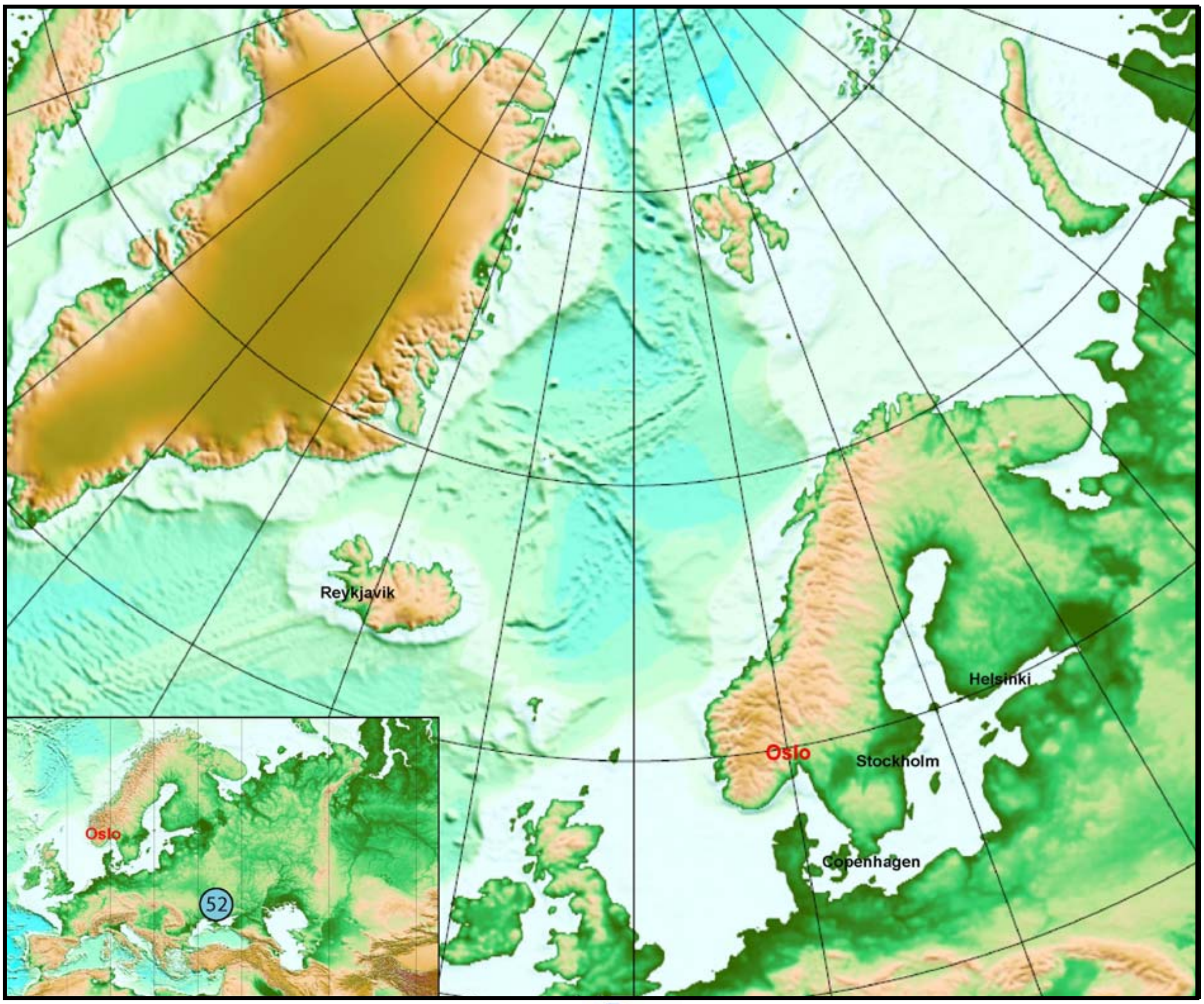
33 IGC excursion No 34, July 31 - August 6, 2008

33 IGC, The Nordic Countries

Geology, Radiological Age, and Metallogeny of Greenstone Complexes in the Ukrainian Shield

Organizers:
Alexander B.Bobrov & Boris I.Malyuk, Ukrainian State Geological Research Institute, Ukraine



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33rd International Geological Congress
Geological Excursions
Excursion No. 52
July 31 - August 6, 2008

1. Heading [and General Schedule]

Title: Geology, Radiological Age, Metallogeny of Greenstone Complexes in the Ukrainian Shield

Leader(s): Alexander B.Bobrov, Ukrainian State Geological Research Institute (UkrSGRI), al_bobrov@rambler.ru; Boris I.Malyuk, Ukrainian State Geological Research Institute (UkrSGRI), bmalyuk@hotmail.com

Start: Kyiv, Ukraine
End: Kyiv, Ukraine

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ASSOCIATED CONTRIBUTORS
Ministry of Environment Protection of Ukraine
Geoscience Department of National Academy of Science of Ukraine
Centre for Russian and Central EurAsian Mineral Studies (CERCAMS)

optional: [General Schedule]

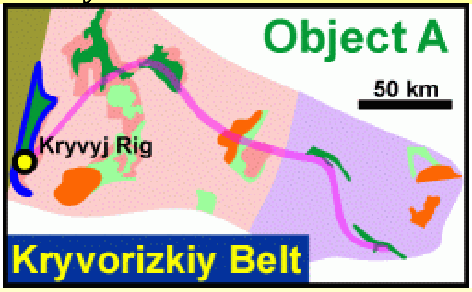
DAY 1. July 31, 2008, Thursday.

First-group participants arrival	07:30-12:30
Travel the first group to Kryvyj Rig (bus)	12:30-21:00
Second-group participants arrival	12:30-19:00
Second-group drive to Kyiv	19:00-20:00
Second-group short dinner	20:00-21:00
Travel the second group to Kryvyj Rig (train)	21:20-07:30
First group arrival & accommodation at Kryvyj Rig	21:00-22:00
First-group short dinner	22:00-23:00

Overnight: Kryvyj Rig / Train

DAY 2. August 1, 2008, Friday.

Breakfast in Kryvyj Rig	07:30-09:00
Drive to the Object A	09:00-09:45
Target A1	09:45-12:00
Drive to the lunch	12:00-12:30
Lunch	12:30-14:00
Target A2	14:00-15:30
Target A3	15:30-17:30
Drive to Kryvyj Rig	17:30-18:00
Refreshing time	18:00-19:00
Welcome dinner in Kryvyj Rig	19:00-23:00



Overnight: Kryvyj Rig

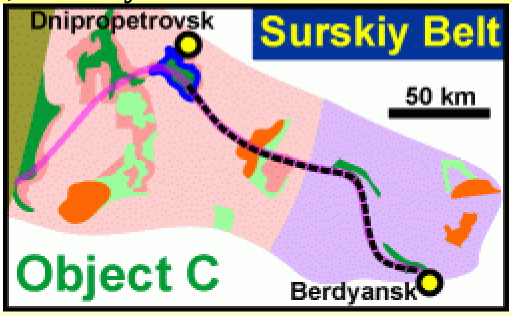
DAY 3. August 2, 2008, Saturday.

Breakfast in Kryvyj Rig	07:30-09:00
Drive to the Object B	09:00-11:00
Target B1	11:00-13:00
Lunch in the field	13:00-14:00
Target B2	14:00-15:00
Target B3	15:00-16:00
Drive to Dnipropetrovsk	16:00-18:00
Arrival & accommodation at Dnipropetrovsk	18:00-18:30
Refreshing time	18:30-19:30
Welcome dinner in Dnipropetrovsk	19:30-23:00

Overnight: Dnipropetrovsk

DAY 4. August 3, 2008, Sunday.

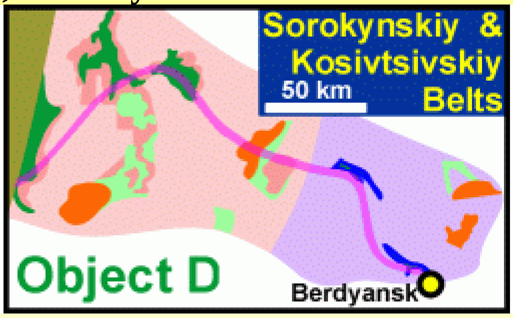
Breakfast in Dnipropetrovsk	07:30-09:00
Drive to the Object C	09:00-10:00
Target C1	10:00-11:30
Lunch in the paleo-volcano	11:30-12:30
Target C2	12:30-13:30
Target C3	13:30-15:00
Travel to Berdyansk	15:00-19:00
Arrival & accommodation at Berdyansk	19:00-19:30
Refreshing time	19:30-20:30
Welcome dinner in Berdyansk	20:30-23:00



Overnight: Berdyansk

DAY 5. August 4, 2008, Monday.

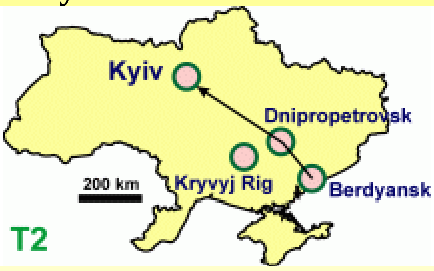
Breakfast in Berdyansk	07:30-09:00
Drive to the Object D	09:00-10:00
Target D1	10:00-13:00
Lunch in the field	13:00-14:00
Target D2	14:00-15:00
Target D3	15:00-16:00
Drive to Berdyansk	16:00-17:00
Refreshing time	17:00-19:00
Resuming dinner in Berdyansk	19:00-23:00



Overnight: Berdyansk

DAY 6. August 5, 2008, Tuesday.

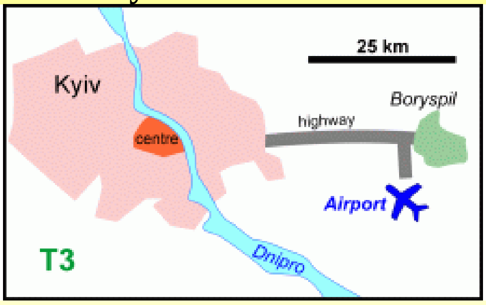
Breakfast in Berdyansk	07:30-09:00
Final check-in	09:00-09:30
Travel to Kyiv	09:30-13:00
Lunch [on stop]	13:00-14:00
Continue travel to Kyiv	14:00-19:00
Arrival and accommodation at Boryspil airport	19:00-19:30
Refreshing time	19:30-20:30
Final dinner	20:30-23:00



Overnight: Kyiv

DAY 7. August 6, 2008, Wednesday.

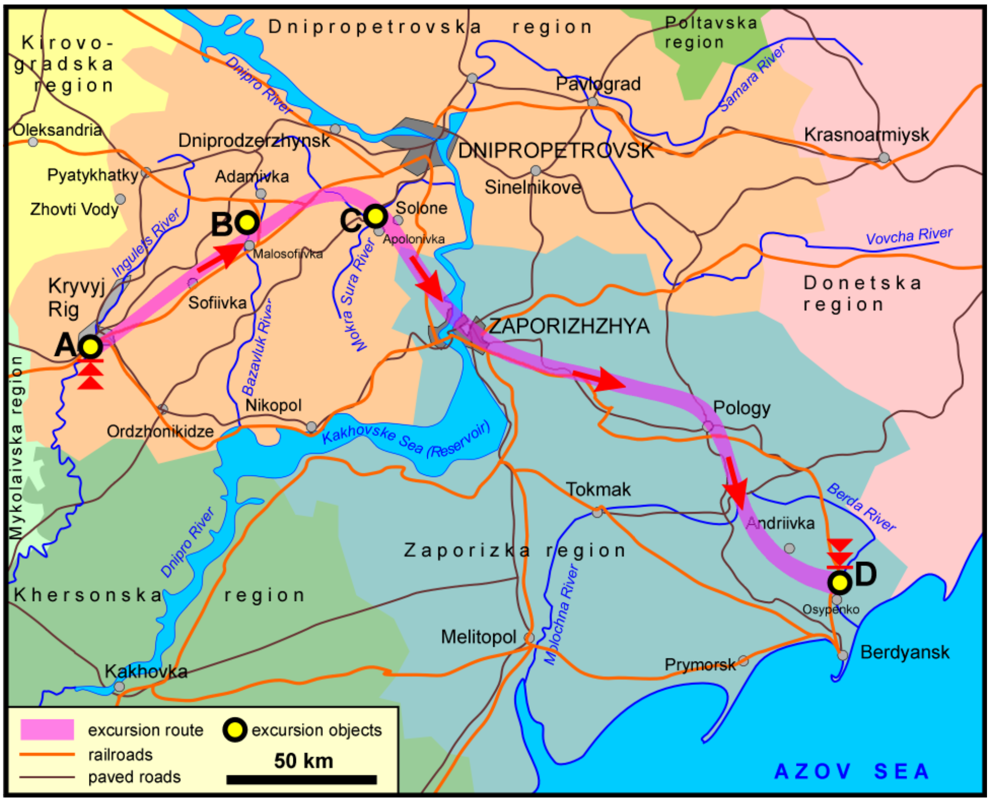
Breakfast in Kyiv	**:**-06:00
Departure to Oslo	06:55-08:00



Overnight: Oslo / on request

optional: [Supplementary Information]

Kyiv Airport “Boryspil”



Excursion Administrative Map

optional: [Local Organizing Committee]

Chairman

Sergiy V.Goshovskiy	Ukrainian State Geological Research Institute (UkrSGRI), Kyiv

Vice-Chairman, Excursion Leader

Alexander B.Bobrov	Ukrainian State Geological Research Institute (UkrSGRI), Kyiv

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Mykola V.Foshchiy	State Treasure Enterprise "Pivdenukrgeologia", Dnipropetrovsk
Mykola A.Kozar	State Treasure Enterprise "Pivdenukrgeologia", Dnipropetrovsk
Leonid V.Isakov	Ukrainian State Geological Research Institute (UkrSGRI), Dnipropetrovsk Branch

2. Introduction and purpose

The Ukrainian Shield, as the principal constituent of the Sarmatia, comprises the south-western counterpart in the triad of crustal segments that constitute the oldest basement of the Eastern-European Platform (Fig. 2-1).

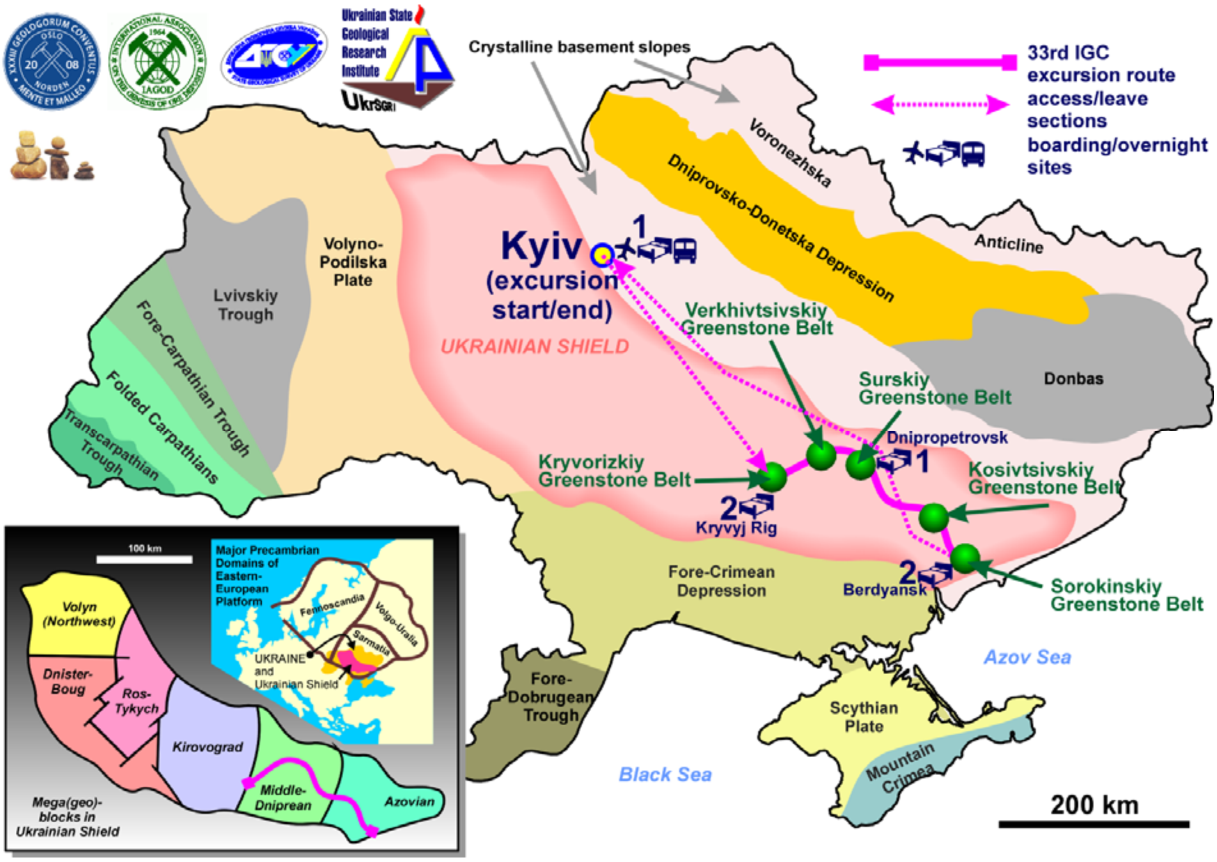


Fig. 2-1. General overview and layout.

Excursion is devoted to the principal features of geology, geochronology and metallogeny of greenstone belts developed in the eastern part of Ukrainian Shield. This is a key region in the understanding of the Archean and Proterozoic history of the Shield. Besides, and it is also the major mineral producing region of Ukraine accounting for the gross-country output of the iron and manganese ores, uranium, mineral sands, and the principal region of mineral prospecting and exploration for gold, copper, nickel, molybdenum, rare metals, rare earths, and diamonds.

The length of the excursion, net of access and leave sections, is about 350 km and within the four full-working days the route will cross two Mega-Blocks of the Shield – Middle-Dniprean tonalite-greenstone and Azovian granulite-greenstone (Fig. 2-1). In view of the excursion goals, the major attention will be paid to the greenstone rock complexes providing most information on the Archean and Proterozoic magmatism, sedimentation, tectonics and mineralization in the time span 3.2-2.1 Ga, while the rocks developed in the greenstone basement (various granite-gneisses, migmatites etc.) will be briefly examined in conjunction with the issues of geochronology.

3. Regional Geology

Historically Ukrainian Shield is divided in six Mega-Blocks or Geo-Blocks (Fig. 3-1), from west to east: Volyn (Northwest), Dnister-Boug, Ros-Tykych, Kirovograd, Middle-Dniprean and Azovian.

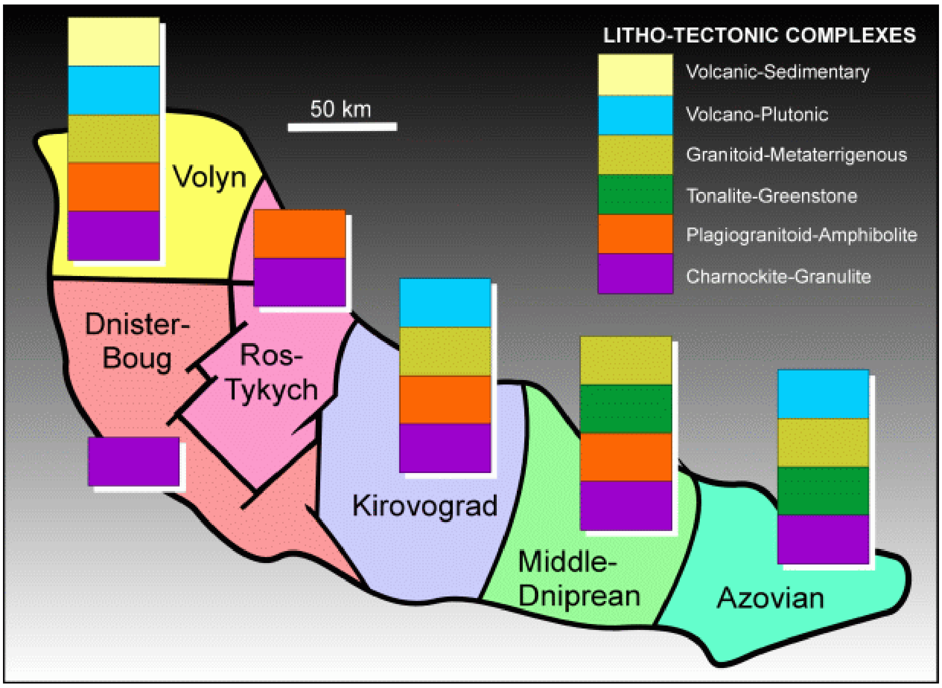


Fig. 3-1. Mega-Blocks of Ukrainian Shield and distribution of their constituent litho-tectonic complexes in simplified vertical columns

At the best of present knowledge, six litho-tectonic complexes (LTC) of different age are distinguished in the Shield. Each one displays the distinct composition, internal regularities and tectonic framework, as well as the variable distribution over the Mega-Blocks (see Fig. 3-1) reflecting diverse crustal evolution trends and events.

Each LTC includes some range of the rock associations that differ in genetic respect: primary-stratified, plutono-metamorphic, plutonic, meta-sedimentary-volcanogenic, meta-terrigenous. Their forming conditions actually define the main patterns of the Mega-Blocks including tectonic framework, metamorphic fabric, and spatial heterogeneity.

The LTC combinations and their specific representatives are variable in different Mega-Blocks. The Mega-Blocks do have their analogues in other shields all around the world and can be grouped into the following four types: charnockite-granulite, plagiogranitoid-amphibolite, granite-greenstone and granitoid-metasedimentary. Likewise the other regions, in the Ukrainian Shield the Mega-Blocks comprise the large segments of Precambrian crust individualized at the certain stages of geological history and thus, they comprise the distinct geodynamic systems with the specific history of development, composition, tectonics, and metallogeny.

The rocks of the oldest charnockite-granulite LTC are developed in all Mega-Blocks but mainly they are known in the Dnister-Boug, Middle-Dniprean and Azovian ones (see Fig. 3-1) where the stratigraphic columns differ depending on preservation extent of the rock associations in vertical sections of the Mega-Blocks, on the variations of PT-conditions and the scale of subsequent transformations (metamorphism, ultra-metamorphism, retrograde metamorphism).

Plagiogranitoid-amphibolite LTC is restricted to the Ros-Tykych and Middle-Dniprean Mega-Blocks (see Fig. S-1) and is observed in a number of minor enclaves within the Northwest Mega-Block and the western part of Kirovograd (Ingul-Ingulets) Mega-Block.

The tonalite-greenstone LTC comprises the major scope of the excursion No. 52. It is distributed in the units of two types: the Middle-Dniprean granite-greenstone terrain and Azovian granulite-greenstone terrain (Fig. 0-3). Respective complexes mainly follow the geographic names - Middle-Dniprean and Kosyvtsivsko-Sorokynskiy complexes.

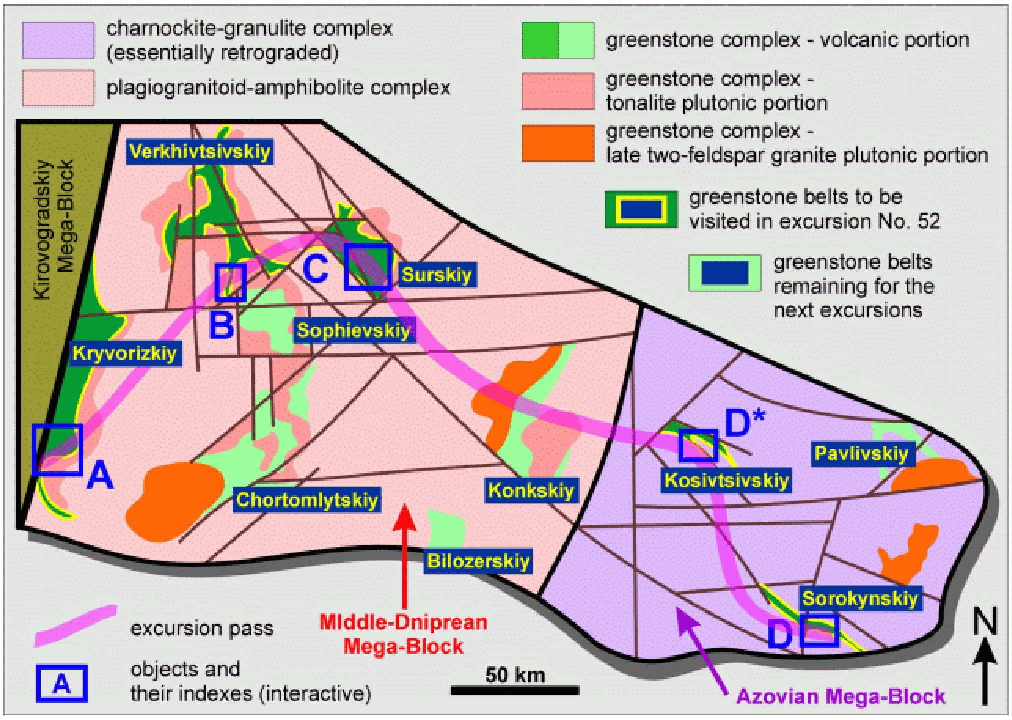


Fig. 3-2. Regional geological frame of the excursion

The column of tonalite-greenstone LTC in the Middle-Dniprean region includes spatially combined essentially volcanogenic (lower) and essentially terrigenous (upper) litho-tectonic levels confined to the greenstone belts. It should be noted however that the terrigenous sequences capping greenstone belts actually belong to the next LTC – granitoid-metaterrigenous.

In the lower volcanogenic portion the distinct volcano-plutonic rock associations (VPA [Bobrov, 1994]) are commonly developed including their volcanic and plutonic counterparts, that is, the rocks of similar composition and age but different facial affinity. In the column these VPA are observed in the single geological bodies providing the basis for their detailed subdivision into the suites and sub-suites. The rocks of VPA display the common greenstone belt major-element patterns and igneous series (Fig. 3-3). Petrology and petrogenesis of these series are described elsewhere [Malyuk, 1986; Zolotukhin, Malyuk, 2001].

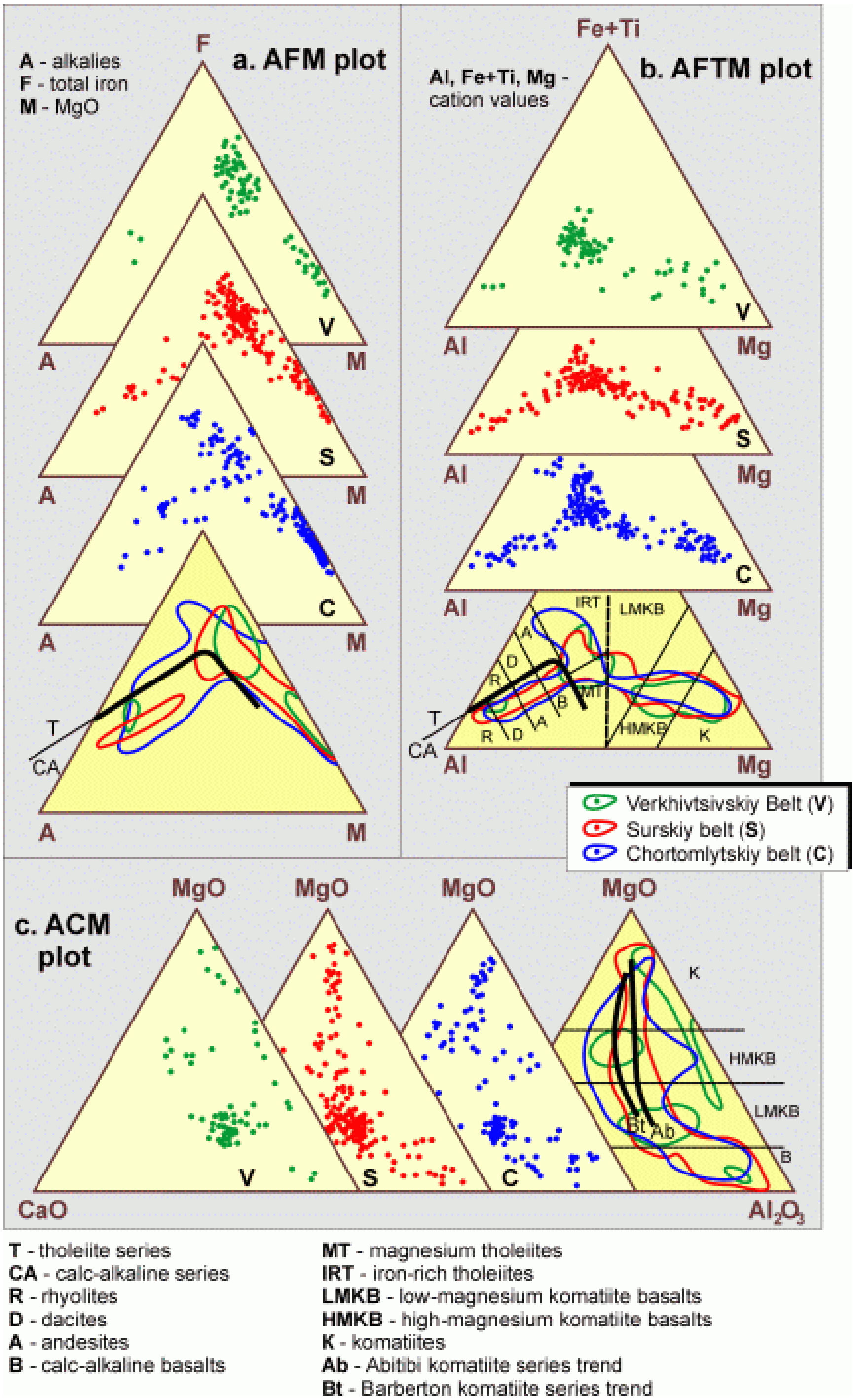
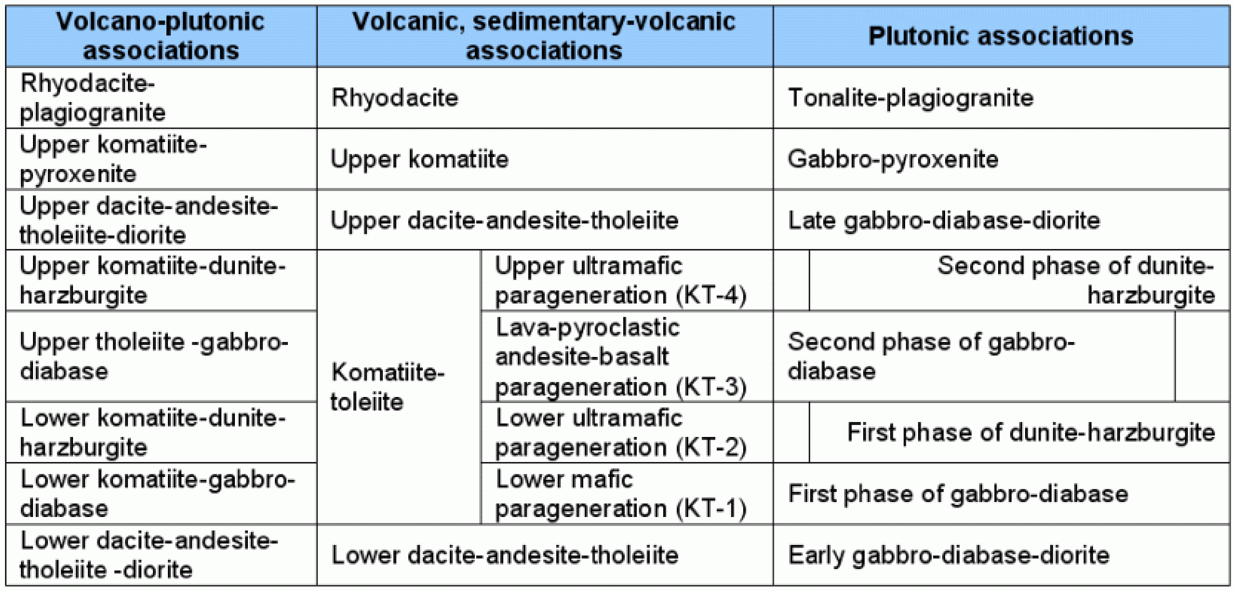


Fig. 3-3. Igneous series and rock major-element geochemistry of tonalite-greenstone complex

Notable characteristic feature of the complex is metamorphism of zoned patterns, from greenschist to epidote-amphibolite, rarely amphibolite facies. In the description below the prefix "meta" is eliminated for simplicity.

In the most details this LTC is studied in Surskiy Belt. The sequence is composed of stratified rock associations of four types: dacite-andesite-tholeiite, komatiite-tholeiite, jaspilite-tholeiite, and rhyolite-dacite (Table 3-1).

Table 3-1. Rock associations in tonalite-greenstone LTC



Volcano-plutonic associations	Volcanic, sedimentary-volcanic associations		Plutonic associations
Rhyodacite-plagiogranite	Rhyodacite		Tonalite-plagiogranite
Upper komatiite-pyroxenite	Upper komatiite		Gabbro-pyroxenite
Upper dacite-andesite-tholeiite-diorite	Upper dacite-andesite-tholeiite		Late gabbro-diabase-diorite
Upper komatiite-dunite-harzburgite	Komatiite-toleiite	Upper ultramafic parageneration (KT-4)	Second phase of dunite-harzburgite
Upper tholeiite -gabbro-diabase		Lava-pyroclastic andesite-basalt parageneration (KT-3)	Second phase of gabbro-diabase
Lower komatiite-dunite-harzburgite		Lower ultramafic parageneration (KT-2)	First phase of dunite-harzburgite
Lower komatiite-gabbro-diabase		Lower mafic parageneration (KT-1)	First phase of gabbro-diabase
Lower dacite-andesite-tholeiite -diorite	Lower dacite-andesite-tholeiite		Early gabbro-diabase-diorite

In the different greenstone belts, each type is comprised of the local varieties and specific associations from the bottom to top are as follows [Bobrov, 1994].

Lower dacite-andesite-tholeiite-diorite VPA includes volcanic lower dacite-andesite-tholeiite and plutonic early gabbro-diabase-diorite associations.

The next major ("basal" by its nature) and most typical komatiite-tholeiite VPA is widely distributed in all greenstone belts attaining thickness of about 5-6 km and more in places. Detailed studies have revealed its four-component structure (see Table 1) defined by concentration of its principal members (tholeiite and komatiite basalts, pyroxenite and peridotite komatiites), in certain parts. As the result, four paragenerations are distinguished: essentially mafic KT-1, essentially ultramafic KT-2 (lower), andesite-basalt lava-pyroclastic KT-3 and essentially ultramafic KT-4 (upper). Taking into account the spatially and genetically linked plutonic rocks these paragenerations are supposed to be the members of respective VPAs: lower tholeiite-gabbro-diabase (volcanic parageneration KT-1 of komatiite-tholeiite association + first-phase sub-volcanic rocks of gabbro-diabase plutonic association); lower komatiite-dunite-harzburgite (volcanic parageneration KT-2 of komatiite-tholeiite association + sub-volcanic rocks of dunite-harzburgite plutonic association); upper tholeiite-gabbro-diabase (volcanic parageneration KT-3 of komatiite-tholeiite association + second-phase sub-volcanic rocks of gabbro-diabase plutonic association), and upper tholeiite-gabbro-diabase (volcanic parageneration KT-4 of komatiite-tholeiite association + second-phase sub-volcanic rocks of dunite-harzburgite plutonic association).

In most greenstone belts the komatiite-tholeiite associations are litho-facially (that is, sideward or by lateral) substituted by the formations of jaspilite-tholeiite type (for example, schist-jaspilite-tholeiite). Besides the mafic and ultramafic extrusives, these associations also include diverse tuff-sandstones, tuff-aleurolites, argillites, and quartzites including magnetite ones.

Further the column is conformably stacked up with the *upper dacite-andesite-tholeiite-diorite VPA*. Contrasted types of the rocks paragenesis and broad development of pyroclastic facies are characteristic to this VPA. One or two cycles consisting of two paragenerations can be distinguished in different belts. In these cycles, the lower parageneration is composed of tholeiite and andesite paragenesises with predomination of the former. Contrasted volcanic paragenesises of mainly basic and felsic composition participate in the upper parageneration of these cycles.

The following, *upper komatiite-pyroxenite VPA* includes volcanogenic upper komatiite and plutonic gabbro-pyroxenite associations. Two different parts are distinguished in the stratified komatiite portion: the lower essentially volcanogenic (composed of pyroxenite komatiite stratified flows in association with basalts) and the upper essentially chemogenic-sedimentary part [Bobrov, 1993a].

The column of greenstone belt is completed with *rhyodacite-plagiogranite VPA* comprised of volcanogenic rhyodacite and comagmatic sub-volcanic to plutonic tonalite-plagiogranite associations [Bobrov, 1993a-c; Bobrov, 1994]. It is assumed that the role of this VPA is unique in view of its fairly significant structure-forming and metallogenic contribution. In greenstone belts, the areas of this VPA development are characterized by emerging high-order folds, by combination of the fold-fault deformations with synchronous rock and ore metasomatic transformations under the effect of fluid systems discharge from the felsic melts on their crystallization. Apparently it was the thermal and metasomatic influence that provided the major control in remobilization of the ore components from surrounding mafic-ultramafic associations and metal re-deposition with a trend to the enrichment under new litho-tectonic conditions. As a result, a number of gold-ore objects like Sergiivske, Balka Zolota, Balka Shiroka deposits had been formed in the greenstone belts [Bobrov, 1994].

Radiological age of rhyodacite-plagiogranite VPA is 3.0-3.2 Ga [Artemenko, 1998] in the Middle-Dniprean Mega-Block and 3.3 Ga in the Azovian Mega-Block [Artemenko, 1998; Shcherbak, 1986].

It is notably that Azovian Mega-Block differs in the reduced rate of the stratified column. Over there, the tonalite-greenstone LTC includes only komatiite-tholeiite and rhyodacite associations and their sub-volcanic (plutonic) equivalents (see Table 3-1).

Considering the regularities of generalized column of tonalite-greenstone LTC, it can be noted the established [Bobrov, 1994] antidromic drift in the rock composition changes over the column expressed in the gradual upward mafic-mode increasing in KT associations. In other words, each parageneration is more felsic at the bottom as compared to the top. However, this drift is observed on the background of general homodromic trend in the given association that becomes less and less mafic upward. For instance, essentially mafic parageneration KT-3 is more "felsic" in comparison to similar mafic KT-1 unit (appeared below in the column), and ultramafic KT-4 parageneration is also more "felsic" being compared to the similar KT-2 unit. Mentioned drifts also can be traced over the whole column. In the mafic-ultramafic KT association the upper unit KT-4 is actually least "mafic"; clearly less mafic dacite-andesite-tholeiite association is further followed by more mafic KT unit. The trend is completed with appearance of essentially felsic rhyodacite association, the last association in the greenstone development. Therefore, on the background of general evolution line KT → DAT → K → RD, three local reverse "antidromic" transitions can be outlined as follows:

1. mafic KT-1 → ultramafic KT-2;
2. andesite-basalt KT-3 → ultramafic KT-4;
3. felsic-intermediate-mafic DAT → ultramafic K.

Studies of the paleo-volcanic conditions [Bobrov, 1994] had shown that the initial stages of lava eruptions in the greenstone belts occurred through the numerous fractures along the parent zones of deep-seated faults. Linearity and considerable extension of the feeding fractures in the period of KT formation provided consistency in the volcanic facial composition and their symmetric-zoned distribution relative to the axial fault lines. Periodic ceasing of volcanic activity accompanied by synchronous development of distinct tuffogenic- and chemogenic-sedimentary piles took place during formation of these associations. Further accumulation of the dacite-andesite-tholeiite and komatiite associations occurred in around the central-type volcanic structures emerged because of the gradual sealing over the fracture channels of the previous stages. Rhyodacite association, which completes the development stage of volcanogenic part of the greenstone belts, was formed under conditions of combined-type volcanic activity.

Metallogenic features of the tonalite-greenstone LTC are defined, on the one hand, by diverse ore deposits syngenetic to particular VPA (iron ores, sulphide and silicate nickel in the weathering crusts) and, on the other hand, by ore mineralization formed due to the re-activating influence of rhyodacite-plagiogranite VPA with the subsequent superposition of epigenetic mineralization over greenstone sequences (rare-metal pegmatites, gold- and molybdenum-ore objects, uranium, etc.).

Granitoid-metasedimentary LTC, in contrast to the previous ones, displays the zoned metamorphic patterns (from granulite to greenschist facies), predomination of primary-sedimentary stratified associations, two-feldspar granitoids in plutonic associations and local occurrence of plutono-metamorphic associations.

Granitoid-metasedimentary LTC overlies three previously described complexes with clear discontinuity. Involved rock associations are extremely heterogeneous laterally and are mainly observed in two geological situations, which allow distinguishing the siliceous and carbonaceous-gneissic types.

The first type is developed in the territory of Middle-Dniprean and Azovian Mega-Blocks (see Fig. 3-2) and consists of primary-sedimentary stratified associations actually lacking of ultra-metamorphic reworking (Kryvorizkiy, Bilozerskiy and Gulyaipole-Osypenkivskiy complexes). The second complex type is encountered in the Volyn (Northwest) and Kirovograd (Ingul-Ingulets) Mega-Blocks (Teterivskiy and Ingulo-Inguletskiy complexes respectively) and somewhere display the extensive ultra-metamorphic transformations of the stratified associations.

The grouping of these associations into a single LTC is under discussion; this concerns not only the two distinguished main types but also the correlation or comparison of the Kryvorizkiy and Bilozerskiy columns.

The isotope age of the first type rocks, according to data available (meta-rhyodacites of the Bilozerskiy Belt) is 3.0 Ga [Artemenko, 1998] and that of mafic rocks from Kryvorizka Series is 2.4 Ga. Gneisses and amphibolites of the Teterivskiy and Ingul-Inguletskiy types are exceptionally related to Paleo-Proterozoic.

Plutonic and volcano-plutonic LTC is characterized by voluminous plutonic associations formed in the same time spans of stratified units. These features allow distinguishing [Bukharev, Polyansky, 1983; Eliseyev et al, 1965; Esipchuk, 1988; Esipchuk et al, 1990] of volcano-plutonic (Osnytskiy), anorthosite-rapakivi-granite (Korostenskiy and Korsun-Novomyrgorodskiy) complexes and the complex of alkaline granitoids (East Azovian). The isotopic age of the complex rocks according to data available is within 2.0 Ga (the former) and 1.8-1.7 (the latter). Zircons from metarhyolites and metadacites are dated to 2.0 Ga.

Molybdenite mineralization (Tomashgorodske ore field including the Viry prospect and a number of mineralized occurrences, and Ustynivske ore field with Verbne Bi-Mo deposit and a number of prospects) is confined to the Osnytskiy complex.

Volcanogenic-sedimentary LTC includes Ovruchskiy complex composed of weakly- and non-metamorphosed volcanic associations developed in Bilokorovychska, Ovrutska and Vilchanska depressions [Paranko, 1987; Yatsenko, Paranko, 1984] in the north-western part of the; copper, lithium, beryllium, and zirconium mineralization is found in these units. Successions begin with sandstone-aleurolite and trachyandesite-rhyolite associations upward followed firstly by quartzite-sandstone, and then by aleurolite rocks associations. The isotope age of the complex rocks, according to data available is within 1.8-1.6 Ga [Verkhoglyad, 1995]. Uranium-lead age of zircons from quartz porphyries of the Vilchanska depressionis 1.17 Ga, and that of the Ovrutska depression is 1.74 Ga [Shcherbak, et al, 1989a].

4. Day by day descriptions

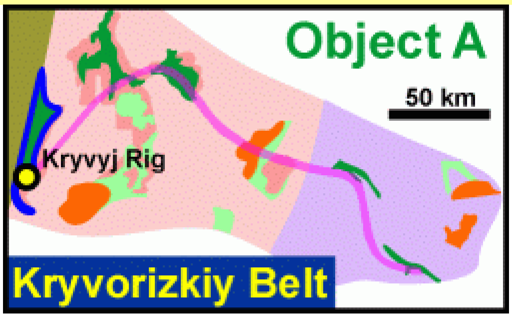
The length of the excursion, net of access and leave sections, is about 350 km and within the four full-working days the route will cross two Mega-Blocks of the Shield – Middle-Dniprean tonalite-greenstone and Azovian granulite-greenstone (see Fig. 2-1, 3-2). In view of the excursion goals, the major attention will be paid to the greenstone rock complexes providing most information on the Archean and Proterozoic magmatism, sedimentation, tectonics and mineralization in the time span 3.2-2.1 Ga, while the rocks developed in the greenstone basement (various granite-gneisses, migmatites etc.) will be briefly examined in conjunction with the issues of geochronology.

Excursion will start in Kryvorizkiy Belt where the lower Archean and upper Proterozoic rock complexes will be examined including the giant Inguletskiy open pit with annual production in excess of 20 Mt of iron ore and approved reserves of 1,758 Mt. Then the excursion participants will observe the various portions of greenstone rock complex in Verkhivtsivskiy and Surskiy belts of Middle-Dniprean region and Sorokynskiy and Kosivtsivskiy belts in Azovian region. In these greenstone belts, the application of the precise geochronological zircono-metric studies in solution the problems of various granitoid rocks relationships also will be presented and discussed over the mini-workshops associated with the excursion targets. In addition to iron ores, the gold and molybdenum mineralization will be examined in Surskiy and Sorokynskiy greenstone belts.

Working day 1, August 1, 2008, Friday. Object A.

Daily Timetable

Breakfast in Kryvyj Rig	**07:30-09:00**
Drive to the Object A	**09:00-09:45**
Target A1	**09:45-12:00**
Drive to the lunch	**12:00-12:30**
Lunch	**12:30-14:00**
Target A2	**14:00-15:30**
Target A3	**15:30-17:30**
Drive to Kryvyj Rig	**17:30-18:00**
Refreshing time	**18:00-19:00**
Welcome dinner in Kryvyj Rig	**19:00-23:00**



Excursion targets are located in the southern part of Kryvorizkiy Belt where in the natural and man-made exposures the fragments of some rock complexes are observed: Meso-Archean Greenstone (Target A1, Stops 1, 2 and 3), and Paleo-Proterozoic Meta-Terrigenous (Target A1, Stop 4; Target A2, Stops 1-4), Meta-Ultramafic (Target A1, Stop 5), and Banded Iron Formation[1] (Target A1, Stop 6; Target A3, Stops 1 and 2).

Target A1. Tarapako-Lykhmanivske extension.
Purpose: assessment the Greenstone and Meta-Terrigenous rock complexes.

Stop 1. Cliff outcrop 250-300 m long and 12-13 m wide. Mica quartzites at the base of greenstone column of Kryvorizkiy belt.

(bus move for 3 km)

Stop 2. Schistose fine-grained meta-basalts, dark-grey to black, with greenish shade.

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[1] In the Ukrainian practice these rocks are commonly being used under the term "jaspilite-siliceous-schist rock association".

Stop 3. Massive meta-basalts with prominent ball-jointing and single quartz and quartz-carbonate vesicles.

Stop 4. Weathered arkosic meta-gravelites and meta-sandstones of meta-terrigenous complex.

Stop 5. Sheared talc schists (meta-ultramafites) arranged in minor folds.

Stop 6. Outcrop of highly-weathered ferruginous quartzites.

Target A2. Ingulets River bank outcrops.
Purpose: assessment the Meta-Terrigenous rock complex, basal meta-conglomerate-sandstone-schist portion.

Stop 1. Cliff outcrop 150-160 m long comprising intercalation of three- and two-component meta-terrigenous rhythms composed of quartz sandstones, gravelites and conglomerates; gravelites and conglomerates; sandstones and conglomerates.

Stop 2. Two cliff outcrops 60-70 m long composed of alternating feldspar-quartz meta-gravelites and meta-sandstones.

Stop 3. Cliff 15-20 m long outcrop of the fine-medium-grained feldspar-quartz sandstones.

Stop 4. Eluvial heaps and minor hard rock exposures of phyllite schists.

Target A3. The major operating iron-ore open pit.
Purpose: assessment the Meta-Terrigenous rock complex, the ferruginous chert-schist portion.

Stop 1. Observation site of the Southern Mining-Beneficiation Plant (PivdGZK) in Skelyuvatske ferruginous quartzite deposit. General view of the open-pit, information on structure of deposit.

Stop 2. Open-pit bench where schist and ferruginous horizons are exposed. Fold and fault structures in the chert-schist sequence.

Working day 2, August 2, 2008, Saturday. Object B.

Daily Timetable

Breakfast in Kryvyj Rig	**07:30-09:00**
Drive to the Object B	**09:00-11:00**
Target B1	**11:00-13:00**
Lunch in the field	**13:00-14:00**
Target B2	**14:00-15:00**
Target B3	**15:00-16:00**
Drive to Dnipropetrovsk	**16:00-18:00**
Arrival & accommodation at Dnipropetrovsk	**18:00-18:30**
Refreshing time	**18:30-19:30**
Welcome dinner in Dnipropetrovsk	**19:30-23:00**

Excursion targets are located in the southern part of Verkhivtsivskiy Belt where in the natural exposures the fragments of Paleo-Archean (Target B3, Stop 1), Meso-Archean Greenstone (Target B1, Stops 1, 2 and 3), and Tonalite-Plagiogranite (Target B2, Stop 1) complexes are observed.

Target B1. Greenstone outcrops in Balka Kalynova, Bazavlutske extension.
Purpose: assessment the lower greenstone portion of the Belt.

Stop 1. Step-face jointing, pillow-lava and other volcanic features in meta-basalts.

Stop 2. Minor outcrop of chlorite-actinolite schists interpreted to be pyroxenite meta-komatiite interbed.

Stop 3. Wide diversity of pillow meta-basalts.

Stop 4. Cutting and conform bodies of aplite-like and pegmatoid granites and quartz veins impregnating the lowermost komatiite-tholeiite rock association.

(--- bus drive for 3.6 km ---)

Target B2. Balka Ovseeva.
Purpose: assessment the Surskiy Complex plagiogranitoids intruded into the lower greenstone portion of the Belt.

Stop 1. Minor outcrop of Surskiy Complex plagiogranitoids in the south-western part of Oleksandropilskiy Massif which from the south intrudes the Bazavlutske tail-like extension composed of lower meta-basite batch of Surska Suite, Konkska Series.

Mini-workshop: mineralogy and precise zircon studies.

Target B3. Bazavluk River bank outcrops.
Purpose: assessment the basement rocks of Verkhivtsivskiy Belt – Dnipropetrovskiy Complex migmatites developed after primary-stratified rocks of Aulska Series.

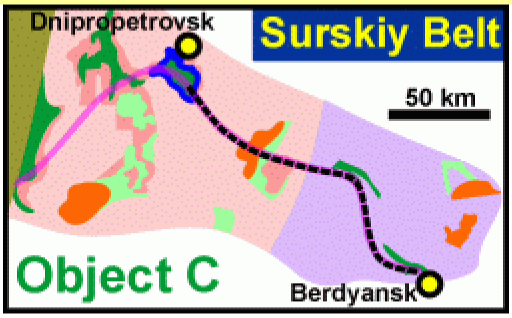
Stop 1. Plagiogranite-gneiss (shadowed plagiomigmatite) of Dnipropetrovskiy Complex developed after plagiogneiss substratum of Aulska Series rocks; the basement of Verkhivtsivskiy Greenstone Belt.

Mini-workshop: mineralogy and precise zircon studies.

Working day 3, August 3, 2008, Sunday. Object C.

Daily Timetable

Breakfast in Dnipropetrovsk	**07:30-09:00**
Drive to the Object C	**09:00-10:00**
Target C1	**10:00-11:30**
Lunch in the paleo-volcano	**11:30-12:30**
Target C2	**12:30-13:30**
Target C3	**13:30-15:00**
Travel to Berdyansk	**15:00-19:00**
Arrival & accommodation at Berdyansk	**19:00-19:30**
Refreshing time	**19:30-20:30**
Welcome dinner in Berdyansk	**20:30-23:00**



Excursion targets are located in the central part of Surskiy Belt where the single stop in the abandoned quarry will be used to examine the full number of Targets comprising wide diversity of Archean paleo-volcanic rocks as well as gold and molybdenum mineralization.

Target C1. Apolonivskiy Paleo-Volcano.
Purpose: assessment the neck and periphery portions of paleo-volcano unit.

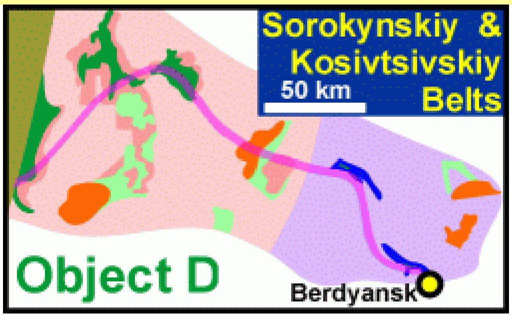
Target C2. Sergiivske Gold Deposit.
Purpose: assessment the general geology, core sections and gold ore types.

Target C3. ***Mini-workshop***: Geology, petrology and geochronology of granitoid rocks.
Purpose: assessment the study results of granitoids from Dnipropetrovskiy and Surskiy complexes.

Working day 4, August 4, 2008, Monday. Object D.

Daily Timetable

Breakfast in Berdyansk	**07:30-09:00**
Drive to the Object D	**09:00-10:00**
Target D1	**10:00-13:00**
Lunch in the field	**13:00-14:00**
Target D2	**14:00-15:00**
Target D3	**15:00-16:00**
Drive to Berdyansk	**16:00-17:00**
Refreshing time	**17:00-19:00**
Resuming dinner in Berdyansk	**19:00-23:00**



Excursion targets are located in the central-southern part of Sorokynskiy Belt, where, besides the rocks of this belt, the core sections from drill-holes of Kosivtsivskiy Belt will be examined. The rock complexes include Meso-Archean Greenstone, Meta-Terrigenous, and Carbonate-Terrigenous.

Target D1. Balka Sobacha gully: geology and gold mineralization in Sorokynskiy Belt.
Purpose: assessment the rock complexes and related gold mineralization.

Stop 1. The outcrops of mafic rocks of KT-1 parageneration.

Stop 2. The outcrop of meta-rhyodacite association volcanic rocks that highlight and delineate the core region of the Surozka Anticline.

Stop 3. The outcrops of mafic rocks in the northern limb of Surozka Anticline.

Stop 4. Essentially ultramafic sequence comprising KT-2 parageneration of meta-komatiite-tholeiite rock association.

Stop 5. The adit and outcrops of the ferruginous quartzites with numerous quartz and carbonate-quartz veinlets poly-sulphide mineralization (ore bodies of Surozke gold deposit).

Stop 6. The rocks of meta-conglomerate-sandstone-aluminous-schist association that unconformably overlies the previous volcanic succession and fills the core portion of Sorokynskiy Belt.

Target D2. Osypenkivskiy granitoid massif.
Purpose: assessment the geology and geochronology of granitoids intruding the greenstone sequence.

Target D3. Kosivtsivskiy Greenstone Belt.
Purpose: assessment the geology of meta-komatiite sequence and geochronology of granitoids intruding greenstone rocks.

Item 1. The ultramafic rocks of Greenstone Complex.

Item 2. The exotic xenolith-bearing rocks of ~ 2.1 Ga Dobropilskiy massif.

5. Detailed descriptions of the excursion objects

OBJECT A. KRYVORIZKIY GREENSTONE BELT

Total itinerary length – 6.2 km, total walking distance – 3.7 km
Guides: Igor Paranko, Kryvorizkiy Technical University, Kryvyj Rig; Boris Malyuk, UkrSGRI, Kyiv

Excursion targets are located in the southern part of Kryvorizkiy Belt (Fig. 5A0-1, 5A0-2, 5A0-3, 5A0-4) where the fragments of some rock complexes are developed: Meso-Archean Greenstone and Paleo-Proterozoic Meta-Terrigenous, Meta-Ultramafic, and Banded Iron Formation (BIF).

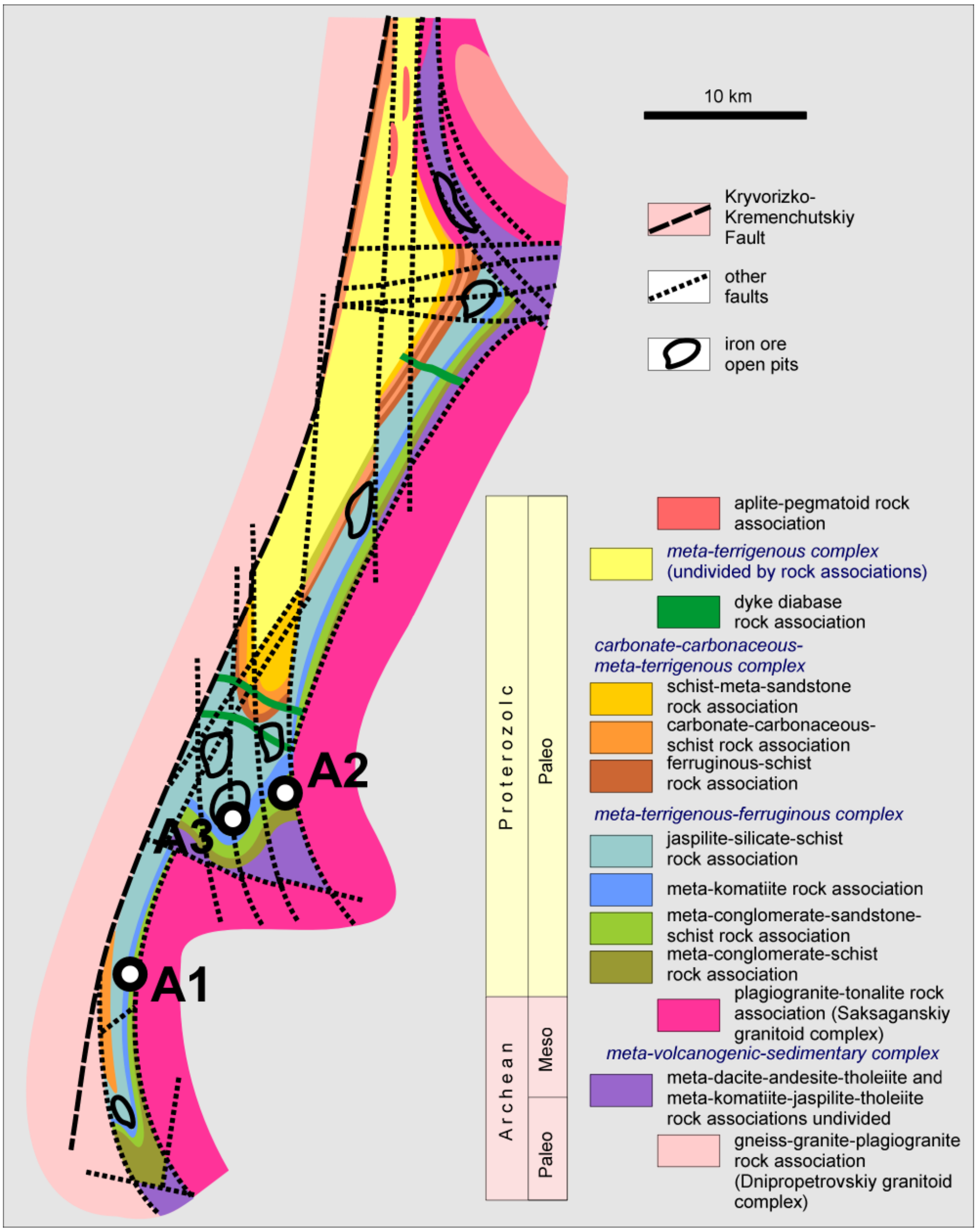


Fig. 5A0-1. Rock complexes of Kryvorizkiy Greenstone Belt.

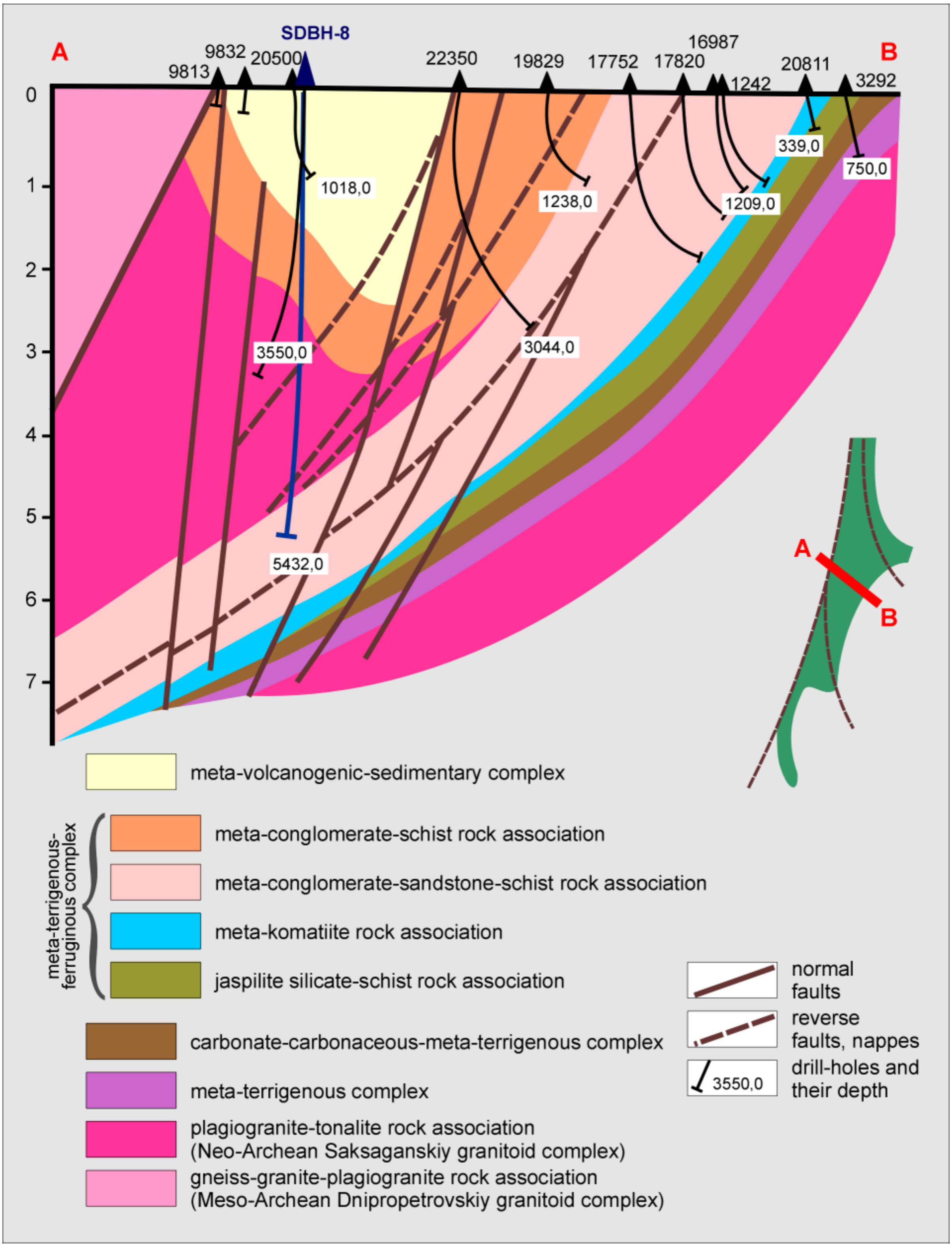


Fig. 5A0-2. Sketch geological cross-section
in the central part of Kryvorizkiy Greenstone Belt.
SDBH-8 – location of the Kryvorizka Super-Deep Borehole (5432 m).

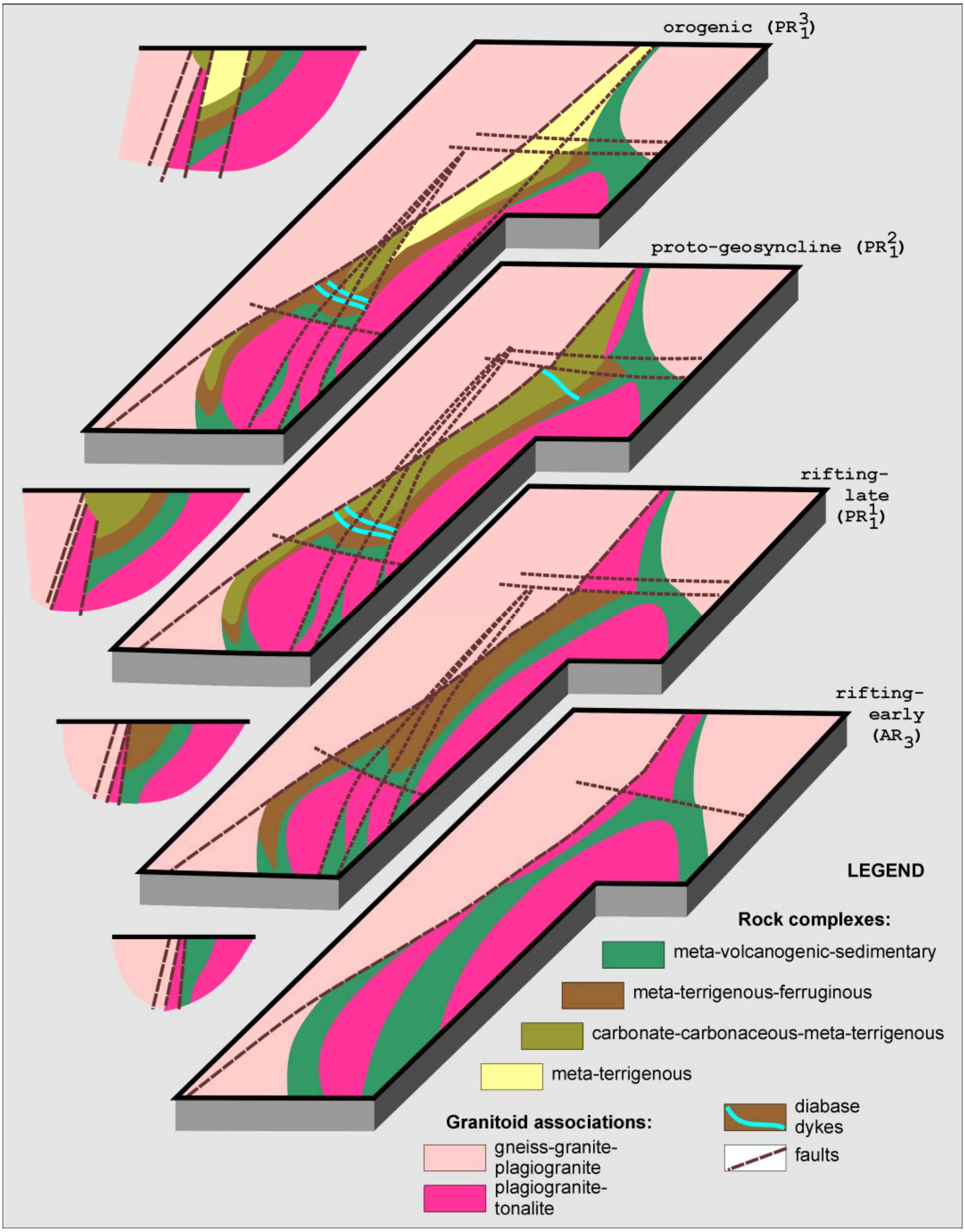


Fig. 5A0-3. Inferred tectonic evolution of Kryvorizkiy Greenstone Belt.

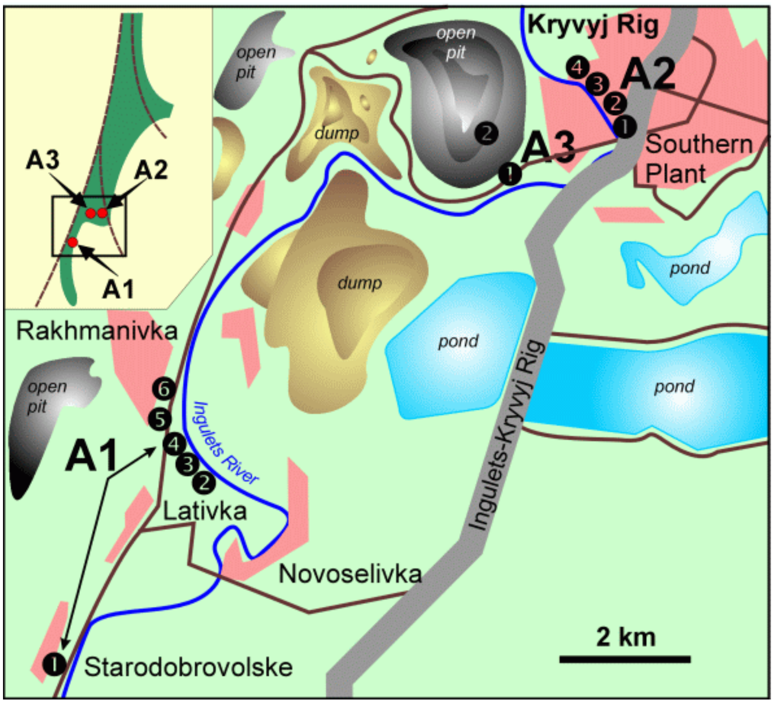


Fig. 5A0-4. Target location in the south of Kryvorizkiy Greenstone Belt.

Unfortunately, there are no direct age determinations of the rocks to be examined in the excursion area. However, their stratigraphic analogues in other parts of the Belt provide the following time frame of the rocks:

- *Greenstone Complex*: the age of granitoids which cut the greenstone sequence in Gannivskiy area of the north-eastern Belt is estimated to 2825-2615 Ma by zircons [Artemenko, 1998; Shcherbak et al, 1989b];
- *Meta-Terrigenous Complex*: the age of lead-zinc mineralization in quartzite pebbles from conglomerates of Skelyuvatska Suite (post-sedimentation vein-type mineralization cutting the pebbles) is estimated to 2800±100 Ma by U-Pb method; mica cement in conglomerates is dated to 2600 Ma by K-Ar method [Tugarinov et al, 1963];
- *BIF Complex*: the age of metasomatites in the siliceous-schist sequence which roughly corresponds to the time of the sequence metamorphism is dated to 2000-1700 Ma by K-Ar method [Eliseev et al, 1961].

Target A1. Tarapako-Lykhmanivske extension.
Purpose: assessment the Greenstone and Meta-Terrigenous rock complexes.

In tectonic respect it is located in the central part of so called Tarapako-Lykhmanivske extension which connects Tarapakivska anticline in the north with Lykhmanivska syncline in the south of Kryvorizkiy Belt. This is the 500-1000 m wide sub-longitudinal steeply-dipping to vertical band of Konkska and Kryvorizka series metamorphic rocks confined to the zone of Kryvorizko-Kremenchutskiy deep-seated fault (see Fig. 5A0-1).

The target includes a range of hard rock exposures of the Greenstone (Stops 1, 2 and 3), Meta-Terrigenous (Stop 4), Meta-Ultramafite (Stop 5) and Banded Iron Formation (Stop 6) complexes in the right bank of Ingulets River between Rakhmanivka village in the north and Starodobrovolske village in the south (Fig. 5A1-1, see also Fig. 5A0-4).

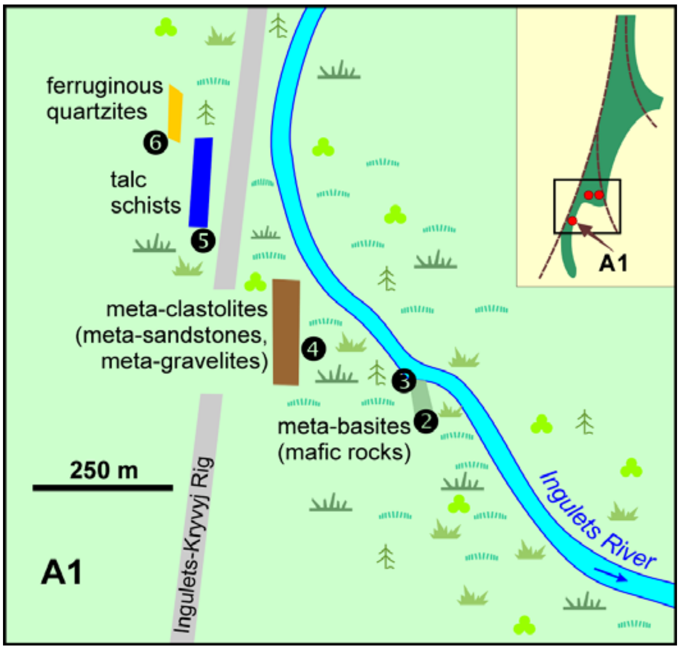


Fig. 5A1-1. Rock lithologies at the stops of Target A1.

<u>STOP A1-1</u> is located on the slope of second over-flood terrace in the right bank of Ingulets River valley in the east of Starodobrovolske village.

In the 250-300 m long and 12-15 m high cliff outcrop to the right of paved road Kryvyj Rig – Rakhmanivka – Lativka – Ingulets the sequence of mica quartzites is exposed (Fig. 5A1-2). This 30-50 m thick rock pile lies at the base of Greenstone Complex. Similar quartzites within meta-basalts in lower part of this Complex are also known in the central and northern Kryvorizkiy Belt.

Fig. 5A1-2. Mica quartzite outcrop.

In the outcrop, quartzites include light-grey and white varieties. Fine-, medium- and coarse-grained rocks are distinguished, of which some resemble meta-sandstones. Fine-grained quartzites predominate while other varieties occur in the interbeds from first centimeters to 0.5 m thick (Fig. 5A1-3). Psephite-class minerals include quartz (60-90%), feldspars, mainly plagioclase (5-30%), and mica (sericite, chlorite, biotite). The micro-grained sericite-quartz fabric provides the rock cement. Minor minerals include staurolite, garnet and tourmaline; accessory: ilmenite, sphene, rutile, leucoxene, titanomagnetite and zircon.

Fig. 5A1-3. Diverse-grained quartzite interbedding.

(--- bus drive for 3.5 km ---)

STOP A1-2 is located in the right flood-land terrace of Ingulets River in 3.5 km to the north-east from the Stop 1.

At the foot of the first over-flood terrace in the right bank of Ingulets River the dark-grey with greenish shade and dark-green fine-medium grained meta-basalts are exposed in the flat outcrop 15-20 m long and 25-30 m wide (Fig. 5A1-4). In the south of outcrop representing the lower part of the column, the rocks are extensively sheared and resemble amphibole schists; abundant iron oxides are developed along the shearing planes. The rocks are composed of plagioclase, hornblende, quartz, biotite and chlorite with minor epidote and minute garnet grains; accessories: zircon, apatite, tourmaline and ore minerals (pyrite and pyrrhotite). Rock texture is nematoblastic, granonematoblastic and fibroblastic with relic blastic and blasto-porphyry ones.

Fig. 5A1-4. Exposure of schistose meta-basalts.

Fig. 5A1-5. Exposure of massive meta-basalts with ball-shaped jointing.

STOP A1-3 is located in the flood-land portion of the Ingulets River right bank, in 15 m higher the river course from the Stop 2.

The massive meta-basalts with prominent ball- and pillow-like jointing are exposed in the small boulder-like outcrops 8 by 7 m in size (Fig. 5A1-5). From the rocks of Stop 2 these basalts differ not only in structure-texture patterns but also in composition. Major minerals include amphibole (actinolite and blue-green hornblende, 30-70%), sodium plagioclase (20-50%), quartz (up to 15%), chlorite (up to 5%), and biotite (up to 5%). Carbonate and epidote occur in subordinate amounts. Accessories include ilmenite, rutile, zircon, apatite, leucoxene, tourmaline, and ore minerals (pyrite and pyrrhotite). Texture of the rocks is blasto-ophitic with typical prismatic plagioclase grains (oligoclase, andesine, rarely oligoclase-albite) with interstices filled up with hornblende apparently developed after pyroxenes. Hornblende is observed in idiomorphic or elongated xenomorphic grains, often with inclusions of the fine quartz grains.

STOP A1-4 is located on the slope of the first over-flood terrace in the right bank of Ingulets River, in 130 m up the river course from the Stop 3. The meta-clastolite sequence is exposed in the small cliff-like outcrop 15-20 m long and 1.5-2 m high. It comprises association of meta-sandstones and meta-gravelites with minor inclusions of quartz and quartzite fine pebble. In the column meta-gravelites predominate being composed of well-rounded ellipsoid fragments of quartz and feldspars. The rocks are highly-weathered with development of kaolinite aggregates. Cement is composed of sericite-quartz material. The rocks are extensively sheared with the signs of dynamo-metamorphism expressed in the oriented arrangement of mica minerals and rolling of quartz and quartzite fragments which look like thin lenses in the section.

STOP A1-5 is located on the slope of the second over-flood terrace of Ingulets River in 260 m to the north-west from Stop 4, just at the paved road side Kryvyj Rig – Rakhmanivka – Lativka – Ingulets (see Fig. 5A1-1 and Fig. 5A0-4).

The sequence of sheared and arranged in tight minor folds talc-bearing schists of Meta-Ultramafite Complex is exposed in the flat outcrops over the distance of 20 m on the terrace slope (Fig. 5A1-6). A range of schist varieties is distinguished in the outcrop, which differ in contents of the rock-forming minerals.

Essentially talc schists containing 70-80% of talc predominate in the exposures. Carbonates and chlorite are observed in the schists in roughly equal amounts. The rocks, mainly composed of ferrous actinolite, 10-30% of talc, about 10% of chlorite and actually no carbonates, are less developed. The third variety contains approximately equal proportions of talc, chlorite, actinolite and carbonate in the range 10-30%. In addition, the schists with predominating chlorite (up to 65-70%) and minor talc, carbonates and actinolite are observed in some amount. The accessories in above rocks include leucoxene, rutile and titanomagnetite.

Fig. 5A1-6. Minor tight folding in talc schists.

Fig. 5A1-7. Weathered ferruginous quartzite outcrop.

STOP A1-6 is located in 50 m to the west of the Stop 5 next to the mound of broken railroad (see Fig. 5A1-1 and Fig. 5A0-4).

The strongly weathered biotite-chlorite schists with 1-1.5 m thick interbeds of barren quartzites and highly-oxidized silicate-magnetite and magnetite quartzites are exposed in the small, 1 × 1.5 m in size, outcrop (Fig. 5A1-7), at the foot of the minor gully right slope, nearby the broken railway bridge. The rock strike is conformable with that of the rocks described above. The outcrop is not representative but the mentioned rock association suggests for the affinity to the Banded Iron Formation rock complex which conformably overlies the talc horizon.

Target A2. Ingulets River bank outcrops.
Purpose: assessment the Meta-Terrigenous rock complex, basal meta-conglomerate-sandstone-schist portion.

In tectonic respect it is confined to the eastern limb of the Main Structure of Kryvorizkiy Belt (see Fig. 5A0-1). The fragments of Meta-Terrigenous Complex are exposed in some cliff outcrops (Fig. 5A2-1) over the distance about 350-400 m along the left bank of Ingulets River close to the inhabited locality affiliated at the Southern Mining-Beneficiation Plant [PivdGZK] (see Fig. 5A0-4).

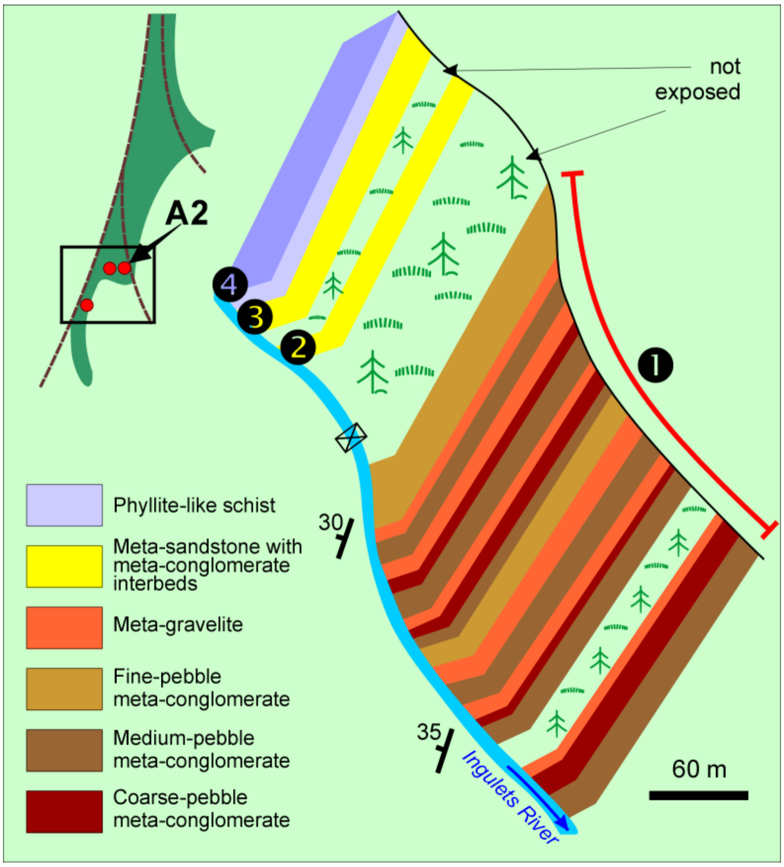


Fig. 5A2-1. Rock lithologies at the stops of Target A2.

STOP A2-1 is located in 190-200 m from the foot-bridge down the Ingulets River course and to the west from the holiday yard in the mentioned inhabited locality. The sequence of diverse-pebble meta-conglomerates, meta-gravelites and meta-sandstones is exposed along the left bank of river valley over the distance of 150-160 m in the cliff outcrops 8-15 m high (Fig. 5A2-2).

Fig. 5A2-2. Meta-conglomerate cliff outcrop.

Two- or three-component rhythms of regressive type are observed (Fig. 5A2-3) where the lower rhythm members comprise meta-sandstones or meta-gravelites and upper ones – meta-conglomerates. Two-component meta-gravelite + meta-conglomerate rhythms predominate. In the south-east of outcrop, where the lower part of Meta-Terrigenous Complex is exposed, the coarse-pebble (up to cobble) meta-conglomerates predominate occurring in the batches 1-5 m thick separated by the meta-gravelite beds and lenses (from first centimeters to 1-1.5 m thick). Meta-conglomerate pebble size in general is 5-7 cm but some pebbles up to 10-15 cm in size also occur. The pebble normally is spindle-shaped with one thin and another swelled side. The thin sides of the pebbles are oriented in specific direction (Fig. 5A2-4) that is characteristic for alluvial-proluvial sediments. The pebble material constitutes about 70-80% of the rock volume. The lower portions of meta-conglomerate batches commonly are composed of the medium- and fine-grained varieties with the pebble size varying from 0.5 to 2.0 cm. The pebble shape is mainly isometric but spindle-shaped well-rounded pebbles are also observed. The pebble material content in these varieties varies from 40 to 60% by rock volume increasing upward in the column. Amount of the fine pebbles gradually decreases in the same direction and meta-conglomerates are changed into the medium-pebble varieties where elongated spindle-shaped pebbles 3.0-3.5 cm in size by long axis predominate.

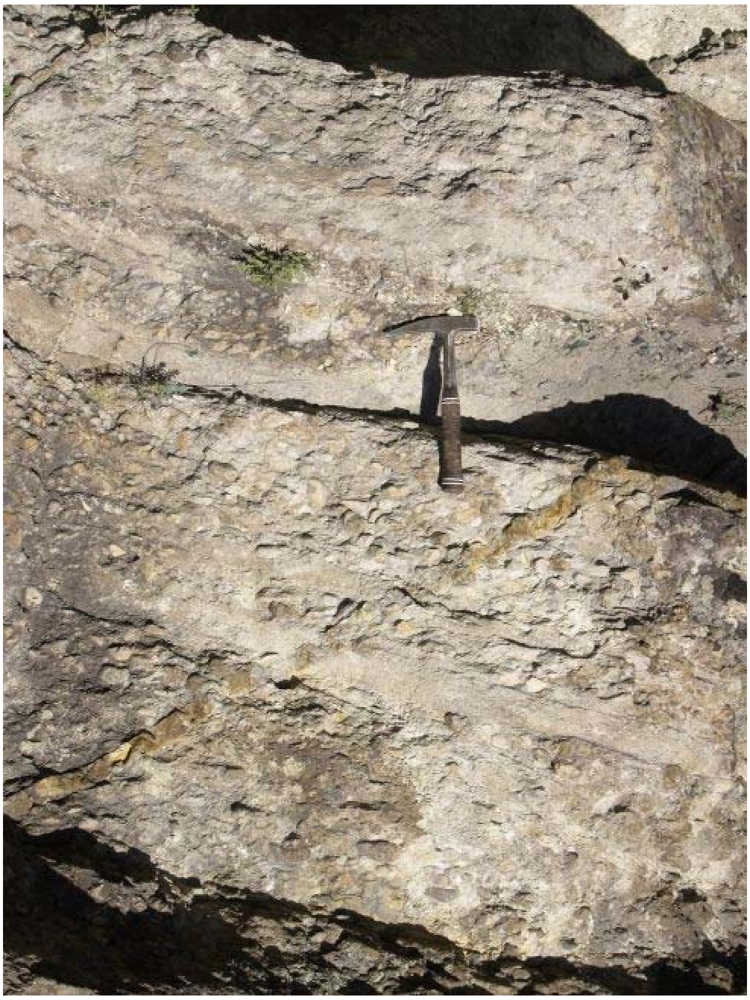


Fig. 5A2-3. Rhythmic bedding in meta-conglomerates.

STOP A2-2 is located in 150-170 m up the river course from the Stop 1. Here, in the steep Ingulets River bank the meta-clastolite sequence is exposed; it is composed of alternating meta-gravelites and meta-sandstones and stacks up the column of Meta-Terrigenous Complex.

In the lower part of exposed section intercalation of meta-gravelite and meta-sandstone beds is observed (Fig. 5A2-5). Thickness of meta-gravelite beds decreases upward in the section from 2-3 m to 10-20 cm, and meta-sandstone bed thickness, conversely, increases. By visual appearance and mineral composition the rocks are identical. These are light-grey diverse-grained feldspar-quartz rocks composed of quartz (75-80%) and feldspar (10-15%) as well as micro-quartzite and mica quartzite (up to 10%) fragments cemented by quartz-sericite material with minute biotite and chlorite flakes. Carbonates, tourmaline, zircon, monazite, apatite, rutile, and ore minerals also occur in the cement.

STOP A2-3 is located in 25-30 m up the river course from the Stop 2. In the steep cliff 12-15 m long and up to 10 m high the sequence of fine-grained feldspar-quartz meta-sandstones with thin (3-5 cm) meta-aleurolite interbeds is exposed (Fig. 5A2-6). Meta-sandstones are similar to those described above. Meta-aleurolites are composed of quartz and sericite with minute grains of carbonates, zircon, and ore minerals (pyrite and pyrrhotite). The prominent primary bedding is observed in meta-aleurolites expressed in alternation of the first millimetres thick quartz and sericite-enriched interbeds.

Fig. 5A2-4. Meta-conglomerate pebbles with certain orientation.

Fig. 5A2-5. Interbedding of meta-gravelites and meta-sandstones.

Fig. 5A2-6. Interbedding of meta-sandstones and meta-aleurolites.

STOP A2-4 is located further in 15-20 m from the Stop 3. Here, the quartz-chlorite-sericite schists known as "phyllites" and "phyllite schist" are exposed on the river valley slope in eluvial heaps and small flat hard-rock outcrops. These are schistose, fine- to micro-grained, dark-grey and light-grey with greenish shade rocks composed of quartz and flaky sericite, in places re-crystallized to muscovite. The biotite and chlorite flakes also occur in the rocks displaying oriented arrangement and are commonly confined to the schistosity planes. Micro-grained calcareous matter in amount of 5-15% is observed in association with chlorite and sericite providing the dark and black colouring of the rocks. Accessories include tourmaline, zircon, magnetite, rutile, and ore minerals (pyrite and pyrrhotite).

The schists conformably lie over the meta-gravelite-sandstone association described above and complete the column of Meta-Terrigenous Complex.

Target A3. The major operating iron-ore open pit.
Purpose: assessment the Meta-Terrigenous rock complex, the ferruginous chert-schist portion.

This one comprises the major operating unit of the Southern Mining-Beneficiation Plant (PivdGZK) (see Fig. 5A0-4) developed in Skelyuvatske ferruginous quartzite deposit confined to the Banded Iron Formation Complex of Kryvorizkiy Belt.

STOP A3-1 is located at the observation site of the open pit from where the panorama of mining works and general structure of Skelyuvatske ferruginous quartzite deposit are spread before the eyes (Fig. 5A3-1). To date, the open pit length is 3 km, width – 2.5 km, and depth by the closed contour – 321 m; number of benches is 26. Mining works are being carried out in 23 benches of 15 m height each. Recorded iron ore reserves by 1.01.2007 are estimated to

1,758 Mt including 1,088 Mt in the open pit contour. Projected open pit capacity is 22 Mt of ore per annum. The mining is carried out by the standard open-cast method by benches while the annual sinking attains 7.5 m. The ore transportation to the beneficiation plant and overburden rocks to the dumps is conducted by railroad facilities and the total length of railroad permanent ways in the open pit exceeds 300 km. In the processing plant the primary ferruginous quartzite ores are beneficiated using technology of wet magnetic separation with production of magnetite concentrate at iron content 64.5-65.2% that further is being supplied for metallurgy.

Fig. 5A3-1. Panorama view of the open pit in Skelyuvatske ferruginous quartzite deposit.

Skelyuvatske deposit is confined to the core of Western-Inguletska second-order syncline which complicates the Main Structure of Kryvorizkiy Belt (Fig. 5A3-2). This is open asymmetric fold with the limb dipping from 25-40^{o} in the core to 50-80^{o} in the north of deposit. The fold hinge plunges to the north under angles 10-25^{o} (Fig. 5A3-3). The limb range in the central part of syncline attains 1400 m and plunging depth is about 1000 m.

<u>STOP A3-2</u> is located in the open pit bench where the section of Banded Iron Formation Complex is exposed with distinct intercalation of the schist and ferruginous horizons. Passing the route by open pit benches from the east to west one can observe the first, second, fourth, fifth and sixth schist and ferruginous horizons.

The rocks are arranged into the minor asymmetric isocline folds and are cut by the series of variously-oriented fractures into the blocks. The major fault structure in the deposit is the sub-longitudinal Skelyuvatskiy (Kateryninskiy) Fault which coincides with the axis of Western-Inguletska Syncline (see Fig. A3-2 and Fig. A3-3). The Fault plane does dip to the west under the angles 65-70^{o}. The block vertical displacement along the Fault varies from 20 to 230 m. Just in the open pit the Fault is expressed with the zone of extensive rock crushing and the signs of linear weathering crust.

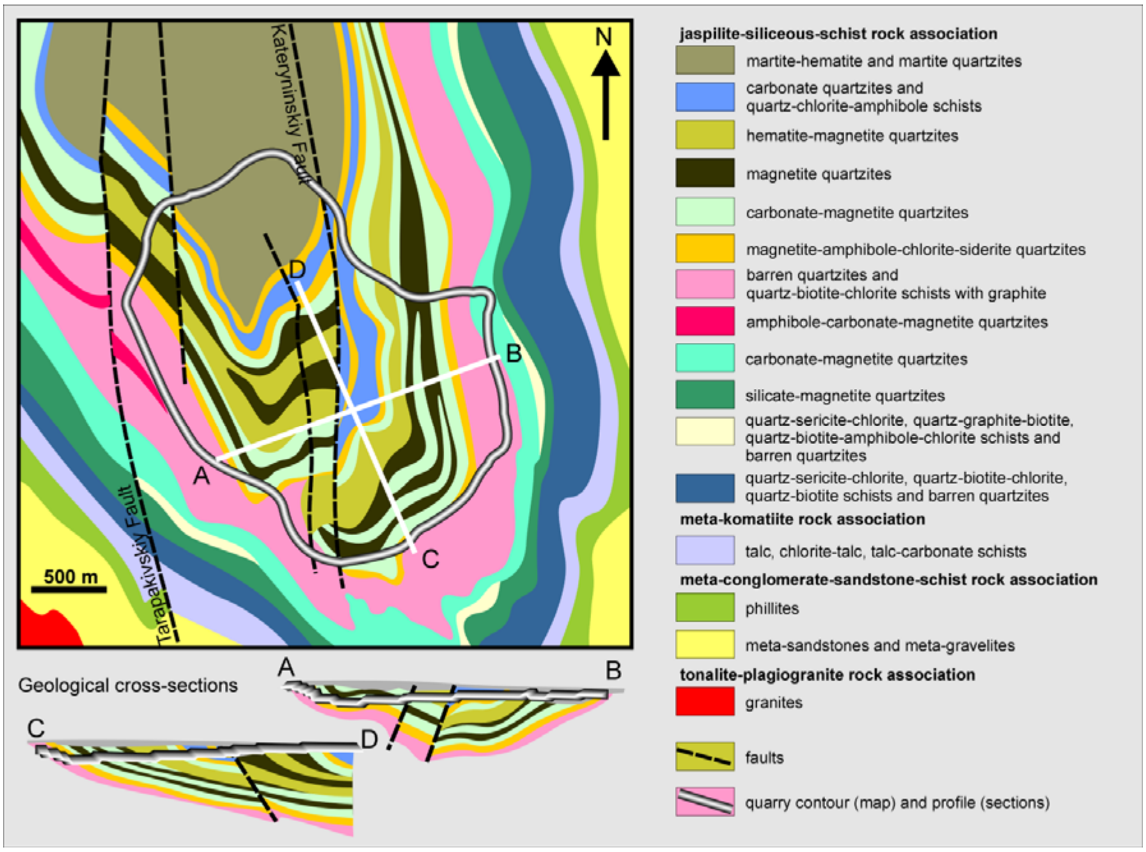


Fig. 5A3-2. Geology and rock lithologies in Skelyuvatske ferruginous quartzite deposit.

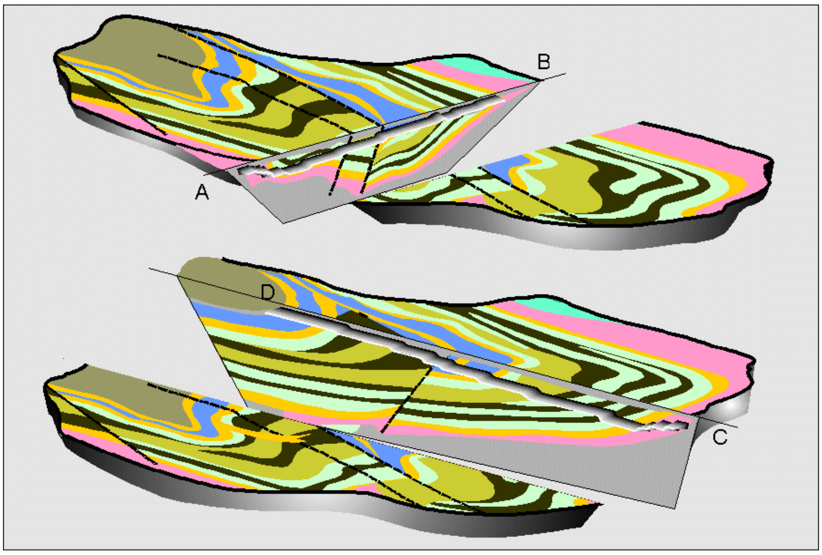


Fig. 5A3-3. Sketch 3D model of the deposit in open pit. See legend in Fig. 5A3-2.

OBJECT B. VERKHIVTSIVSKIY GREENSTONE BELT

Total itinerary length – 5.7 km, total walking distance – 2.1 km
Guides: Alexander Bobrov, Leonid Stepanyuk, Igor Merkushyn, Boris Malyuk, UkrSGRI, Kyiv

Target B1. Greenstone outcrops in Balka Kalynova, Bazavlutske extension.
Purpose: assessment the lower greenstone portion of the Belt.

Verkhivtsivskiy Greenstone Belt is located in the north of Middle-Dniprean granite-greenstone terrain (see Fig. 3-2). And Bazavlutske extension comprises the narrow (1 × 10 km) south-eastern branch or tail of the Belt (Fig. 5B1-1). The tail is composed of the lowermost greenstone rock sequences that are considered to be representatives of the lower unit of Surska Suite in the volume of komatiite-tholeiite rock association. These rocks are exposed in the unique series of outcrops along Balka Kalynova gully in the right bank of Bazavluk River. Here, the layered meta-basalt lava flows with relic syn-magmatic structures and zones as well as their embedded comagmatic meta-gabbroids and meta-dolerites are exposed over the distance about 600 m from the gully mouth to its upper course.

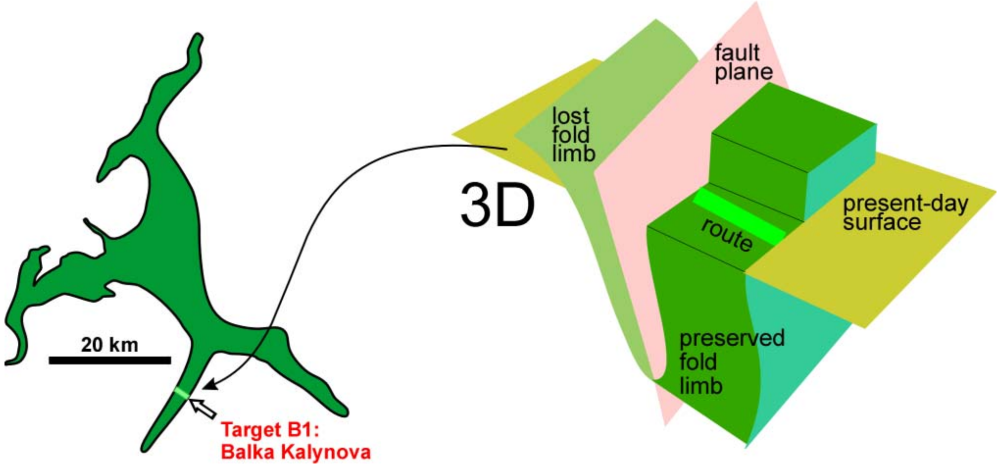


Fig. 5B1-1. Excursion route position in the local tectonic frame of Bazavlutske extension

STOP B1-1 is located in the mouth down-swell portion of the Balka Kalynova gully where excursion participants can observe the classical step-face jointing in meta-basalts (Fig. 5B1-2, Fig. 5B1-3).

The jointing is expressed in the system of 0.3-0.8 m high steps. Almost each step surface displays distinct syn-volcanic structures like grooving, scratching, lineation etc. that are common for exposed mafic lava flows. Step surface orientation is mainly western and dipping angle is about 10^o. From these evidences one can assume the sub-horizontal bedding of the entire meta-basalt pile in the same direction. This assumption seems to be not unequivocal however since other records clearly contradict to the flat bedding of the meta-basalt sequence. These are as follows:

- sub-vertical orientation of the vesicular meta-basalt flow contacts (point C-10 etc.) which coincides with the major schistosity plane;
- sub-vertical orientation of the tight clenched pillow forms in meta-basalt lavas (points V-2, V-15, Fig. 5B1-4);

- similar orientation of the contacts between the principal and minor rock types in the section, for instance, meta-basalts and actinolitites.

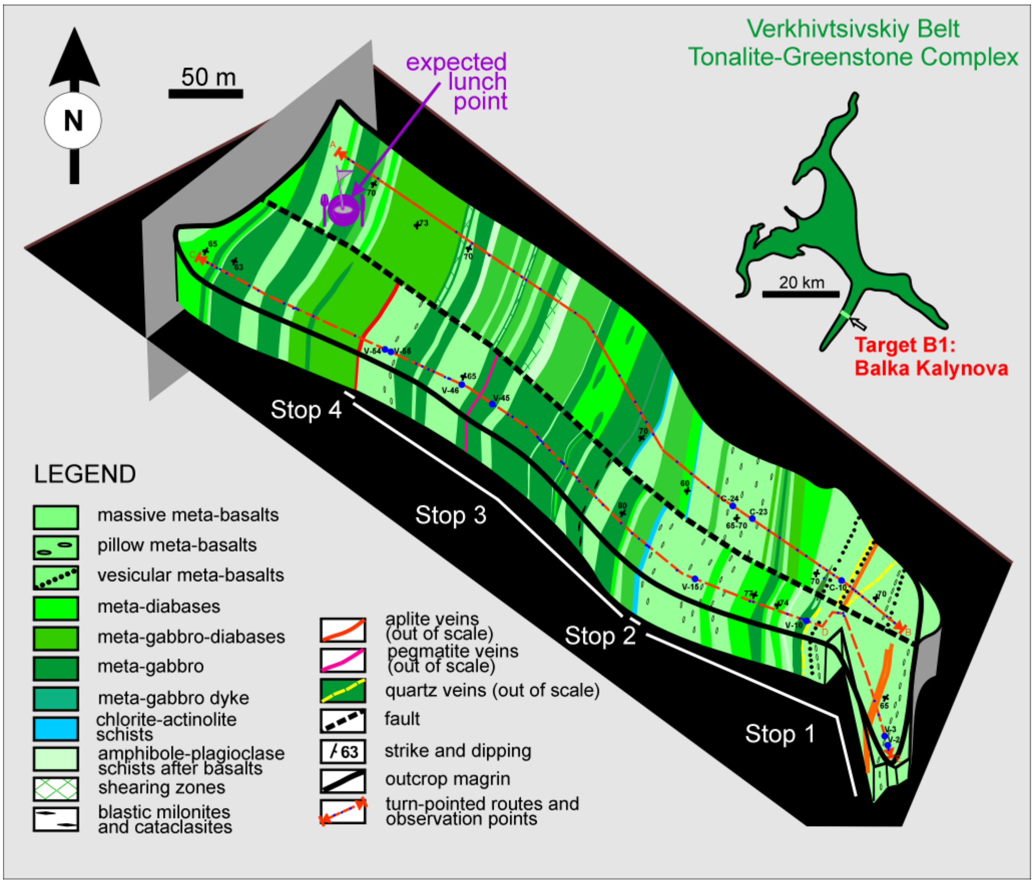


Fig. 5B1-2. Excursion stops over detailed mapping turning-route along Balka Kalynova gully.

Fig. 5B1-3. Step-face jointing in meta-basalts (general overview).
Orange lines indicate surface slopes of the individual meta-basalt flows.

Fig. 5B1-4. Meta-basalt pillow lava.
Inter-pillow space is impregnated by pegmatite, aplite, and vein quartz.

In the down-swell part of the Kalynova gully (point V-2 and interval between the points V-3 - V-10) fine-vesicular ("mandelstone") zones in meta-basalt flows are observed. Vesicles are mainly rounded and irregularly distributed inside the meta-basalts, up to 1-2% by volume. Individual bubbles are filled with quartz and calcite, their size is about 1-3 mm.

By major-element geochemistry the mafic meta-volcanics of Verkhivtsivskiy Belt including the rocks from Balka Kalynova gully do clearly correspond to the greenstone belt basalts of tholeiitic affinity.

STOP B1-2 comprises the minor outcrop of chlorite-actinolite schists interpreted to be pyroxenite meta-komatiite interbed (see Fig. 5B1-2). Similar thin interbeds are also known in the opposite bank of the gully.

STOP B1-3 encompasses the route section where one can observe the wide diversity of pillow meta-basalts (see Fig. 5B1-2). The pillows display extensive flattening (up to 1:5) in schistosity plane (SW270, dip 85^{o}). Crosswise individual pillows look like ellipses or lenses from first centimeters to 30-40 cm wide and from 25-35 cm to 60-90 cm long. Meta-basalt pillow shape is clearly highlighted by 0.5-1.5 cm thick marginal chilling zones mainly composed of re-crystallized and enlarged amphibole grains. In the pillow junction areas the doubling of chilling zones is observed in places while the inter-pillow space is filled with quartz-chlorite-epidote-carbonate mineral aggregate probably of hydrothermal origin (Fig. 5B1-5).

Morphology of the described structure forms and especially their chilling zones are very useful in restoring the patterns of the flow bedding. In case of the contrasted appearance (see Fig. 5B1-5a) orientation of the individual pillow tails suggests for the dipping of the flow internal portions and, consequently, for the direction of stratigraphy stacking prior to the extensive tectonic overprinting.

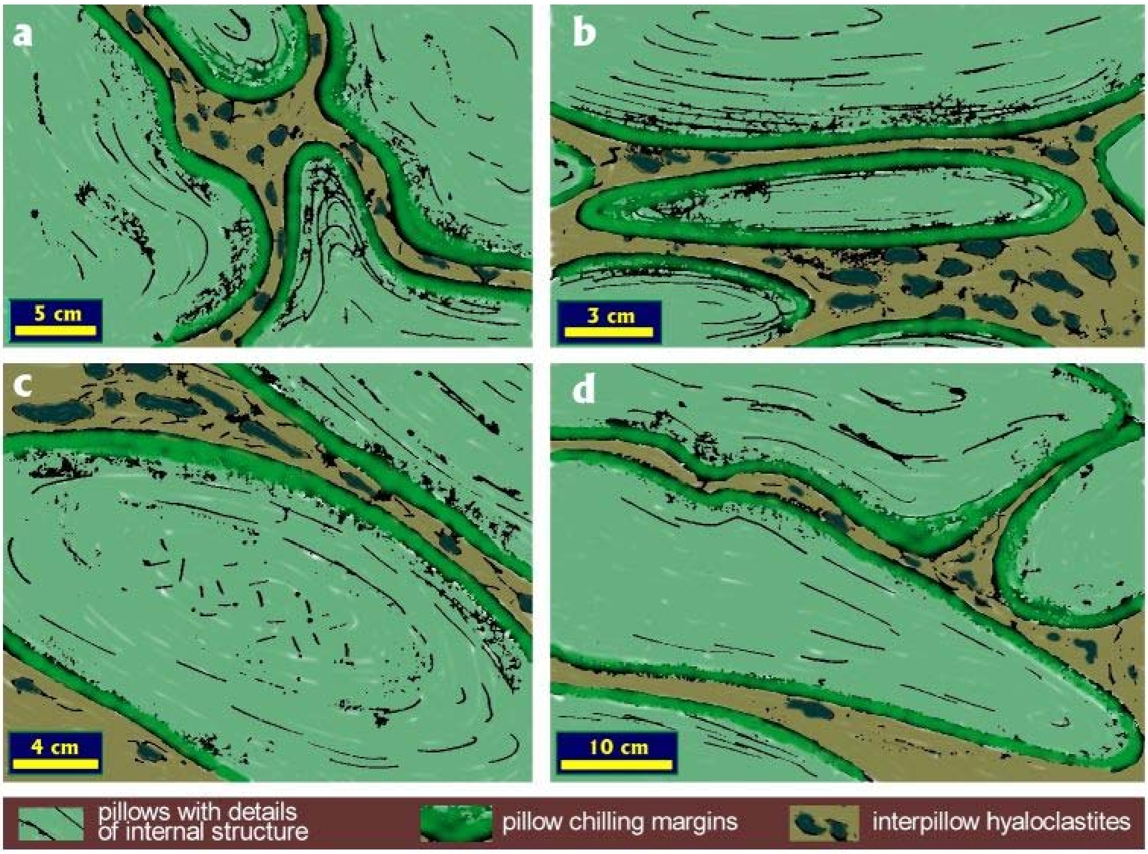


Fig. 5B1-5. Pillow morphology, inter-pillow and interior patterns

Depending on the development degree of the pillow core portion, composed of the aggregate of quartz, carbonate, epidote, chlorite and other minerals of hydrothermal origin, the pillows can be subdivided into the non-zoned (Fig. 5B1-5a, b, d) and zoned (Fig. 5B1-5c); the former varieties predominate whereas the latter are found in places only.

In the exposed meta-basalts the fragments of polygonal or columnar jointing are also observed (Fig. 5B1-6). Individual columns size varies from 10-15 cm to 45-55 cm and more across.

Almost throughout in the meta-basalt section the comagmatic meta-gabbro bodies are widespread. Their amount increases toward the upper course of the Kalynova gully. The bodies have sill- or dyke-like appearance.

The contact of meta-gabbro and meta-basalts can be seen in the points V-45 – V-46 (see Fig. 5B1-2 and Fig. 5B1-7). Meta-basalt flows are represented here by the fragments of ball-pillow, vesicular and massive zones composed of meta-basalts, meta-diabases (lower portions of restored flows), and various schists developed after above rocks and connected with them through the gradual transitions.

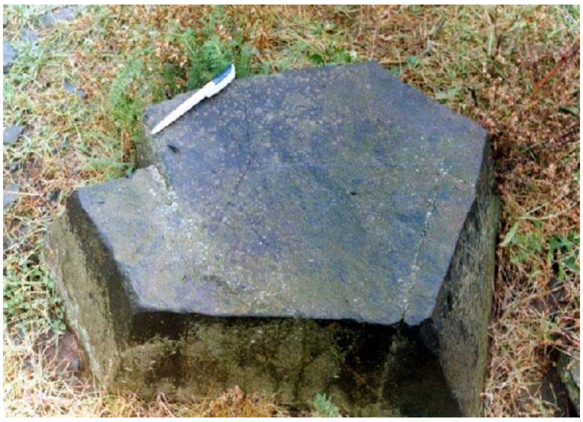


Fig. 5B1-6. Polygonal fragment of the columnar jointing in meta-basalts. Columns elongation is normal to the flow surface.

Fig. 5B1-7. The contact patterns between the comagmatic meta-basalt (top) and meta-gabbro (bottom).

STOP B1-4. The whole section of the lowermost komatiite-tholeiite rock association is impregnated by the individual cutting and conform bodies of aplite-like and pegmatoid granites and quartz veins. Example of the aplite-like granite vein deformed into pseudo-fold is observed in the upper course of Kalynova gully (Fig. 5B1-8). Meta-basalt schistosity abuts against the contact of the fold. Schistosity-induced lineation resembles axis-plane cleavage of this fold. It is characteristic that the texture elements in meta-basalts do not follow the "fold" geometry and, therefore, the cutting vein received its shape upon the horizontal compression of the meta-basalt sequence.

Fig. 5B1-8. Diverse aplite veins.
Left: Lensed aplite vein in vesicular basalts.
Right: Aplite veins deformed into the pseudo-fold.

(--- bus drive for 3.6 km ---)

Target B2. Balka Ovseeva.
Purpose: assessment the Surskiy Complex plagiogranitoids intruded into the lower greenstone portion of the Belt.

Further on excursion passes over 2.5 km in south-western direction through the gully-ravine system to the mouth of Ovseeva gully which is almost unexposed. Just in its mouth, which spatially corresponds to the contact of the south-western Bazavlutske tail-like extension with the basement migmatites intruded by plagiogranitoids of Surskiy Complex, the minor (up to 15 × 10 m) outcrops of the latter are observed (Fig. 5B2-1).

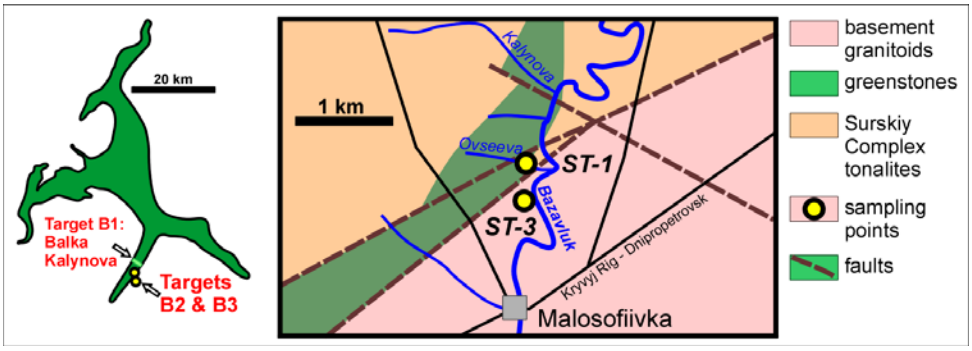


Fig. 5B2-1. Location of sampling points ST-1 and ST-3 for the Targets B2 & B3

Here, the rocks of KT-1 parageneration (massive and ball-pillow meta-basalts) are intruded by tonalites and plagiogranites of Surskiy Complex (tonalite-plagiogranite rock association) sampled (ST-1) for radiological dating of granitoids (Fig. 5B2-2).

Fig. 5B2-2. Samples taken for radiological studies

STOP B2-1.
Plagiogranites of Surskiy Complex constitute the south-western part of Oleksandropilskiy Massif which from the south intrudes the Bazavlutske tail-like extension composed of lower meta-basite batch of Surska Suite, Konkska Series (parageneration KT-1 of meta-komatiite-tholeiite rock association). The minor (3 × 6 m) outcrop of these plagiogranitoids (see Fig. 5B2-1) is located in sub-mouth part of Ovseeva gully (about 300 m up the stream course), the right branch of Bazavluk River.

Plagiogranite, studied for isotopic dating, comprises yellowish-grey porphyry-blastic unclear-gneissose rock composed of relatively coarse (1-3 mm) grains of idiomorphic plagioclase in the groundmass of more fine-grained (0.05-0.8 mm) plagioclase-quartz-microcline aggregate where biotite, epidote and minute amphibole grains also occur. Opaque minerals are arranged in sub-parallel bands and chains of grains and flakes. The accessories include garnet, apatite, zircon, sphene, and ore minerals (magnetite, pyrite).

The rock texture is hetero-blastic to porphyry-blastic (in places – relic hypidiomorphic), in biotite-enriched zones – lepidograno-blastic, in places blasto-cataclastic.

Chemical composition of plagiogranite (%): SiO_2 – 75.75; TiO_2 – 0.23; Al_2O_3 – 12.31; Fe_2O_3 – 0.71; FeO – 2.33; MnO – 0.06; MgO – 0.36; CaO – 2.06; Na_2O – 3.15; K_2O – 2.68; P_2O_5 – 0.06; SO_3 – 0.16; CO_2 – 0.25; H_2O^- – 0.05; LOI – 0.61; Total – 100.77.

Plagioclase: about 35% (0.05-3 mm), polysynthetic-twinned isometric idiomorphic and irregular grains. In places saussuritized, epidote grains sometimes occur.

Quartz: about 35% (0.1-0.8 mm), oval and isometric grains. In places of silicification it is observed mainly in veinlets, lenses and band-like segregations.

K-feldspar (microcline): 8-10%, in place up to 20% (0.1-0.8 mm), xeno-blastic and isometric grains with typical lattice texture. In some grains irregular inclusions of plagioclase relicts occur.

Biotite: up to 8% (0.1-1 mm) greenish-brown flakes with pleomorphism from greenish-yellow by Np and become non-transparent dark-brown by Ng. In places chloritized flakes and fine chlorite particles replacing biotite are observed in the aggregate of blastic quartz.

Epidote: up to 5% (0.1-0.8 mm), isometric, rhombic and elongated crystals, often in association with biotite. In places it is observed inside the coarse plagioclase crystals.

Amphibole (common hornblende): fine (up to 0.1 mm) idiomorphic crystals, pleomorphism from light-green to bluish-green; it is observed in single crystals in the intergrowth with tabular grains of polysynthetic-twinned plagioclase.

Apatite: less than 1%, fine prismatic crystals included mainly in plagioclase and quartz.

Zircon: well-faceted light-pink, pink (first variety) and pink-brown, light-brown (second variety) crystals.

The *first-variety zircon crystals* are transparent, with characteristic simple graining provided by combination of obtuse bipyramid {111} and prism {110} facets – zircon type, in places {100} – hyacinth type. In places acute bipyramid {311} facets are known. The facet surface is flat, bright.

The first-variety crystals display distinct concentric-symmetry zoning that replicates the internal crystal contour, high birefringence (Fig. 5B2-3a, b). Normally the internal zones are more prominent while in the core zonation is weak and often is observed under high enlargement only. The crystals contain transparent mainly needle-shaped inclusions, in places – black non-transparent isometric and elongated inclusions. Overgrowth of younger zircon (envelope) is not observed visually.

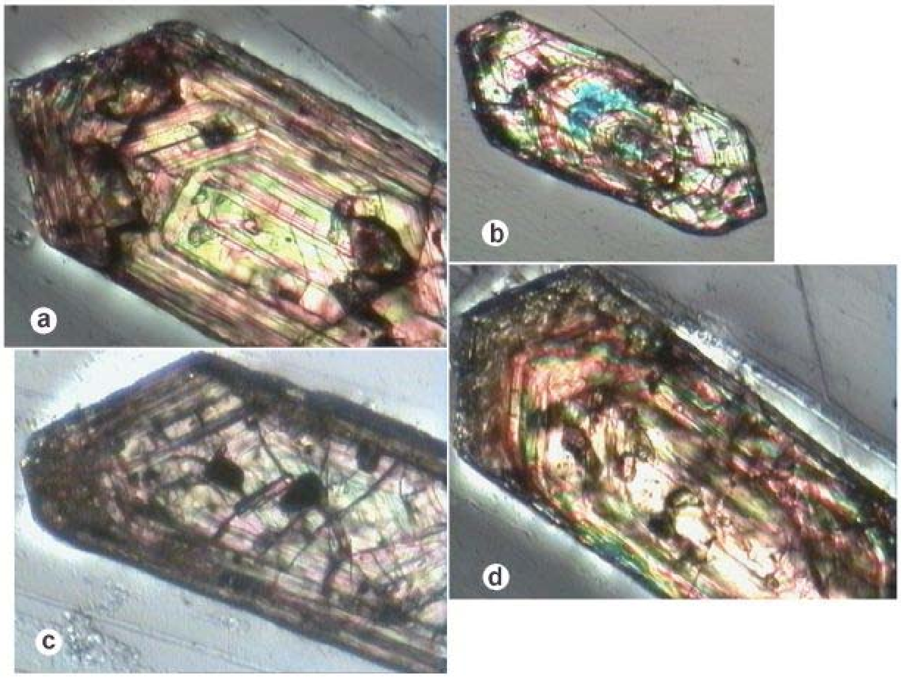


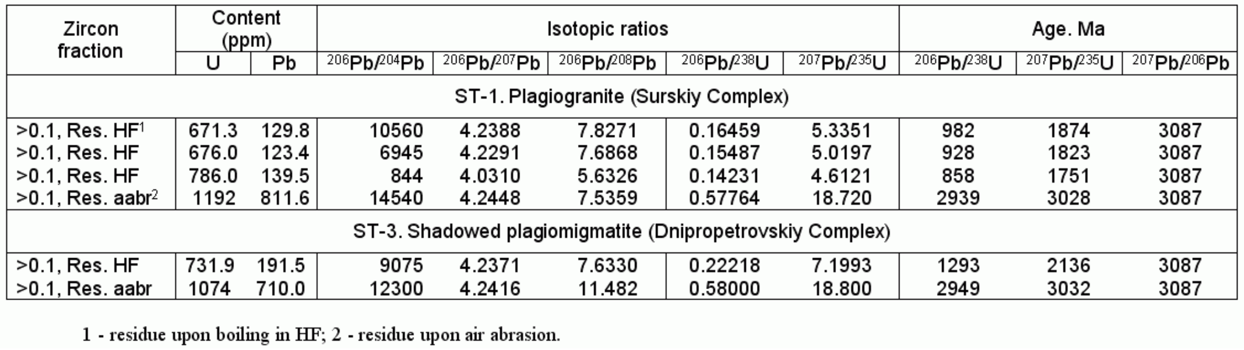
Fig. 5B2-3. Microphotographs of zircon crystal slices from plagiogranite of Surskiy Complex (sample ST-1). Cross-polarized light, enlargement 240×. See text for details.

The *second-variety zircon crystals* are semi-transparent and more coloured – non-transparent. The graining is provided by combination of obtuse bipyramid {111} and prismatic belt {110} and {100} facets developed in almost equal extent. The facet surface is flat, bright although the crystals with distinct shagreen facet surface are often observed. In many crystals the white "sprinkles" are observed on the facet surfaces which probably can be interpreted as highly-fractured thin envelopes.

The second-variety crystals display complex internal structure in the crystal cross-sections. Two zircon generations are identified [the relic substratum zircon is not found (in contrast to the migmatite leucosome in sample ST-3, see Target B3)]. The first, apparently igneous zircon generation constitutes the cores (90-95% by crystal volume) with high birefringence and thin concentric zoning (Fig. 5B2-3c, d) which mirrors the core contours. By optical and crystal-morphology properties the first-generation zircon is identical to the above first-variety crystals. Alike the latter, the crystal zones are more prominent by the periphery while in the core the zoning is less expressed. The second-generation zircon is observed in relatively thin envelopes with low birefringence colours and probably was formed along with K-feldsparization process. Often the "envelopes" do not surround entire crystal but are overgrown on its heads. Some fine crystals are coreless and are composed of the "envelope" zircon only being low-birefringence, almost isotropic grains. The core zircon contains numerous needle-shaped and prismatic transparent inclusions, it is cut by fractures. In places dark non-transparent isometric and short-prismatic inclusions occur. In some crystals the thin-zoned zircon sites are isotropized. These sites are expressed by dark irregular spots in cross-polarized light.

In purposes of radiological dating the pink and light-pink prismatic crystals of the first variety were collected. Alike the zircons in the sample ST-3, to avoid the late envelope zircon inclusion into the sample for dating [Shcherbak et al, 1989a], prior to the dissolution three of selected probes were boiled in 10% HF for 15 minutes, and one probe was abraded in the steel cylinder with diamond dusting under compressed air stream. The chemical interaction of three probes with fluorine acid had caused essential breaking in closure of zircon isotopic systems (discordant ratio about 70%), probably resulted from more extensive lead removal in comparison to uranium. At the same time, mechanically abraded probe provides the discordant ratio of 4.8% only. However, irrespective the modes of probe preparation, all zircon fractions yield similar age of 3087 Ma by ^{207}Pb/^{206}Pb isotopic ratio (Table 5B2-1).

Table 5B2-1. Uranium and lead content and lead isotopic composition in zircons from plagiogranites of Verkhivtsivskiy Belt



Zircon fraction	Content (ppm)		Isotopic ratios					Age. Ma		
	U	Pb	^{206}Pb/^{204}Pb	^{206}Pb/^{207}Pb	^{206}Pb/^{208}Pb	^{206}Pb/^{238}U	^{207}Pb/^{235}U	^{206}Pb/^{238}U	^{207}Pb/^{235}U	^{207}Pb/^{206}Pb
ST-1. Plagiogranite (Surskiy Complex)										
>0.1, Res. HF[1]	671.3	129.8	10560	4.2388	7.8271	0.16459	5.3351	982	1874	3087
>0.1, Res. HF	676.0	123.4	6945	4.2291	7.6868	0.15487	5.0197	928	1823	3087
>0.1, Res. HF	786.0	139.5	844	4.0310	5.6326	0.14231	4.6121	858	1751	3087
>0.1, Res. aabr[2]	1192	811.6	14540	4.2448	7.5359	0.57764	18.720	2939	3028	3087
ST-3. Shadowed plagiomigmatite (Dnipropetrovskiy Complex)										
>0.1, Res. HF	731.9	191.5	9075	4.2371	7.6330	0.22218	7.1993	1293	2136	3087
>0.1, Res. aabr	1074	710.0	12300	4.2416	11.482	0.58000	18.800	2949	3032	3087

1 - residue upon boiling in HF; 2 - residue upon air abrasion.

The age of plagiogranites (sample ST-1), calculated from the upper concordance intersection by regression line (hand-made isochrone) revealed from results of isotopic dating of all four zircon fractions (see Table 5B2-1), is 3086±0.5 Ma (Fig. 5B2-4). Although the isochrone is hand-made, the age value obtained from its upper intersection with concordance does reflect reliably enough the time of igneous zircon crystallization since it fully coincides with the age calculated by ^{207}Pb/^{206}Pb isotopic ratio.

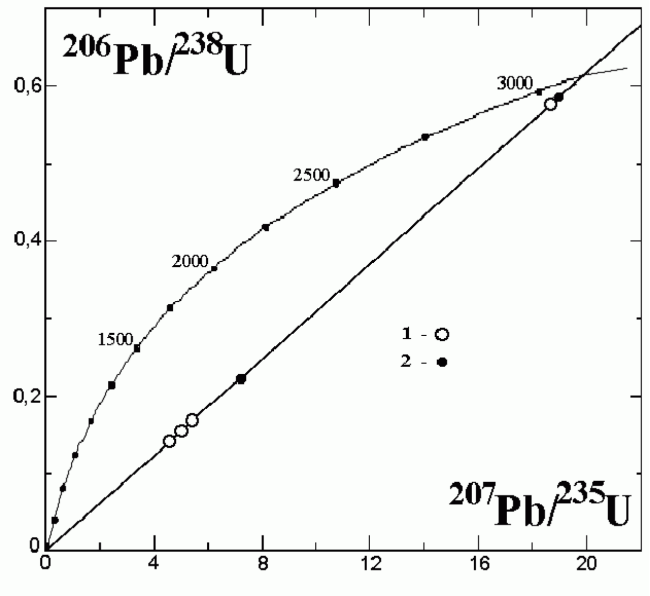


Fig. 5B2-4. U-Pb diagram with concordia for zircons
from plagiogranites of Surskiy (1) and Dnipropetrovskiy (2) complexes.
1 - plagiogranite, sample ST-1, right bank of Bazavluk River,
mouth part of Ovseeva gully, age 3086.7±0.5 Ma;
2 - shadowed plagiomigmatite, right bank of Bazavluk River, abandoned quarry nearby high-voltage power line; calculated age for all estimated points – 3086.8±0.3 Ma.

The age value calculated from the intersection with disconcordance designed for the zircons from two samples (see Fig. 5B2-4) is 3086±0.3 Ma.

Target B3. Bazavluk River bank outcrops.
Purpose: assessment the basement rocks of Verkhivtsivskiy Belt – Dnipropetrovskiy Complex migmatites developed after primary-stratified rocks of Aulska Series.

Further on from the Target B2 in the west-south-western direction toward the area of high-voltage power line the basement rocks of Verkhivtsivskiy Belt are exposed in the Bazavluk River bank outcrops.

STOP B3-1.
Plagiogranite-gneiss (shadowed plagiomigmatite) of Dnipropetrovskiy Complex (sample ST-3) is developed after plagiogneiss substratum of Aulska Series rocks; this composite unit comprises the basement of Verkhivtsivskiy Greenstone Belt.

The sample is taken in the quarry on the right bank of Bazavluk River (see Fig. 5B2-1 and Fig. 5B2-2), in 2.5 km to the north from the bridge in Malosofiivka village (Dnipropetrovsk – Kryvyj Rig highway). The migmatite-like rocks of paleosome type with substratum of Aulska Series stratified rocks are observed in the cliff outcrops. The latter rocks comprise the relic lens-like bodies of amphibolites and biotite plagiogneisses of various replacement and, respectively, preservation degrees. The migmatite leucosome is composed of band-shaped linear or irregularly-smoothed shadow-type plagiogranites. The sample ST-3 was taken from the minor (0.5 × 0.8 m) fragment of these granitoids (see Fig. 5B2-1 and Fig. 5B2-2).

The studied migmatite leucosome comprises K-feldspatized plagiogranite composed of relatively coarse oval and sub-tabular plagioclase porphyry-blasts arranged in the "eyes" (2-8 mm) of separated grains, and the lens-like aggregates in the intergrowth with quartz occurring in the fine-grained garnet-epidote-chlorite-plagioclase-quartz-biotite groundmass. Microcline is developed irregularly in the films and drop-like aggregates (in places – in the individual xeno-blastic grains). Biotite is observed in poikilo-blasts in plagioclase. Accessories, besides garnet, also include apatite and zircon. The ore minerals include magnetite and pyrite. Texture is porphyry-blastic, ocellar, with lepido-granoblastic texture of the inter-augen mass. In places the elements of poikilo-blastic texture are observed.

Chemical composition of plagiomigmatite (%): SiO_2 – 72.50; TiO_2 – 0.25; Al_2O_3 – 14.07; Fe_2O_3 – 0.77; FeO – 2.44; MnO – 0.06; MgO – 0.61; CaO – 2.04; Na_2O – 4.94; K_2O – 1.22; P_2O_5 – 0.05; SO_3 – 0.10; CO_2 – 0.05; H_2O^- – 0.13; LOI – 0.71; Total – 99.94.

Plagioclase (oligoclase No. 20-22): about 48% by rock volume, porphyry-blastic (1-3.5 mm) and isometric (0.1-0.8 mm) grains in the inter-granular aggregate. Both polysynthetic twins and twinned porphyry-blasts are observed. Frequently enough plagioclase is saussuritized, most extensively in the cores. In the coarse porphyry-blasts the irregularly-shaped relicts of early plagioclase are often observed and in some places – the regularly-oriented very fine (less than 0.01 mm) biotite flakes.

K-feldspar (microcline): about 3-5% (0.01-0.4 mm), it is irregularly distributed and mainly observed in the interstices of plagioclase and quartz grains.

Quartz: up to 30% (0.1-2 mm); together with plagioclase and biotite fills up the inter-granular space, in places it is observed in the coarser grains. Sometimes it is observed in the lens-shaped aggregates of some grains.

Biotite: about 10%, in places up to 17% (0.08-1.5 mm), isometric and elongated flakes, greenish-brown by Ng and dark-brown non-transparent by Ng. Biotite often is observed in the intergrowths with epidote and the individual garnet grains.

Epidote: about 3% (0.05-0.25 mm), is associated with biotite and chlorite.

Garnet: about 1% (0.04-1.2 mm), is observed mainly in minor chain-like aggregates, often in the intergrowths with biotite, rarely in the individual separated grains.

Three zircon varieties are distinguished in the rock. The *first zircon variety* comprises light-pink, pink, transparent and well-faceted crystals (about 5% of the total zircon mass). Among the facets the obtuse bipyramid {111} and prismatic belt {100} (hyacinth type) are developed. In contrast to the pink zircon crystals from Surskiy Complex plagiogranite (sample ST-1), faceted mainly by the prism {110}, the latter facets in the given zircons are much rare and in most cases in combination with acute {311} or even more acute bipyramid. The crystal elongation is 3-4, rarely more than 5. Studies of the crystal cross-sections reveal concentric-symmetrical zoning characteristic for the igneous rock zircons. The zones are relatively wide and more smoothed (Fig. 5B3-1), in contrast to the zircon crystal zoning in Surskiy Complex plagiogranite. In the cross-polarized light they normally display high and medium, rarely low birefringence colours.

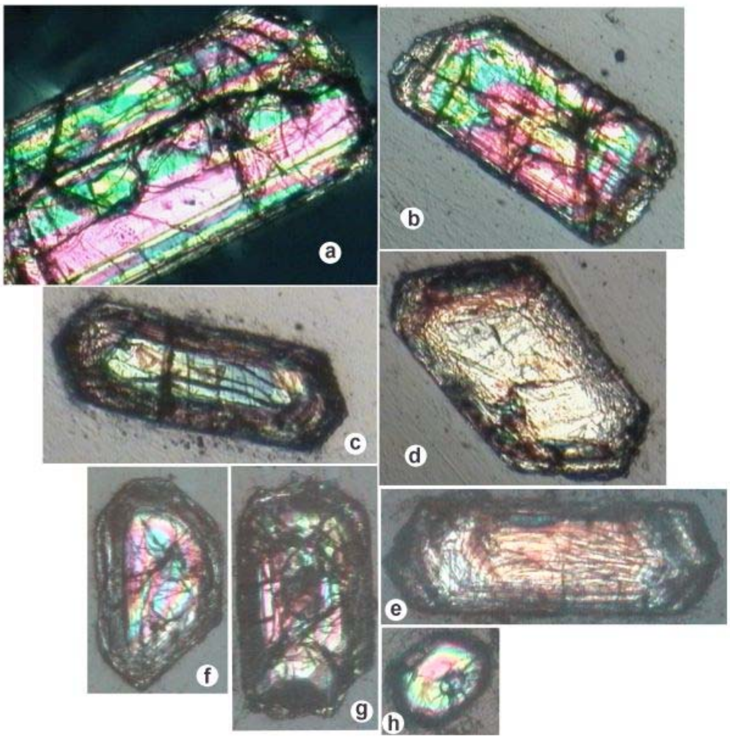


Fig. 5B3-1. Microphotographs of zircon crystal slices from shadowed plagiomigmatite of Dnipropetrovskiy Complex (sample ST-3). Cross-polarized light, enlargement 240×. See text for details.

The *second zircon variety* comprises pink-brown, light-brown crystals (about 99% of the total zircon mass). Their faceting is provided by the combination of obtuse bipyramid {111} and prismatic belt {100} and {110}. The latter normally are subordinate. In places the crystals with acute {311} bipyramid facets are developed. In some (spear-like) crystals acute facets are more developed than obtuse ones. The crystals are transparent, semi-transparent, and non-transparent. Their elongation often is in the range 2-3, rarely more than 3. In some cases the short-prismatic crystals occur with elongation coefficient about unity.

In the cross-sections of the second variety crystals the composite internal structure is observed. The cores, similar by morphological and optical properties to the first variety zircon crystals (zoned with regular crystallographic contours and high, medium and low birefringence colours), are surrounded by the late envelopes composed of non-zoned, almost isotropic zircon (see Fig. 5B3-1b, c, d, e). Its crystallization, in our view, is caused by the K-feldsparization process. Some correlation between the thickness of the envelopes and the grain transparency is noted. The envelopes are almost lacking in around of the transparent crystals while in case of non-transparent crystals the envelope volume in places attains 50% by the crystal volume.

The time gap between the endogenous geological processes resulted in crystallization of zoned "magmatogenic" zircon and isotropic envelope zircon is evidenced by the cores composed of crystal fragments grown up with the isotropic envelope zircon (see Fig. 5B3-1e).

In some cases the weakly-preserved relicts of pre-migmatite (substratum) zircon are observed inside the "cores" of magmatogenic zircon. The relicts are mainly weakly-preserved, without clearly-expressed crystal-morphology contours (see Fig. 5B3-1f) and in places only well-faceted grains occur (see Fig. 5B3-1g).

The *third zircon variety* comprises milky-white, snow-white, dirty-white to dirty-grey non-transparent crystals (single grains). In their cross-sections, alike the crystals of the second variety, the zircons of two late generations are observed. Of these, the first one comprises minor weakly-zoned cores similar to the cores in the second variety zircon crystals, and the isotropic grow-up envelopes represent the second one. The core volume (normally) does not exceed 50% of the crystal volume and in places entire crystal is composed of the isotropic zircon. Thus, the third zircon variety differs from the second one in colour only, perhaps, due to the thicker envelopes. The relic substratum zircon is not found (probably because of limited number of studied crystals).

Presented observations on accessory zircon crystal morphology and anatomy allow conclusion on three zircon generations contained in the plagiomigmatite. The oldest "pre-migmatite" generation is observed in the relicts inside the zoned "magmatogenic" second-generation zircons, which, with the time interruption, are overgrown by the optically isotropic third-generation zircon. In addition, it can be reliably assumed that the crystals of the first variety ("magmatogenic" zircon generation) crystallized from the silicate melt; this provides new opportunities in the dating the time of migmatites neosome formation.

For the age determination the light-pink and pink transparent crystals were selected (first variety). To avoid the probe contamination by the crystals with latest zircon envelopes [Shcherbak et al, 1989a], one zircon probe was boiled in 10% HF for 10 minutes and another probe was abraded in the steel cylinder with diamond dusting under compressed air stream.

The chemical interaction of three probes with fluorine acid had caused essential breaking in closure of zircon isotopic systems (discordant ratio is 58%). Perhaps, likewise the first case (sample ST-1) this is resulted from more extensive lead removal in comparison to uranium. At the same time, mechanically abraded probe provides the discordant ratio of 4.5% only. It should be noted that irrespective the mode of probe preparation, both zircon fractions yield the similar age of 3087 Ma calculated by $^{207}Pb/^{206}Pb$ isotopic ratio (see Table 5B2-1). This means we are enabled to select the zircon crystals without later zircon overgrowths or these latter were removed either by chemical or mechanical processing. The latter method is more efficient leaving unbroken the zircon isotopic system.

On the ground of the age values received, in the line of common practice it could be quite logically concluded that the complexes and their rocks are coeval. However, this conclusion would be not only incorrect but also spurious in term of practical application for radiological dating of some petrotypes. Available U-Pb isotopic data received for the zircons from plagiogranitoids of Dnipropetrovskiy and Surskiy complexes suggest for long-term evolution of both complexes (2.95-3.17 Ga) [Artemenko, 1998; Samsonov et al, 1993; Shcherbak et al, 1989] over several phases of granite formation.

The problem is that (according to the recent studies) the zircons in the granitoid samples of both complexes are principally different in the internal structure since only some zircon crystals from migmatites of Dnipropetrovskiy Complex (e.g. samples ST-3, ST-5) do have clearly identified relict cores (see Fig. 5B3-1h) in amount of about 30% by crystal volume. These are the core portions of zircon crystals which provide the information on the age of "pre-migmatite" stage of these granitoids indeed, but by technical reasons (lacking the opportunity for dating the crystal specific zones by ion-ionic mass-spectrometer) they were not studied. In other words, the isotopic features of those zircons from pre-migmatite relic cores have been identified in these rocks whose age coincides with the age of plagiogneiss substratum in the studied migmatites (sample ST-3).

It is followed by the obvious conclusion that in the course of Surskiy Complex granitoid intrusion into the migmatite-granite-gneiss country rocks (under conditions estimated in [Bobrov, Sivoronov, 1987]) the natural re-mobilization of stratified sequences of Aulska Series (substratum of the studied migmatites) occurred with formation of respective zoned zircon crystals which mark the magmatic stage. Since the process was developing in time and under influence of the Surski plagiogranitoids (with respective heat and fluid flows), the age of important geological events, including the massifs formation and coeval crystallization of "magmatogenic" zircon crystals and their growth over the early formed zircons of migmatite substratum (relict cores), is similar and is quite reasonably explained geologically.

Concerning the envelopes in the studied zircon crystals both from migmatites of Dnipropetrovskiy Complex and from plagiogranitoids of Surskiy Complex, which crystallization is probably caused by the K-feldsparization process, they are identical by major optical properties and, perhaps, by the age.

At the same time, occurrence of the relic cores in zircons from migmatites suggest for the older "isotopic" age of "pre-migmatite" plagiogranite-gneiss substratum of Dnipropetrovskiy Complex granitoids as it was previously shown in the studies of zircon crystals from the rocks of Bazavlutska Sequence using ion-ionic mass-spectrometer [Samsonov et al, 1993].

Thus, emplacement of allochthonous plagiogranitoids of Surskiy Complex, developed in Verkhivtskivskiy greenstone belt (sample ST-1), and the final stages of migmatization of the Aulska Series substratum (granitoids of Dnipropetrovskiy Complex, sample ST-3) occurred coevally at about 3087 Ma.

At the same time, the age of early phases of plagiogranites-gneisses migmatization (or at least their plagiogneiss substratum) is older as it is evidenced by the experience of the zircon dating by means of ion-ionic mass-spectrometer [Artemenko, 1998] and relic cores occurrence in the zircons from migmatites of Dnipropetrovskiy Complex.

OBJECT C. SURSKIY GREENSTONE BELT

Total itinerary length – 0.3 km, total walking distance – 0.3 km
Guides: Alexander Bobrov, Leonid Stepanyuk, Igor Merkushyn, Boris Malyuk, UkrSGRI, Kyiv; Vitaliy Sukach, Leonid Isakov, UkrSGRI, Dnipropetrovsk; Mykola Foshchiy, Mykola Kozar, State Treasure Enterprise "Pivdenukrgeologia", Dnipropetrovsk

Surskiy Greenstone Belt is the most studied greenstone object in the Middle-Dniprean Mega-Block (Fig. 5C0-1). And besides the other records, here is encountered and described the only place in Ukrainian Shield where the neck fragment of the large more than 3 Ga paleo-volcanic central-type unit is exposed. In the outcrops one can observe the well-preserved fragments of meta-basalt lava flows, diverse tuff and tuff-lava varieties (volcanic bombs, lapilli, psephitic and psammitic tuffs and tuff-lavas). The volcano is also studied in the numerous drill-holes. And results of geological mapping in around the volcano will be offered to the excursion participants.

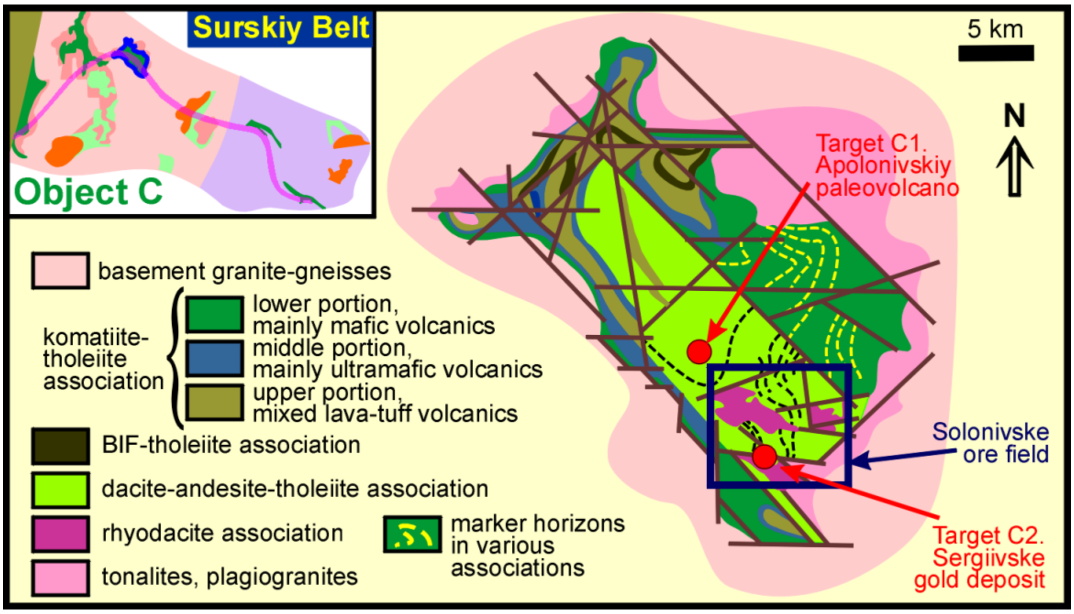


Fig. 5C0-1. Geology and tectonic of Surskiy Greenstone Belt

The single stop in the abandoned quarry will be used to examine the full number of Targets included in this excursion Object. The total itinerary length is 300 m (in the bottom of abandoned quarry) and it will include the neck fragment rocks, their contacts with various lava, lava-pyroclastic and pyroclastic rocks, cutting veins of gold-bearing quartz and rare asbestos-like tourmaline.

Exclusively, the field lunch will be organized for the participants in the crater of ceased Archean paleo-volcano.

Then the quarry bottom will be also used to demonstrate the core sections representing Sergiivske gold deposit located in the south of the Belt.

Finally, the field mini-workshop will be held at the same place devoted to the results of detailed radiological studies ("shrimping") over pre-ultra-metamorphic Dnipropetrovskiy

Complex tonalites and post-greenstone Surskiy Complex tonalites (already known from the Object B, Target B3 and Target B2 respectively) in the basement of the eastern Belt envelope.

Target C1. Apolonivskiy Paleo-Volcano.
Purpose: assessment the neck and periphery portions of paleo-volcano unit.

It is located in the central part of the Belt (see Fig. 5C0-1). This is the only place where the wide range of pyroclastic rocks (volcanic bombs, lapilli, psephitic and psammitic tuffs and tuff-lavas) can be studied in the outcrops. The neck (sub-volcanic and abyssal meta-gabbroids) and periphery (diverse lava-pyroclastic and pyroclastic rocks) portions comprise the paleo-volcano unit composed of the rocks of dacite-andesite-tholeiite association (upper part of greenstone column, 3.05 Ga Chortomlytska Suite of Konkska Series).

In the abandoned quarry to the north of Apolonivka village the fragment of Archean paleo-volcano erupted with mafic lava is exposed. Analysis of the various meta-volcanic facies suggests for their regular spatial distribution. In general, concentric-symmetry zonation of the volcanic facies is observed which gradually change one another from the volcano centre to its periphery (Fig. 5C1-1). In the gravity map of Vzz one may clearly distinguish the distinct gravity field patterns in the volcano area. Gabbroid rocks in the volcano necks provide highest anomalies whereas tuff and lava units display low and background values respectively.

The quarry cuts the eastern portion of the individual neck and adjacent caldera (Fig. 5C1-2). In this case caldera complex includes alternating lava flows, coarse- (agglomerate, lapilli) and medium-clastic tuffs and tuff-lava of mafic composition.

The neck portion of the eruptive centre is composed of meta-gabbro. This body 500 × 300 m in size is ellipsoid-shaped and slightly elongated to the north. The rocks of the body can be examined in the western and central parts of the quarry (Fig. 5C1-3).

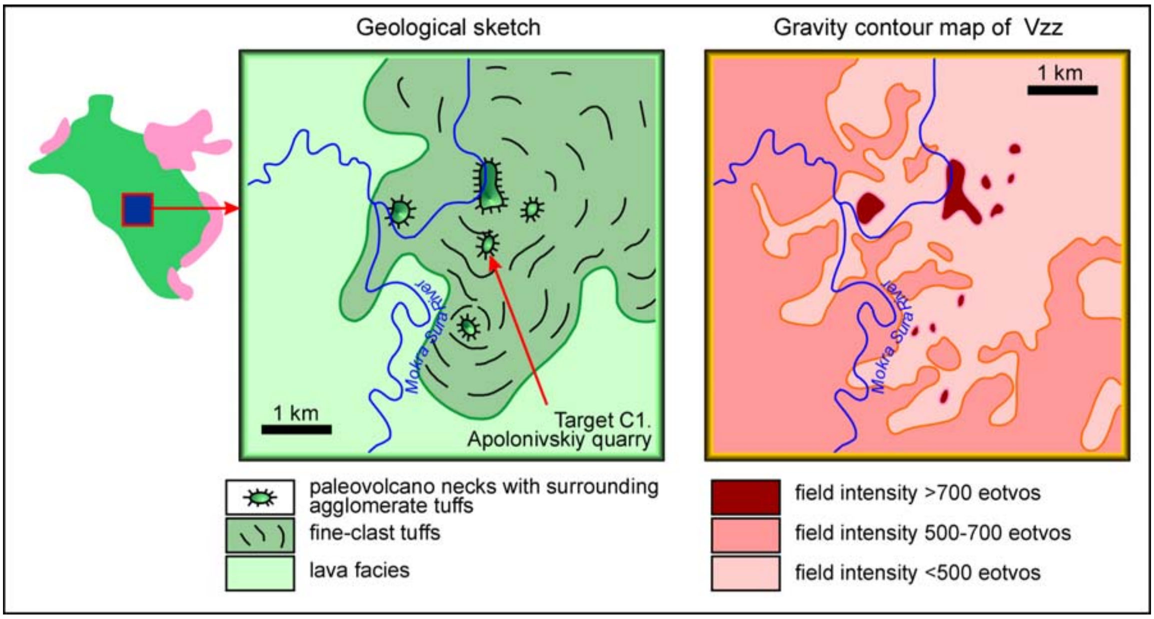


Fig. 5C1-1. Geological sketch and Vzz (d=0) map of the Apolonivskiy paleo-volcano

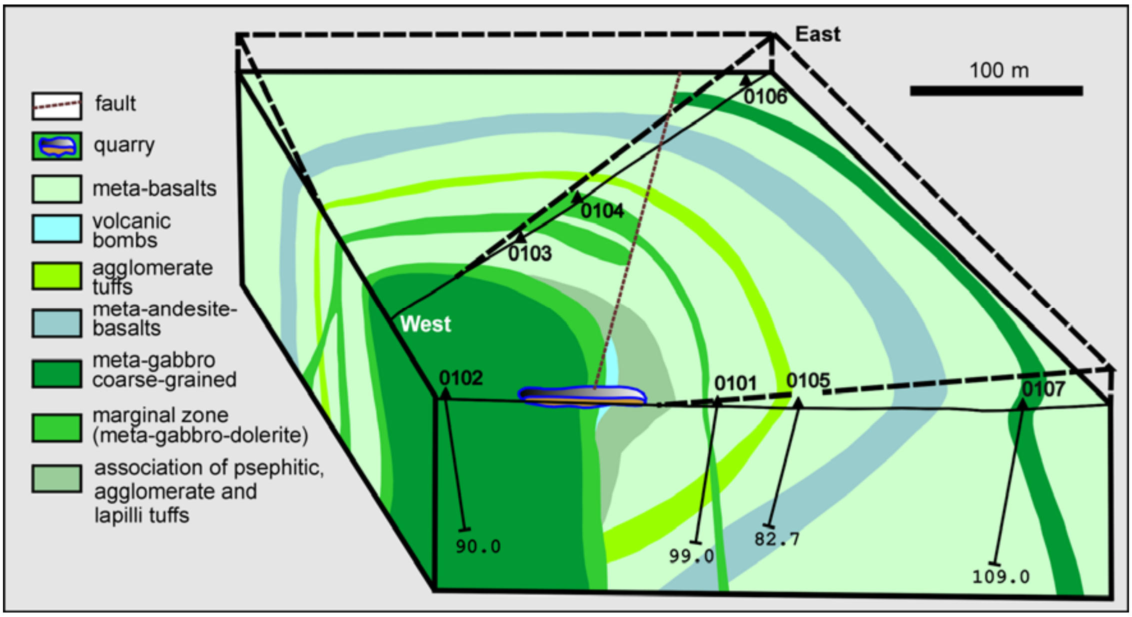


Fig. 5C1-2. The fragment of Apolonivskiy paleo-volcano

In the marginal portion of the gabbro neck the gradual outward transition of the rock grain size from coarse-medium-grained meta-gabbro to the fine-grained meta-dolerite is observed. This 15-20 m thick marginal zone is also expressed in the decreasing of amphibole and groundmass grain size while the mineral and chemical composition of the rocks remains unchanged (Table 5C1-1).

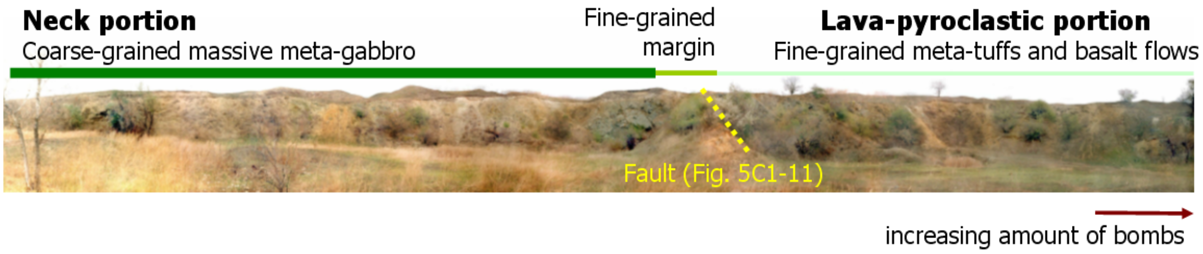


Fig. 5C1-3. Panorama image of the Apolonivskiy quarry.
See text for description of the paleo-volcano portions.

In the hand specimens these are dark-green massive porphyry-like rocks. Amphibole grains vary from isometric-prismatic 2-3 mm long with elongation as 1:(1-1.5) to prismatic 5-6 mm long with elongation as 1:(4-5). In thin sections (Fig. 5C1-4a, b) the random laths of twinned saussuritized oligoclase (0.4×0.2) – (0.5×1) mm in size are observed. The rocks display gabbro and sometimes gabbro-dolerite texture.

In the frame of other meta-volcanics, these rocks mark the neck of volcanic centre. The lava facies represented by the massive and pillowed tholeiite basalts are distributed in around the necks and by periphery of the paleo-volcano [Bobrov et al, 1981].

Table 5C1-1. Chemical composition of the Apolonivskiy volcano rocks

#	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SO_3	LOI	Total	H_2O
5	47.83	0.88	14.66	2.35	11.40	0.200	6.50	9.72	2.84	0.43	-	0.020	1.72	98.55	0.08
9	52.33	0.90	13.70	1.09	11.90	0.230	6.39	8.03	2.29	0.18	-	0.050	2.20	99.29	0.17
10	50.96	0.90	14.10	3.03	9.52	0.200	6.79	9.18	3.03	0.24	-	0.110	1.67	99.73	0.07
11	52.28	0.96	14.00	2.08	9.84	0.192	7.08	6.20	3.77	0.38	0.072	0.062	3.58	100.49	0.05
12	51.44	0.92	13.60	2.20	9.91	0.203	6.70	6.50	3.47	0.35	0.082	0.078	3.54	98.98	0.05
1	47.82	0.62	17.92	2.45	6.71	0.180	7.20	9.82	2.97	0.52	-	0.020	2.82	99.05	0.10
2	47.00	0.58	18.70	2.75	7.07	0.183	7.73	9.59	3.24	0.47	-	0.036	2.98	100.33	-
3	46.20	0.30	9.30	4.26	6.35	0.300	18.50	7.01	1.20	0.09	-	0.090	5.24	98.84	0.20
4	47.93	0.42	9.44	2.09	8.66	0.290	17.72	7.40	1.20	0.10	-	0.040	4.14	99.43	0.18
6	47.66	0.85	14.92	2.71	10.89	0.200	7.39	9.45	3.17	0.29	-	0.09	1.75	99.37	0.27
7	46.68	0.88	17.52	10.06	2.38	0.110	3.73	11.50	2.57	0.14	-	0.070	3.18	98.82	0.76
8	46.00	0.96	18.00	10.26	2.42	0.144	3.30	11.92	2.83	0.14	-	0.055	3.46	99.48	-
13	48.26	0.66	13.00	4.32	11.43	0.224	7.24	9.40	1.70	0.13	0.072	0.078	3.84	100.35	0.05
15	48.56	0.98	15.00	4.48	9.48	0.182	7.35	6.60	3.07	0.39	0.080	0.078	4.24	100.49	0.20
16	49.76	0.98	14.00	3.45	8.97	0.172	6.61	6.80	3.07	0.60	0.070	0.039	3.83	98.35	0.20
14	34.02	1.12	20.00	4.82	13.68	0.278	7.75	10.40	0.18	0.08	0.095	0.101	7.05	99.57	0.06
17	41.04	0.96	14.00	12.96	9.05	0.192	7.30	8.90	2.80	0.25	0.075	0.086	2.73	100.35	0.15
18	49.41	0.90	14.00	3.65	8.47	0.192	6.75	8.70	2.53	0.28	0.060	0.094	3.68	98.71	0.55
19	49.41	0.88	14.00	4.11	8.82	0.192	6.90	9.40	2.57	0.30	0.082	0.117	3.36	100.14	0.40
20	49.00	1.12	13.00	3.64	11.14	0.224	6.03	9.30	1.95	0.28	0.095	0.039	3.86	99.67	0.30

Lava units: 5, 9, 10 – amphibolites after meta-basalts; 11, 12 – meta-basalts crypto-grained; 1, 2 – vesicular amphibolites after meta-basalts (foam flow top); 3, 4 – plagioclase-actinolite schists after pyroxene komatiites;
Zones in meta-basalt pillow lavas: 6 – pillow meta-basalt; 7, 8 – central ("pillow core") parts of single pillows;
Pyroclastic rocks: 13 – fine-clastic meta-tuff; 15, 16 – medium-clastic meta-tuff; 14 – chlorite schist in cement of agglomerate tuff (Fig. 5C1-8);
Neck portion: 17 – meta-gabbro-dolerite fine-medium-grained (marginal zone); 18, 19 – meta-gabbro medium-coarse-grained; 20 – meta-gabbro coarse-grained (neck center).

Directly close to the neck (see Fig. 5C1-3) the wide range of rock varieties is exposed (Fig. 5C1-5a-c): the coarse-clastic agglomerate tuffs (fragments > 20 cm in size), psephitic giant- (3-20 cm) and coarse-grained (1-3 cm), psammitic (0.1-1 cm) tuffs without any signs of the clast sorting by their size and shape.

Volcanic bombs (Fig. 5C1-6a, b) with fragment size up to 1-1.5 m and more by long axis are observed in the vertical wall of quarry eastern part (see Fig. 5C1-3). They have elongated angular isometric outlines. It is characteristic that the fragments of various size and composition do coexist in the space, from basalt lava clast (meta-basalt) to their comagmatic sub-volcanics (meta-gabbro).

Relatively small fragments (0.5-3 cm) are commonly rimmed by 0.5-3 mm wide lighter zoned material (see Fig. 5C1-5a-e) which in places also surrounds the coarser fragments.

Agglomerate tuffs include two varieties that differ in the cement groundmass. The latter includes coarse (more than 3 cm) fragments of two types:

1. clasts are enclosed in cryptic almost non-crystallized basalt fabric (Fig. 5C1-7) of the following mineral composition (in %): actinolite – 43-45, chlorite – 20-25, plagioclase – 12-25, epidote – up to 10, leucoxene – 10;

2. clasts occurring within medium-grained (clast size 0.5-2.5 cm) groundmass (Fig. 5C1-5a-d; Fig. 5C1-8) which mineral composition is exactly the same to the coarse fragments (meta-gabbro).

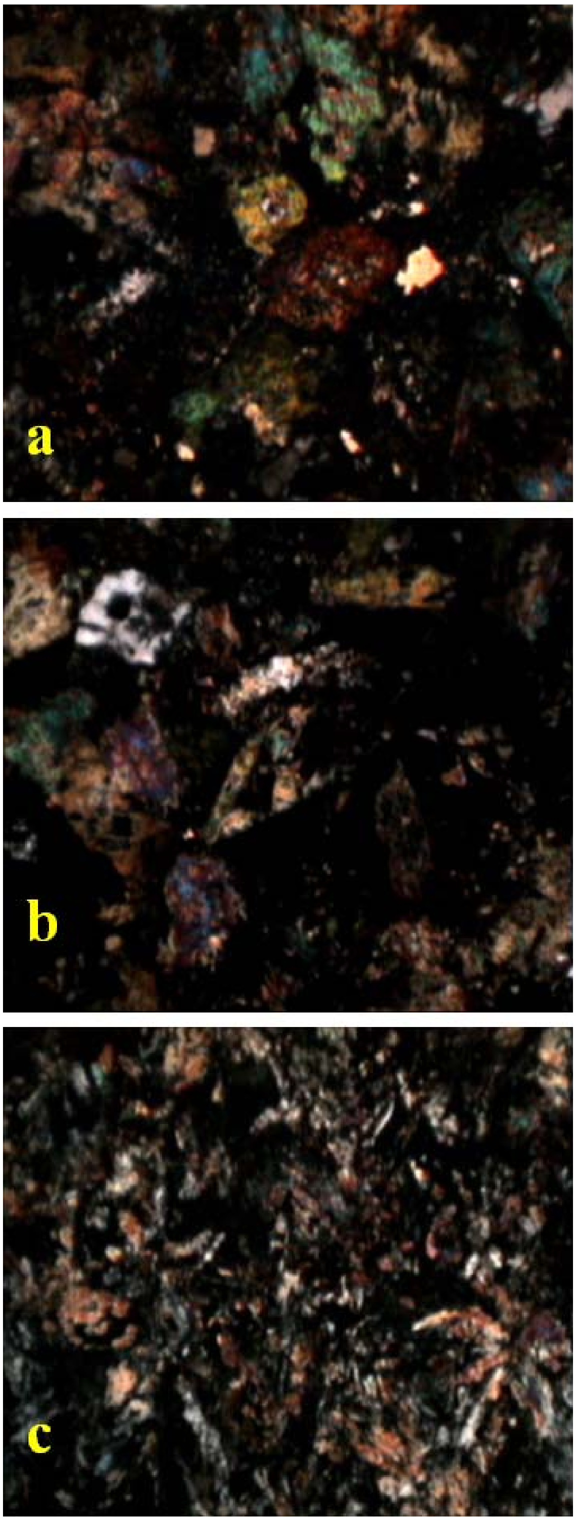


Fig. 5C1-4. Microphotographs of meta-gabbro (a, b) and meta-gabbro-dolerite (c) from paleo-volcano neck. Cross-polarized light, enlargement 15×.

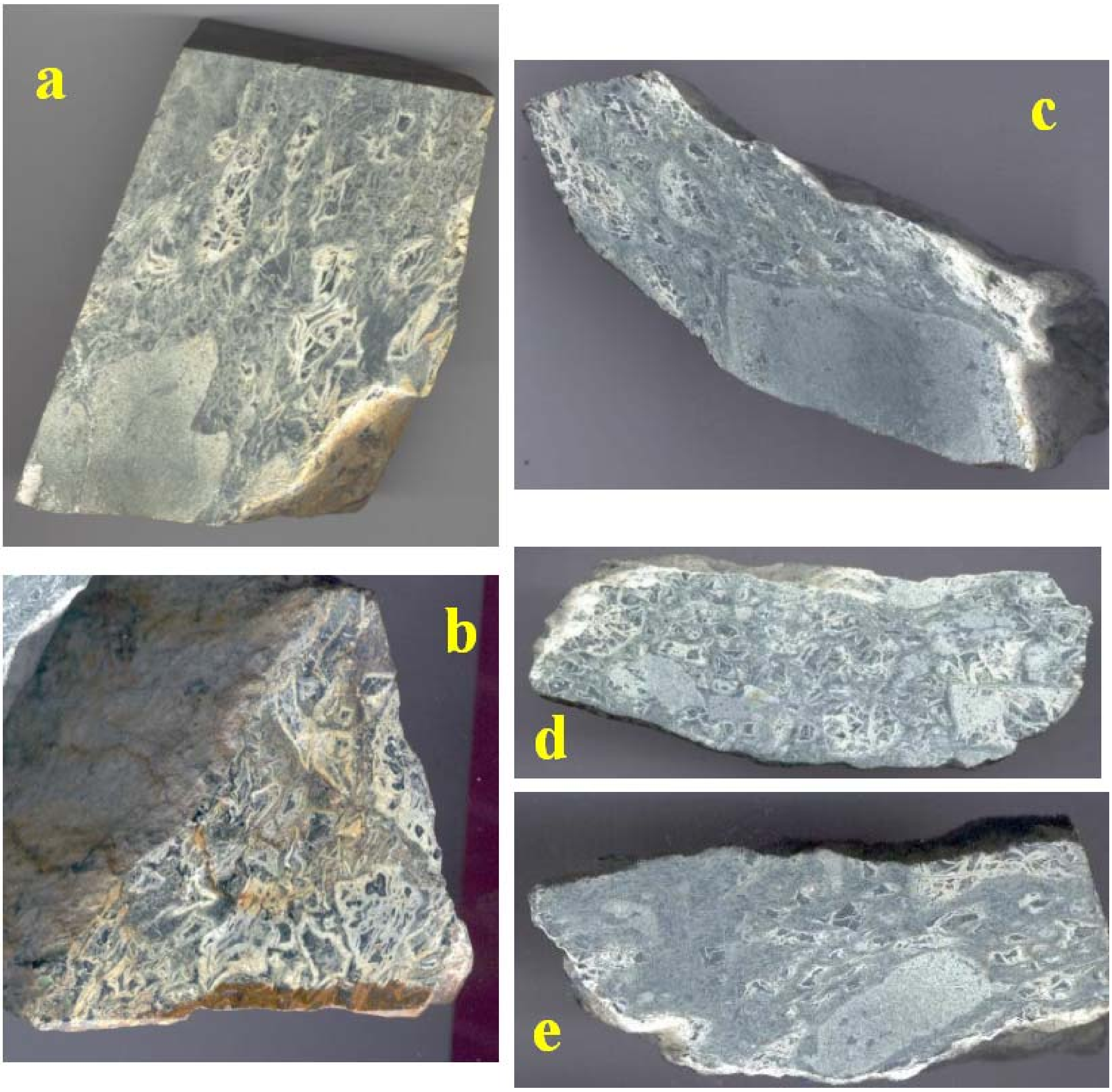


Fig. 5C1-5. Angular fragments of meta-basalt and meta-gabbro-dolerite in the medium-clast tuff groundmass.
Interstices are filled with quartz-epidote aggregate, iron-oxidized.
Specimen size by long axis: a – 9 cm, b – 11 cm, c – 9 cm, d – 11 cm, e – 6 cm.

Fig. 5C1-6. Meta-gabbro-dolerite fragments in meta-basalts.
At the fragment contacts – marginal alteration (chilling, sintering). Fragment size: a) 7 cm, b) 4 cm.

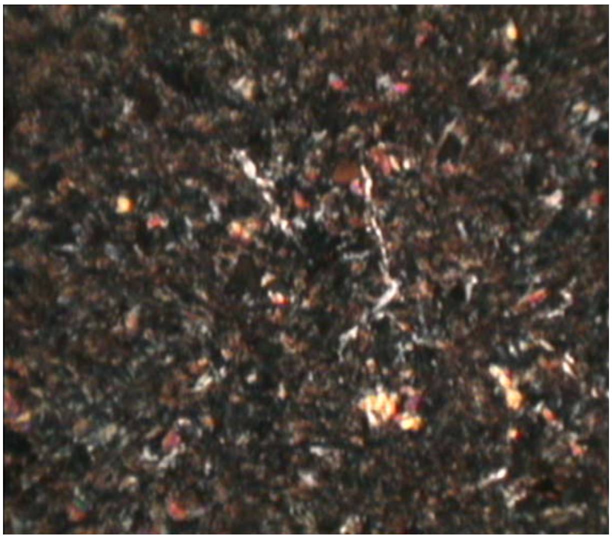


Fig. 5C1-7. Meta-basalt microphotograph. Cross-polarized light, enlargement 18×.

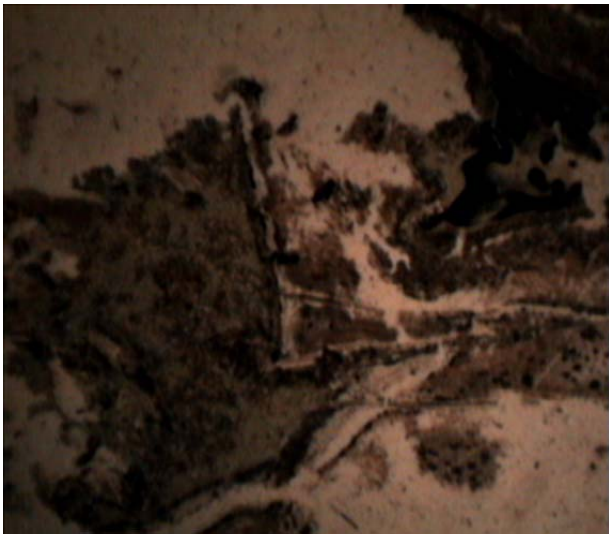


Fig. 5C1-8. Meta-tuff microphotograph. Space between the fragments – zoned groundmass. Plane-polarized light, enlargement 18×.

Fine fragments display some zonation in the margins. The outer 1-2 mm wide light envelope is composed of epidote whereas the inner thin (less than 1 mm) dark rim consists of chlorite. Interstices between the fragments are filled with quartz, epidote and are highly iron-oxidized. This type of tuffs contains a lot of fragments in the cement (70-80%). Some sites of the iron-oxide-cemented fragments resemble sintered tuffs.

The large fragments (from 3 to 150 cm) are of meta-gabbro composition and diverse shape: from isometric to irregular, angular, spindle-like.

Occurrence of the fine (first centimeters) and individual giant (up to 1.5 m) fragments (Fig. 5C1-9) in the same bodies suggests for lacking of any material sorting by size due to the direct proximity to the volcanic eruptive centre.

Around periphery of the fragments, enclosed in the fine-grained meta-basalt cement, the signs for marginal processes and sintering of the directly-contacting clastic material over the distance of some millimetres (see Fig. 5C1-6) are observed. This could happen due to the sinking of the chilled fragments into the hot lava.

Chemical composition of the fragments and groundmass of the agglomerate meta-tuffs, meta-basalts and meta-gabbro is given in Table 5C1-1.

The contact portion of meta-basalt flows is exposed in the quarry bottom (Fig. 5C1-10). The lower flow is massive and uniform whereas the upper one is of the same composition but contains a number of the fragments (5-20 cm in size) that were lightened by syn- and post-volcanic hydrothermal alteration. The contact line is sharp, irregular, with numerous bends.

Described paleo-volcano section is also studied in the drill-hole cores at some distance away from the neck (see Fig. 5C1-2). As noted before, the paleo-volcano is symmetry-concentric and outward the centre the substitution of coarse-fragment, non-sorted tuffs, with more fine-clast varieties is observed (see Fig. 5C1-1). The periphery portions of Apolonivskiy volcano include the intricate systems of layered meta-basalt lava flows, cutting and sub-conformable co-magmatic meta-gabbro and meta-gabbro-dolerite as well as individual meta-tuff, meta-tuff-sandstone, and meta-tuff-aleurolite beds [Bobrov, Sivoronov, 1987].

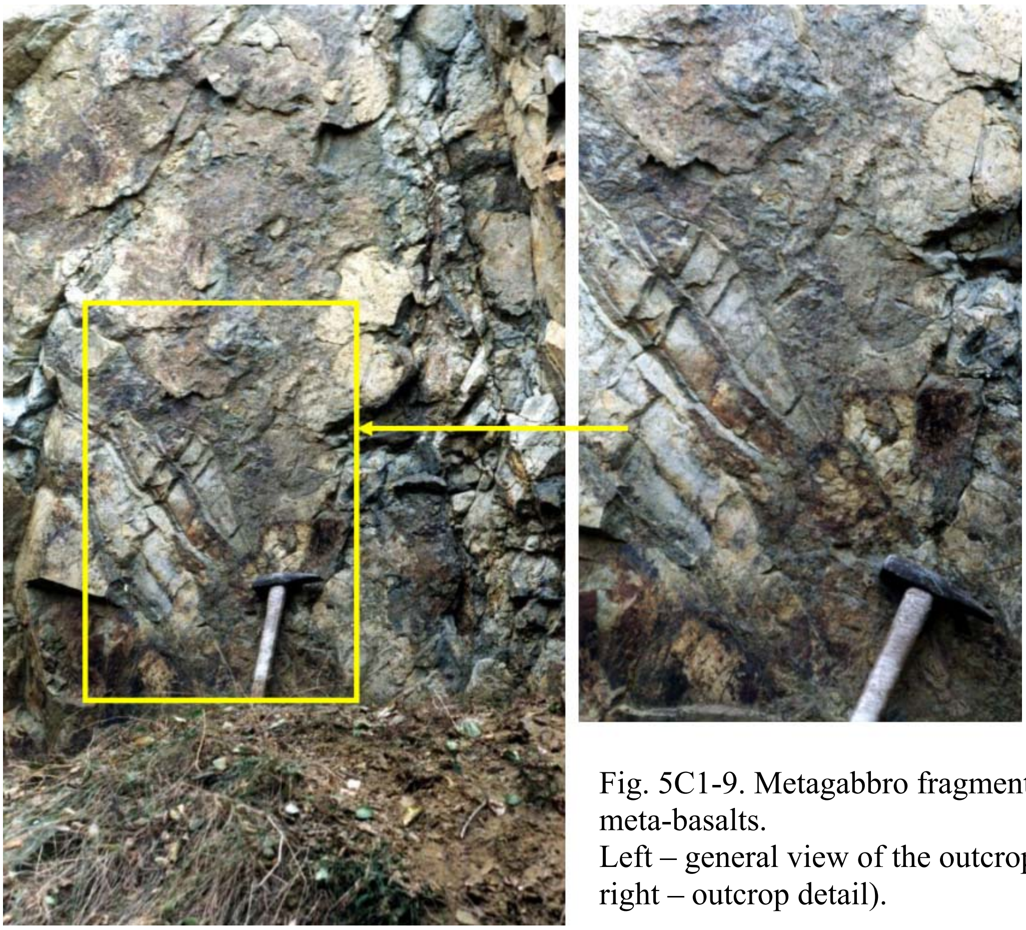


Fig. 5C1-9. Metagabbro fragments in meta-basalts.
Left – general view of the outcrop, right – outcrop detail).

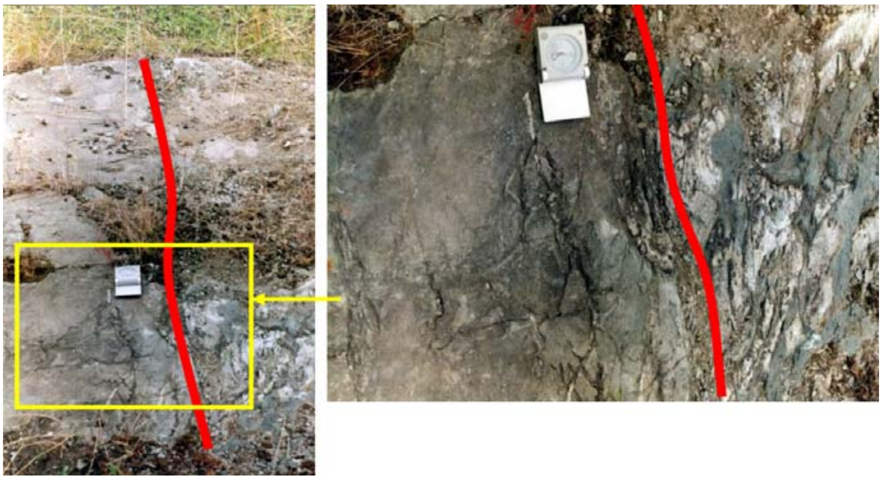


Fig. 5C1-10. Contact (red curve) between meta-basalt flows (with and without fragments). Left – general view of the outcrop, right – outcrop detail).

In the quarry central part, some first meters thick faults are observed, marked by the linear weathering crust after meta-basites and extensive iron oxidation with formation of the limonite-hydrogoethite-hematite concretions (Fig. 5C1-11). In places the faults are injected by the quartz veins with limonitized sulphides and asbestos-like bluish-greenish-grey tourmaline. According to the chemical-spectral analysis, gold content in these veins is about 0.1-0.3 g/t.

Fig. 5C1-11. Weathering crust in the fault zone

Target C2. Sergiivske Gold Deposit.
Purpose: assessment the general geology, core sections and gold ore types.

In the Middle-Dniprean Mega-Block the Surskiy Greenstone Belt is one of the most studied and significant in term of gold mineralization. Important gold object are located in the southern part of the belt in Solonivske ore field (Fig. 5C0-1, Fig. 5C2-1). These include Sergiivske and Balka Zolota gold deposits as well as several least studied prospects like Apolonivske, Rozrahunkove and Pivdenne. Administratively these objects are situated in Solonivskiy area of Dnipropetrovskiy region in 25-30 km to the south of Dnipropetrovsk.

Preliminary exploration is finished in Sergiivske deposit and prospecting completed in Balka Zolota deposit. It is concluded that both objects are of reasonable economic value and can be involved into further development.

Deposit is located close to Sergiivka village in 7 km to the southwest from Solone town. With respect to geology deposit is confined to the southern part of Solonivske ore field (see Fig. 5C2-1). Deposit was discovered by A.B.Bobrov during prospecting works in 1982-1985.

Deposit is completely overlain by the sedimentary cover with overburden thickness in the range 80-120 m. Thus, no part of the deposit is exposed and it is studied by drill-holes only.

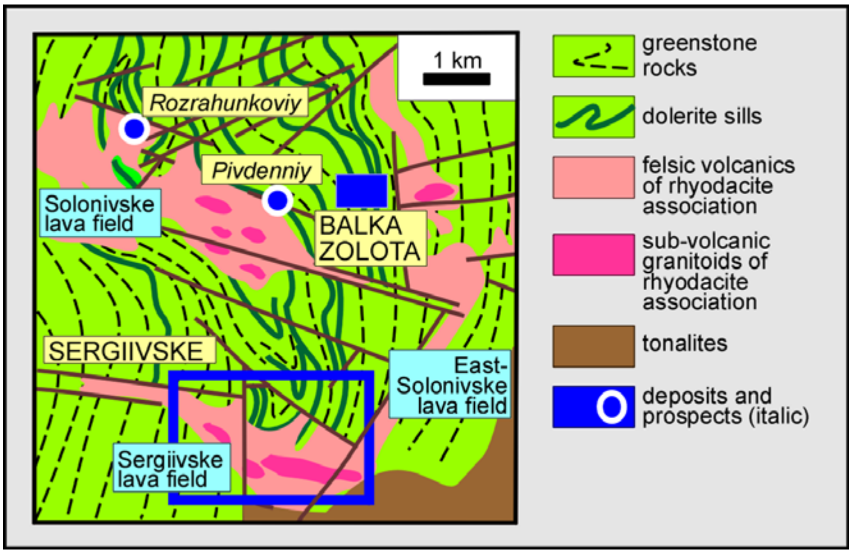


Fig. 5C2-1. Geology and gold-ore objects in Solonivske ore field.
See Fig. 5C0-1 for regional setting.

This is why examination of this target in excursion is only possible in the core sections to be brought at the site of the Target C1 together with the associated geological materials.

Host rocks. Gold mineralization is encountered in the rocks of two Neo-Archean volcano-plutonic associations (VPA) [Bobrov, 1989]: early mafic (upper metamorphosed dacite-andesite-tholeiite-diorite VPA) and late plagiogranite (metamorphosed rhyodacite-plagiogranite VPA). The early one includes meta-basalt flows and differentiated meta-gabbro-dolerite sills. The late VPA (ore-control and ore-forming) cuts the older mafic rocks. The given VPA comprises Sergiivske and Solonivske sub-volcanic bodies and series of parallel dykes of the felsic composition (Fig. 5C2-2).

Owing to the differences in physical properties (density, magnetic susceptibility and resistance) the rocks of these VPA are clearly expressed in the maps of geophysical fields. Meta-gabbro-dolerites are marked with high-contrast positive magnetic anomalies and less prominent areas of increased gravity, whereas felsic rocks, conversely, display negative gravity and magnetic fields. Meta-basalts are intermediate in this range providing background values.

Meta-basalts (olivine basalts) comprise the major host rock type. In the lava flows two meta-basalt varieties are distinguished: 1) fine-grained, porphyry, aphyric, sometimes vesicular, and 2) massive aphanitic that occur mainly in the eastern part. Aphyric rock texture gradually changes from the fine- to medium-grained toward the centre or bottom of the lava flow. These rocks are normally schistose while porphyry rocks are massive.

Meta-gabbro-dolerites are encountered in the two sill-like bodies in the central and eastern parts. The central body is extended in longitudinal direction and displays complicated geometry (see Fig. 5C2-2). The body has clear layered structure that includes four zones. The outer contact zones I and IV are composed of meta-dolerite-A with relic poikilo-ophitic texture. Zone III consists of porphyry-like meta-gabbro-dolerite-C of apparently cumulative origin in the lower portion of emplaced body. It is followed upward by the full-crystalline medium-grained uniform gabbro-dolerite-B suggesting for the stable conditions of igneous crystallization.

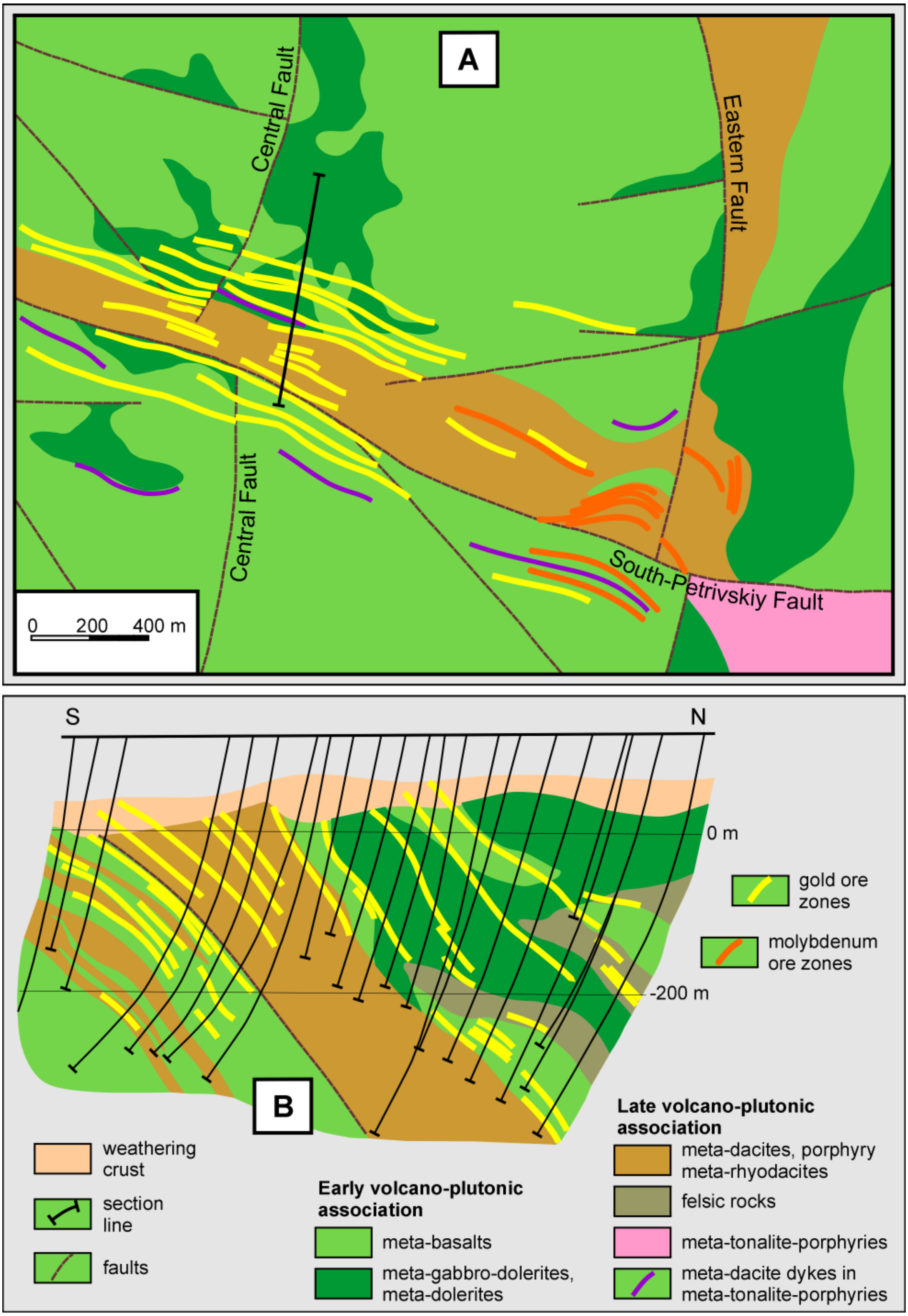


Fig. 5C2-2. Geological map (A) and cross-section (B) of Sergiivske deposit

Comagmatic relationships of meta-basalts and meta-gabbro are revealed from their close spatial association within a single magmatic structure, as well as similar mineral and chemical composition.

In the contact zones of the host mafic VPA and Sergiivske felsic body essential tectonic overprint of the former is encountered [Bobrov, 1989]. For instance, newly formed biotite (evidence for thermal influence of the felsic intrusion) is oriented in different manner and its laths elongation follows the late schistosity developed conformably to the felsic body margins.

The felsic sub-volcanic rocks are mainly porphyry meta-dacites (80-90%) with subordinate meta-rhyodacites, meta-tonalite-porphyries, and sericite-quartz-albite schists after above rocks. Numerous dykes accompany Sergiivske sub-volcanic body and have the same strike. The dykes are composed of porphyry meta-dacites, meta-rhyolites, and meta-tonalite-porphyries. Thickness of the dykes varies from 0.1 to 10-15 m being commonly 3 m thick.

Sergiivske sub-volcanic body actually comprises the thick sheet-like dyke. At the basement surface it is 150-400 m wide band that attains 3.5 km in some swells. Measured thickness of this body varies from 80 to 180-200 m. It plunges to the north-east at the angles $50\text{-}60^{o}$ in central part and is more flat ($45\text{-}50^{o}$) in the west. The body has general west-north-western strike and in the south-east it joins another Solonivska felsic dyke.

In the southern part of Sergiivske body A.B.Bobrov [Bobrov, 1989; 1993b, c; 1994] has described in the sub-volcanic meta-rhyodacites the enclosed relic fragments of quartz meta-greywacke as the remnants of paleo-volcanic structure. The rocks display evidences for short-distance transport (weak sorting, coarse-grained mixed composition) due to the submarine accumulation of terrigenous material derived from the host mafic-ultramafic associations as well as initial felsic rocks. Greywackes contain characteristic blue quartz from porphyry sub-volcanic meta-ryodacites. Presented evidences imply mixed composition of the Sergiivske body including not only prevailing igneous material but also relicts of the stratified components of the felsic volcanic structure that underwent extensive erosion.

Relationships of the sub-volcanic bodies and dykes (tonalite-plagiogranite VPA [Bobrov, 1989]) with the host rocks are sharp and cutting. In the outer contacts the altered mafic xenoliths often occur. Furthermore, in the contacts of Sergiivske massif the discontinuous 5-6 m thick bodies composed of tectonic breccia are encountered. The breccia matrix may consist of sheared meta-basalts, meta-gabbro whereas meta-dacite and meta-tonalite-porphyries comprise the fragments. In other case the fragments of extensively altered mafic rocks are found in the felsic cement aggregate.

Isotopic age of porphyry meta-dacites and tonalite-porphyries of this late VPA determined by U-Pb method on zircon is 3080±20 Ma [Artemenko, 1998].

The crystalline rocks are overlain by 20-60 m thick weathering crust that also contains the proven evidences for gold mineralization in amount of about 15% of the total deposit resources. In turn, Paleogene up to Quaternary clayey and sandy sediments overlie paleo-weathering crust.

Structure of the deposit can be briefly summarized as follows:

- Sergiivske sub-volcanic body, that controls the gold mineralization, is sharply cutting in relation to the longitudinal host meta-gabbro-dolerites and meta-basalts. Tectonic discontinuity angle is estimated to 80-90^o.
- Host meta-basalt lava flows do form the monocline sequence dipping at 20-35^o northward. It is the relic counterpart of paleo-volcanic structure deformed into the brachyform belt at the final stages of the Belt development.
- Sergiivske felsic body is of extrusive-intrusive origin; its upper part is removed by erosion and in the preserved lower portion the sub-volcanic rocks from porphyry dacites to tonalite-porphyries are observed.

The fault tectonics of Sergiivske deposit is defined by three main systems: diagonal north-west, sub-longitudinal and late sub-latitudinal. South-Petrivskiy fault represents the first system (see Fig. 5C2-2). It dips at 30-40^o to the north-east and is expressed by thick (100-200 m) zone of shearing and cataclasm that bounds deposit from the west. Sub-longitudinal Central and Eastern faults control development of gabbro intrusions. The latter fault is conventionally used as the eastern deposit boundary. The ore-control and ore-bearing North-Sergiivskiy fault belongs to the later tectonic system that cuts all previous faults. Gold mineralization is confined to the junction of North- and Central-Sergiivskiy faults whereas molybdenum mineralization is related to East-Sergiiskiy fault.

Spatial arrangement of the geological bodies and tectonic units allows conventional subdivision of the deposit into four blocks:

- Central (Sergiivske sub-volcanic body).
- Northern and Southern (hanging-wall and footwall contacts of the sub-volcanic body respectively).
- Eastern (junction of Sergiivske and Solonivske sub-volcanic bodies).

Three first blocks contain gold mineralization and fourth one – molybdenum.

Ore body location, types and composition of the ores. Most of the ore bodies occur in the close proximity (up to 10-35 m) to the contact of Sergiivske sub-volcanic body and are restricted to the accompanied thin meta-dacite and meta-tonalite-porphyry dykes. Minor ore bodies are encountered inside the sub-volcanic body and away (up to 300-400 m) from it.

More than 30 individual ore bodies are distinguished in the deposit. In eleven of them gold grade exceeds 3 g/t and average thickness is about 2.1 m. Gold-bearing zones are traced over the distance of more than 500 m along strike and dip, about 300 m in average.

According to the accepted tectonic model of the deposit, all ore bodies are located in the plane being parallel to the contact of Sergiivske sub-volcanic body. However, more complicated cases are also known where gold mineralization occurs along the weakened contacts of gabbro and basalts as well as diverse gabbro varieties. Normally these contacts are sheared and injected by the felsic dykes. Evidently this mineralization is connected to the already noted one and comprises extensions of other ore bodies.

The ore bodies in extensively sheared and metasomatically altered rocks (axial zones of the ore-metasomatic aureoles) consist of three ore types:

- Zones of vein-disseminated sulphide mineralization that are bound by some cut-off grade. Gold is distributed uniformly enough in the ore body volume. Sulphide content considerably varies from 1 to 40%; zone thickness rarely exceeds 10 m.
- Quartz-carbonate, carbonate-quartz and amphibole-quartz-carbonate veins and lodes up to first meters thick and up to 100 m long. Gold is restricted to the external contacts of the veins.
- Veins and lenses of the second type being contained in the first-type zones.

All the altered host rocks belong to the medium-temperature metasomatites formed by means of acid leaching with prominent potassium affinity.

Mineral composition of the ores in great extent depends on the host rock composition. Pyrite is the major ore mineral, less abundant are pyrrhotite, arsenopyrite, ilmenite, magnetite, chalcopyrite, molybdenite, and galena; minor minerals include tellurides, sphalerite, scheelite, sulphosalts of copper, iron, lead and bismuth, native bismuth, and kozalite. Gangue minerals include carbonate, quartz, chlorite, amphibole, feldspar, and epidote. Veinlet, banded and breccia structures predominate.

The gold mineralization is grouped in two ore associations:

- Gold-quartz (sulphide content does not exceed 5%; ores are restricted to the Northern and Central blocks).
- Gold-sulphide-quartz (5-15% of sulphides in average; ores are found mainly in the Southern block).

Main accompanied elements include Cu, Ag, W, and Mo. The latter is encountered in the Eastern block of Sergiivske deposit that significantly increases its practical value and makes the deposit complex gold-molybdenum. Previously A.B.Bobrov has shown [Bobrov, 1993c; 1994] that distribution of molybdenum mineralization reflects some kind of geochemical zonation formed under control of the felsic magma emplacement. Southern (high-temperature) part of deposit corresponds to the neck of paleo-volcano where had been placed the early rare-metal mineral-forming stage of evolved paleo-fluid system. In the north-west direction these high-temperature gold-rare-metal associations are replaced by the low-temperature mineral assemblages.

Gold in Sergiivske deposit is mainly of high fineness (up to 930). Mineralogical and technological studies have shown that 85-90% of gold occur in the free mode. It is confined to quartz and in lesser extent to carbonate, quartz-sulphide and sulphide-sulphide grain junctions. Dispersed and trapped gold accounts for about 15%.

Gold morphology is defined by the hosting micro-crack geometry. Particles of isometric, droplet, dendrite and irregular shape are known. In the carbonate-quartz veins gold occur in the single fine (up to 0.5-1.0 mm) aggregates or bunches up to 0.5-1.0 cm across. Particles involved in the intergrowth with sulphides do not exceed 0.1 mm in size. Most of gold particles are of micron dimensions.

Available evaluations of gold resources in Sergiivske deposit allow promising conclusions on the medium-scale object, which may be extended by studies of the deposit flanks. Taken together with molybdenum mineralization (see below) this deposit may be later re-estimated as potentially large-scale one.

Molybdenum mineralization. As noted above, the gold mineralization is followed eastward by molybdenum one that is confined to the junction of Sergiivske sub-volcanic body and southern extension of Solonivske body. This kind of ore mineralization includes fine- and medium-flaky molybdenite, and as the fine chalcopyrite-pyrite dissemination is observed in quartz and quartz-carbonate veins and veinlets as well as in the extensively altered host rocks (meta-basalts, meta-dacites and meta-tonalite-porphyries). Molybdenite mineralization is confined to the contacts of these rocks and is mainly located in the felsic varieties or in the mafic xenoliths. Molybdenite age is determined (DH 3221, depth 189 m) by Re-Os dating to 3128±13 Ma [Stein et al, 1998].

More than 20 molybdenum-ore bodies are encountered in the deposit. These are mainly linear vein-dissemination zones up to 10-150 m thick. Inside the zones the intricate systems of thin random quartz veinlets (up to 1-3 cm thick) occur. Molybdenite is restricted to the veinlet boundaries and often occurs as the solid rims around or it is dispersed through the whole vein in flakes but with prominent enrichment toward the external contacts.

Associate minerals include pyrite and chalcopyrite (< 1%) as well as native gold (up to 10 g/t in some samples). Molybdenum grade in the ores varies from 0.001 to 0.25% over thickness of ore bodies from first to hundred of meters. The ore enrichment in Cu (0.007-0.03%), W (0.0005-0.03%), Ag (up to 10 g/t), as well as Re and Os is determined.

The *forming conditions* are thought to include the metamorphic-hydrothermal processes. It is assumed the ore-producing role of the felsic sub-volcanic rocks with addition of some metamorphic matter. In this respect the mineral complexes – rare-metal, early sulphide and late sulphide-gold, probably reflect the general sequence of gold-molybdenum ore formation. Major stage of gold deposition was released through the circulation of water-salt solution at NaCl concentration about 30-35% in the temperature range 240-320^{o}C under the pressure in the system of 100-136 MPa.

Target C3. Mini-workshop: Geology, petrology and geochronology of granitoid rocks.
Purpose: assessment the study results of granitoids from Dnipropetrovskiy and Surskiy complexes.

The mini-workshop to be held in the crater of the "ceased" Archean Apolonivskiy paleo-volcano is devoted to the problem of relationships between the granitoid rocks of various ages and the timing of their emplacement. The unique results will be presented which follow the data received in the Object B of Verkhivtsivskiy Belt, Target B3 and Target B2 respectively.

Particularly, in the first half of the mini-workshop the study results will be demonstrated concerning biotite meta-tonalites which intrude the primary-stratified substratum of Aulska Series and together with the latter are involved in migmatization and ultra-metamorphism being united in Dnipropetrovskiy Complex. The "shrimping" data suggest for the meta-tonalite intrusion into the rocks of Aulska Series about 3.2 Ga with subsequent ultra-metamorphism and migmatization about 3.0 Ga. The cores of relic zircon also provide the information on the 3.4-3.3 Ga age of the primary-stratified substratum of Aulska Series.

Further on, in the second half of the mini-workshop, the data on biotite tonalites of Surskiy Complex will be presented. In the contacts of Surskiy tonalite massif with the eastern flank of the Belt the xenoliths of greenstone meta-basalts and meta-gabbroids are identified as well as the basement rock xenoliths. By radiological data the timing of tonalite magmatism is estimated to 2.97 Ga.

OBJECT D. SOROKYNSKIY AND KOSIVTSIVSKIY GREENSTONE BELTS

Total itinerary length – 0.7 km, total walking distance – 0.7 km
Guides: Alexander Bobrov, Leonid Stepanyuk, Alexander Lysenko, Igor Merkushyn,
Alexey Voloshyn, Boris Malyuk, UkrSGRI, Kyiv; Leonid Isakov, UkrSGRI, Dnipropetrovsk

Sorokynskiy Greenstone Belt is the only well-studied structure of the greenstone family in the Azovian Mega-Block (see Fig. 3-2). Uniqueness of this place is defined by the spatial combination of three litho-tectonic levels of which two first are accessible for examination in the outcrops:

- the lowest essentially *greenstone level* with well-preserved fragments of the layered meta-basalt and meta-komatiite lava flows with comagmatic intrusions of respective composition (meta-gabbroids, meta-dolerites, meta-pyroxenites, meta-peridotites). The column is intruded by sub-volcanic and abyssal plagiogranitoids comprising the gold ore-producing rock association, which contact portions control the numerous gold occurrences in Sorokynskiy Belt, including the only in Ukrainian Shield Surozke gold deposit, exposed at the surface and accessible for studies in the adit and in outcrops. In addition, this is the only place where the major counterparts of the gold ore-producing rhyodacite-plagiogranite volcano-plutonic association are developed: lava, lava-pyroclastic, sub-volcanic and abyssal igneous rocks of felsic composition;
- *meta-terrigenous level* (analogue of the lower part of Kryvorizka Series of the Middle-Dniprean granite-greenstone terrain) composed of meta-gravelites, meta-conglomerates, meta-sandstones, which overlie aforementioned meta-volcanogenic complex with the angular and tectonic unconformity;
- *carbonate-terrigenous level* which unconformably lies over the two previous levels and comprises the rhythmic sequence.

Kosivtsivskiy Greenstone Belt, located in 70 km to the north from Sorokynskiy one (see Fig. 3-2), is less exposed and studied so these two geological targets to date seem to comprise the interest in the frame of excursion. In both cases the most representative data available come mainly from the drill-holes, and this is why the Belts itself (overlain by Phanerozoic sediments) will not be visited by the excursion participants, while the mentioned materials will be presented as the mini-workshop along with the field examination of the targets in Sorokynskiy Belt.

Target D1. Balka Sobacha gully: geology and gold mineralization in Sorokynskiy Belt.
Purpose: assessment the rock complexes and related gold mineralization.

Sorokynskiy Belt is clearly controlled by the fault system (Fig. 5D1-1), which apparently fed the magma and bounded the paleo-basin. It is evidenced by the coincidence of the main fault directions and distribution of volcanic and sub-volcanic rocks, especially those of ultramafic composition. The length of main Sorokynska syncline, from Andriivska area in the north to Surozka area in the south, is about 35 km. Over entire this interval the syncline is overturned to northeast. Conventionally, the syncline can be divided into the fragments corresponding to the particular studied areas. The latter, in turn, can be further subdivided into the tectonic blocks according to the local fault systems. Thus, the fold structure of Sorokynskiy Belt is simple enough, and in Surozka area it is merely complicated due to the active influence of rhyodacite-plagiogranite volcano-plutonic association.

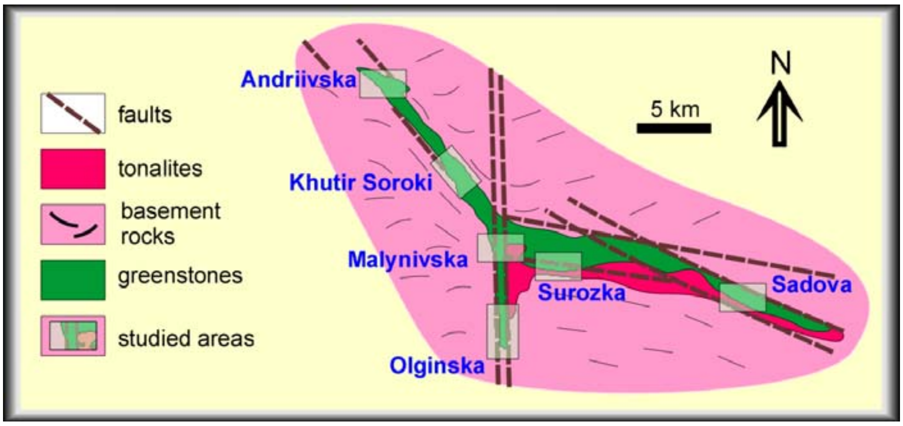


Fig. 5D1-1. Sketch map of Sorokynskiy Belt.

The fault-controlled nature of Sorokynskiy Belt and its unconformable relationships with the basement rocks suggest for the superposed origin of the Belt. It looks likely the Belt formed in some trough with lacking of any initial folding and primary flat bedding of the deposited rocks. The folded appearance of the modern structure is thought to be the result of tonalite-plagiogranite magma intrusion. It should be noted that such the intrusions were emplaced mainly along the southern and south-eastern margins of the Belt. At almost no granite emplacement in the opposite side of the Belt, the southern limb of main syncline was overturned with appearance of some reverse faulting. The latter is thought to be the reason for local displacement observed between the Balka Kruta and Surozka areas.

Thus, two stages can be distinguished in the formation of Sorokynskiy (as well as Kosivtsivskiy) Belt. The early, trough stage was released under conditions of prevailing vertical movements and development of volcano-tectonic structures. The later stage was accompanied by the main folding events under the local compression regime influenced by the tonalite-plagiogranite intrusion and diapirism.

The Target D1 in Balka Sobacha gully (Fig. 5D1-2, Fig. 5D1-3) comprises almost discontinuous section in the natural exposures of meta-komatiite-tholeiite, meta-rhyodacite and meta-conglomerate-sandstone-aluminous-schist rock associations that fill up Sorokynskiy Belt. In the outcrops and core sections the unique intercepts of lower-greenstone meta-basalts, middle-greenstone differentiated meta-komatiite flows (Olginska Suite), upper-greenstone felsic volcanics (Surozka Suite) and comagmatic rhyodacites as well as the meta-terrigenous rocks (Krutobalkinska Suite), and the younger rock complex of Sadova Suite will be demonstrated in the route and accompanied mini-workshop.

STOP D1-1 starts the route in the southern limb of Surozka Anticline where the outcrops of mafic rocks of KT-1 parageneration are observed. The mafic rocks include amphibolites after basalts, basalt tuffs and tuff-lava, and their comagmatic (sub-volcanic) meta-gabbro-dolerites. Specifically, in the outcrops of Berda River left bank the ball-shaped meta-basalt lavas are encountered (Fig. 5D1-4). Deformed balls are observed in ellipsoids 15-55 cm long and 5-23 cm wide. Marginal chilled zones of the balls are dark-coloured and coarse-grained (due to secondary re-crystallization). The basalt lava balls and pillows also show distinct "tails" in the bottom that commonly make possible definition the flow top direction. The lava flow spatial position restored in this way suggests for the overturned southern limb of Sorokynskiy Belt.

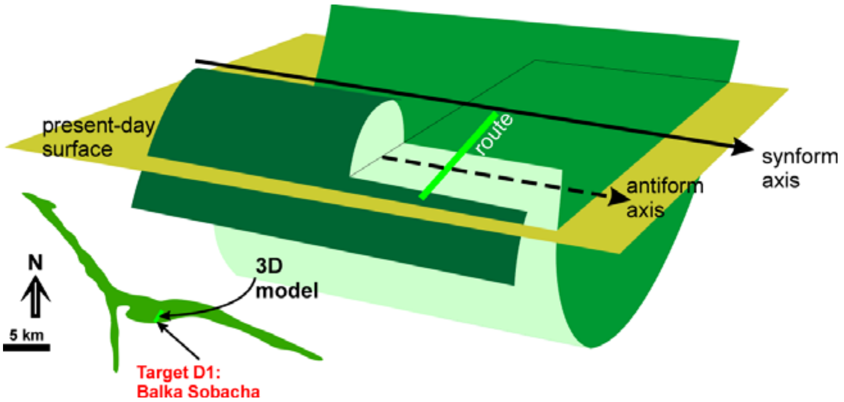


Fig. 5D1-2. Location of the excursion route
in the local tectonic framework of Sorokynskiy Belt.

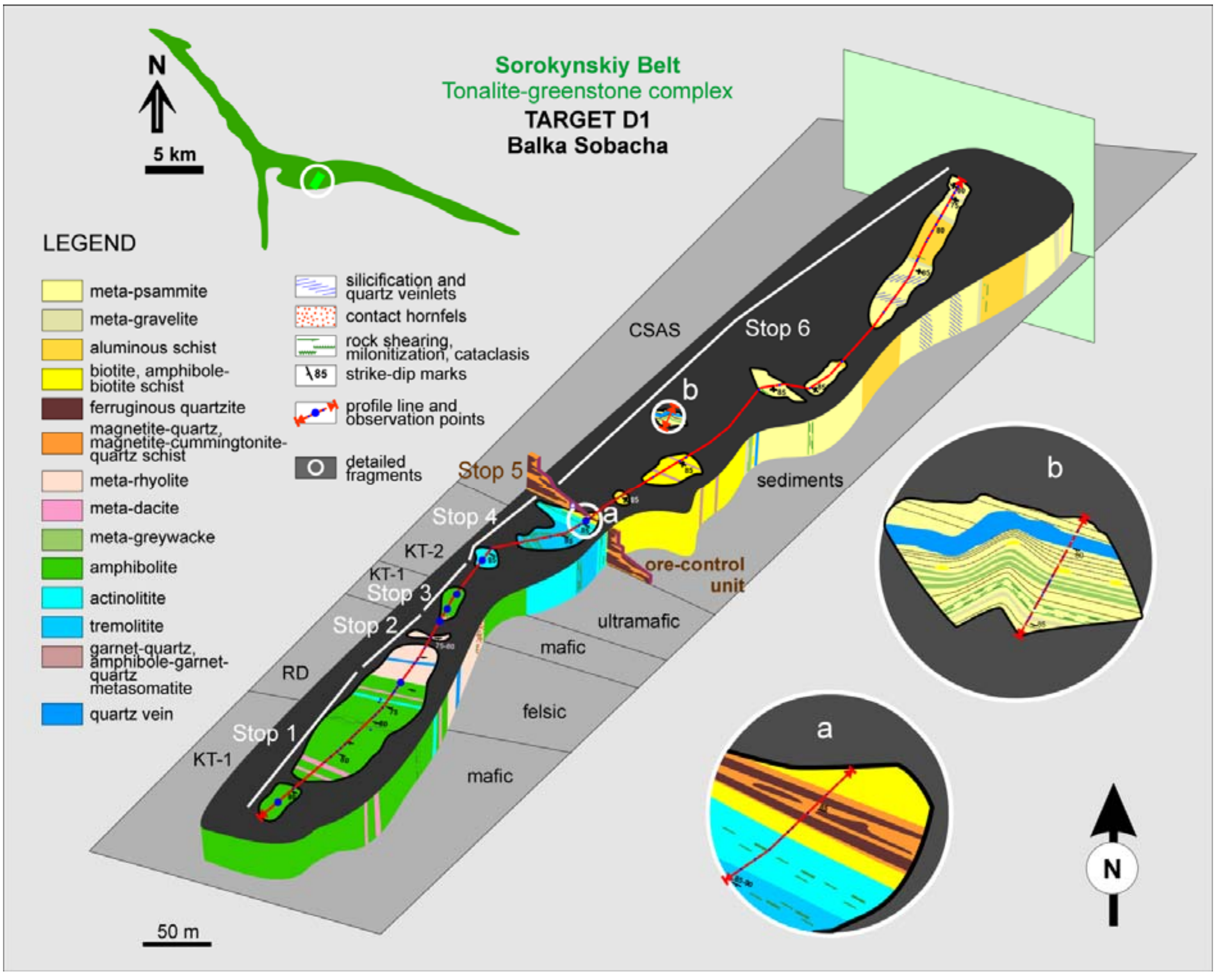


Fig. 5D1-3. Detailed turning-route mapping along Balka Sobacha gully
in the right bank of Berda River.

Fig. 5D1-4. Ball-shaped and pillow meta-basalt lava.

STOP D1-2 further continues the excursion route comprising the outcrop of meta-rhyodacite association volcanic rocks (see Fig. 5D1-3) that highlight and delineate the core region of the Surozka Anticline. The pile is composed of meta-rhyodacites, meta-rhyolites of porphyry texture defined by relatively large quartz and plagioclase grains 0.8-1.8 mm in size in the fine-micro-grained (0.06-0.15 mm) feldspar-plagioclase-quartz groundmass. G.V.Artemenko [Artemenko et al, 2001] had obtained U-Pb isochrone age of 3160±140 Ma on zircons collected by A.Bobrov from meta-rhyolites.

Apart from this stop, meta-rhyodacite rock association in the large bodies is also developed in Andriivskiy area (see Fig. 5D1-1) in the south-western flank of the main Sorokynska syncline. The felsic 50-150 m thick meta-volcanics are observed in the rim along the contact between the intrusive plagiogranites (plutonic counterpart of meta-rhyodacite association) and mafic-ultramafic rocks of komatiite-tholeiite association.

STOP D1-3 comprises the mafic rocks in the northern limb of Surozka Anticline which are similar to those mentioned above (see Fig. 5D1-3).

STOP D1-4 encompasses essentially ultramafic sequence comprising KT-2 parageneration of meta-komatiite-tholeiite rock association. Together with comagmatic intrusions the latter forms the lower meta-komatiite-dunite-harzburgite volcano-plutonic association. This association is defined and well studied in the Middle-Dniprean granite-greenstone terrain. In

Sorokynskiy Belt volcanic counterpart of this association is encountered in the exposures along excursion route as well as is studied in the numerous drilling profiles.

The lava-facies mafic (quartz-plagioclase-chlorite-actinolite schists, amphibolites after tholeiite basalts and basaltic meta-komatiites) and ultramafic (diverse chlorite-actinolite, actinolite, tremolite-actinolite, serpentine-talc and serpentine-talc-carbonate schists after pyroxenite and peridotite komatiites) volcanics in the ratio 1-3 : 10 respectively are tightly paragenetically associated in the parageneration KT-2.

The boundaries of KT-2 are outlined by the sudden appearance of voluminous ultramafic rocks in the section (see Fig. 5D1-3). Lacking of cutting relationships coupled with the uniformity in dynamic and metamorphic conditions suggest for conformable relations between KT-2 and KT-1 in the entire section of the Sorokynskiy Belt.

Essentially ultramafic composition of KT-2 defines the distinct physical properties of the rocks that are clearly reflected in the physical fields by positive linear magnetic and gravity anomalies and make these rocks useful marker horizon. Occurrence of mafic and ultramafic rocks (as well as magnetite-bearing schists and quartzites in case of the facies transition) provides considerable variability in the physical properties: dense and high-dense rocks, low-magnetic and high-magnetic rocks.

Parageneration KT-2 is discontinuously distributed over the Belt and in the facies transitions is being substituted by the schist-jaspilite-tholeiite rock association. Total thickness varies from 25 to 342 m.

Besides the mentioned important features, parageneration KT-2 also includes ultramafic rocks of diverse texture and composition. Restoration of the primary textures of these rocks makes it possible to distinguish the system of layered lava flows with the concordant bodies of the comagmatic intrusions of similar mineral and chemical composition. The flow zonation is expressed in repetition of the parts (zones) composed of the rock varieties with different texture and composition.

Likewise very common komatiite cases, three types can be distinguished in the studied lava flows: (Fig. 5D1-5).

- undifferentiated, presented by just one zone (usually cumulative or massive porphyritic rocks);
- incomplete-differentiated, where the well developed cumulative zone is established with sequential upwards transition into the zone of massive porphyritic rocks and further into the zone of coarse spinifex (transitional to the classical spinifex-texture zone);
- full-differentiated, which include whole number of the zones from cumulative to fine-spinifex.

In term of major-element geochemistry, the most of the studied rocks are clearly confined to the fields of komatiite series in the typical ternary plots (Fig. 5D1-8).

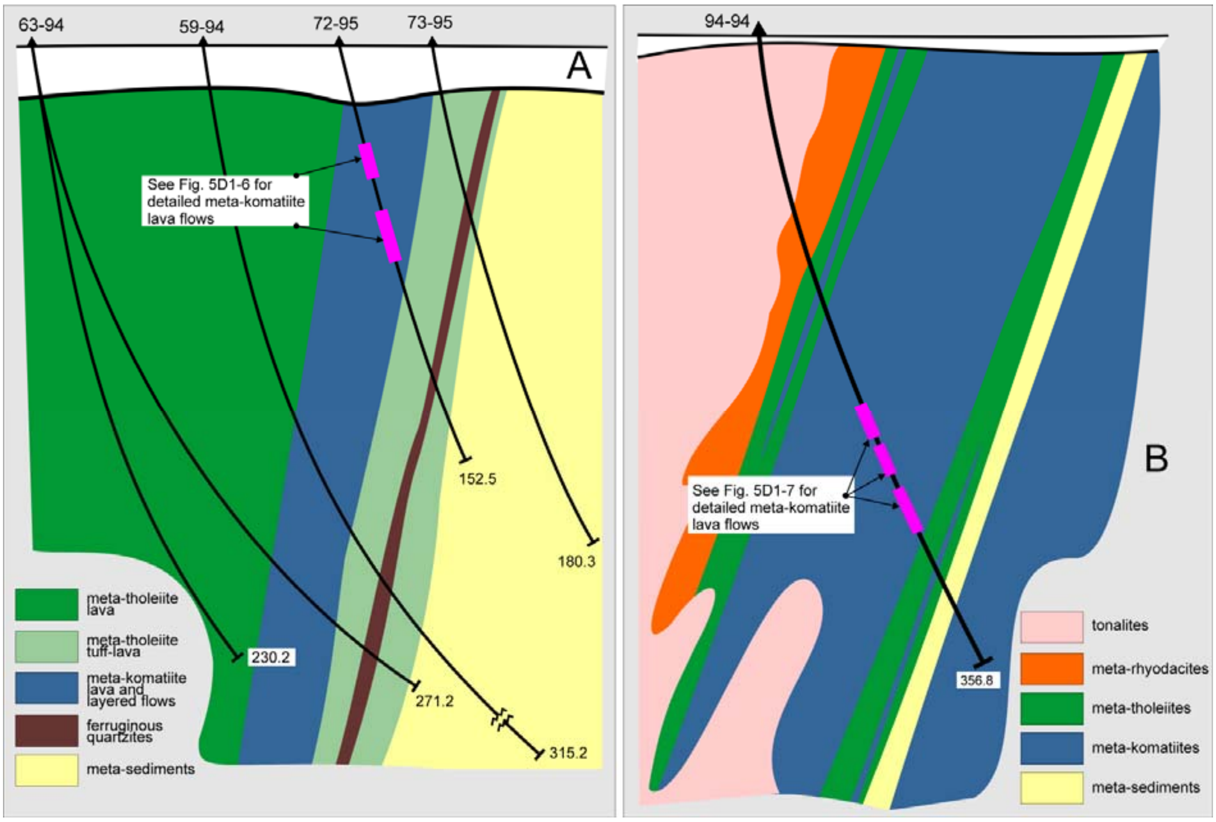


Fig. 5D1-5. Geological cross-sections in drill-hole profiles
DH 63-94 – 59-94 – 72-95 – 73-95 (left) and DH 94-94 (right).

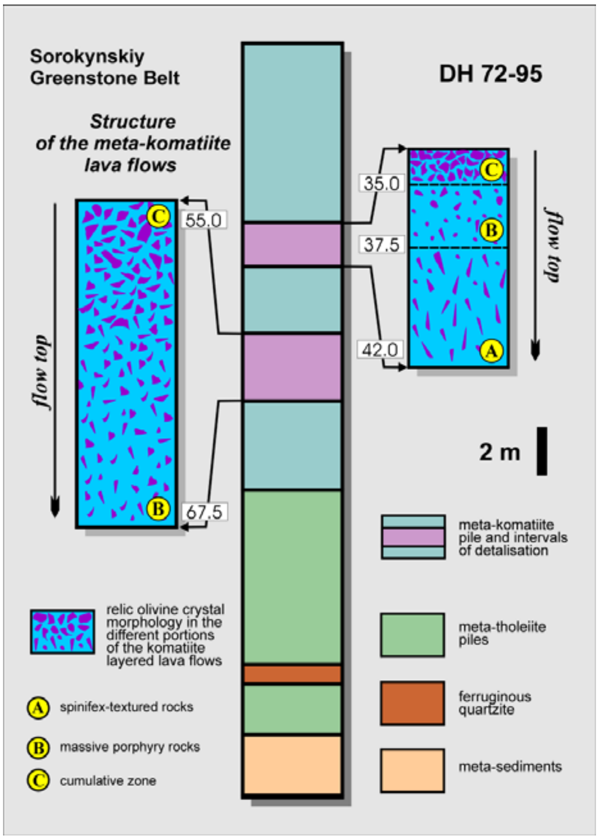


Fig. 5D1-6. Meta-komatiite lava flows encountered in DH 72-95.

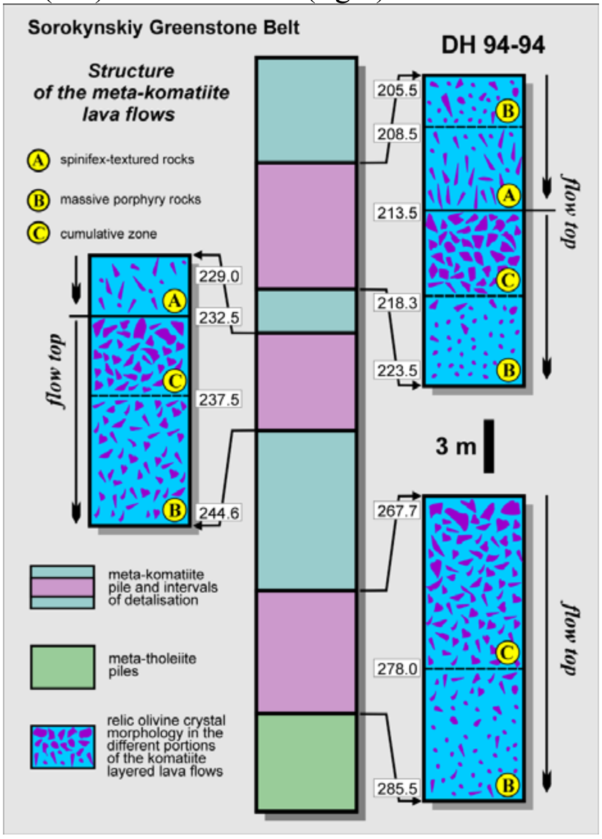


Fig. 5D1-7. Meta-komatiite lava flows encountered in DH 94-94.

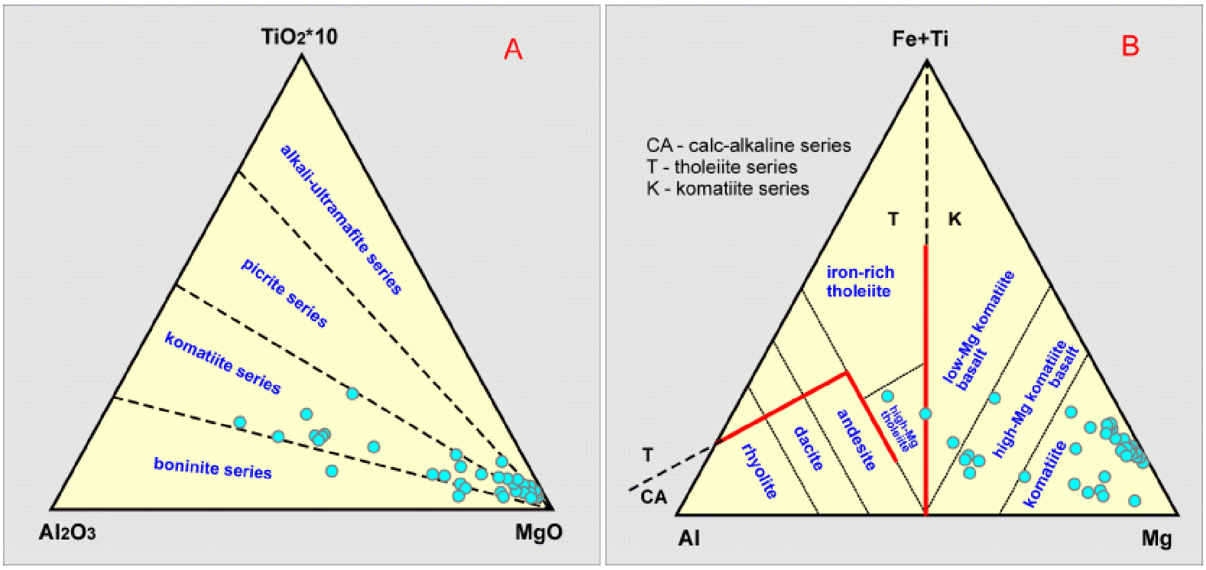


Fig. 5D1-8. Major-element geochemistry of komatiitic rocks in the ternary plots.
A. Kulikov plot for classifying ultramafic series rocks.
B. Jensen cation plot for classifying sub-alkalic volcanic rocks.

STOP D1-5 further on the route (see Fig. 5D1-3) includes the adit and outcrops of the ferruginous quartzites with numerous quartz and carbonate-quartz veinlets containing poly-sulphide (pyrite, pyrrhotite, chalcopyrite) mineralization of the productive stage in the gold deposition (ore bodies of Surozke gold deposit). The geological-tectonic and physico-chemical models will be presented for the only gold deposit in the Ukrainian Shield which is accessible for the direct studies in the exposures.

STOP D1-6 actually marks the second half of the excursion which up to the end (see Fig. 5D1-3) passes through the rocks of meta-conglomerate-sandstone-aluminous-schist (CSAS) association (Krutobalkinska Suite) that unconformably overlies the previous volcanic succession and fills the core portion of Sorokynskiy Belt.

This meta-sedimentary pile comprises association of coarse-clastic sediments (meta-conglomerates, meta-gravelites, sandstones; Fig. 5D1-9) associated with terrigenous normal-aluminous rocks (quartz-sillimanite-garnet schist) and meta-sandstone-mudstone aluminous and high-aluminous (andalusite-staurolite-cordierite schists) varieties. It is notable that coarse-clastic rocks are confined to the section base and their amount decreases upward.

The sediments include diverse garnet-biotite-feldspar-quartz, biotite-feldspar-quartz, two-mica, tourmaline-muscovite-biotite-feldspar-quartz (somewhere with graphite and tourmaline), staurolite-garnet-biotite-feldspar-quartz, sillimanite-garnet-biotite-feldspar-quartz and other schist varieties with relic blastic psammite textures.

The age and stratigraphic position of this sedimentary association is not equivocal yet. The clastic zircon from aluminous schists yields Archean age [Artemenko, 1998; Shcherbak et al, 1990]. Detritic zircon from quartz meta-conglomerates after G.Artemenko et al. [Artemenko, 1998; Artemenko et al, 2001] yields U-Pb age about 3330±40 Ma. These authors found the signs of extensive abrasion of the zircons from basement granite-gneisses during long-term water transport and some features of basement granitoid (tonalities and enderbites) – the low

U and Pb content. Apparently the zircon displays the isotopic age of the clastic material source region for the "Krutobalkinskiy" time.

Thus, described section is a natural historic-geological mark of the fairly gradual change in petrogenesis from essentially volcanic (meta-komatiite-tholeiite association) to mainly sedimentary (meta-conglomerate-sandstone-aluminous-schist) one. This general trend is expressed in the upward amount of meta-sediments gradual increasing and their mineral and composition variability. Close-contemporary time relations between the volcanic and sediment parts are also supported by the encountered cutting intrusive contacts of tonalite-plagiogranite body with both units. The intrusion is accompanied by the clear contact-marginal changes just close to the granites and extensive schist re-crystallization outward. Hence, the meta-sediments are older than comagmatic complex of volcanogenic rhyodacite and intrusive tonalite-plagiogranite association which completes development of Sorokynskiy Greenstone Belt.

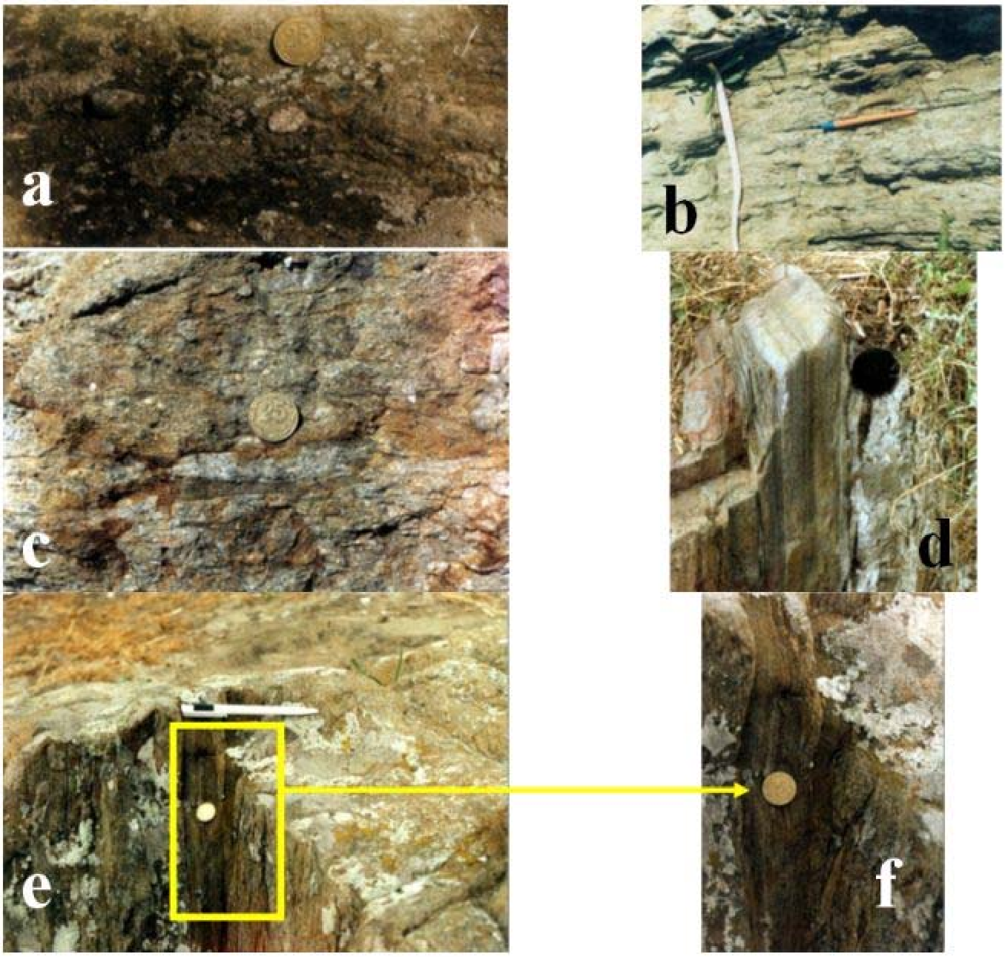


Fig. 5D1-9. Coarse-terrigenous meta-sediments of meta-conglomerate-sandstone-aluminous-schist rock association.

a - meta-conglomerate with quartz and plagiogranite pebbles (centre of the photo);
b - interbedding of meta-gravelites and meta-sandstones;
c - coexistence of clastic material and "pseudo-pebbles" (boudinaged quartz veins);
d - meta-quartzite-sandstone in between meta-gravelites;
e - meta-sandstone in between meta-conglomerates with coarse plagiogranite pebble;
f - details of photo "e" (coarse plagiogranite pebble right to the coin).

Target D2. Osypenkivskiy granitoid massif.
Purpose: assessment the geology and geochronology of granitoids intruding the greenstone sequence.

Plutonic massifs composed of plagiogranites of tonalite-plagiogranite rock association are extended in almost discontinuous chains along the both limbs of Sorokynskiy Belt from Andriivska area through Khutir Soroki to Malynivska, Olginska, Surozka, and Sadova areas (see Fig. 5D1-1). Of these numerous bodies Osypenkivskiy massif is most studied. It is located in the southern part of Sorokynskiy Belt where it intrudes the south-western belt flanks and occurs in discontinuous exposure chain from the top of Balka Kruta gully to far south of Sadova area being traced over 8-9 km. The width of exposed fragments is about 0.5-4 km.

Intrusion is studied in the outcrops of the right and left banks of Berda River and also in the numerous drill-holes. The single-stop excursion Target D2 is located just in the right bank of Berda River reservoir in 1.6 km to the east from Sobacha gully (Target D1). Excursion participants may observe granites of the mentioned Osypenkivskiy massif that occur in the outcrop chain, small bank cliffs just above the river stream, and in the adjacent system of minor gullies.

The massif consists of the tonalite-plagiogranite association rocks. These include wide range of abyssal and hypabyssal (great- and shallow-depth) plagiogranites: hornblende diorite, quartz diorite, biotite, hornblende-biotite, epidote-hornblende-biotite tonalite and plagiogranite, thin (from 5-15 cm to 2 m) linear veins of the fine-grained weakly-porphyry leucocratic plagiogranite, porphyry mesocratic biotite, hornblende-biotite plagiogranite and biotite plagiogranite(tonalite)-porphyry, hornblende tonalite. In places, where these rocks are spotty overprinted with potassium feldspar, they get the composition of granodiorite [Bobrov et al, 1990].

Described plagiogranitoids intrude meta-komatiite-tholeiite and meta-conglomerate-sandstone-aluminous-schist greenstone associations (see Target D1). However, in the Sadova area (Fig. 5D2-1) plagiogranitoids are overlain by the Lower Proterozoic basal psephites [Glevasskiy, Eremeev, 1997].

The studied zircons from described tonalities in Sadova area (DH 35, depth 78.0-83.0 m) yield U-Pb isochrone age of 2701±5 Ma [L.Stepanyuk, O.Bobrov, O.Lysenko, unpublished data]. Taking into account the older dates obtained on zircons from granodiorites, exposed in the Target D2 [Artemenko et al, 1985], the time span of Osypenkivskiy massif formation is estimated to 2.79-2.70 Ga.

The xenoliths of variously re-crystallized medium- and coarse-grained amphibolites (after meta-basalts) are observed in tonalities. The shape of xenoliths is elongated (Fig. 5D2-2), angular. Size is about 2-3 m by long axis and more.

The contacts of plagiogranites with country rocks are sharp with the common "tongues" and irregular boundaries. For instance, in the outcrops of Berda River left bank we observed the contacts of medium-coarse-grained or slightly-gneissic tonalities with the fine-grained thin-banded meta-basalts of meta-komatiite-tholeiite association (parageneration KT-1). The contact plunging azimuth is 160^o, dipping angle 85-90^o. The contact transition zone from tonalities to almost fresh, unaltered meta-basalts is about 6 m thick and is expressed in complete biotitization of meta-basalts which are injected with numerous quartz (quartz-pyrite) veins oriented along the schistosity.

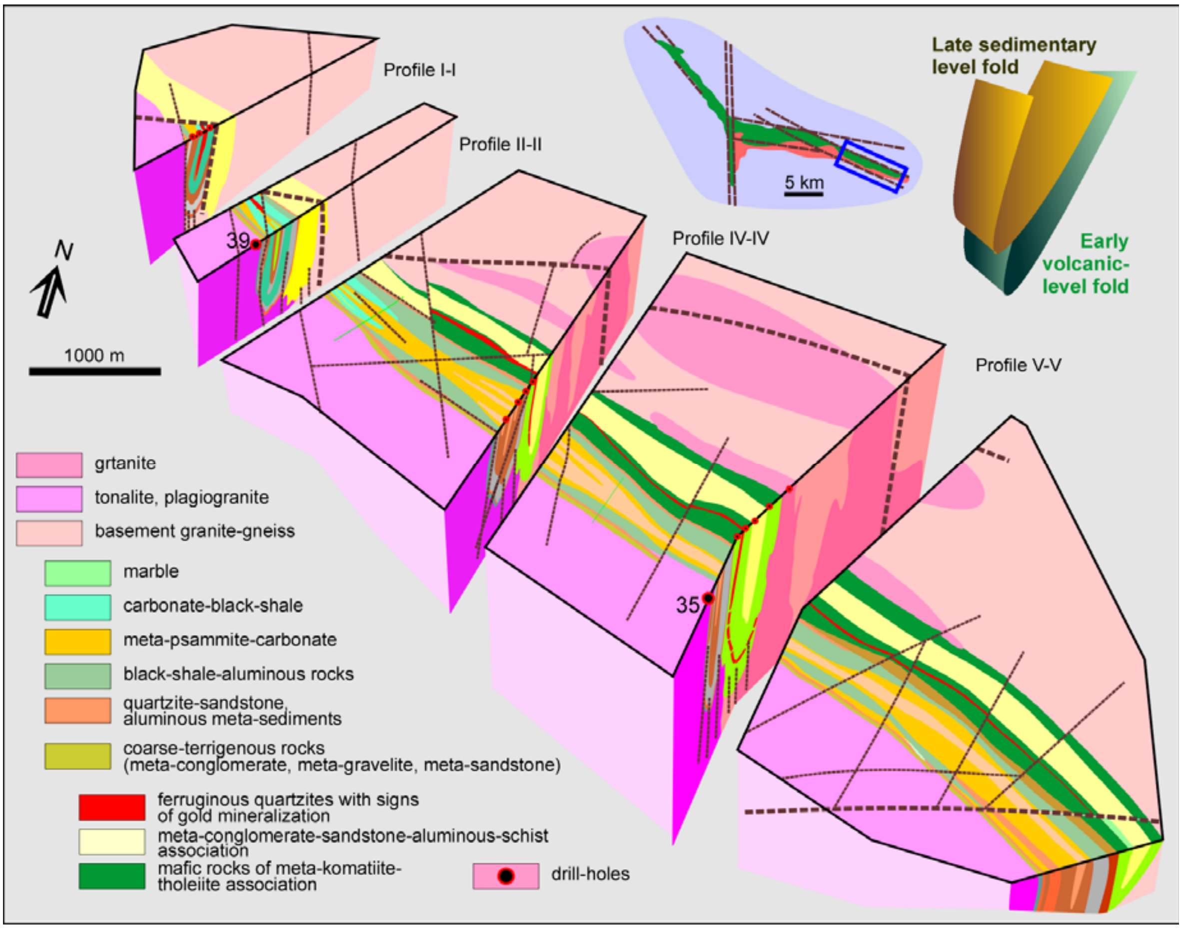


Fig. 5D2-1. Sketch geological model of Sadova area
displaying intricate folding and tonalite location.

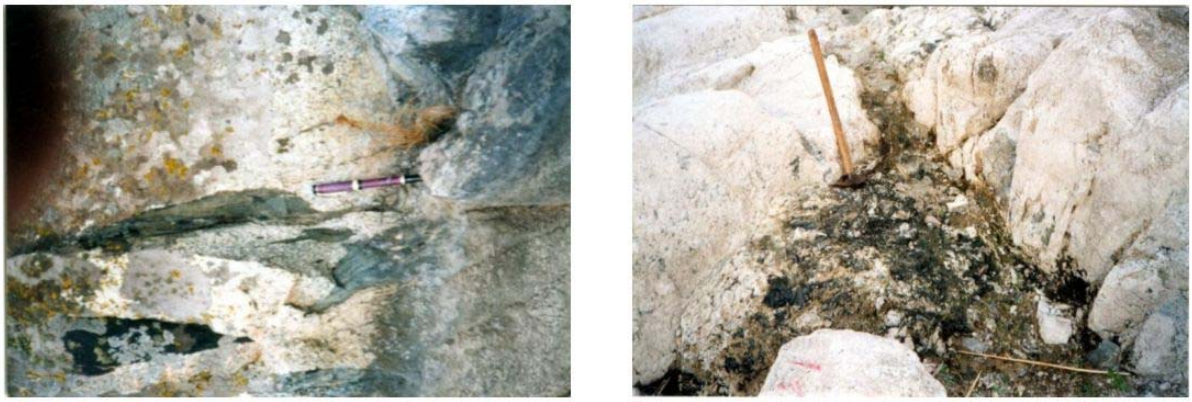


Fig. 5D2-2. Xenoliths in tonalites.
Left: angular and elongated xenoliths of actinolitites (black),
medium- and coarse-grained amphibolites (dark-grey).
Right: large (black in the photo centre) and small (exposure walls) xenoliths of mafic rocks.

Target D3. Kosivtsivskiy Greenstone Belt.
Purpose: assessment the geology of meta-komatiite sequence and geochronology of granitoids intruding greenstone rocks.

Since the Belt is completely overlain by the sedimentary cover and is studied by drill-hole data, the Belt will not be visited by excursion participants and, instead, respective materials and the core sections will be delivered to the site of Target D1 for the observation over the field mini-workshop. Particularly, it will include two items:

- Item D3-1: the ultramafic rocks of Greenstone Complex;
- Item D3-2: the exotic xenolith-bearing rocks of ~ 2.1 Ga Dobropilskiy massif.

ITEM D3-1. The column of Kosivtsivskiy Belt includes three rock sequences:

The *Lower Mafic* sequence is composed of amphibolites with minor ultramafic interbeds and corresponds to the parageneration KT-1 of meta-komatiite-tholeiite rock association.

The *Middle Ultramafic* sequence includes primary-volcanogenic serpentinites and serpentine-chlorite-actinolite schists with talc, carbonate, and relic olivine (meta-komatiites) arranged in series of layered flows (Fig. 5D3-1). The lateral correlation of these flows allows conclusion about sub-horizontal bedding in this part of the Belt; it is flat in the core and becomes steeper by the periphery. In the internal structure of this sequence the layers of various thicknesses are distributed symmetrically. The thin beds are confined to the column central part whereas thickest layers are observed in the lower and upper parts. In turn, the internal structure of the layers is also variable. The massive porphyry and basal cumulative lava varieties are mainly developed in the thick flows of the lower and upper parts. Together they comprise 80-95% of the bulk flow volume. In the middle, thin-layer part, the spinifex-textured zones predominate providing up to 70-75% of the flow volume. The lateral variability in layered meta-komatiite flows is expressed in the regular thickness increasing of the most lava flows and syn-volcanic brecciation zones toward the centre of paleo-volcanic activity, in considerable thickness variability of individual flows and in some structure-texture patterns of volcanic rocks.

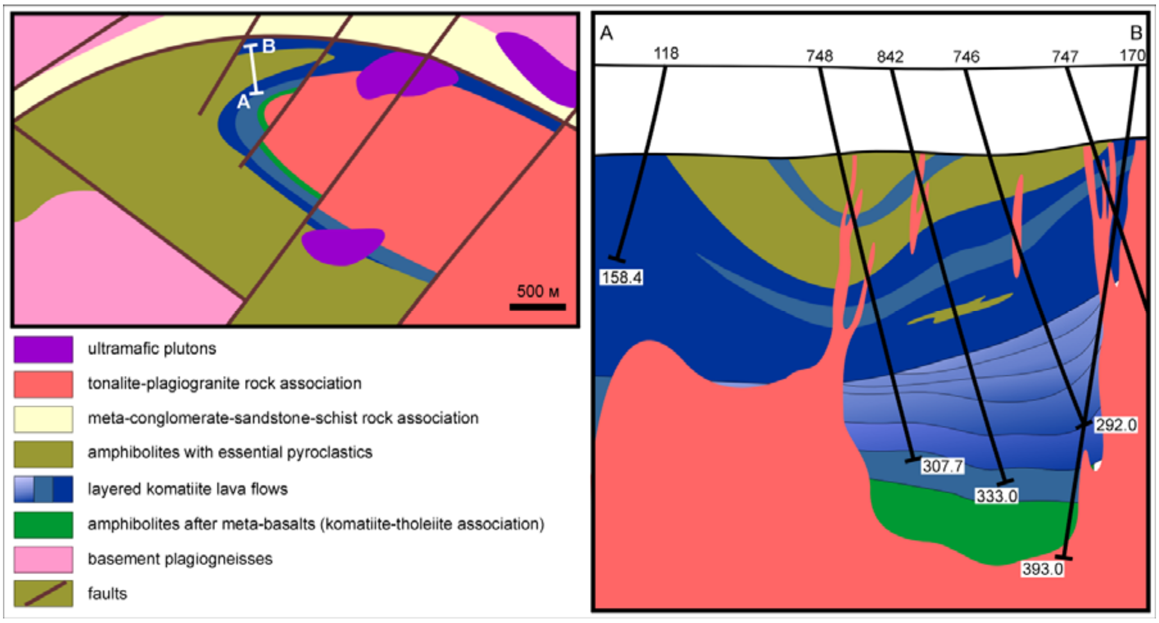


Fig. 5D3-1. Sketch geology of Kosivtsivskiy Belt.

Three massive serpentinite bodies of plutonic nature are defined in the sequence; the bodies are being mapped as the sills and minor massifs.

The *Upper Mafic* sequence is composed of amphibolites with meta-ultramafic interbeds (massive porphyry meta-komatiite lava) and corresponds to the parageneration KT-3 of meta-komatiite-tholeiite rock association.

Described column of Kosivtsivskiy Belt is injected by the cutting bodies and veins of K-feldspatized plagiogranites and granites. Plagiogranites may form large enough massifs and one of such bodies is developed in between the two "horns" of Kosivtsivskiy Belt (see Fig. D3-1) being surrounded by the greenstone sequences.

Obtained results suggest for the similar tectonic setting of the typical Middle-Dniprean and Azovian greenstone belts. The column of Kosivtsivskiy Belt is roughly identical by composition and structure to the column of other greenstone belts in Ukrainian Shield providing no reasons for their contraposition.

The data available suggest for the similar age of greenstone belts in Ukrainian Shield; these belts are filled with Kosivtsivska Sequence (Kosivtsivskiy Belt), Olginska and Krutobalkinska suites (Sorokynskiy Belt) and the rock associations of Konkska (Surska, Chortomlytska, Alferivska, Solonivska suites) and Kryvorizka and Bilozerska (Skelyuvatska Suite) series of greenstone belts. Based on these results, Kosivtsivska Sequence of Azovian region was switched to Neo-Archean as the compositional and age analogue of Konkska Series, with simultaneous cancellation of previously distinguished "early greenstone belt generation" in Ukrainian Shield.

ITEM D3-2.

Concerning the rocks of Dobropilskiy massif, it was thought for a long time that their age is about 3.3 Ga and, respectively, so called early generation of greenstone belts was distinguished. Recent studies had disproved these statements and the data concerned will be presented to the excursion participants.

The distinct composition of Dobropilski granitoids (from quartz diorites, monzo-diorites to tonalites and granites), occurrence of numerous minor xenoliths and scarcity in the Azovian region make them exotic and meaningless in term of their correlation. However, upon receiving in 1990 the spurious old (3.3 Ga) age determinations, these rocks became outstanding. It was their uncommon old radiological age which was taken by the Ukrainian National Stratigraphic Committee as the ground for definition of the separate Dobropilskiy granitoid complex first, and then – the early generation of greenstone belts in Ukrainian Shield; the sequence of Kosivtsivskiy Belt intruded by the Dobropilskiy granitoid complex rocks was ascribed to this early generation.

Dobropilskiy massif occupies the space about 25 km^2; its length is 12 km by the long axis and width – from 600 m to 3 km. In the plane it is dumbell-like, extended in the north-western direction. In the cross-section it is sheet-like extended to the depth of more than 5 km by geophysical calculations. The contacts with country rocks are cutting and the contact planes are sub-vertical with numerous apophyses. In the north-eastern direction, along the Gaychurska fault system, the 1.5 km wide and about 10 km long zone of closely-spaced vein and dyke bodies (0.5 to 25-30 m thick) of Dobropilski granites is distinguished; apparently they form the "dyke belt" which marks the fault zone.

The rocks contain a great number of minor xenoliths providing their "breccia-like" structure. Conventionally they can be divided in the two varieties containing 25-35% and 10-15% of xenoliths by volume respectively. Both varieties are similar in composition. The xenoliths are composed of amphibololites (predominate), amphibolites and granites. The size of xenoliths varies from 3-5 mm to 3-4 cm. The shape of xenoliths is variable: isometric rounded, acute, elongated.

Performed "shrimping" of the rocks allowed dating the symmetrically-zoned envelopes of the magmatogenic zircon generations to 2.1 Ga while the cores of pre-magmatogenic zircons are older and do form at least two populations 3.4 and 3.1 Ga.

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