novokryvorizka Suite* (PR_1nk) consisting of three subdivisions.

Lower part (nk_1) is composed of amphibolites with quartz vesicles, quartzites, quartzite-sandstones, muscovite, andalusite-staurolite-muscovite, quartz-staurolite-muscovite and sillimanite-muscovite schists of sedimentary origin.

Middle part (nk_2) includes amphibolites (sometimes biotitized) with relic vesicular and ophitic textures and fragments of porphyry with pilotaxite texture, quartz-plagioclase metatuff-sandstones with biotite-amphibole cement.

Upper part (nk_3) consists of metatuff-aleuropelite quartz-plagiolase-hornblende-biotite schists with thin beds of metatuff-sandstones and metatuff-aleurolites.

Higher in the local stratigraphy SDBH-8 crossed the section of *Skelevatska Suite* (see Fig. A.1) that differs from the section in Saksaganska syncline (where it is three-fold) by lesser thickness and reduced composition being presented by the lower part only. It is composed of arkosic metatuff-sandstones and aleuropelitic graphite-muscovite-biotite schists of metaconglomerate-sandstone-schist rock association, and (in upper portion) of the carbonate-chlorite-talc and tremolite-chlorite-talc schist layer (upper metakomatiite association) with interbeds of metaaleurolite quartz-plfgioclase-actinolite-biotite schist (so called "talc horizon").

Upward in the section the rocks of *Saksaganska Suite* were encountered. This suite in the Annivska syncline is represented by the lower portion only composed of martite-magnetite, silicate-magnetite, martite quartzites as well as amphibole, garnet-chlorite-biotite, sericite-chlorite graphite-bearing schists. These rocks belong respectively to the first and second ferruginous and schist horizons.

The rocks of *Gdantsivska Suite* overlie above rocks. Two subdivisions are distinguished. The lower part (gd_1) is composed of fine-grained metaquartzite-sandstones, quartzites with interbeds of metapelitic graphite-andalusite-biotite schists and single layers of magnetite-silicate quartzites. The upper portion (gd_2) is in turn subdivided into three units:

- Lower – metaaleuropelite graphite-andalusite(staurolite)-biotite (sometimes two-mica) schists, metaaleurolitic graphite-biotite-plagioclase-quartz schists with interbeds of magnetite-silicate quartzites, calcite-dolomite marbles, quartz metasandstones (with carbonate cement);
- Middle – aleuropelitic graphite-biotite, graphite-garnet-biotite, graphite-actinolite-biotite schists and metaaleurolitic graphite-biotite-quartz-plagioclase schists;
- Upper – metaaleurolitic garnet-graphite-biotite-quartz-plagioclase and metaaleuropelitic garnet-graphite-biotite schists with interbeds of garnet-biotite-plagioclase-quartz metasandstones.

The section of Annivska syncline completes with *Gleevatska Suite* that unconformably overlie previously described rocks. This Suite is two-folded.

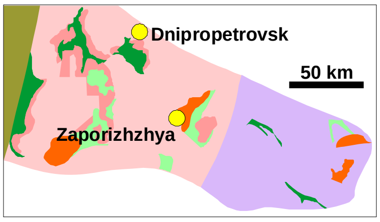
The lower sub-suite includes diverse metasandstones of biotite-quartz-plagioclase, garnet-biotite-quartz-plagioclase, actinolite-quartz-plagioclase composition in association with metaaleuritic schist of garnet-actinolite-biotite-quartz-plagioclase composition.

In the upper portion of lower sub-suite occur coarse-fragment rocks (polymictic metaconglomerates, garnet-actinolite-biotite-quartz-plagioclase metasandstones) in various associations with metaaleurolitic actinolite-biotite-quartz-plagioclase schists and interbeds of silicate marbles.

The upper sub-suite is composed of metaaleurolitic, metaaleuropelitic andalusite-garnet-biotite-plagioclase-quartz schists in association with garnet-biotite-quartz-plagioclase metasandstones.

The rock complex in the basement of Kryvyj Rig belt is also intersected by SDBH-8 (see Fig. A.2). It includes diverse granite-gneisses and migmatites with relicts of hornblende amphibolites, biotite-amphibole mafic gneisses and plagiogneisses that are assumed to be the members of the mafic gneiss-amphibolite stratified rock association, which is characteristic for the plagiogranitoid-amphibolite litho-tectonic complex in the basement of greenstone belts of the Ukrainian Shield.

Day 3, Wednesday, May 22, 2013



Object B. Khortytskiy Granite Massif

Rough distance 160 km, estimated duration 7 hours.

Of the granite vast variety developed in the Middle-Dniprean area, Khortytskiy granite massif seems to be most attractive because of the nice steep cliffs observed in the Dnipro River bank walls down the stream from DniproGES electric power station and dam. However, the general geology of the area is simple enough (Fig. B.1, B.2).

Fig. B.1. Khortytsya Island overview.

Surskiy Complex Neo-Archean plagiogranites are distinguished because of their active contact with the rocks of Bilozerska Series observed along the western limb of Konkska greenstone belt where 0.6-2.0 km wide band of these rocks is mapped over the distance of 12-13 km. The schists at the contact with plagiogranites are silicified and pyrytized. Apparently, essential part of the western limb of Konkska greenstone belt has been assimilated by plagiogranites during emplacement of Khortytskiy masssif. Plagiogranite microclinization under influence of Mokromoskovskiy Complex suggests for their older age. Thus, the time span of Khortytska plagiogranite association is within the range from 3100 Ma (Surskiy Complex) to 2835 Ma (Mokromoskovskiy Complex). Single isotope age determinations of zircons from Khortytsya Island plagiogranites (2970 Ma) also fall into this range. Genesis of plagiogranites is palingenic-anatectic (ultra-metamorphic).

The rocks of this association do form in the area the biggest in size Khortytskiy massif elongated in the south-eastern direction, 7.2-7.5 km long and from 1.2-1.4 to 3-6 km wide. The massif includes plagiogranites at Zaporizhzhya city outskirt, nearby the south-western limb of Konkska greenstone belt, to the south from Shcherbakivskiy massif and to the west from Novogorivska greenstone belt.

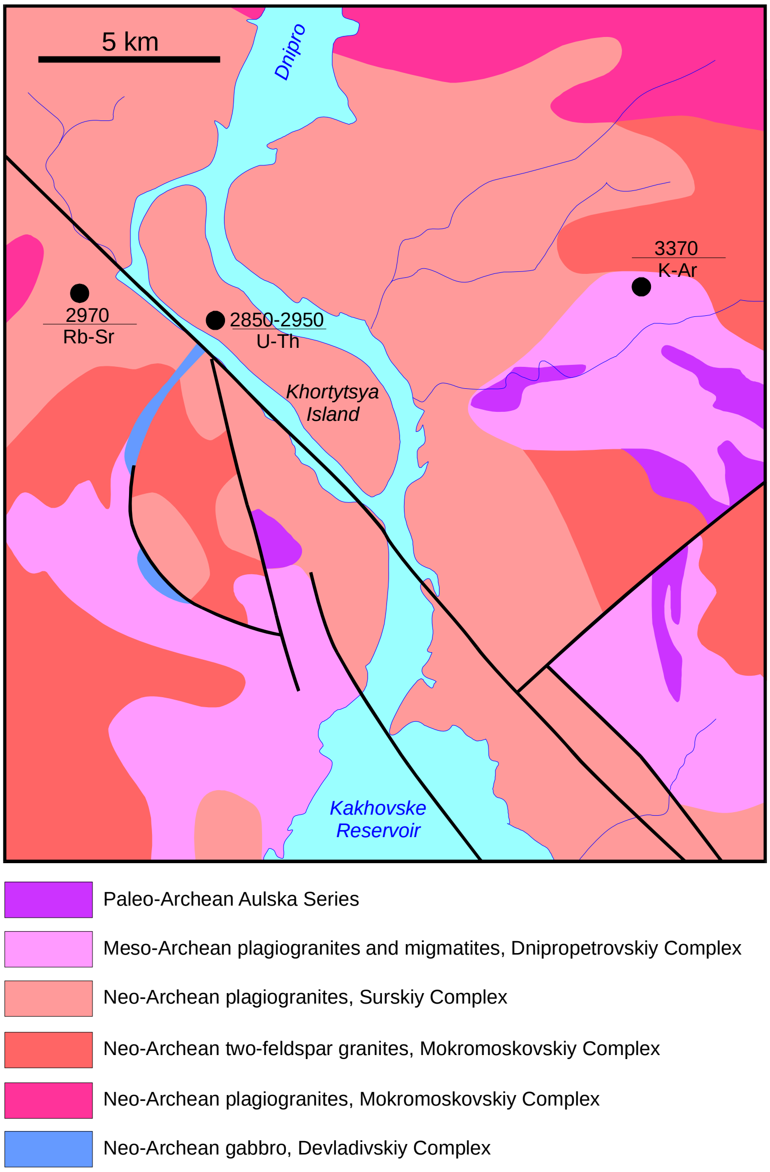
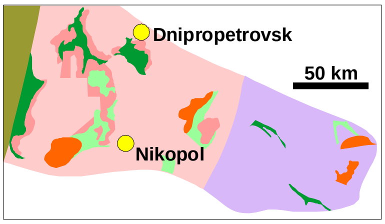


Fig. B.1. Geology around Khortytsya Island.

Composition of plagiogranites is typical. Biotite varieties predominate whereas amphibole-biotite ones are scarce. In the south-western limb of Konkska greenstone belt, in the zone of Khortytskiy fault, plagiogranites are extensive gneissed, cataclased and milonitized up to cataclasites and milonites while subsequent processes are resulted in blasto-tectonites. Cataclasis was accompanied by epidotization, chloritization, silicification and microclinization.

In the physical fields Khortytskiy massif coincides with negative magnetic field and reduced gravity field.

Day 4, Thursday, May 23, 2013



Object C. Nikopol Manganese-Ore Mining Camp

Rough distance 250 km, estimated duration 9 hours.

The manganese industry of Ukraine is supplied from Nikopol manganese-ore basin located in the territory of Dnipropetrovska, Khersonska and Zaporizka regions (oblasts).

In term of geography, the basin belongs to the northern slope of Fore-Black Sea lowland, mainly in the area between Ingulets and Molochna rivers, and is separated by Dnipro River in two parts: left-bank including Velyko-Tokmatske deposit and Skelkivskiy prospect, and right-bank including several manganese-ore fields: Marganetska (Eastern), Ordzhonikidzivska (Western), Inguletsko-Dniprovska and Inguletska (Fig. C1). In turn, these are divided into minor deposits and blocks.

The Eastern field consists of Maksymo-Tymoshivska, Grushivsko-Basanska, Komintern-Maryivska, Zakamenska, Novoselivska-2, Novomykolaivska and Yakivlivska, as well as Zakhidno-Sulytska, Pokrovska, Pivnichno-Zakhidna, Chkalovska, Chortomlytsko-Oleksiivska blocks. Except the first block, all others comprise the common ore body.

Inguletsko-Dniprovska field is divided into Fedorivske and Novovorontsivske deposits whereas Inguletska field – Novoselivska, Inguletska and Nikolozelska blocks.

The central portion of Nikopol basin is occupied by Kakhovske water reservoir.

Manganese ores are confined to Paleogene Oligocene sediments and located in the southern slope of Ukrainian Shield. In the northern and partly eastern parts these sediments overlie Precambrian rocks or their weathering crust, and in the southern part they occur above Eocene clays and marls.

Two factors have controlled development of Nikopol manganese-ore basin: ore deposition in the coastal marine environment along the southern slope of Ukrainian Shield and subsequent extensive erosion of manganese-ore layer which have limited in fact the ore distribution area, especially in the flanks.

The ore layers in the basin are irregular and include three ore types depending on the oxidation degree: oxide, carbonate and mixed ones.

Manganese-ore layer is composed of sand-clay rocks containing the ore in nodules, concretions, oolites, pisolites or friable clayey mass.

Most typical ore structures are nodular and concretion, rarely pisolite, oolite and friable. The main rock-forming minerals include psilomelane, pyrolusite and manganite.

The typical textures in carbonate ores are patchy with minor earthy, solid and cementation ones. The ores are composed of mangano-calcitic and calcitic rhodochrosite.

Amount of ore inclusions in the layer, their structure and mineral composition are irregular and vary both in vertical and horizontal directions. In the layer column one can observe from 3 to 10 beds of different lithology although normally 3-4 beds predominate.

In the zone of oxide ores the upper bed consists of patchy-earthy ore of manganite-psilomelane composition with minor pyrolusite in sand-clay rock. Thickness of the bed is 30-80 cm.

The middle bed is composed of patchy-concretion and pisolite ore of psilomelane-pyrolusite-manganite composition in sandy rock. Thickness of the bed is 40-60 cm.

The third bed consists of patchy-earthy ore composed of psilomelane and manganite or pyrolusite. Thickness of the bed is 04.-1.5 m.

The fourth, lowermost bed is developed throughout and composed of ore patches or pisolites in diverse-grained quartz sand. Thickness of the bed is up to 0.5 m.

In the sites of mixed ores, oxide varieties are normally developed in the upper part of ore-bearing layer whereas oxide-carbonate and carbonate ores are observed in the middle and bottom parts respectively.

Manganese ore reserves are estimated to 2.3 billion tons (about 770 Mt are in production).

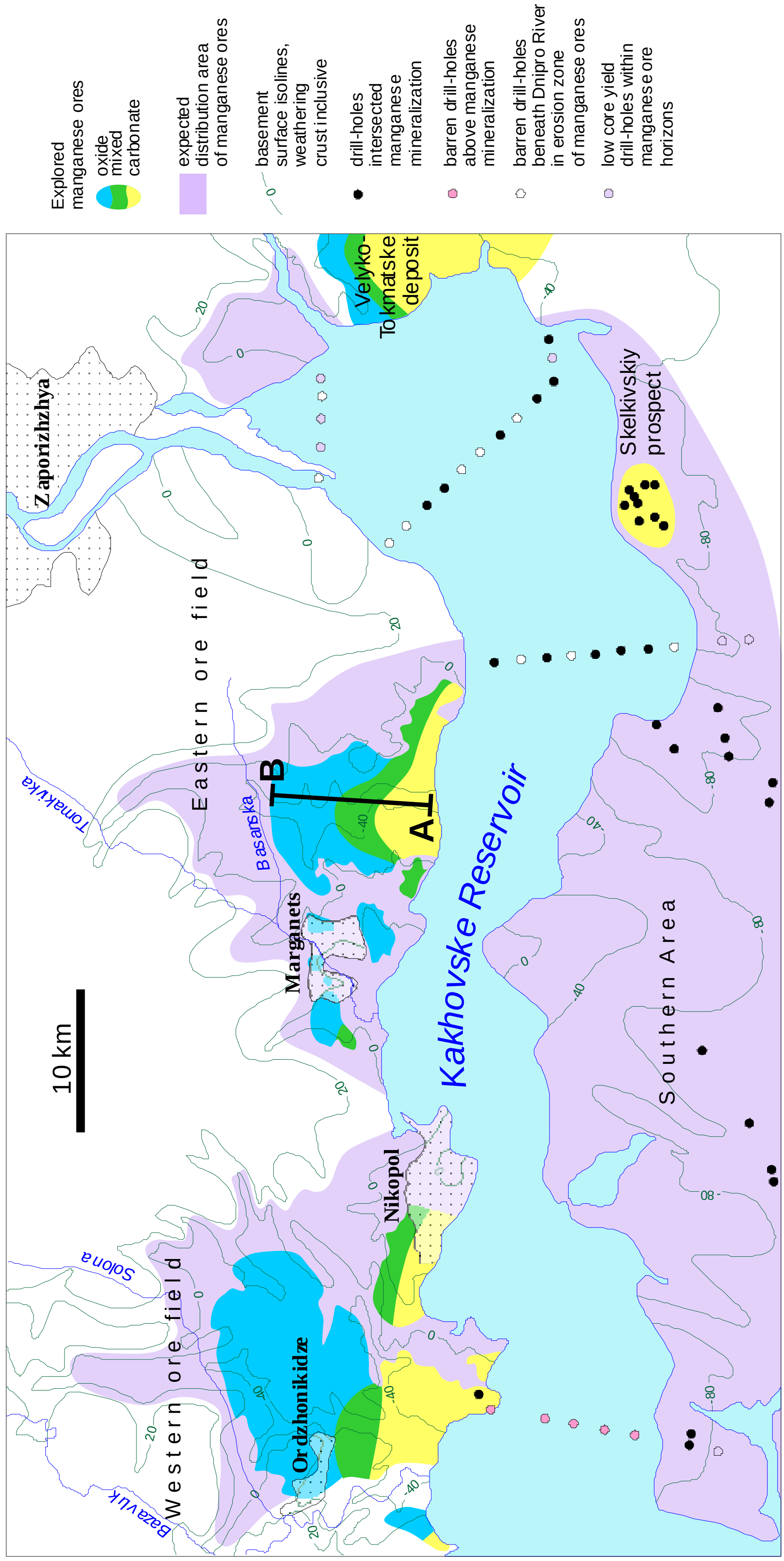


Fig. C.1. Nikopol manganese-ore camp.

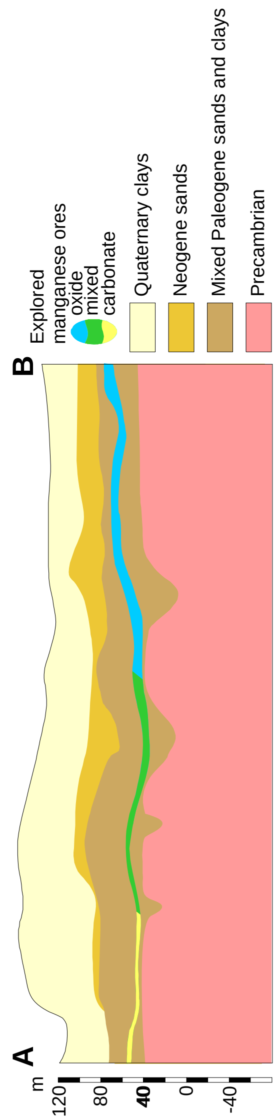


Fig. C.2. Geological cross section along line A-B.

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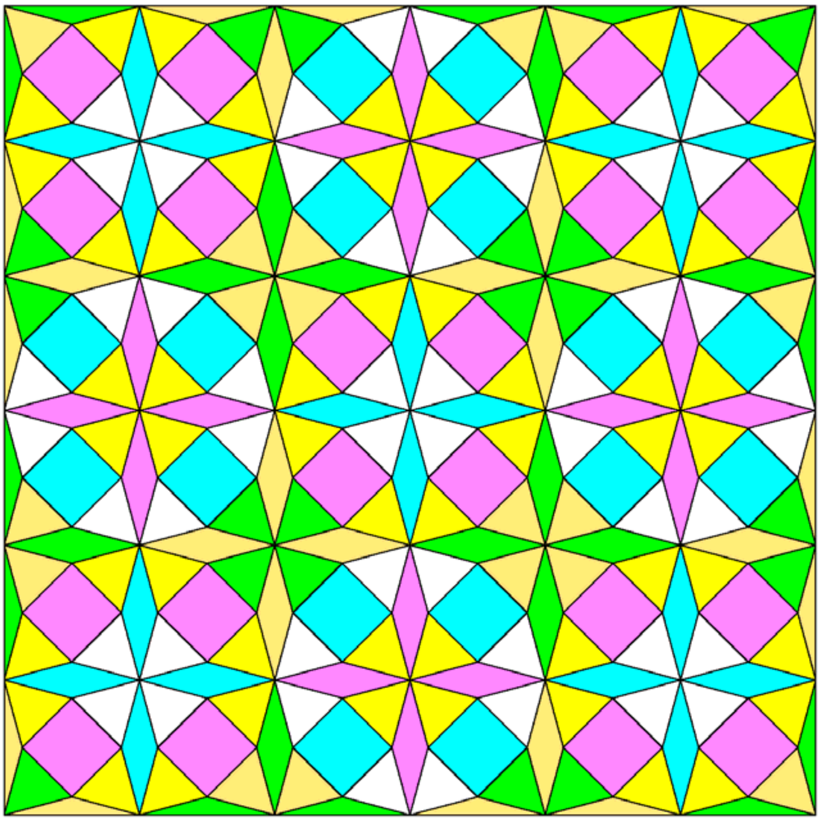

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