MINISTRY OF ECOLOGY AND NATURAL RESOURCES OF UKRAINE
STATE GEOLOGICAL SURVEY

SE "PIVDENUKRGEOLOGIYA", KRYVORIZKA CGG
UKRAINIAN STATE GEOLOGICAL RESEARCH INSTITUTE
“UkrSGRI”

STATE GEOLOGICAL MAP OF UKRAINE

Scale 1:200 000

CENTRAL-UKRAINIAN SERIES
MAP SHEETS M-36-XXXIV (ZHOVTI VODY), L-36-IV (KRYVYJ RIG)

EXPLANATORY NOTES

Compiled by: V.V.Zakharov, A.V.Martynyuk, Yu.M.Tokar

Editors: M.S.Kurlov, B.D.Vozgrin

Expert of Scientific-Editorial Council: B.Z.Berzenin

English Translation: B.I.Malyuk

Kyiv - 2002 (2009)

UDC 550.8:528.94(084.3M200) (477.45:477.63:477.72:477.73) '2000'

State Geological Map of Ukraine. Scale 1:200 000. Central-Ukrainian Series. Map sheets M-36-XXXIV (Zhovti Vody), L-36-IV (Kryvyj Rig). Explanatory Notes. Explanatory notes. Kyiv: Geoinform, 2002 (State Geological Survey, SE "Pivdenukrgeologiya", Kryvorizka CGG). 108 p. 13 figures, 63 references, 3 annexes.

Authors:

V.V.Zakharov, A.V.Martynyuk, Yu.M.Tokar

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English translation

B.I.Malyuk, Doctor of Geological-Mineralogical Sciences, UkrSGRI

Explanatory notes to the set of maps, containing the geological map and mineral commodity map of pre-Quaternary units, Quaternary units, and crystalline basement, as well as stratigraphic column of the area, there are described Archean, Proterozoic and Phanerozoic series, suites and complexes, tectonics and history of geological development. There are also outlined mineral deposits and occurrences in crystalline basement and sedimentary cover, and further perspectives of the area are evaluated. In addition, ecological-geological situation is analyzed.

The set of maps can be used in planning the geological exploration works within Kryvorizkiy iron-ore basin.

Results are examined and approved for publication by Scientific-Editorial Council of the Department of Geology and Subsurface Use on November 29, 2000 (Protocol No. 108).

CONTENTS

Abbreviations used in the text

BCC - Bulk Concentration Coefficient
CGG – Complex Geological Group
Derzhgeolkarta-200 - State Geological Map 1:200 000 (State Program)
DGM-50 - Deep Geological Mapping in the scale 1:50 000
DH - drill-hole
EGSF-200 - Extended Geological Study of the Fields in the scale 1:200 000
GEE - Geological Exploration Expedition
GMW-50 - Geological Mapping Works in the scale 1:50 000
GSF - Geological Study of the Fields
IGE - Industrial Geological Enterprise
KIOB - Kryvorizkiy Iron-Ore Basin
KKDSF - Kryvorizko-Kremenchutskiy Deep-Seated Fault
LTZ - Litho-Tectonic Zone
MBP - Mining-Beneficiation Plant
MTP – Method of Transitional Processes
SE – State Enterprise
TAC – Top Admissible Concentration
TMZ - Tectono-Mineragenic Zone

INTRODUCTION

The second edition of the State Geological Map of the map sheets M-36-XXXIV (Zhovti Vody) and L-36-IV (Kryvyj Rig) in the scale 1:200,000 comprises a new phase in the geological study of the territory of Ukraine. It is designed on the ground of examination of enormous fact sheet material as well as studies of deep structure in Kryvorizkiy area. Derzhgeolkarta-200 is a multi-purpose complex base for the rational use of natural resources.

Administratively, the map sheets are included into Dnipropetrovska Ragion and partially also cover the areas of Kirovogradska, Khersonska and Mykolaivska Regions. In orographic respect the territory is weakly hilled (more eroded in northern part) steppe plain with altitudes from +80 m in the south to +220 m in the north. Up to 10% of this plain is broken from the surface by quarries, dumps, shaft collapse sites, tailings, artificial water reservoirs, and other technogenic forms which had considerably changed natural landscape and relief in around Kryvyj Rig, Zhovti Vody, Petrove, Oleksandriya and other towns.

The major water artery in the area is Ingoulets River with its branches – Zhovta, Zelena, Saksagan, and Bokova Rivers. At the latter one inflow into Ingoulets River it is created Karachunivske water reservoir. In the south-eastern part of the area it is located Kakhovske water reservoir to which small branches of Dnipro River – Bazavluchok and Kamyanka – stream in. From Kakhovske water reservoir the channel Dnipro-Kryvyj Rig is constructed and along the channel course two more water reservoirs are created: Zelenodolske and Pivdenne. The dense network of diverse-type roads is developed throughout the territory including electrified railroads, highways and paved roads. In the centre of territory is located the highest world-output Kryvorizkiy Iron-Ore Basin (KIOB). Respectively, the major industries in the area are iron-ore mining (over 80% in Ukraine) and metallurgy as well as metal processing, machinery and building construction. In the northern part of the area the open-cast mining include brown coal deposits (Balakhivske), titanium-zirconium placers (mineral sands, Samotkanske), and in the southern part – limestones (Bila Krynytsya, Osokorivske) and facing granites (Tokovske). Besides these, a number of small-scale quarries for the local construction needs are distributed over the territory of map sheets.

In the studied area, especially in its northern part, the extensive gully-ravine network is developed which in most cases (up to 90%) are passable appropriately and in some places (in around quarries, dumps and tailings) are hard. Erosion causes well exposing of Quaternary sediments (up to 70%) and medium one of Paleogene and Neogene rocks (up to 40%). Exposure of crystalline basement rocks along the rivers does not exceed 10%.

By degree of geological complexity, Precambrian basement of Ukrainian Shield belongs to highly-complex and extremely-complex in roughly equal proportions. Respectively, the geophysical fields over these domains are mainly complex and are subjected to the hard interpretation. Cenozoic rocks mainly display simple geology. Airborne image deciphering category is bad (100%). The whole territory is supported with satellite-images and high-precision geophysical data.

The direct base for map design and explanatory note preparation was accepted from the report on extended geological study of the fields in the scale 1:200 000 (EGSF-200) conducted in 1991-1998 [42]. Over these works in the whole area there were collected descriptions of more than 25000 drill-holes, examined 20056 m of core sections derived from the third-parties, performed geological and ecological deciphering of airborne images, as well as conducted partial re-interpretation of geophysical data over the sites where volcano-tectonic structures were defined for the first time. In addition, over EGSF-200 it was carried out significant amount of own filed works (geological and ecological routes – 612 km, basic sections – 2300 m, and core sections – 37278 m) as well as analytical studies (measurements: spectral analyses – 2763, chemical – 298, mineralogical – 308, paleo-faunistic – 187, paleo-magnetic – 101, thermo-luminescent – 111, X-ray – 63, REE – 49, isotopic – 21) were conducted in laboratories of Institute of Geological Sciences, NAS; Institute of Geochemistry, Mineralogy and Ore Formation, NAS; Institute of Mineral Resources, and Kryvorizka GEE. Significant methodic assistance was provided by Geoprognoz (Geoinform), Institute of Geological Sciences, NAS; Institute of Geochemistry, Mineralogy and Ore Formation, NAS; Institute of Mineral Resources, and Scientific-Editorial Council of the State Geological Survey.

Besides the mentioned works, in some cases related to crystalline basement map design it was used data from report "Drilling and complex studies of Kryvorizka Super-Deep Bore-Hole NG-8" [53].

The set of the State Geological Maps was prepared to publishing by V.V.Zakharov (group head), A.V.Martynyuk, Yu.M.Tokar. Cartography was performed by I.V.Oskina and S.V.Dyachenko. Edition of the maps and explanatory notes was provided by M.S.Kurlov and B.D.Vozgryn. Map design and preparation were considerably assisted by A.S.Drannyk, D.F.Volodin, V.Ya.Velikanov, A.I.Nekryach, V.K.Baturin. Ukrainian edition is prepared by K.P.Rizdvyanskiy. The map is designed under the factual base as of 01.01.2000.

1. STUDY DEGREE

The territory of map sheets M-36-XXXIV and L-36-IV is most studied over Ukrainian Shield since the world-biggest Kryvorizkiy Iron-Ore Basin is located there. The basin studies were essentially contributed by (to the first edition of Derzhgeolkarta-200 in former USSR) V.O.Domger, S.O.Kontkevych, O.V.Fass, M.I.Bezborodko, M.I.Svitalskiy, P.P.Pyatnytskiy, Yu.G.Gershoyg, V.I.Luchytskiy, I.Yo.Tanatar, M.P.Semenenko, I.S.Usenko, Yu.B.Bass, Ya.M.Belevtsev, Z.O.Krutykhovska, K.F.Tyapkin, O.P.Nikolskiy, and many others.

In 1960-1961 over the both map sheet areas were published the State Geological Maps of Central-Ukrainian Series in the scale 1:200,000 (M-36-XXXIV, V.M.Gladkiy; L-36-IV, K.O.Bezner). These maps, with weak geophysical support, lack of isotopic-geochemical studies (for crystalline basement), and incomplete subdivision of Cenozoic sediments, were quickly outdated. In the late 50th over entire territory was performed geological mapping in the scale 1:50,000 (G.M.Karpov, 1957; O.O.Zaytsev, 1958; B.T.Osadchiy, 1958; I.F.Zlobenko, 1959; O.I.Zhaldak, 1959; V.F.Kiktenko, 1960; M.O.Samarin, 1960; Yu.B.Babkov, 1965; I.M.Etingof, 1965; S.Yu.Fedyushyn, 1971; V.O.Fedortsov, 1973). These work considerable upgraded the territory study degree to new higher level, especially in term of pre-Cenozoic units which stratification is valuable still. At the same time, the shallow-deep (up to 10-50 m) study of Precambrian rocks caused a number of disputable points in stratigraphy and tectonics of Ingulo-Inguletskiy and Middle-Dniprean areas as well as in their mutual division. Nevertheless, results of geological mapping in the scale 1:50,000 were taken in 1970 as the ground for designing the first unified stratigraphic schemes of Cenozoic and Precambrian rocks in Ukrainian Shield.

Besides the geological mapping, 60th and partially 70th were characterized by the wide range of fence-drilling, prospecting, research and other geological works in Kryvbas and surrounding areas, performed under participation of R.I.Tkach, G.M.Strueva, O.O.Semergeeva, M.I.Chernovskiy, N.I.Kukhareva, M.S.Raevska, M.T.Ryaguzov, E.V.Dmytriev, M.O.Bushuev, M.G.Efimenko, V.V.Reshetnyak and many others. They had contributed a lot to adjustments of geology in Kryvorizkiy area.

In the beginning of 70th over the both sheets territory commenced targeted (for DGM-50) geophysical surveys (L.G.Bezyuk, 1973; M.G.Klyuev, 1974; G.G.Miller, 1975; V.F.Klyueva, 1976; L.O.Irza, 1983; Y.M.Vovchuk, 1981-1983; L.Y.Zolotaryova, 1981-1985, etc.) with high-precision gravity-magnetic studies and prospecting electric (IP, MTP) works which are quite necessary for deciphering of Precambrian basement geology.

From the mid of 70th it was commenced new, deeper, phase of regional studies over the territory of map sheets M-36-XXXIV and L-36-IV – large-scale deep geological mapping (DGM-50) with considerable amount of the deep (up to 300-500 m in hard rocks) drilling and modern rock study methods. These were the works (A.S.Kyselyov, 1974, 1983; S.Yu. Fedyushyn, 1976; V.V.Zakharov, 1979; A.V.Martynyuk, 1988; O.B.Bobrov, 1989; G.E. Zmievskiy, 1994) covered about 35% of the territory, which became the ground for modern ideas on the crystalline basement geology. By these results, the stratigraphic scheme of Precambrian rocks in Ingulo-Inguletskiy and Middle-Dniprean areas had been changed and amended several times.

In parallel to GMW-50 and DGM-50 in both map sheets, Precambrian rocks mainly were subjected to prospecting for uranium (with huge drilling amounts) by the geological teams of Eastern Mining-Beneficiation Plant and Kirovske Industrial Geological Enterprise (B.N. Bogoyavlenskiy, E.O.Zykov, and others). Obtained results were used in deciphering the map sheet geology both during mentioned GMW-50 and DGM-50, and in research map design works in the scale 1:200,000 (Yu.B.Babkov, 1973; V.V.Zakharov, 1975; B.Z.Berzenin, 1981, 1988).

Considerable contribution to the Precambrian studies over the map sheets in this period was also made by scientific and research organizations and these results are published in works of G.I.Kalyaev, R.Ya.Belevstsev, V.A.Ryabenko, G.V.Artemenko, L.S.Galetskiy, V.L.Boyko, M.P.Shcherbak, E.B.Glevasskiy, V.G.Pastukhov and many others.

As a result of generalization, mainly of geological mapping works, there were published in 80th the State Geological Maps in the scale 1:50,000 for the areas of Pravoberezhni magnetic anomalies (A.S.Kyselyov, 1980), Northern and Central Kryvbas (I.S.Paranko, 1987). Reflecting new stratigraphic and metallogenic data in the mentioned areas, the first Derzhgeolkarta [12] was however characterized by rather imprecise schematic kind of tectonic subdivisions, and the second map [19] – by controversy of Kryvbas geological interpretation to the fence-drilling data and the drilling results of Kryvorizka Super-Deep Bore-Hole and its satellites available for that time [53].

In addition to multi-purpose geological studies in Kryvorizkiy area it was in 90th only when the special geo-ecological works were performed in the scale 1:50,000 (O.I.Gulyak, 1997) which provided particular examples of geological environment contamination at various levels and allowed recommendation for geo-ecological situation improvement.

Establishment in 1984 the super-deep bore-hole (SD-8) within Kryvorizka structure marked the new deeper phase of regional studies – geological study of the fields in the scale 1:200,000 – 1:500,000 (GSF-1 and GSF-2) with lateral expansion over surrounding fields the super-deep drilling data interpretation.

Over GSF-1 (V.K.Butyrin, 1985) in the map sheets M-36-XXXIV and L-36-IV there were found many new elements of Precambrian basement geology and metallogeny, particularly, it was suggested new version of stratigraphic scheme according to which it was proposed for Kryvbas to define Ingulo-Inguletska Series (Gdantsivska and Rodionivska Suites) that overlies the rocks of Kryvorizka Series (Saksaganska and Skelyuvatska Suites). And Kryvorizka structure was considered as monocline (westward dipping) that was further confirmed by super-deep drilling.

Almost simultaneously to the GSF-1 there were performed the works in the scale 1:50,000 with prospecting drilling within Kryvorizka structure (V.P.Zhuk, 1986). It was the valuable contribution to the adjustment of Kryvbas geology but some of suggested proposals (Ingulo-Inguletska Series laying over Kryvorizka Series, consideration of Skhidnogannivska structure rocks as Konkska Suite, etc.) were not further confirmed neither by own fence drilling [37, 39] nor by super-deep drilling [53[.

As a result of GSF-2 works (G.E.Zmievskiy, 1990) over both map sheets there were designed geological maps in the scale 1:500,000 on the geodynamic ground with definition the geodynamic environments analogues to Phanerozoic ones. Leaving behind the reliability of these definitions in Early Precambrian, it should be noted that these subdivisions were argued with huge exaggerations and are not supported by results of super-deep drilling [53] and EGSF-200 [42]. The stratigraphic scheme version designed on the geodynamic ground does not correlate to the valid stratigraphic scheme. However, associated metallogenic studies were carried out at the high-degree level. Similar metallogenic works had also been performed before (T.M.Sumtsova, 1978, 1981) and they were used in planning the geological mapping and prospecting works in Kryvbas and surrounding areas.

Kryvorizka bore-hole core section studies [53] coupled with seismic works, magnetic survey and logging (V.I.Starostenko, V.B.Sollogub, M.M.Baysarovych, M.O.Borodulin, V.M.Zavoyskiy, 1987-1992) allowed recognition of Kryvorizka structure geology to the depth 6-7 km. It was ontained enormous amount of the complex systematic information on the area geology, stratigraphy, mineralogy, isotopic geology, rock physico-mechanic and petrographic features, metamorphism, metasomatism, and related ore-forming processes. This information was used in preparation of the maps to publishing.

The works over SD-8 had confirmed not monocline [19, 34, 45] but syncline structure of Kryvbas, according to which its western part along deep-seated Kryvorizko-Kremenchutskiy Fault (through Tarapakivskiy thrust) is thrusted over Saksaganska syncline overturned to the east. And, finally, it was solved the problem of Far Western iron-ore bands. Similar conclusions were obtained also over EGSF-200 in the map sheets M-36-XXXIV and L-36-IV [42]. The main result of these works was the set of maps with geological background (approved by Scientific-Editorial Council in 1998), and these works were mainly the ground during preparation of the maps to publication. It should be noted that different study degree of Precambrian and Cenozoic works had caused irregular support of the maps prepared.

2. STRATIFIED UNITS

Integrated stratigraphic column over the map sheets M-36-XXXIV and L-36-IV, according to the "Legend of Geological Map of Ukraine in the scale 1:200 000" (Kyiv, 1996), "Correlation Stratigraphic Scheme of Precambrian Units in Ukrainian Shield" (of 22.06.2000), and territory zonation (for different stages of its development) is designed as follows:

PHANEROZOIC

Cenozoic Eratheme
Quaternary System

Northern-Inguletskiy sub-area (zone of northern loess fields)	Southern-Inguletskiy sub-area (zone of southern loess fields)

Holocene Division (H)
Holocene Climatolith (hl)
Pleistocene Division
Neo-Pleistocene Branch (P)
Upper Neo-Pleistocene (P_{III})
Prychornomorskiy Climatolith (p)
Dophinivskiy Climatolith (df)
Buzkiy Climatolith (b)
Vytachivskiy Climatolith (vt)
Udayskiy Climatolith (ud)
Prylutskiy Climatolith (pl)
Middle Neo-Pleistocene (P_{II})
Tyasminskiy Climatolith (ts)
Kaydatskiy Climatolith (kd)
Dniprovskiy Climatolith (dn)
Zavadivskiy Climatolith (zv)
Lower Neo-Pleistocene (P_I)
Tyligilskiy Climatolith (tl)
Lubenskiy Climatolith (lb)
Sulskiy Climatolith (sl)
Martonoskiy Climatolith (mr)
Pryazovskiy Climatolith (pr)
Shyrokivskiy Climatolith (sh)
Eo-Pleistocene (E)
Upper Eo-Pleistocene (E_{II})
Illichivskiy Climatolith (il)
Kryzhanivskiy Climatolith (kr)
Lower Eo-Pleistocene (E_I)
Berezanskiy Climatolith (br)

Neogene System

Pliocene Division
Lower and Upper Pliocene
Sequence of red-brown clays (N_2b)
Lower Pliocene
Sequence of alluvial sands (N_2ap)

Southern area of Ukrainian Shield Shyrokivska LTZ	Central area of Ukrainian Shield Vilnogirska LTZ

Miocene Division
Upper Miocene

Kosivski Layers (N_1ks)	
Limestone Pile (N_1v)	Pile of parti-coloured clays (N_1s)
Bagerivski Layers (N_1b)	
Geliksovi Layers (N_1l)	Geliksovi Layers (N_1l)
Pile of limestones and marls (N_1vm)	Pile of sands (N_1p)
Zbruchski Layers (N_1zb)	

Lower-Middle Miocene
Poltavska Series

Chokrakski Layers (N_1k)	Novopetrivska Suite (N_1np)

Paleogene System

Vysokopilska LTZ	Oleksandriysko-Apostolivska LTZ

Oligocene Division

Maykopska Series	
Molochanska, Sirogozka and Askaniyska suites undivided ($\text{Ᵽ}_3ml\text{-}as$)	Kharkivska Series
Borysfenska Suite (Ᵽ_3bs)	Mezhygirska Suite ($\text{Ᵽ}_3m\check{z}$)

Eocene Division

Alminska Suite (Ᵽ_2al)	Obukhivska Suite (Ᵽ_2ob)
Khadzhybeyska Suite (Ᵽ_2hd)	Kyivska Suite (Ᵽ_2kv)
Pile of coaliferous clays and sands (Ᵽ_2vg)	Buchatska Series (Ᵽ_2bu)

Mesozoic Eratheme

Cretaceous System

Lower Division

Kodymska Suite (K_1kd)	Novopetrivska Suite (N_1np)

Ingulo-Inguletskiy area of Ukrainian Shield	Middle-Dniprean area of Ukrainian Shield

PRECAMBRIAN

Proterozoic Acrotheme
Paleo-Proterozoic Eonotheme

Kirovogradska LTZ	Inguletsko-Kryvorizka LTZ	Kryvorizko-Kremenchutska LTZ
	Gleyuvatska Suite (PR$_1$*gl*)	Gleyuvatska Suite (PR$_1$*gl*)
Ingulo-Inguletska Series		
Checheliivska Suite (PR$_1$)		Kryvorizka Series
Spasivska Suite (PR$_1$*sp*)		
Rodionivska Suite (PR$_1$*rd*)	Rodionivska Suite (PR$_1$*rd*)	Gdantsivska Suite (PR$_1$*d*)
	Artemivska Suite (PR$_1$*ar*)	Saksaganska Suite (PR$_1$*sx*)
	Zelenorichenska Suite (PR$_1$*zr*)	Skelyuvatska Suite (PR$_1$*sk*)
		Novokryvorizka Suite (PR$_1$*nk*)

Archean Acrotheme
Neo-Archean Eonotheme

Konkska Series (AR$_3$*kn*)	Verkhivtsivsko-Chortomlytska LTZ
undivided rocks	Konkska Series
	Solenivska Suite (AR$_3$*sl*)
	Alferivska Suite (AR$_3$*al*)
	Chortomlytska Suite (AR$_3$*čr*)
	Surska Suite (AR$_3$*sr*)

Meso-Archean Eonotheme

	Bazavlutska Sequence (AR$_2$*bz*)

The stratigraphic column presented above includes two age-different complexes of geological units: upper one – Meso-Cenozoic which constitutes the flat-laying platform cover, and lower one – Precambrian that form the composite folded crystalline basement. The latter, according to the “Correlation stratigraphic scheme of Precambrian rocks in Ukrainian Shield” (Kyiv, 2000), is located in two tectonic areas – Middle-Dniprean and Ingulo-Inguletskiy ones. And Kryvorizko-Kremenchutskiy Deep-Seated Fault (KKDSF) comprises the border between the two.

PRECAMBRIAN

ARCHEAN

Archean units comprise mainly volcanogenic rocks (with radiologic age above 2600 Ma) which are developed in Middle-Dniprean area and are locally known in the Ingulo-Inguletskiy area. Of these, there are distinguished: Bazavlutska Sequence (Meso-Archean) and Konkska Series (Neo-Archean) separated by the age boundary of 3200 Ma.

Meso-Archean

Bazavlutska Sequence (AR$_2$*bz*)

It is distributed in the Middle-Dniprean area over the land between Bazavluchok and Kamyanka rivers (L-36-IV sheet). There the sequence rocks are the oldest ones and constitute diverse-size remnants within plagiogranitoids of Dnipropetrovskiy Complex forming together with the latter Bazavlutske arc uplift. Small-scaled greenstone remnants, known in the core section of domes composed of Saksaganski plagiogranitoids, also belong to this Sequence.

The Sequence comprises (the stratotype is developed along Bazavluchok River) amphibolites, rarely – amphibole, biotite-amphibole, biotite gneisses and mafic gneisses with sporadic thin (up to 0.7 m) interbeds of silicate-magnetite quartzites. In details this sequence is described in a range of works [6, 9, 12, 31, 32 etc.].

Hornblende amphibolites are composed of plagioclase (35-50%), normal hornblende (40-50%), relic grains of clinopyroxene (rarely orthopyroxene) (0.5-4%), single grains of magnetite, apatite, sphene, and ilmenite. In granitized varieties there is observed up to 20% of quartz-plagioclase metatectite. The rocks are of high density (2.99 g/cm^3) and are being clearly expressed in gravity fields of less dense plagiogranites. The rocks, by paragenetic mineral assemblages and clear evidences for granitization, belong to amphibolite facies of regional metamorphism. Petrochemical data [42] allow classifying the rocks as volcanogenic early-crustal basalt-tholeiite range members.

Within amphibolites (at Zhovtneve village) in DH 23611 and DH 23612 there are intersected conformable thin (2-3 m) bodies of actinolite tremolitites. The body shape, gradual transitions to amphibolites and other secondary evidences allow these rocks definition as ultramafic extrusives (basaltic komatiites).

Direct contact of Bazavlutski rocks with overlaying volcanics of Konkska Series, described below, is not observed in the area. In contrast to the latter which fill up rift structures with zoned metamorphism, volcanics of Bazavlutska Sequence are characterized by aerial distribution type, mono-facial metamorphism and bulk-sequence migmatization. Apparently, they comprise the relics of the oldest greenstone belts that is confirmed by their radiogenic age – 3300 Ma (Sm-Nd method) [31] and development of the similar rocks in Baltic Shield (Bilomorska Series) and other shields.

Neo-Archean

Konkska Series (AR$_3$*kn*)

The rocks of Konkska Series include mainly diverse metavolcanics, rarely – metasedimentary rocks which constitute in the Middle-Dniprean area all greenstone syncline and volcano-tectonic (depression) structures. There Series column is divided into four suites (upward): Surska, Chortomlytska, Alferivska, and Solenivska which are distinguished within Verkhivtsivsko-Chortomlytska LTZ.

Undivided rocks of the Series are known only in the Ingulo-Inguletskiy area where they are observed in the remnant chains within Inguletski plagiogranites with the age 2850-3074 Ma [53]. There Series column (within relicts of Karachunivsko-Lozuvatska structure where it is most preserved) comprises mainly amphibolites, rarely amphibole and biotite-amphibole gneisses and mafic gneisses up to 850 m of total thickness. The column upper part contains abundant interbeds of biotite gneisses with lenses (up to 7 m) of silicate-magnetite quartzites. Due to the latter the numerous remnants of Konkska Series within granitoids of Inguletskiy Complex are being well mapped by geophysical (magnetic) methods.

Surska Suite (AR$_3$*sr*) is mainly composed of mafic volcanogenic rocks which fill up riftogenic syncline structures of liner type (Vysokopilska, Zhovtovodska, Alferivska – of deep setting, and a range of smaller structures – Mykolaivska, Novopavlivska etc.), the basic portions of Inguletska, Saksaganska and Skhidnogannivska synclines of Kryvorizka structure (Fig. 2.1, 2.2), as well as all central-type volcano-tectonic structures defined in the area for the first time (Yavdotivska, Dovgyntsivska, Oleksandrivska and smaller ones). The most complete section of the Suite is encountered in Vysokopilska syncline structure. There, at the section lower part (up to 2000 m thick), are developed amphibolites (metabasalts) with interbeds of amphibole gneisses, actinolite-chlorite schists and barren quartzites. In the section upper part (1200 m thick) actinolite, chlorite-actinolite and chlorite schists predominate with interbeds of chlorite-mica metasandstones, barren and ferruginous quartzites. Similar but variously metamorphosed column is also encountered in two major syncline structures – Zhovtovodska and Alferivska [33, 34, 61]. Besides that, in the Suite lower part there are observed conformable thin bodies composed of actinolites, tremolitites, serpentinites and schists developed after these rocks.

Within volcano-tectonic structures there is preserved (or developed) the lower part of Surska Suite only – amphibolites with interbeds of schists and gneisses. In places these rocks from linear syncline structures gradually change by strike into the ring-shaped volcano-tectonic structures with similar internal structure of the column [42].

By physical properties amphibolies and, in lesser extent, chlorite-amphibole schists are characterized by high density (2.94-3.00 g/cm^3) and this is why the fields of their development are being well mapped within the host granitoids by gravity anomalies up to 6-11 mGl. In geomagnetic fields in places are being expressed only bodies of magnetite-bearing rocks – ferruginous quartzites, rarely ultramafic rocks, providing the linear chains of anomalies above the rocks in syncline structures, and isometric-ring anomalies in volcano-depressions.

Amphibolites of Surska Suite are composed of hornblende, actinolite, plagioclase, and epidote, normally these are fine-medium-grained varieties, often alternating with fine- to obscure-grained ones. The latter in places contain fine vesicles and rounded aggregates of amphibole-epidote composition (relicts of lava ball-pillow jointing). Under microscope often are observed the relicts of porphyry, poikilitic and doleritic textures, in places – ophitic and intersertal textures.

Aforementioned evidences suggest for primary extrusive nature of the most of amphibolites formed mainly through metamorphism of basalts, dolerites, rarely – andesites. This is also confirmed by occurrence, instead of amphibolites, in the lower part of the Suite, in Alferivska structure, less metamorphosed varieties of amphibolites, specifically, metabasalts, metadolerite-basalts, and metaandesite-basalts with typical ball-pillow lava forms [33]. In actinolitites, tremolitites and serpentinites, which are being traced in thin conformable bodies within amphibolites, apart from relicts of primary pyroxenes in places spinifex textures are observed (DH 23604, 23655). Occurrence of these mineral-texture features, petrochemical calculations, as well as internal fine layering of these rocks and gradual transitions into the host amphibolites allow their definition to be ultramafic extrusive rocks – pyroxenite komatiites [42].

Within actinolite-chlorite-micaceous schists in the Suite column upper part there are known re-crystallized tuffs and tuffites [50, 56], as well as relicts of blasto-porphyry and intersertal textures [46] which clearly indicate the extrusive nature of most rocks in the column upper part. There, occurrence in the core parts of syncline structures (and sometimes in the marginal parts) the numerous zones of dynamometamorphism and retrograde metamorphism had caused development of various green schists in the section (epidote, chlorite) which complicate stratification of volcanogenic rocks.

By chemical composition [42] the most widespread rock of Konkska Suite – amphibolites and amphibole schists, do correspond to tholeiitic basalts, and actinolitites and tremolitites – to pyroxenitic komatiites. Looking at the rock association, the Suite corresponds to metakomatiite-tholeiite formation. Accessory-mineral specialization of metabasalts (amphibolites) is sphene-apatite-magnetite [53]. Their lanthanoid spectrum is homogenous that is typical for the primary-crustal rocks.

Absolute age of amphibolites by zircons from Vysokopilska structure [46] is estimated to 3120-3050 Ma. The age of granitoids, which do impose migmatization onto above rocks, is 3041-2971 Ma (DH 23221, 23606), and this also confirms recognition of these rocks to be Surska Suite members.

By laying conditions and other evidences the mentioned extrusives mainly belong to lava facies which is developed both in syncline structures – in fissure flows, and in volcano-tectonic structures – in the ring flows and flow sheets around inferred volcano calderas. Within lavas, rather in volcano-depression than in syncline structures, there is also observed sub-volcanic facies presented by sills and dyke-like bodies of gabbro-pyroxenites and their metamorphosed analogues of intrusive Verkhivtsivskiy Complex. Their spatial and age proximity, similarity in petrographic composition, petrochemical and geochemical features [42] allow their recognition in a single volcano-plutonic association favourable for gold, nickel, and copper prospecting.

The upper boundary of Surska Suite is defined in Alferivska structure only [33] where its conformable contact is encountered with overlaying rocks of Chortomlytska Suite, as well as appearance of abundant intermediate volcanics in the section.

Chortomlytska Suite (AR_3*čr*) is defined in Alferivska Syncline only where these rocks are being traced in a narrow, semi-closed band in the core portion of structure [33].

The Suite is mainly composed of metaandesite-basalts and metaandesites, as well as quartz-plagioclase-chlorite-actinolite schists developed after above rocks. Metabasalts and metadacites are observed in the interbeds. Distribution of these rocks in column displays certain regularity [33]: in the lower part predominate metaandesites with abundant metabasalt interbeds, in the middle part – metaandesites with metadacite interbeds, and in upper part – metaandesites with metabasalts interbeds. This rock association allows recognition the Suite to be metadacite-andesite-tholeiite formation and in this respect it differs from underlaying metakomatiite-tholeiite formation (Surska Suite).

By physical properties, metaandesites and schists after these rocks differ from metabasalts of Surska Suite in lesser density (2.82-2.92 g/cm^3), and very weak magnetization. The contact with overlaying rocks of Alferivska Suite is conformable; rock thickness varies from 80 to 240 m.

Alferivska Suite (AR_3*al*) is developed in the northern part of the same-named syncline where these rocks are distinguished to be metakomatiite formation [33]. Lower boundary is set by abrupt appearing and bulk predominance of ultramafic volcanics in the column. Relationships with overlaying rocks of Solenivska Suite are not defined. In the central part of syncline the rocks are intruded by diorites of Surskiy Complex.

The Suite is constituted of [33]: in lower portion mainly pyroxenite metakomatiite, rarely metabasalts, that formed after massive lava facies; in upper portion – alternation of metasandstones, metaaleurolites and quartzites with metabasalts and pyroxenite metakomatiites. The latter at the bottom comprise full-crystalline actinolitites and tremolitites, and at the top – the same fine-grained rocks. Transition of metakomatiites (at the top) to metasediments is observed through chlorite schists.

Lithological-petrographic, geochemical and petrophysical features of Alferivska Suite volcanics are similar to those of Surska Suite. Alferivska Suite rock thickness varies from 140 to 360 m.

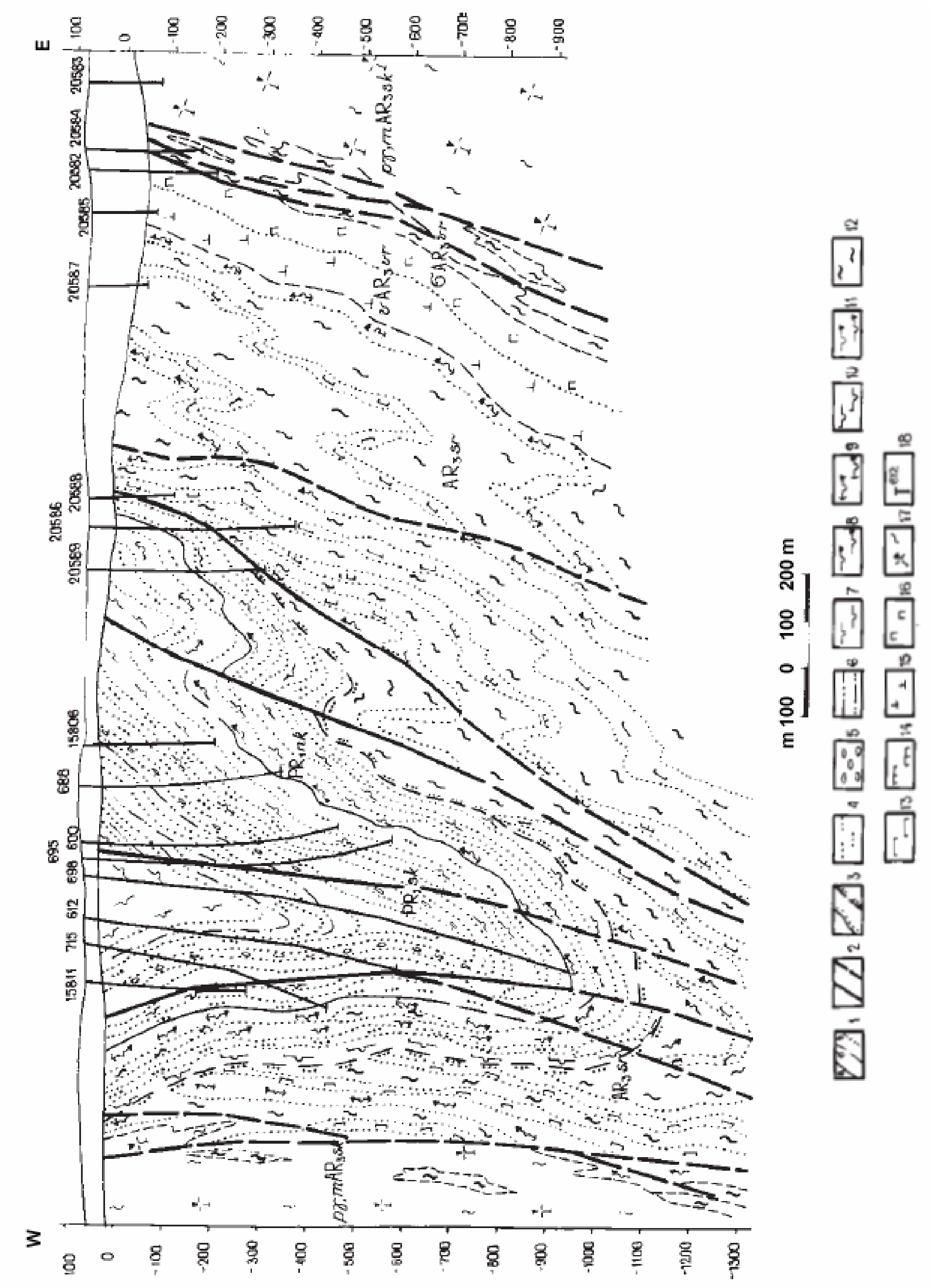


Fig.2.1. Geological cross-section across Inguletska syncline (southern part of Kryvorizka structure).

See next page for captions.

Fig. 2.1. Continued.

1 – geological boundaries: proven (a), possible (b), facial (c); 2 – faults: proven (a), possible (b); 3 – stratigraphic unconformities. Kryvorizka Series: Skelyuvatska Suite – PR_1*sk* (4 – metasandstones, 5 – metagravelites, 6 – metaaleurolites, 7 – biotite schists); Novokryvorizka Suite – PR_1*nk* (8 – actinolite schists, 9 – chlorite-actinolite schists, 10 – quartz-sericite, sericite schists). Konkska Series; Surska Suite – AR_3*sr* (11 – amphibole schists, 12 – amphibolites, 13 – actinolitites, 14 – tremolitites). Verkhivtsivskiy Complex – AR_3*vr* (15 – pyroxenites, 16 – serpentinites). Saksaganskiy Complex – AR_3*sk* (17 – biotite-amphibole plagiogranites and plagiomigmatites). 18 – drill-holes and their numbers.

Solenivska Suite (AR_3*sl*) is defined to be metarhyodacite formation [33]. The rocks are observed in the narrow band at northern extension of Alferivska Syncline where they unconformably overlie the lower portions of Surska Suite column. The Suite is characterized by diverse composition of volcanics – from metaandesite-dacites to metarhyolites. Metarhyodacites predominate being presented by rhyolites and quartz-plagioclase-sericite and quartz-chlorite-sericite schists developed after the former ones. Among these volcanics there are distinguished lava, pyroclastic and sedimentary-pyroclastic facies. The latter comprise greywackes.

The Suite rocks are often being cut by vein- and dyke-like bodies of Surskiy Complex blue-quartz plagiogranitoids. This fact coupled with estimated radiogenic age of metadacites – 3073$\pm$21 Ma [1] suggest for the highest position of Solenivska Suite rocks in the stratified Neo-Archean column.

Making a summary to Archean stratified rocks it should be noted that volcanic processes had essentially contributed to their formation. In Meso-Archean, regarding the spatial development of Bazavlutska Sequence volcanic rocks, the volcanism apparently was aerial. In Neo-Archean the volcanism was clearly homodromic and is expressed in two types of lava extrusions – fissure and central at the boundaries of plagiogranites diapiric domes, and also had formed all greenstone structures.

Metamorphism of Konkska Series volcanogenic rocks displays zoned patterns – from low-temperature amphibolite to greenschist facies. Amphibolite facies is locally developed and does not extend outside the lower portion of Surska Suite (at the contact with plagiogranitoids). In all greenstone belts epidote-amphibolite facies is most developed with typomorphic minerals (pale-green hornblende, actinolite, epidote, sodic plagioclase, brown biotite). In this facies rocks there are preserved relic signs of primary rocks. Greenschist facies is widespread in Alferivska Syncline only while in other structures this facies is locally observed at the core portions.

Close to the massifs of Neo-Archean granitoids all metavolcanic rocks of Konkska Series underwent migmatization and granitization: in the linear synclines at the peripheral (marginal) parts with formation of amphibole-bearing migmatites, and in the ring volcano-tectonic structures – both at periphery (with formation of migmatites) and in the central parts (with formation of diorite-granodiorite rocks).

Relatively low metamorphism of volcanics and their mainly local granitization had preserved the high ore-forming potential of Konkska Series volcanic rocks.

PROTEROZOIC

Paleo-Proterozoic

Paleo-Proterozoic units include mainly metasedimentary rocks with radiogenic age 2600-2000 Ma that form Kryvorizka and Ingulo-Inguletska Series. According to “Correlation stratigraphic scheme of Precambrian rocks in Ukrainian Shield” (Kyiv, 2000), Ingulo-Inguletska Series is developed in the Ingulo-Inguletskiy area whereas Kryvorizka Series – in the Middle-Dniprean area. The contact between the two is thought to be tectonic – along Kryvorizko-Kremenchutskiy Deep-Seated Fault (KKDSF) which in Kryvbas for a long time had been considered to be Western Thrust – the western axis of KKDSF.

Most researchers had concluded [6, 12, 13, 22, 29, 34, 52, 53, 54, 60 etc.] that the rocks of both Series are stratigraphic analogues. Recent works over the map sheets M-36-XXXIV and L-36-IV [42, 53] had revealed iso-faciality (identity) of the rocks in lower part of Ingulo-Inguletska Series (Zelenorichenska, Artemivska and Rodionivska Suites) and Kryvorizka Series rocks developed in western part of Kryvbas within Main (Kryvorizka) Syncline (Fig. 2.2, 2.3). In these works there is also set the new boundary between the two Series (and respectively two geological areas) within Kryvbas – along the central axis of KKDSF represented by Tarapakivskiy Thrust which type and morphology are defined by drilling results of Kryvorizka super-deep bore-hole SD-8 [53].

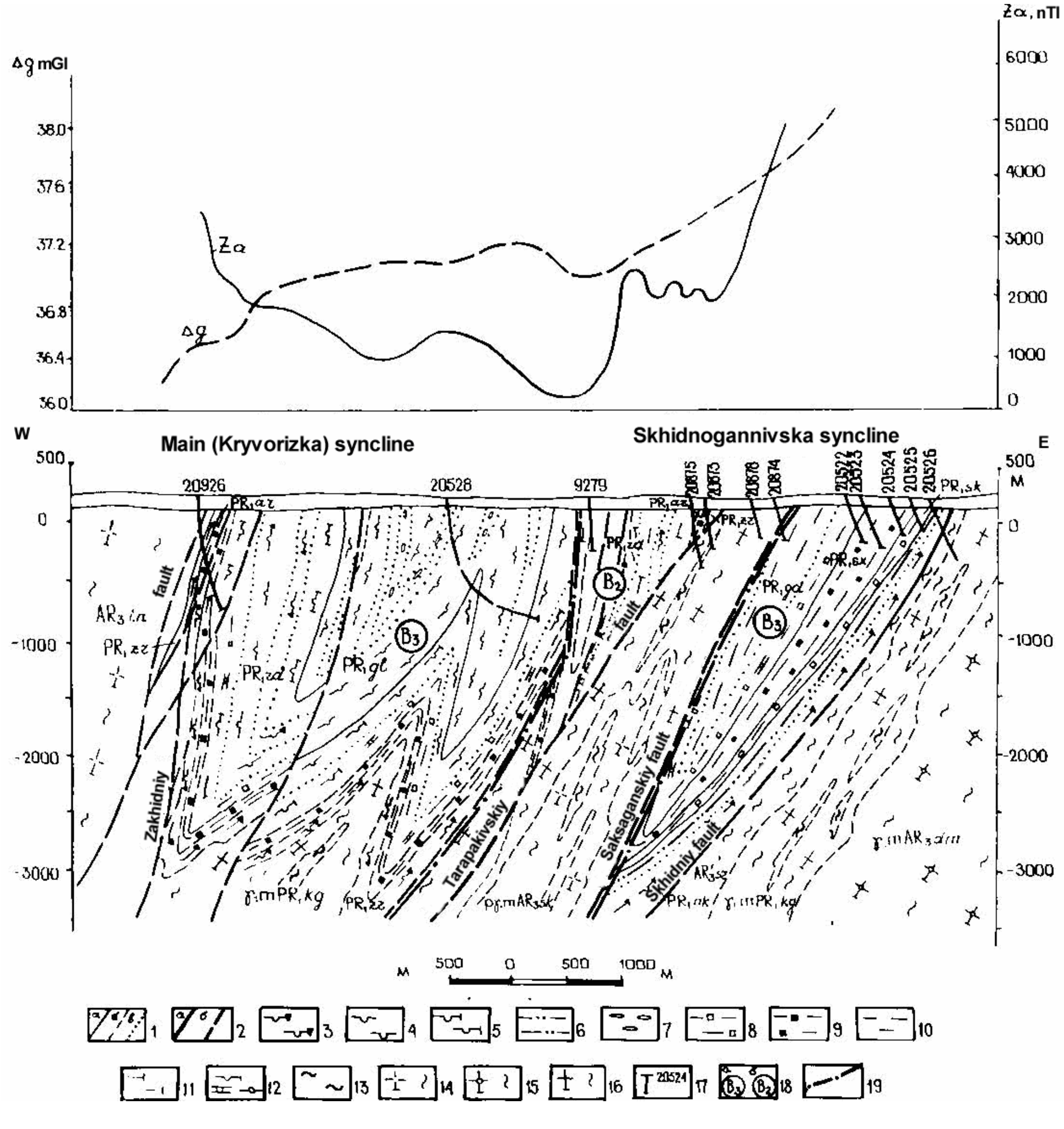


Fig. 2.2. Geological cross-section through Skhidnogannivska and Main (Kryvorizka) synclines (northern part of Kryvorizka structure).

Konkska Series: Surska Suite – AR_3*sr*; Kryvorizka Series: Novokryvorizka Suite – PR_1*nk*; Skelyuvatska Suite – PR_1*sk*; Saksaganska Suite – PR_1*sx*; Gdantsivska Suite – PR_1*gd*; Ingulo-Inguletska Series: Zelenorichenska Suite – PR_1*zr*; Artemivska Suite – PR_1*ar*; Rodionivska Suite – PR_1*rd*. Gleyuvatska Suite – PR_1*gl*. Kirovogradskiy Complex – PR_1*kg*; Demurynskiy Complex – AR_3*dm*; Inguletskiy Complex – AR_3*in*; Saksaganskiy Complex – AR_3*sk*.

1 – geological boundaries (a – proven, b – probable, c – facial); 2 – faults (a – proven, b – probable); 3 – biotite-amphibole schists; 4 – biotite schists; 5 – biotite-graphite schists; 6 – metaaleurolites; 7 – metagravelites; 8 – mono-mineral quartzites; 9 – ferruginous quartzites; 10 – biotite gneisses; 11 – biotite-graphite gneisses; 12 – intercalation of biotite-graphite gneisses, quartzites, marbles; 13 – amphibolites; 14 – biotite plagiogranites; 15 – two-feldspar biotite granites and migmatites; 16 – biotite granites and migmatites; 17 – drill-holes and their numbers; 18 – metamorphic facies: epidote-amphibolite (a), amphibolite (b); 19 – boundaries of metamorphic facies.

In view of mentioned new results the Paleo-Proterozoic stratified rocks are grouped as follows: Kryvorizka Series – within Kryvorizka-Kremenchutska LTZ (eastern Kryvbas and its northern extension to the east from KKDSF) in the Middle-Dniprean area; lower part of Ingulo-Inguletska Series – within Inguletsko-Kryvorizka LTZ (Pravoberezhni magnetic anomalies and western Kryvbas) in the Ingulo-Inguletskiy area; upper portion of Ingulo-Inguletska Series (Spasivska and Checheliivska Suites) – within Kirovogradska LTZ in the same Ingulo-Inguletskiy area. The border between two latter LTZs in the single area is set to be Inguletskiy normal fault.

Kryvorizka Series

Kryvorizka Series is approved to be Paleo-Proterozoic stratotype of Ukrainian Shield and is described in details in numerous works [4, 6, 12, 19, 22, 34, 37, 39 etc.]. The rocks are developed to the east from KKDSF (in Kryvbas – Tarapakivskiy fault) where they fill up the strike-elongated chain of narrow synclines: Inguletska, Saksaganska, Skhidnogannivska, Zhovtovodska, Popelnastivska. In the deepest Saksaganska syncline there is distinguished complete section of Kryvorizka Series which comprises four Suites: Novokryvorizka, Skelyuvatska, Saksaganska and Gdantsivska.

Novokryvorizka Suite (PR_1nk) is being discontinuously traced along the eastern margin of Kryvorizka structure. The Suite stratotype is located at the southern closure of the Main Syncline where the Suite rocks are widespread. There the rocks lie with angular unconformity over eroded surface of Neo-Archean plagiogranitoids [32] or Surska Suite amphibolites, with 0.5-1.0 m to tens of meters thick metamorphosed weathering crust at the base. The latter normally comprises: staurolite-sericite-quartz schist after plagiogranitoids (DH 20631 etc.); chlorite-biotite-quartz schist after amphibolites, rarely – siliceous metatuffs with scoria and ash fragments (DH 20526 etc.) [14, 42].

The schists of ancient weathering crust are often overlain by muscovite-andalusite quartzite-sandstones (re-deposited crust) enriched with rutile, zircon and ilmenite [53].

The column of the Suite is mainly composed of chlorite-actinolite and biotite-actinolite schists.

In the tight association with these rocks are observed interbeds of vesicular metabasalts (amphibolites) up to 20 m thick as well as fine-grained quartz metasandstones. Thickness of the latter gradually increases upward in the column from first tens of centimeters to first meters. By its primary genesis the Suite is sedimentary-volcanogenic. Study of the schists by various researchers [14, 19, 30 etc.] had revealed the primary material for these rocks were the products of hard chemical weathering of mafic and ultramafic rocks. And sedimentary nature of the rocks is supported by intercalation with metasandstones involved in gradual transitions [53]. Occurrence of vesicular amphibolites suggests for ceasing (inherited from Archean) of volcanic activity in Novokryvorizkiy time.

By chemical composition, amphibolites belong to slightly differentiated series of basalt close to Surska Suite rocks but more alkaline and less siliceous [53]. From underlaying amphibolites these rocks differ in accessory-mineral specialization (sphene-magnetite-ilmenite). REE spectrum of Paleo-Proterozoic amphibolites is also more differentiated in comparison to Neo-Archean rocks [53]. Paleo-Proterozoic features of the rocks are also supported by the deposition age of Novokryvorizka Suite volcanics determined on zircon by isochrone method to 2328 ± 25 Ma [26].

Thickness of the Suite by strike of Kryvorizka structure varies in the range from 50 to 400 m.

Skelyuvatska Suite (PR_1sk) is developed throughout in the eastern limbs of all syncline structures of Kryvorizko-Kremenchutska LTZ. The rocks lie with stratigraphic interruption over Novokryvorizka Suite [12] and in places of lacking this Suite – over eroded surface of Neo-Archean plagiogranitoids with metamorphosed weathering crust at the base, similar to one at the base of Novokryvorizka Suite [53].

The section nearby the former Skelyuvatka village, in southern closure of Main Syncline, is considered as stratotype one. Three sub-suites are clearly distinguished there: Lower – arkose-quartzite, Middle – phillite, and Upper – talc-carbonate; these units are indicated in stratigraphic columns only. By strike the rocks are often discontinuous, and by depth (up to 3 km) they are relatively continuous but their thickness is considerably reduced.

Lower Sub-Suite (PR_1sk_1) is developed throughout and is mainly composed of arkose metasandstones and quartzites with interbeds of polymictic metaconglomerates. The latter predominate in the column at the Main Syncline closure. Thickness of Sub-Suite is 10-160 m.

Middle Sub-Suite (PR_1sk_2) is composed of sericite, chlorite-sericite, rarely – two-mica schists. There are observed interbeds of quartzites, metasandstones, in places metagravelites at the bottom. By strike Sub-Suite is continuous in composition but thickness varies from 20 m to 180 m.

Upper Sub-Suite (PR_1sk_3) comprises talc, talc-carbonate, rarely – talc-chlorite-actinolite schists with interbeds of phillites, metasandstones and minor marbles. All these rocks are fairly widespread in Kryvorizka syncline structure and are locally developed in Zhovtovodska and Popelnastivska structures. Thickness of Sub-Suite is 20-180 m.

All mentioned rock varieties are linked by gradual transitions. It is thought [12, 19, 53] that the rocks of Lower and Middle Sub-Suites comprise clear expressed transgressive column of shallow-water and deep-water facies. The primary nature of Upper Sub-Suite talc rocks is disputable. Some authors [19, 34] thought the rocks to be metamorphosed ultramafic extrusives while others [42, 53, 60] consider these are carbonate rocks. Most of the facts suggest for the latter point of view although it is not excluded that part of these rocks can be metamorphosed komatiites. Moreover, the fault zones are normally developed after the talc rocks in association with considerable dislocation-metamorphic processes which essentially mask the primary nature of the rocks.

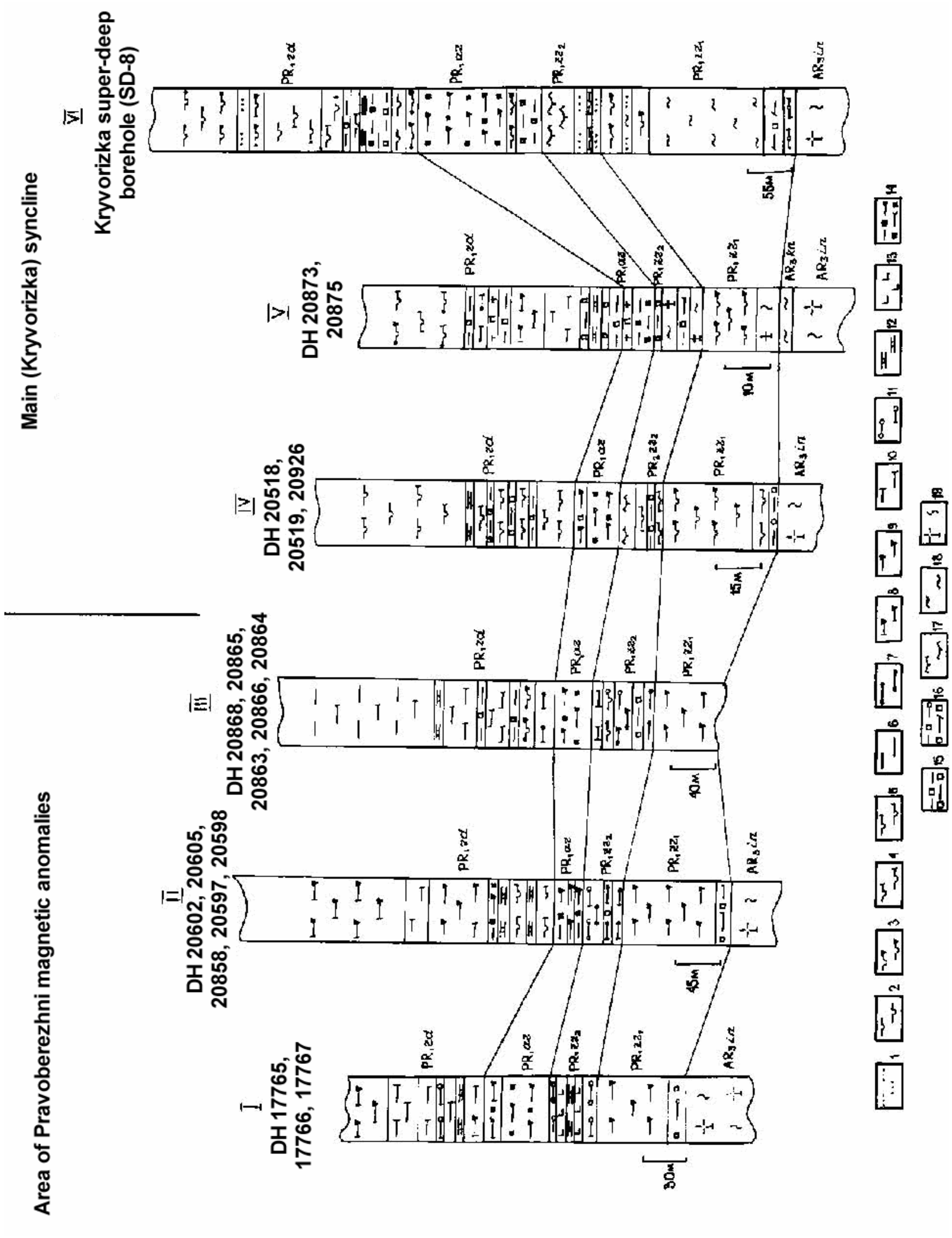


Fig. 2.3. Correlation of generalized columns of Ingulo-Inguletska Series in the area of Pravoberezhni magnetic anomalies and in Main (Kryvorizka) Syncline.

See next page for captions.

Fig. 2.3. Continued.

Ingulo-Inguletska Series: Zelenorichenska Suite – Lower Sub-Suite – PR_1zr_1, Upper Sub-Suite – PR_1zr_2; Artemivska Suite – PR_1ar; Rodionivska Suite – PR_1rd.

Konkska Series – AR_3kn.

Inguletskiy Complex – AR_3in.

1 – metasandstones; 2 – biotite schists; 3 – biotite-amphibole schists; 4 – biotite-graphite schists; 5 – biotite-sericite schists; 6 – biotite gneisses; 7 – garnet-biotite gneisses; 8 – amphibole gneisses with graphite; 9 – amphibole gneisses; 10 graphite-biotite gneisses; 11 – sillimanite-biotite gneisses with graphite; 12 – calciphyres; 13 – diopsidites; 14 – silicate-magnetite quartzites; 15 – mono-mineral quartzites; 16 – quartzites with sillimanite; 17 – talc-carbonate rocks; 18 – amphibolites; 19 – plagiogranites and plagiomigmatites.

I – Zelenivska Syncline; II – Kamchatska Anticline; III – Khutor Petrovskiy structure; IV – western limb of Main (Kryvorizka) Syncline; V – Skhidnogannivska Syncline; VI – western limb of Main (Kryvorizka) Syncline (Saksaganska site, section of super-deep bore-hole).

Conventionally accepted lower age boundary of the Suite rock formation does correspond to 2300±100 Ma [22]. The remnants of Paleo-Proterozoic micro-fossils and algae trichotomes are found in the schists of this Suite.

Saksaganska Suite (PR_1sx) is the major producing sequence of Kryvorizkiy Iron-Ore Basin. It is developed in the limbs of Inguletska, Saksaganska and Skhidnogannivska synclines, as well as in their northern extensions – Zhovtovodska and Popelnastivska synclines. The Suite stratotype is located in the north of Saksaganska Syncline where its thickness attains 1200 m. The Suite conformably lies over the rocks of Skelyuvatska Suite although within Saksaganska Syncline its contact with underlaying Suite is mainly tectonic (along Skhidniy Fault).

The Suite is mainly composed of ferruginous quartzites and schists which occur in rhythmically-alternating horizons. In the complete Suite column there are distinguished seven schist and seven ironiferous horizons connected one to another by gradual transitions [4]. By strike, and in places by dip, the number and thickness of horizons are irregular and change even within a single structure. All horizons are grouped into sub-suites: Lower, Middle, and Upper which, when possible, are indicated in the map.

Lower Sub-Suite (PR_1sx_1) includes first and second schist and ironiferous horizons which are mainly composed of quartz-sericite, quartz-actinolite, biotite-chlorite, rarely – chlorite-carbonate schists, as well as magnetite-martite jaspilites and magnetite-chlorite (amphibole) quartzites. Thickness of Sub-Suite is 40-500 m.

Ferruginous quartzites of Lower Sub-Suite provide the ore-source base to the Northern MBP (Gannivskiy open pit), Central MBP (Velyka Gleyuvatka open pit) and, partially, Southern MBP.

Middle Sub-Suite (PR_1sx_2) comprises third and fourth schist and third ironiferous horizons. The column is composed of sericite-biotite, chlorite-actinolite, quartz-graphite-sericite, rarely – hematite-chlorite schists, as well as chlorite-magnetite and magnetite-amphibole-biotite quartzites. Thickness of the Suite does not exceed 260 m. Ferruginous quartzites are being partly mined by Inguletskiy MBP and Novokryvorizkiy MBP.

Upper Sub-Suite (PR_1sx_3) includes fourth, fifth, sixth and seventh ironiferous and fifth, sixth and seventh schist horizons. In the section hematite-magnetite, magnetite-hematite-carbonate, amphibole-magnetite and hematite quartzites and jaspilites predominate, as well as hematite-chlorite, sericite-chlorite, chlorite-biotite and biotite-amphibole schists. Sub-Suite contains major bodies of metamorphogenic-hypergenic rich iron ores of Kryvbas, and its ferruginous quartzites provide the source base for all five operating mining-beneficiation plants in Kryvbas, and in the future – Kryvorizkiy MBP of oxide iron ores. Thickness of the Suite in Saksaganska Syncline attains 640 m and more.

Among other rocks of Kryvorizka Series the ferruginous quartzites and schists of Saksaganska Suite are studied in most details [3, 4, 6, 12, 19, 22, 34, 36, 37, 39, 52, 53]. Majority of researchers follow the idea on sedimentary nature of the Suite ferruginous quartzites through removal of chemogenic material from volcanic ridges located to the east from Kryvorizka structure. Remaining disputable points include tectonic position of the Suite rocks and the depth of their development. In the latter respect, according to the result of super-deep drilling by SD-8 (within the major ore-bearing Saksaganska Syncline), the Suite is traced to the depth of 6 km at least with ferruginous quartzite thickness decreasing by a factor of several times [53].

The age of the Suite is weakly studied, mainly by K-Ar determinations on biotites and amphiboles, providing 1800-2100±100 Ma. In the schist horizons there are found the remnants of Paleo-Proterozoic micro-phitofossils, as well as fragments of organic films and algae trychotomes [19].

Gdantsivska Suite (PR_1gd) is also iron-productive: in places it contains the layers and bodies of ironiferous quartzites and rich iron ores. The Suite is well studied in the southern closure of the Main Syncline and in Saksaganska Syncline where the Suite rocks stratigraphically unconformably overlie the rocks of Saksaganska Suite. In places the Suite rocks, due to tectonic contact, specifically, along Saksaganskiy Fault, overlie various horizons of Saksaganska Suite that allows some authors [19, 39] supposing the angular unconformity between these two Suites.

The Suite rocks constitute the core portions of syncline structures in Kryvorizko-Kremenchutska LTZ. The Suite stratotype is located in the southern closure of the Main Syncline where the unit is clearly subdivided into two sub-suites: Lower – essentially clastogenic, and Upper – carbonaceous-carbonate-terrigenous. Despite of the facial variability in some Suite counterparts by strike and depth, both sub-suites are being reliably mapped over entire Kryvorizko-Kremenchutska LTZ through particular marker rock varieties (carbonate, graphite and quartzite).

Lower Sub-Suite (PR_1gd_1) is composed of metasandstones, barren and ironiferous quartzites, as well as chlorite-mica and graphite-mica schists. Thickness of ferruginous quartzites attains 40 m and more. At the base of column normally occur sandstones with interbeds of monomictic conglomerates, rarely - sedimentation breccia with chlorite-magnetite schist interbeds and lenses of sedimentary-metamorphosed, carbonate-magnetite and hematite-magnetite rich ores. Thickness of the Suite varies from 200 to 800 m. Outside the Kryvbas (Zhovtovodska and Popelnastivska structures) this Suite in places pinches out from the column.

Upper Sub-Suite (PR_1gd_2) is developed throughout having gradual transitions to the underlaying rocks. It is mainly composed of mica-graphite, graphite-actinolite-biotite, chlorite-mica schists and calcite-dolomite marbles with minor interbeds of quartz metasandstones with carbonate cement and ferruginous quartzites 10-15 m thick [36]. Graphite-bearing schists contain characteristic pyrite (rarely pyrrhotite) mineralization, both syngenetic and related to the late hydrothermal-metasomatic processes. Thickness of Sub-Suite in the stratotype area attains 1 km.

Radiogenic age of autigenic apatite is estimated to 2025$\pm$35 Ma, and biotite formed under regional metamorphism – 1800$\pm$100 Ma [53]. In graphite-bearing schists and marbles there are found [6] organic remnants including spheromorphide, oncolites, and other forms. Isotopic composition of carbon and oxygen from carbonates and graphite [42] suggests for primary rock deposition under coastal-marine and lagoon environments and humid climate.

Regional metamorphic degree of Kryvorizka Series rocks within Kryvorizko-Kremenchutska LTZ does mainly correspond to two facies: greenschist and epidote-amphibolite. Greenschist facies is developed over most of Saksaganska and Popelnastivska synclines, and epidote-amphibolite facies – in the northern and southern portions of Kryvbas (respectively, Skhidnogannivska and Inguletska synclines), as well as in Zhovtovodska structure. More detailed description of the lateral and deep metamorphic patterns is given elsewhere [3, 4, 12, 19, 53 etc.].

In course of Kryvorizka SD-8 drilling [53] the metamorphic amphibolite facies (with temperature 560-630^oC and pressure 5-5.8 Kbar) was encountered in the Kryvorizka Series rocks in the narrow band along the Tarapakivskiy Thrust. This high-temperature zone encompasses the rocks in the western margin of Skhidnogannivska Syncline (up to the latitude of the Frunze Mine). There in schists of Gdantsivska Suite are also granitization processes encountered which are expressed in formation of thin bodies of microcline-plagioclase granites and akerites dated as 1870-2000 Ma.

According to the deep [46] and super-deep [53] drilling data within Saksaganska Syncline, there is also encountered the metamorphic degree change from greenschist to epidote-amphibolite facies at the depth about 2.0 km. At the bottom of Kryvorizka SD-8 bore-hole (5432.0 m) there are found amphibolites which belong to Novokryvorizka Suite. These rocks are metamorphosed under amphibolite facies.

Besides zoned regional metamorphism, the recent works [42, 53] had also revealed abundant dislocation-type rock units, mainly in the zone of Tarapakivskiy, and locally – in the zones of Saksaganskiy and Skhidniy faults. Thickness of these units varies from tens to hundreds of metres. These units are composed not only of brittle tectonites and retrograde rocks (breccia, cataclasites, milonites, various “green schists”), but also of re-crystallized rocks with “flow” textures (blasto-cataclasites, blasto-milonites, eye-gneissouse tectonites, boudinage, various mafic gneisses). In association with the latter over Kryvorizka Series rocks are superimposed alkaline, carbonate and silica-acid metasomatism expressed in alkalinity increase in amphiboles and ferruginous quartzites, formation of quartz-carbonate aggregates in schists and quartzites, marble skarning, greisenization and other processes. Apart from that, in the zone of Tarapakivskiy Fault the rocks of Gdantsivska Suite display the features of tectonic melange with elements of selective melting and extensive rock corrugation evidencing for significant horizontal tension and thrust motions.

Ingulo-Inguletska Series

The rocks of Ingulo-Inguletska Series are developed to the west from central axis of Kryvorizko-Kremenchutskiy Fault. Over there, the Series column consists of two parts. In the area, bounded by Kryvorizko-Kremenchutskiy Fault and Inguletskiy Fault (Inguletsko-Kryvorizka LTZ), there is developed the lower part of the Series (upward): Zelenorichenska, Artemivska and Rodionivska Suites. This part of column consisting of mentioned suites does well correlate with all suites of Kryvorizka Series being stratigraphic analogues in different areas. Thus, Inguletsko-Kryvorizka LTZ with a given type of column is actually transition zone between Ingulo-Inguletskiy and Middle-Dniprean areas. To the west of Inguletskiy Fault (in Kirovogradska LTZ) there are developed the rocks of mainly upper part of Ingulo-Inguletska Series (upward): Spasivska and Checheliivska suites. In the boundary area of this zone throughout are observed the rocks of Rodionivska Suite from adjacent Inguletsko-Kryvorizka LTZ but with different type of column. This confirms that junction of Ingulo-Inguletskiy area with Kryvorizko-Kremenchutska LTZ (Middle-Dniprean area) is featured to be the gradual transition [42].

As it is evidenced by drilling [39, 41, 43, 51, 52, 53], the rocks of both Series parts (in both LTZs) with angular unconformity lie over eroded surface of Archean plagiogranitoids (in places remobilized over Proterozoic). At the sites of low metamorphic grade (Rodionivska – DH 17167, 15408 etc,; Zakhidnokryvorizka – DH SD-8, 20519 etc.) at the base of Zelenorichenska and Rodionivska suites there is identified the old metamorphosed weathering crust with clear expressed zoning (upward): muscovite-bearing plagiogranites, andalusite (staurolite)-muscovite-quartz schist, andalusite (staurolite)-muscovite schist. And at the sites of high metamorphic grade (Pravoberezhni magnetic anomalies – DH 17765, 20862 etc.) the old weathering crust is modified into various sillimanite-bearing mafic gneisses and is almost not distinguishable from metasedimentary rocks. In places instead of these rocks there is developed re-deposited crust [41, 51, 53] composed of sillimanite-bearing quartzites.

Zelenorichenska Suite (PR_1zr) fills up the bottom of most Paleo-Proterozoic syncline structures in Inguletsko-Kryvorizka LTZ. At the surface it is traced in the narrow, often arc-shaped (discontinuous in places) bands, up to 400 m wide in marginal parts of Ovnyanska, Zelenorichenska and other synclines, in both limbs of the Main (Kryvorizka) Syncline, as well as in the cores of second-order anticlines (Kamchatska and others). The stratotype section is thought to be the column intersected by drill-holes in Zelenorichenska Syncline where by recent data the Suite is divided into two sub-suites: Lower (mainly volcanic) and Upper (terrigenous-sedimentary). Despite of some facial variability in certain rock types by strike, both sub-suites are reliable traced in syncline structures over the area of Pravoberezhni magnetic anomalies toward the western limb of the Main (Kryvorizka) Syncline (Fig. 2.3).

Lower Sub-Suite (PR_1zr_1) is mainly composed of amphibolites (in places vesicular) and amphibole and biotite-amphibole gneisses (schists) in the upper portion. In subordinate amount (in lower portion) there are observed metasandstone interbeds and horizon of sillimanite-bearing quartzites which represent re-deposited weathering crust (DH 17765, 20868, 20599 and others). Thickness of the Suite there does not exceed 100 m. In the western limb of Main (Kryvorizka) Syncline (DH 20926, SD-8 and others) the column of Sub-Suite is further divided into three parts where specific rocks predominate: quartzites and quartzite-sandstones – in the lower part, amphibolites (often vesicular) – in the middle part, amphibole-biotite schists – in the upper part; these subdivisions by their composition and position in the column are analogues to those in Novokryvorizka Suite of Kryvorizka Series [53]. Like the latter, the Lower Sub-Suite of Zelenorichenska Suite in places is pinched out from the column and in these cases Ingulo-Inguletska Series commences with quartzite-sandstones (sometimes with metaconglomerates at the base – DH 6620, 13122, 16609 and others) of the Upper Sub-Suite of Zelenorichenska Suite [12].

Upper Sub-Suite (PR_1zr_2) comprises alternation of sillimanite-biotite, garnet-biotite and two-mica schists and gneisses with frequent interbeds of arkose metasandstones and quartzite-sandstones at the base (DH 17765, 20598, 20865 etc.). In the upper Sub-Suite portion there are developed chlorite-actinolite, chlorite-carbonate-talc and carbonate-graphite-serpentine rocks with lenses of skarnoids, diopsidites and contained relicts calciphyres. Total thickness of all mentioned rocks does not exceed 80 m.

In the western limb of the Main (Kryvorizka) Syncline (DH SD-8, 20519, 20926 and others) the Sub-Suite is mainly composed of: arkose metasandstones with interbeds of biotite and graphite-two-mica schists – in the lower portion; carbonate-chlorite-talc and actinolite-tremolite schists with metasandstone interbeds and inclusions of calcite-magnesite marbles – in the upper portion [53]. In general, the rock composition and structure of this section are completely analogues to those of Skelyuvatska Suite of Kryvorizka Series.

Through petrochemical recalculations and by other evidences [42, 43, 53] it is established that Lower Sub-Suite amphibolites correspond to basaltoids similar first of all to volcanics of Novokryvorizka Suite. By

REE spectrum [42] and principal accessories (magnetite-ilmenite specialization) [53] the rocks are also similar to the latter but not to the volcanics of Konkska Series.

The Upper Sub-Suite rocks are apparently of sedimentary origin as it is evidenced by psammitic textures of quartzite-sandstones, metasandstone interbeds and relic carbonate rocks in talc schists. Two-mica schists do correspond to metapelites [6, 14, 34, 53]. Occurrence of conglomerates at the base of Upper Sub-Suite and pinch out the Lower Sub-Suite from the column suggest altogether for the local stratigraphic interruption between sub-suites, coeval with the interruption between Novokryvorizka and Skelyuvatska Suites.

Single age determinations of amphiboles from the Suite's amphibolites (in Zelenorichenska and other synclines) yield 2300-2500 Ma [12, 27] which is close to the age dating of Novokryvorizka Suite. Determination of amphibolite age by zircons (western limb of Main Syncline) yields 2190±30 Ma [53].

Artemivska Suite (PR_1ar) comprises major productive iron-ore sequence in the Inguletsko-Kryvorizka LTZ. Together with the rocks of Zelenorichenska Suite it constitutes the limbs of Zelenorichenska, Petrivska, Artemivska and other synclines, rarely – core portions of second-order anticline structures (Kamchatska, Burozaliznyakova), as well as is found in the limbs of Main (Kryvorizka) Syncline. At the surface the Suite ironiferous rocks are being traced in the 50-300 m wide and up to 5 km long narrow, lens-shaped bands, many of which are out of the scale to be indicated in the maps.

The Suite stratotype is described in Alferivska Syncline (at the same-named deposit) where it is composed of silicate-magnetite and magnetite quartzites with minor amphibole-biotite and biotite gneisses and mafic gneisses and lenses of skarnoids in the upper portion. Transition to the underlaying rocks of Zelenorichenska Suite is gradual, with appearance of low-grade quartzites in the schists (including talc ones) of the latter. At the same time, within Ovnyanska, Zhovtyanska and some other syncline structures in the area of Pravoberezhni magnetic anomalies the Suite rocks are completely pinched out from the column marking interruption in deposition of ferruginous-siliceous sediments. The same relationships are also observed within Main (Kryvorizka) Syncline where encountered alternation of at least two ferruginous and two schist horizons [53] of which the latter are often pinched out by strike of syncline.

Among the members of Ingulo-Inguletska Series the productive rocks of Artemivska Suite are studied in most details [4, 6, 12, 13, 19, 22, 36, 43, 53]. According to recent data (S.P.Lashko, 1997) there are distinguished (area of Pravoberezhni magnetic anomalies) up to six horizons (quartzite, quartzite-schist and quartzite-gneisses) grouped into two sub-suites: Lower (iron-ore) and Upper (low-ore). Most of authors consider these rocks to be analogues of Saksaganska Suite but of lower thickness and rhythmic features caused by distinct sedimentation environments. Study of oxygen isotope composition of magnetite from ferruginous quartzites performed during SD-8 drilling [53] does strongly confirm these conclusions. The most prominent feature of the rocks – higher metamorphic grade (up to amphibolite facies) associated in places with granitization of ferruginous-siliceous rocks of Artemivska Suite.

Thickness of the Suite in Petrivske deposit does not exceed 200 m.

Single age determinations obtained on biotites from gneisses and ferruginous quartzites fall into the range 1900-2100 Ma and are similar to the age dating of Saksaganska Suite. The minimum value of the upper age boundary to both suites can be taken one of 2050 Ma obtained on zircon from granodiorites which cut the rocks of Artemivska Suite [26].

Rodionivska Suite (PR_1rd) is fairly widespread in the Inguletsko-Kryvorizka LTZ where these rocks fill up the core portions of most syncline structures (Zelenivska, Zelenorichenska, northern part of Main (Kryvorizka) and other synclines). In Kirovogradska LTZ the Suite is much less developed and is known in marginal parts only where it fills up the bottom portions of synclines (Rodionivska, Chervonokostyantynivska and others). Respectively, in the mentioned zones the Suite includes two types of columns [13]: the first one – Rodionivskiy with predomination of quartzites (non-ore) and marbles over graphite-bearing schists (gneisses), characteristic for Kirovogradska LTZ; the second one – Zhovtyanskiy with predomination of graphite-bearing schist and gneisses over marbles and non-ore quartzites, characteristic for Inguletsko-Kryvorizka LTZ (Fig. 2.4). Carbonate rocks are more developed in the first type. This one is less thick but more variable in facies by strike.

The rocks of Zhovtyanskiy type overlie Artemivska Suite with gradual transitions. At the same time, in places (DH 19602, 20519, 20858, 20862) there are observed the local breaks in sedimentation expressed in pinching out the underlaying suites or the Lower Sub-Suite of Rodionivska Suite [12, 34, 42]. The rocks comprising Rovionivskiy type of column overlie either Archean granitoids through the old weathering crust or Proterozoic granitoids (remobilized Archean) with active contacts [41, 51].

According to data available both column types of Rodionivska Suite are being reliably divided into two sub-suites: Lower – clastogenic, and Upper – carbonaceous-carbonate-terrigenous. At the same time, in Kirovogradska LTZ, due to low thickness of defined sub-suites (except the stratotype area) the Suite is indicated as undivided.

Lower Sub-Suite (PR_1rd_1) is mainly composed of quartzites and quartzite-sandstones with interbeds of graphite-andalusite(sillimanite)-biotite schists and gneisses (in amphibolite facies). In case of Rodiovinskiy column type the amphibole(pyroxene)-bearing quartzites are normally barren whereas in Zhovtyanskiy column type (Inguletsko-Kryvorizka LTZ) often these quartzites contain one to three up to 25-30 m thick layers (lenses in places) of banded silicate-magnetite quartzites. Magnetite content in these rocks attains 25% and more [43]. These quartzites together with ferruginous quartzites of Artemivska Suite are included into Petrivske deposit (being mined by Central MBP) and, probably, more extended (and deeper) mineralization occurs within Burozaliznyakova Anticline where extensive magnetic and gravity anomalies are observed [12, 47]. Thickness of Sub-Suite varies from 200 to 700 m in Rodionivskiy column type and from 260 to 1200 m – in Zhovtyanskiy column type.

Upper Sub-Suite (PR_1rd_2) in Rodionivskiy column type is mainly composed of marbles (calciphyres) and mica-graphite schists (gneisses in amphibolite facies) which are major marker horizons. Amphibole-biotite and biotite with graphite schists and gneisses, quartzites, metasandstones and para-amphibolites are observed in subordinate amounts. In case of Zhovtyanskiy column type, besides these rocks of low thickness, biotite and amphibole-biotite with minor graphite schists and gneisses are developed.

Apart from that, specifics of Upper Sub-Suite in Rodionivskiy column type comprises occurrence of ore-kind (findings and deposits) graphite accumulations within mica-graphite schists and gneisses (under high-degree metamorphism), as well as development of zoned magnesium skarns, containing rare-metal and polymetallic mineralization [41], at the contact between marbles and calciphyres with granitoids of Kirovogradskiy Complex. In turn, in case of Zhovtyanskiy column type graphite-bearing schists and carbonate rocks contain layers and lenses of ferruginous quartzites (DH 11568, 12384, 20602, SD-8 and others) [43, 53]. Thickness of Upper Sub-Suite with Zhovtyanskiy column type in Inguletsko-Kryvorizka LTZ varies from 400 to 1300 m and from 500 to 1000 m – in case of Rodionivskiy column type (in Rodionivska and Grafitova synclines) up to complete pinching out from the section – in Olimpiadivska, Golovkinska and other structures. Transitions between sub-suites are gradual.

By their primary genesis the Rodionivska Suite rocks of both column types represent typical sedimentary association formed in shallow-water basin under humid climate conditions [6, 41, 42, 53]. Their sedimentary origin is supported by occurrence of blue-green algae and other micro-organic remnants in carbonate rocks, graphite-bearing schists and quartzites [6, 19].

Isotopic studies of carbon and oxygen from carbonates and graphite suggest for slight only facial differences in conditions of both Suite column types formation [42]. At the same time, oxygen isotope data on magnetites from ferruginous quartzites of Artemivska and Rodionivska (Zhovtyanskiy type) suites, as well as Saksaganska and Gdantsivska suites of Kryvorizka Series suggest for uniform conditions of their formation [53]. Isotopic age of biotites and amphiboles from the both types of Rodionivska Suite columns is estimated to 1760-2000 Ma including data on SD-8 [53] – 1870-2000 Ma. Apatite age from carbonate rocks determined by lead isotope method falls in the range 2030-2200 Ma. These estimations are comparable to the age of the same minerals from Gdantsivska Suite of Kryvorizka Series.

Spasivska Suite (PR_1sp) is fairly widespread in Kirovogradska LTZ being observed mainly in the limbs (in places in cores) of all syncline structures of this zone. Some remnants of Spasivska Suite rocks are being traced within granitoids (Verblyuzhskiy, Bokovyanskiy massifs) and gabbroids (Novovolodymyrivskiy Massif) of Novoukrainskiy Complex. The Suite almost throughout lies over the rocks of Rodionivska Suite and displays gradual transitions to underlaying rocks [41, 51, 54].

The column of Spasivska Suite is variable along the strike of Kirovogradska LTZ. To the north from Bokovyanskiy Massif, in the area of the Suite stratotype (Spasove village), there predominate two-pyroxene, pyroxene and biotite-pyroxene gneisses and mafic gneisses metamorphosed up to granulite and high-temperature sub-facies of amphibolite facies. Within these rocks in the interbeds are known graphite-amphibole(pyroxene)-biotite and magnetite-pyroxene gneisses in the lower portion, and biotite and garnet-biotite gneisses and mafic gneisses – in the upper portion of Suite column.

Within graphite-bearing gneisses there are observed diopsidite lenses with calciphyre relicts [51]. In the northern part of Bokovyanskiy Massif endo-contact [60] and in some places that underwent metasomatism [54] to the north from Dobronadiivskiy Fault, there are found amphibolites which are thought to be para-rocks by some evidences [12, 41]. The total thickness of the Suite in the stratotype area attains 1500 m.

To the south of Bokovyanskiy Massif (up to the latitude of Devladivskiy Fault) there are mainly developed biotite-amphibole and pyroxene-amphibole-biotite gneisses, often with graphite in the lower portions. These rocks are metamorphosed under low-temperature sub-facies of amphibolite facies. Thickness of the Suite in the southern area does not exceed 1000 m.

Described changes in the Suite composition along the strike of Kirovogradska LTZ are caused not only by metamorphic degree but also by northward facial changes in composition of involved sediments. This is revealed from the regional works [41, 51, 52, 60] performed over the area from Rodionivska site to Spasove village; these works also pointed out that source rocks of pyroxene gneisses were apparently sedimentary rocks of marl composition.. Analytical studies (V.N.Kobzar, 1981) of CaO, Sr and Ba distribution and other approaches had supported conclusion on formation of pyroxene-plagioclase boudines and layers through metamorphism of marleous sediments.

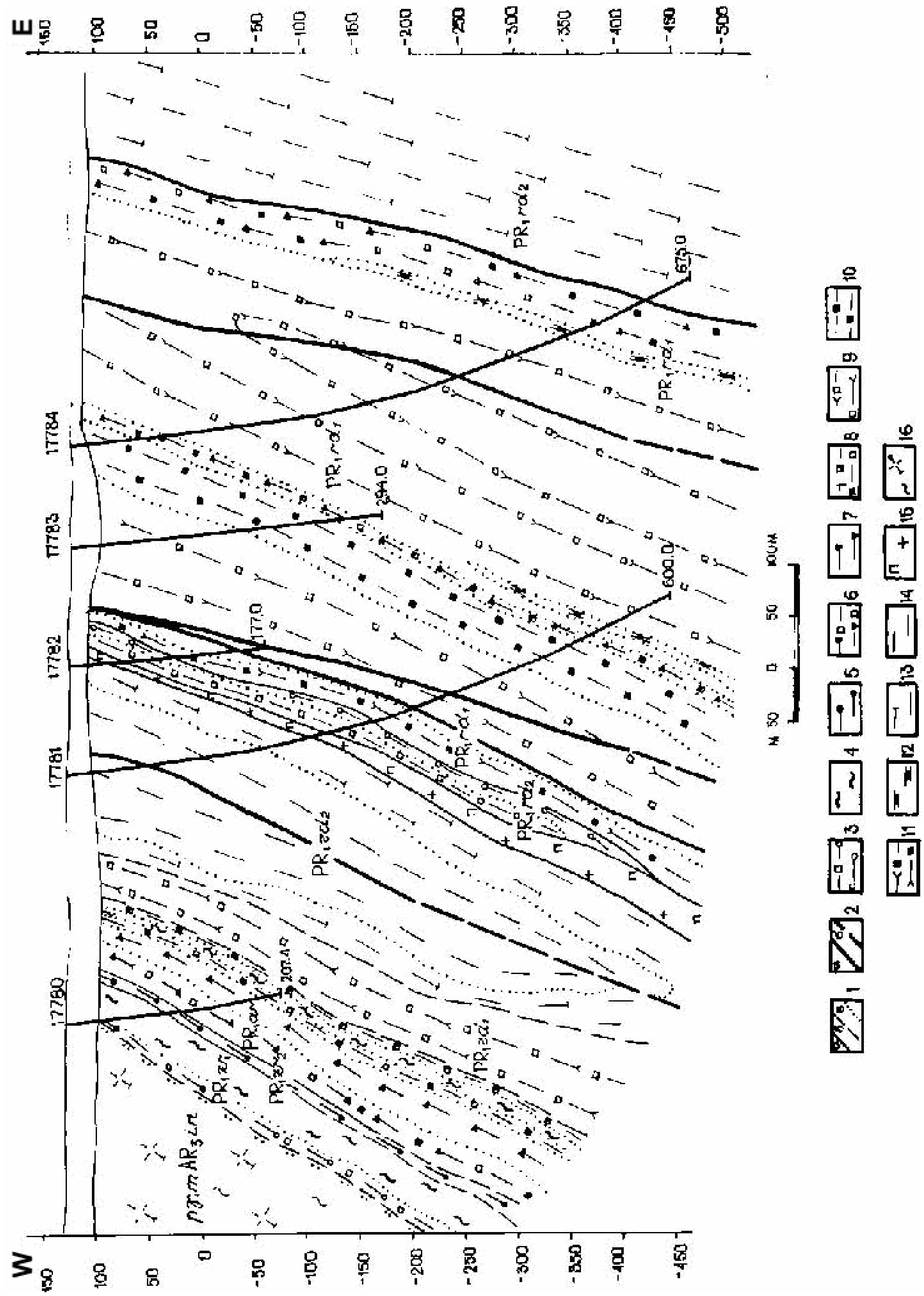


Fig. 2.4. Geological cross-section through Zhovtyanska structure (Zhovtyanskiy column type).

See next page for captions.

Fig. 2.4. Continued.

1 – geological boundaries: proven (a), probable (b), facial (c); 2 – faults: proven (a), probable (b).

Ingulo-Inguletska Series:

Zelenorichenska Suite – Lower Sub-Suite – PR_1zr_1 (3 – sillimanite quartzites, 4 – amphibolites); Upper Sub-Suite – PR_1zr_2 (5 – garnet-biotite gneisses);

Artemivska Suite – PR_1ar (6 – amphibole-magnetite quartzites, 7 – amphibole gneisses, 8 – quartzites with magnetite).

Rodionivska Suite – Lower Sub-Suite – PR_1rd_1 (9 – pyroxene-bearing quartzites, 10 – magnetite quartzites, 11 – pyroxene-magnetite quartzites, 12 – calciphyres); Upper Sub-Suite – PR_1rd_2 (13 – biotite and biotite-graphite gneisses, 14 – biotite gneisses).

Kirovogradskiy Complex: igPR_1kg (15 – aplite-pegmatoid granites).

Inguletskiy Complex: pg,mAR_3in (16 – biotite plagiomigmatites)

Pyroxene gneisses are high-density rocks (2.82-2.84 g/cm^3) providing gravity maximums over most syncline structures. Magnetic properties of pyroxene and other schists and gneisses of Ingulo-Inguletska Series are less prominent except magnetite-bearing rocks (quartzites of Artemivska and Rodionivska suites) which form the local magnetic anomalies [42].

Isotopic age of the Suite pyroxene-biotite gneisses on biotite is estimated to 1900-2000 Ma, and on zircon and monazite – 2000-2150 Ma [22, 26].

Checheliivska Suite (PR_1*čč*) is most widespread in Kirovogradska LTZ where these rocks constitute the core portions of most syncline structures. Throughout they lie over the rocks of Spasivska Suite. Transitions between the two are gradual with appearance in the column the uniform sequence of biotite gneisses.

The column of Checheliivska Suite, likewise Spasivska one, is variable along the strike of Kirovogradska LTZ.

In the northern part, in the stratotype area (Checheliivks village) biotite and garnet-biotite gneisses predominate in the column. Thin boudined interbeds and lenses of pyroxene and biotite-pyroxene gneisses are characteristic. Petrochemical calculations [51] had revealed these rocks formation due to metamorphism of clayey graywackes deposited under aridic climate. Pyroxene interbeds had formed after marleous sediments. In the southern part of Kirovogradska LTZ (southward of Bokovyanskiy Massif) biotite gneisses and metaaleurolite alternation is observed in the Suite column. The latter rock type may locally predominate. Apparently, this part of sedimentary basin was shallower or it was located closer to the coast line. Thickness of the Suite in both parts of Kirovogradska LTZ does not exceed 1500 m.

The upper age boundary of Checheliivska Suite and entire Ingulo-Inguletska Series is obviously defined by the dates 1800-2150 Ma obtained on monazites, amphiboles and partly biotites [26, 41, 51]. A.M.Snizhko (1979) had found some varieties of Paleo-Proterozoic blue-green algae in gneisses of Checheliivska Suite.

As one can see from above description of the total Ingulo-Inguletska Series, in both LTZs the rocks are regionally metamorphosed from epidote-amphibolite to granulite facies. The lowest-temperature facies within Inguletsko-Kryvorizka LTZ is widespread in the Main (Kryvorizka) Syncline only, and within Kirovogradska LTZ it is locally observed in Rodionivska Syncline. Amphibolite facies encompasses most of the area in both LTZs, especially in their marginal parts. Granulite facies is developed within Kirovogradska LTZ only, to the north from Bolovyanskiy Massif. There locally also rather extensively developed granitization processes (accompanied emplacement of Kirovogradskiy and Novoukrainskiy complexes) which caused additional modifications of Ingulo-Inguletska Series rocks (removal of old weathering crust, re-crystallization of unstable rocks – ultramafic and carbonate, inter-layer metatectite penetration up to formation of granite and migmatites bodies, metasomatic changes, etc.).

In general, the rocks of Ingulo-Inguletska Series display high degree of regional metamorphism. Conversely [13], the rocks of Kryvorizka Series are metamorphosed under lower facies of regional metamorphism that, in addition to changes provided by sedimentation in different conditions, strongly complicates their mutual correlation.

Gleyuvatska Suite

According to recent data [42, 53], Gleyuvatska Suite (PR_1*gl*) is developed mainly in the core of Main (Kryvorizka) Syncline of Ingulo-Inguletskiy area and partly – in the core of Saksaganska Syncline of Middle-Dniprean area. Some authors had reported [16, 19] the Suite overlies the rocks of Gdantsivska and Rodionivska suites with stratigraphic (and even angular) unconformity. Studies of core sections from SD-8 and its satellites (22350, 19929 and others) did not reveal any signs of interruption between the Suite and underlaying rocks. According to these data, the Suite base (in western limb of Main Syncline) is composed of metasandstones with actinolite-biotite cement and garnet-biotite-actinolite-plagioclase schists, which are gradually changed upward by garnet(actinolite)-graphite-biotite schists of Rodionivska (Gdantsivska) Suite. At the same time, occurrence of marble pebbles (with algae relicts) from Gdantsivska Suite in metasandstones within metaconglomerates of Gleyuvatska Suite [53], as well as sharp lithological contrast between contacting piles [19] suggest for the hidden stratigraphic break between the suites [42] obscured due to deformations and metamorphism.

Higher in the Suite column there is observed sequence of polymictic metaconglomerates where pebble of non-ore quartzites and quartzite-sandstones predominate, rarely – plagiogranitoids, as well as amphibolites, marbles, graphite schists and ferruginous quartzites from all suites of Kryvorizka Series in Saksaganska Syncline suggesting for internal erosion within Gleyuvatska Suite. Mentioned conglomerates often rhythmically alternate with metasandstones and schists similar to those at the base of Suite and normally are discontinuous by strike and depth. Within these rocks there are found for the first time (DH 20500-Sputnik 1) two interbeds of calcite-dolomite marbles up to 2 m thick [53].

In the upper portion of the Suite there lie andalusite-biotite-plagioclase-quartz and garnet-biotite-plagioclase-quartz schists with metasandstone interbeds with lack of amphiboles. Total thickness of the Suite in Main Syncline attains 3000 m.

According to the detailed studies [53] the rocks of Gleyuvatska Suite were deposited under conditions of predominantly mechanic weathering with sedimentation of primary material in tectonically active graben basin which quickly subsided due to earth crust extension. This is supported not only by high thickness of the Suite but also by induced oxidation-reduction parameters of sedimentation environments [6].

In many rock types of the Suite there is observed a wide range of Precambrian and Paleozoic fossil remnants [19]. Recent studies (A.M.Snizhko, 1998) had revealed that previous findings of Paleozoic fossil remnants in the rocks of Gdantsivska and Gleyuvatska suites are actually external and were introduced into the rocks (flew-in) by pores and fissures. Paleo-Proterozoic age of the Suite rocks is definitely supported by the same metamorphic grade of Gleyuvatska and underlaying Rodionivska and Gdantsivska suites (up to amphibolite facies) with age of metamorphism (by biotite) about 1870-2020 Ma [53], the same type of granitization encountered in all mentioned units up to formation of conformable granite bodies with zircon age 1890±75 and 2000±20 Ma [53], involvement of Gleyuvatska Suite rocks in the same folding structures together with underlaying rocks with local interruptions in between the units [42], findings in Gleyuvatska Suite rocks the microphitolite and cyanobacteria remnants similar to Proterozoic ones in Jatulian sequences of Baltic Shield (A.M.Snizhko, 1988).

PHANEROZOIC

MESOZOIC

Mesozoic rocks include Cretaceous sediments and according to the zoning scheme ("Legend to Central-Ukrainian Series map sheets of Derzhgeolkarta-200", Kyiv, 1996) they belong to the Southern Slope of Ukrainian Shield.

Cretaceous System

Lower Division

This Division comprises Kodymska Suite (K_1*kd*) which is developed in the far south-western part of the map sheet L-36-IV in the small area about 1.5 km long and up to 1 km wide. The rocks lie over weathering crust of crystalline rocks and are overlain by Eocene sediments. The hanging-wall altitude varies from -53.5 to -140.0 m, maximum thickness – 17 m.

The Suite is composed of coastal-marine sediments. The column consists of (upward): kaolines, quartz sands, coaliferous clays, aleurite lenses and interbeds. The spore-pollen complex is found in the rocks with predomination of *Senonicus Ross, Plicitera delicats (Bolch), Clavifera triplex* [62].

CENOZOIC

Cenozoic units include Paleogene, Neogene and Quaternary systems. Their distribution was strongly affected by relief of crystalline basement. Paleogene sediments fill up basement depressions and lie almost horizontally or with slight inclination toward Prychornomorska depression. Neogene sediments are much more widespread and not only fill up all relief depressions but together with Quaternary sediments form continuous cover which overlies all underlaying units including Precambrian rocks.

Upon formation over period from Middle Eocene to recent the Cenozoic sediments underwent erosion both at the land uplifts and by river streams, as well as erosion in the coastal zones of marine basins, resulted in abundant island or peninsular shape of sediment enclaves.

Paleo-geographic environments of Paleogene-Neogene sediments in the northern and southern parts of studied territory were considerably different. This is related to the area location within two tectonic regions with different history of development and sedimentation conditions – the Central (axial) part of Ukrainian Shield and its Southern Slope. Respectively, in accordance with “Legend to Central-Ukrainian Series map sheets of Derzhgeolkarta-200”, Kyiv, 1996, Paleogene and Neogene sediments are subdivided within poly-zones of the Central and Southern regions of Ukrainian Shield. In turn, each one is further subdivided into some LTZs where the column was formed under different paleo-tectonic and paleo-geographic environments.

Paleogene System

Paleogene sediments include marine and continental facies of Middle-Upper Eocene and Oligocene.

Two types of column are clearly distinguished by Paleogene sedimentation environments confined to two LTZs.

1. The first column type is characterized by predomination of marine clayey sediments with manganese ores (sequence of coaliferous clays, Khadzhybeyska and Alminska suites, Maykopska Series) which are aerially distributed under considerable thicknesses. This column type is confined to Vysokopilska LTZ within Southern Slope of Ukrainian Shield.

2. The second column type is developed in the Central part of Ukrainian Shield and comprises thin sand-clayey marine and continental sediments of Buchatska Series, Kyivska Suite, Obukhivska and Mezhygirska suites of Kharkivska Series with semi-peninsular shape of sediment enclaves confined to the most subsided sites in the basement relief. This column type is developed within Oleksandriysko-Apostolivska LTZ.

Location areas of two above column types are separated in space. Conventional border between them is set by the line of villages Pakhmanivka-Apostolove-Leninske (Fig. 2.5, 2.6).

Middle Eocene

Buchatska Series (₽$_2$*bu*) is locally developed over the map sheet M-36-XXXIV whereas in the map sheet L-36-IV it is more widely distributed within Skhidno- and Zakhidnokryvorizki depressions (see Fig. 2.5).

The sediments lie directly over Precambrian rocks and are overlain by Kyivska Suite, rarely – Kharkivska Series or Neogene sediments. Maximum thickness is encountered in the axial portions of depressions where it attains 25-32 m. The footwall altitudes of Buchatski sediments change northward from +20 to +105 m.

The sediments fill up ancient river valleys. The Series comprises continental formations of river-course and lake-swamp facies grouped respectively into Lower (sub-coaliferous) and Upper (coaliferous) piles.

The Lower Pile is composed of sands, secondary kaolines, bauxite-like rocks, and clays. The Pile is confined to the river-course sites of the ancient hydro-network and includes mainly quartz and quartz-feldspar sands with coaliferous matter, in lower part – diverse- and coarse-grained sands, in places gravelites. In upper part sands are more fine-grained and sometimes contain up to 3 m thick interbeds of coaliferous clays. Secondary kaolines are commonly confined to the depression slopes and overlie primary kaolines. Their thickness varies from 0.5 to 6-10 m. Bauxite-like rocks are characteristic to the upper slope of Skhidnokryvorizka depression, their lens thickness does not exceed 3 m.

Coaliferous pile at the top of Buchatska Series comprises lake-swamp facies – coaliferous clays and sands as well as brown coal. Sands are quartz, fine-grained, brown-grey or brown-black through coal matter impurity. Thickness of sands is 1-4 m. Brown coal normally lies over coaliferous sands and is known both in slope and axial portions of depressions. Normally brown coal occurs in a single layer which in places is split into two or three interbeds. In lower part of the layer coal is more uniform, low-ash. Coal seams are confined to Skhidnokryvorizka, Oleksandriyska and other depressions of which a number are of economic value and are being mined by quarries in the north-western part of M-36-XXXIV map sheet. Maximum thickness of coal seams is 15 m, average – 2.3-4.7 m [46, 49, 59].

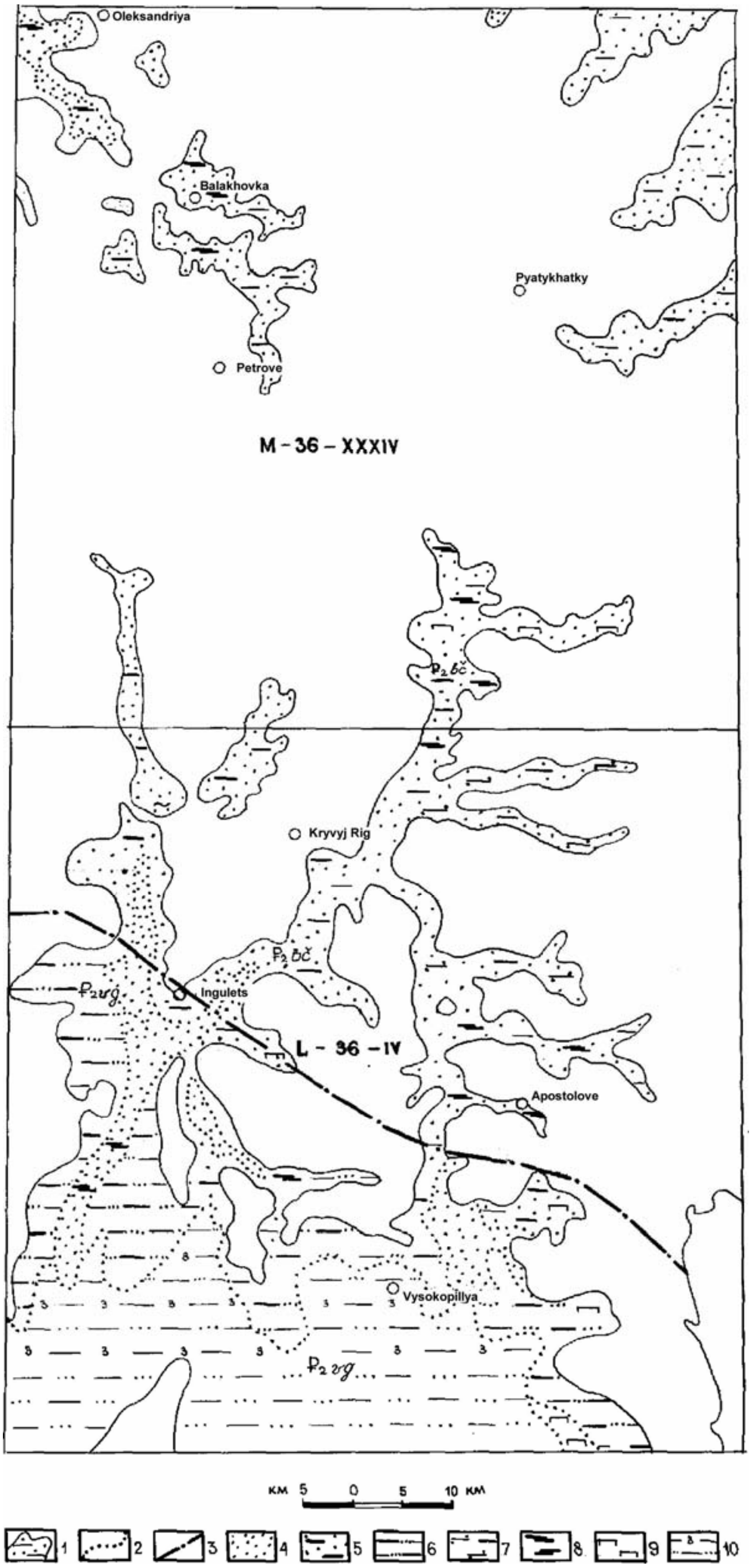


Fig. 2.5. Schematic map of Middle Eocene sediments distribution (Buchatska Series Ꝑ$_2$*bu* and Pile of coaliferous clays and sands - Ꝑ$_2$*vg*).

1 – boundary of Middle Eocene sediments modern distribution; 2 – facial boundaries; 3 – distribution boundary of Buchatska Series and Pile of coaliferous clays and sands; 4 – diverse-grained sands; 5 – quartz coaliferous sands; 6 – coaliferous sandy-clayey sediments (coaliferous clays, coaliferous sands); 7 – coaliferous clays, sandy in places; 8 – brown coal; 9 – secondary kaolines; 10 – sandy-clayey sediments, greenish-grey clays, ductile.

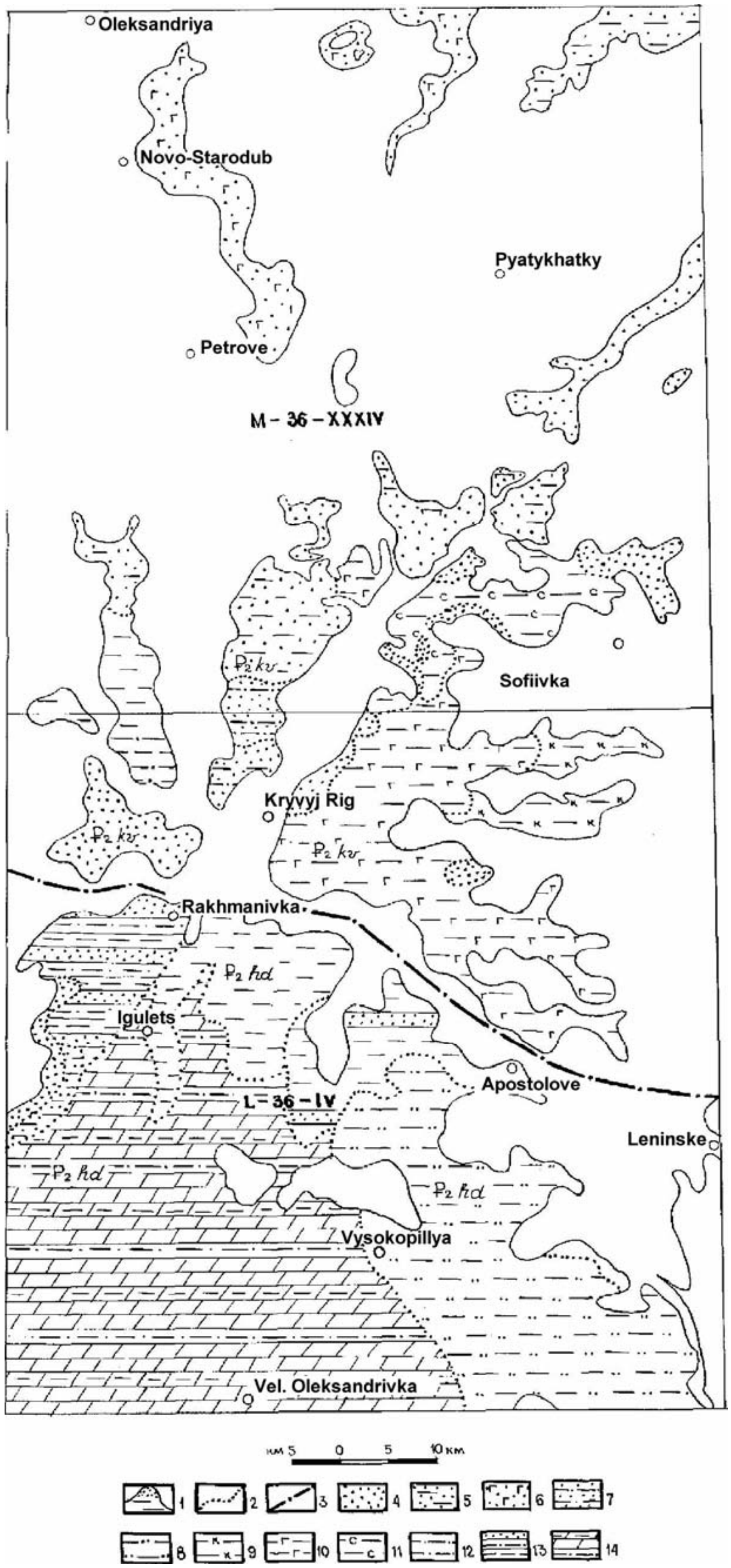


Fig. 2.6. Schematic map of Middle Eocene sediments distribution (Khadzhybeyska – ₽$_2$*hd* and Kyivska – ₽$_2$*kv* suites).

1 – boundary of Middle Eocene sediments modern distribution; 2 – facial boundaries; 3 – distribution boundary of Khadzhybeyska and Kyivska Suites; 4 – quartz sands; 5 – clayey sands; 6 – glauconite sands and sandstones; 7 – alternation of aleurites and sands; 8 – aleuritic greenish-grey clays; 9 – kaolinous clays; 10 – green clays with glauconite; 11 – grey clays; 12 – aleurites; 13 – grey clayey sands, aleuritic rocks, greenish-grey sandy clays; 14 – marls, marleous clays, aleurites, aleuritic-marleous rock.

Coaliferous clays mainly comprise the hanging-wall of brown coal, rarely these rocks overlie coaliferous sands or alternate with the latter. Clays are mainly kaoline in composition with traces of coaliferous matter, as well as sandy and mica material. Thickness of clays is up to 6-8 m, in places it decreases to 2-3 m.

Buchatski sediments are well characterized by spore-pollen complex [40] with predomination of *Ilex, Nyssa, Rhus* and others.

The *Pile of coaliferous clays and sands* (₽$_2vg$) is developed in southern part of map sheet L-36-IV (Vysokopilska LTZ) where it overlies crystalline rocks (see Fig. 2.5) and is overlain by Eocene and Oligocene rocks. The hanging-wall altitudes varies from +2-3 to +50 m. Thickness of the Pile is not consistent and increases in the south-western direction where it exceeds 35 m.

The Pile consists of continental rocks of river-course and lake-swamp facies, as well as marine sediments [42, 46]. Continental sediments constitute the lower part of the Pile. They include weakly-sorted medium-coarse-grained and gravelous sands with coalified remnants and coaliferous clays, interbeds and lenses of secondary kaolines, brown coal, re-deposited bauxites and bauxite-like rocks. Prominent regularities in their alternation are not established.

Among coastal shallow-water and marine deep-water sediments (upper part of the Pile) are developed green clays, ductile, fairly dense, with thin interbeds of black or dark-grey clays. Rarely are observed marleous and sandy clay varieties. Within clays there are known interbeds of secondary kaolines and fauna remnants of molluscs *Barbatia appendiculata (Sow.), Corbula abavata (Koen.) Miocardiopsis carinata (Desh.)* [30, 42]. Aleurites are developed in subordinate amounts, at their bottom in places are found lenses of light-grey carbonate sands with coalified organic remnants. Thickness of these rocks is normally 2-3 m, rarely up to 6-7 m. The 3-4 m thick sands of coastal shallow-water facies are encountered in the south-western part of map sheet L-36-IV.

The Pile of coaliferous clays and sands developed in Vysokopilska LTZ is well correlated to coeval sediments of Buchatska Series in Oleksandriysko-Apostolivska LTZ.

Kyivska Suite (₽$_2kv$) is developed in Oleksandriysko-Apostolivska LTZ (Fig. 2.7) filling mainly basement depressions. It overlies Buchatska Series or crystalline rocks.

Hanging-wall altitude over the territory varies from 30 m in the south to 100 m in the north. Rock thickness is from 2 to 35 m.

The Suite is composed of marine sediments of relatively deep-water and coastal shallow-water facies. Their gradual transition is observed in direction from south-east to north-west.

Deep-water rocks are developed in the northern part of L-36-IV map sheet and are composed of clays. Three clay varieties are distinguished:

- bluish-green or greenish-grey clay, greasy by touch, montmorillonite in composition, normally lies over Kyivski sediments. Maximum thickness is 17.5 m. In clay there is found micro-fauna *Nonion umbilicatuew (Mont.), Cibicides sp.* and others [49, 55];
- grey, dark-grey to black clay, maximum thickness 12 m, often contains micro-fauna similar to above;
- white, greasy, kaolinite, refractory clay; occurs in lenses within sands, in places alternates with green clay; maximum thickness 5.5 m.

Sandy-clayey rocks of coastal shallow-water facies are confined to the slope portions of depressions and are developed mainly in the southern part of M-36-XXXIV map sheet. They include greenish-grey, dark-grey sandy clays, clayey sands, aleurites, sands and sandstones, very rarely – tripoli. At the bottom occur greenish-grey clays which further upward are changed by clayey sands. In the column upper parts are developed either clayey sands or grey quartz sands.

In the northern part of map sheet M-36-XXXIV there are developed mainly quartz, glauconite-quartz, fine-grained sands up to 15 m thick. Thin interbeds within these rocks are composed of quartz, calcareous and marleous sands with fauna *Turitella turgida v. Koen., Crassatella woodi Koen., Nucula sp.* [49, 54, 55].

Khadzhybeiska Suite (₽$_2hd$) is developed in the map sheet L-36-IV only (Fig. 2.6). There it is composed of shallow-water and deep-water marine sediments of aerial distribution which overlie the Pile of coaliferous clay and sands as well as crystalline rocks. The Suite is overlain by Oligocene and Miocene marine sediments. Hanging-wall altitudes vary from +5 to -42 m. Maximum thickness of the Suite is 75 m [42].

The Suite is mainly composed of marleous rocks, aleurites and aleuritic clays. Marleous rocks include marls with calcareous clay interbeds. Marls are white, with excess of carbonate matter, friable. Thickness varies from 1 m to 50 m. The rocks contain foraminifera fauna.

Marls normally are underlain by aleuritic light-greenish-grey marleous clays. In places clay completely constitutes the column of Khadzhybeyska Suite and at its bottom the bunches and lenses of sandy material as well as glauconite accumulations are observed. Thickness of aleuritic clays is 5-20 m. Aleurites are greenish-grey, often marleous or clayey, 5-25 m thick, do contain nummulite fauna. Transitions between the marls, aleurites and clays are gradual and in general the rocks comprise the uniform pile of alurite-marleous rocks with some 0-5 m thick quartz and glauconite-quartz sands at the bottom.

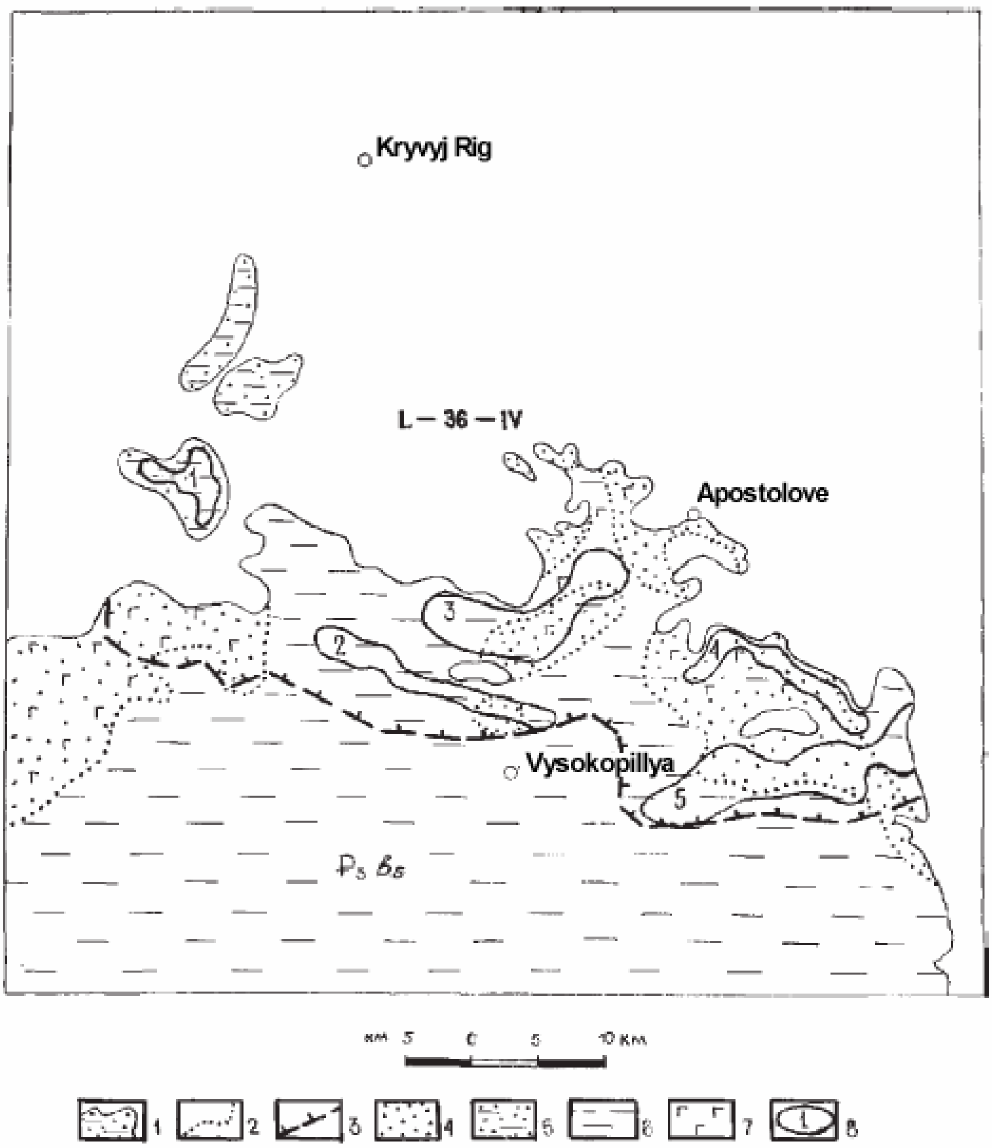


Fig. 2.7. Schematic map of Oligocene sediments distribution (Borysfenska Suite – P_3*bs*).

1 – boundary of Borysfenska Suite sediments modern distribution; 2 – facial boundaries; 3 – southern boundary of manganese-bearing sediments; 4 – glauconite-quartz sands; 5 – sandy-clayey rocks; 6 – aleuritic dark-grey and greenish-grey clays; 7 – rocks with glauconite; 8 – contours of manganese ore fields and their numbers: 1 – Inguletska, 2 – Vysokopilska, 3 – Fedorivska, 4 – Kostromska, 5 – Novovorontsovska.

In the northern part of Khadzhybeyska Suite sediments development area the facial composition of the rocks is changed a bit. There are mainly occurred sands of quartz-carbonate composition which contain aleurite and clay lenses.

In places at the base of Suite there are observed conglomerates composed of bauxite, phosphorite and brown coal pebbles.

Aleuritic-marleous rocks contain mollusc fauna: *Barbatia appendiculata (S o w .), B.lamellosa (D e s h .), Ostrea prona (W o o d .), Chlamys bellicostata (W o o d .), Nucula sulcifera (Koen.)* [30] as well as foraminifera fauna: *Nodosaria sp., N.capitata Boll., Bulimina truncana Gumbel., Angulogerina pulchell* [30, 42].

Described complex of organic remnants is characteristic for Middle Eocene in Northern Prychornomorya.

Khadzhybeyska Suite is well-correlated with Kyivska Suite in Apostolivsko-Oleksandriyska LTZ. Reasonability of such the correlation is supported by the uniformity of some mollusc and foraminifera types.

Upper Eocene

Alminska Suite (₽$_2$*al*) is quite locally developed in the north-eastern part of L-26-IV map sheet within Apostolivska LTZ. Thickness of Alminski sediments is 1.5-8.6 m [42, 46]. It is composed of grey and greenish-grey sandstones with ochreous stains, tripoli-like, siliceous, as well as clays, often with glauconite. These rocks were formed by shallow-water marine facies and underwent essential erosion being preserved in the crystalline basement depressions.

The Suite sediments contain mollusc fauna including varieties characteristic for Alminskiy horizon: *Spondylus Buchi (Phil)* and others [23, 42].

Upper Eocene-Oligocene

Kharkivska Series (₽*hr*) is developed in the central and northern parts of M-36-XXXIV map sheet (Oleksandriysko-Apostolivska LTZ). The Series marine sediments lie over eroded surface of Kyivska Suite, in places – over Buchatska Series, or over the rocks of crystalline basement. In turn, they are overlain by Poltavska Series sediments. The hanging-wall altitude is +85…+98 m.

Kharkivski sediments are fairly uniform in composition and include sands and clays, greenish-grey, green, non-carbonate, with abundant glauconite (from 5 to 63%). Most widespread are glauconite-quartz and quartz-glauconite sands, clayey in various degrees, weakly sorted. Besides clayey there are also known friable sand varieties. Maximum thickness of sands is 10 m. At the bottom they get to be coarser-grained, in places with pebble of crystalline rocks, and in upper parts the sands are often greenish-yellow and stain-brown containing lenses and interbeds of greenish-grey glauconite sandstones. In the Vilnogirsk area the fauna *Corbula cf. sokolovi (K a r l .), Cardium (Cerastoderma) sp* and others is encountered in the sands. This mollusc complex is similar to Sirogozkiy complex of Prychornomorska Depression and is dated to Late Oligocene [23].

Greenish-grey and stain-yellow clays are less developed in the column of Kharkivska Series. Clay material is comprised of montmorillonite by 80-90%. Thickness of clays is 1-10 m. The clays from bottom column parts contain "Mandrykivski-type" fauna including *Barbatia ex gr. modioliformi Desh., Dentalium cf.* Normally the clays are sandy over entire unit and contain glauconite.

More detailed subdivision of Kharkivska Suite is complicated due to its lithological uniformity and weak paleontologic study. Aforementioned clays with Mandrykivska fauna occurring at the column bottom can be included into Obukhivska Suite (₽*ob*) whereas upper sandy and sandy-clayey part – into Mezhygirska Suite (₽*mo*).

In Vysokopilska LTZ there is distinguished Maykopska Series to be coeval to Kharkivska Series.

Oligocene

Maykopska Series

The Series is aerially-developed in the southern part of L-36-IV map sheet (Vysokopilska LTZ). The column is characterized by uniform clayey composition, weak or complete lack of carbonates, and depletion of the fossil remnants. Taken together these features make certain complication in Oligocene sediments subdivision. In Maykopska Series there are distinguished Borysfenska Suite and undivided Askaniyska, Sirogozka and Molochanska suites.

Borysfenska Suite (₽$_3$*bs*) is fairly widespread in the southern part of L-36-IV map sheet (Fig. 2.7) within Vysokopilska LTZ, and it is productive containing manganese deposits and occurrences. The Suite lies over eroded surf ace of Middle-Upper Eocene sediments or over Precambrian rocks. It is overlain by Oligocene and Miocene sediments. Thickness of the Suite is not consistent and varies from 5.0 to 90.0 m. It is observed some thickness increase in the south-south-western direction. The hanging-wall altitudes vary from -13…+5 m to +1…+45 m.

The Suite is composed of sands and non-calcareous but aleuritic clays. The sands are quartz-glauconite, fine- and medium-grained, clayey in places, from some decimeters to 4.5 m thick, developed mainly at the base of pile. Higher lie sandy-clayey rocks developed in the northern part of Borysfenski sediment distribution area (Fig. 2.7). The rocks are grey with greenish shade, display irregular lens-like distribution of sandy and clayey material, contain abundant glauconite. This part of column contains the major manganese ores composed by 50-60% of sandy-clayey material and by 40-60% of ore one. Thickness of manganese ore layers varies from 0.5 to 3.45 m, their depth – from 46 to 75 m [46, 56]; ore distribution is mainly controlled by altitude about 0 m.

Manganese ores include three types – oxide, oxide-carbonate and carbonate. The ores were deposited in the coastal zone of Oligocene sea under conditions of slowed transgression that caused regular distribution of various sediments and respective manganese ores.

The upper part of Suite column throughout is composed of clays of various appearances. Most widespread are dark-grey clays with slight greenish shade, layered, aleuritic. Their thickness normally is 10-40 m, in places 80-90 m. The clays contain foraminifera: *Spiroplectammina spectabilis (Gs.), S. carinata oligocenica I.Nikit., Saccammina variabilis Bogd.* [42].

The lower boundary of Borysfenski sediments is clearly expressed due to their transgressive laying over eroded surface of Upper Eocene.

Undivided *Askaniyska, Sirogozka* and *Molochanska* suites (₽$_3$*ml-as*) comprises upper part of Oligocene column within Vysokopilska LTZ. This column part is mainly composed of aleuritic clays with aleurite interbeds. The rocks conformably overlie Borysfenska Suite. The hanging-wall altitudes vary from -20 to +5 m, thickness varies from 5 to 30 m attaining 45 m.

Aleuritic clays are carbonateless, with rare fauna of molluscs *Corbula, Dentalium* etc. The lower part of column is composed of light-grey clay whereas upper part – of dense, greasy grey clay with greenish shade. It is characteristic for the upper part the penetration of rocks by iron hydroxides with formation of ochre and brownish-yellow spots and stains.

Sometimes in the lower part of column (south-western part of L-36-IV map sheet) are observed calcareous aleuritic light0grey clays with ostracoda accumulations. Their occurrence in this part of area suggest for the boundary with underlying Borysfenska Suite. Greenish-grey fine-grained 1-5 m thick sands are developed in subordinate amounts in this part of column.

Neogene System

Neogene sediments include both shallow-water marine and coastal facies as well as continental ones. Two types of columns are characteristic for these sediments which display strong differences in rock facies and are confined to two LTZs.

1. The first type of column was formed under marine sedimentation, it is characterized by abundant clayey-carbonate rocks and is confined to the Southern Slope of Ukrainian Shield. There are developed Middle and Upper Miocene sediments (Chokrakski and Zbruchski Layers, Pile of limestones and marls, Geliksovi and Bagerivski Layers, Pile of limestones, Kosivski Layers). This type of column is confined to Shyrokivska LTZ.

2. The second type of column is characteristic for the Central (axial) part of Ukrainian Shield. In the section there are mainly developed sandy marine and continental Miocene sediments (Novopetrivska Suite, Pile of sands, Geliksovi Layers and Pile of parti-coloured clays) which contain economic concentration of rutile, ilmenite, zircon. This type of column is developed in Vilnogirska LTZ.

Conventional border between two mentioned column types and respectively between two LTZs is positioned by the line Khrystoforivka-Gleyuvatka-Sofiivka villages (Fig. 2.8).

Lower and Middle Miocene

Undivided Lower and Middle Miocene rocks comprise Novopetrivska and Poltavska Series.

Novopetrivska Suite (N_1*np*) is fairly widespread in the north-eastern part of M-36-XXXIV map sheet only where the Suite outcrops are known over the slopes of Zelena, Saksagan and Omelnyk river valleys. The rocks overlie Kharkivska Series or crystalline rocks. And they are overlain by the Sarmatskiy Regio-Stage Pile of sands. The Suite hanging-wall altitude varies from +90.0 to +120.0 m. Thickness of the Suite attains 30 m.

The Suite is composed of quartz sands, fine-grained, well-sorted, fine-floated. The sands are light – from snow-white to light-grey. The Suite column display remarkable stable composition almost over entire area of the rock distribution. The sands are mainly composed of quartz with minor feldspar and heavy minerals. In places at the base of column are observed grey and dark-grey clays with interbeds and lenses of coaliferous clays and sands. Thickness of this part of column varies in the range of 0-10 m.

Characteristic feature is development of yellow, ochre-yellow, pink and red stains in the rocks of upper part of Suite column. The rocks are iron-enriched in various extents. By this rock diversity it is established the boundary with overlaying Sarmatskiy Regio-Stage Pile of sands. In places thin lenses of greenish-grey montmorillonite clays are observed at this boundary. In this part of column are also developed the interbeds of platy sandstone, sparkled due to iron hydroxide imposing.

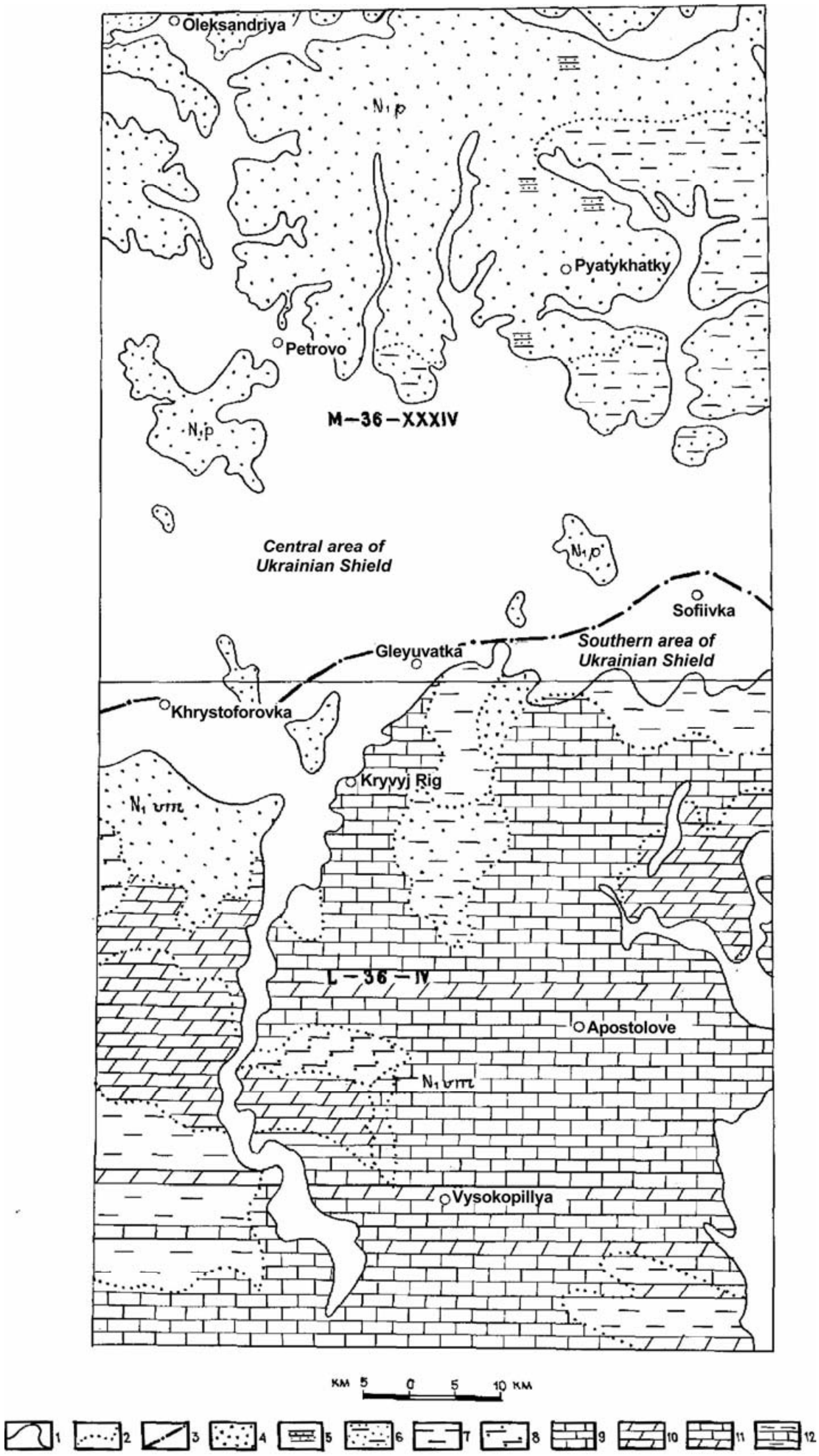


Fig. 2.8. Schematic map of Middle Sarmatski sediments distribution (Pile of limestones and marls – N_1*vm* and Pile of sands – N_1*p*).

1 – boundary of Middle Sarmatski sediments modern distribution; 2 – facial boundaries; 3 – boundaries of the Central and Southern regions of Ukrainian Shield; 4 – diverse-grained quartz sands; 5 – sandstones; 6 – clayey sands; 7 – clays; 8 – sandy clays; 9 – oolite and shell limestones with marl interbeds; 10 – marls; 11 – alternating limestones and marls; 12 – fine-layered clay with limestone and marl interbeds.

Middle Miocene

Chokrakski Layers (N_1*čk*) are only developed in the south-eastern part of L-36-IV map sheet where these rocks lie over Oligocene Maykopska Series and are overlain by Zbruchski Layers and Sarmatskiy Regio-Stage Pile of limestones and marls. The hanging-wall altitude varies from -10 to +30 m, thickness normally is 3.5-4 m, in places attaining 15-20 m. The rocks include dense dark-green, greenish-grey clays, in places with marl inclusions and interbeds. At the column bottom are normally developed diverse-grained, in places gravelous, green and apple-green sands. At the western margin of Chokrakski Layers distribution area there are mainly developed green clayey sands. In Chokrakski sediments there is determined foraminifera complex including *Discorbs aff. tschocrahensis Bogd.*, as well as ostracodes.

Upper Miocene

L o w e r   S a r m a t s k i y   S u b - R e g i o - S t a g e

Zbruchski Layers (N_1*zb*) are developed in the south-eastern part of L-36-IV map sheet (Shyrokivska LTZ) where these rocks are exposed along Ingulets River nearby Shyroke and Zagradivka villages. These sediments are locally distributed and lie over eroded surface of Middle Miocene-Oligocene. Throughout the area these rocks are overlain by the Pile of limestones and marls. The hanging-wall altitude varies from +15 m to +40 m.

The column of Zbruchski Layers is mainly composed of clays and sands, and in lesser extent of limestones and marls. The sands are fine- and medium-grained, grey, light-grey, greenish-grey, in places they replace one another by strike. In clays the following fauna is found: *Ervilia pusilla dissita (Eichw.), Paphia tricuspia (Eichw.)* and others [17]. Rarely in the Layers there are observed marls and greyish-white detritus limestones with *Cerastoderma plicatum (Eichw.), Ervilia pusilla dissita (Eichw.).*

In the south of the map sheet L-36-IV the Layers mainly comprise clayey rocks. The clay is grey, dark-grey to black, with remnants of Lower Sarmatska fauna of molluscs: *Cerastoderma aff. unratamense (Koles.) C.subfitton (Andrus.), Mactra eichwaldi (Lask.)* and others.

Occurrence of *Ervilia* among molluscs suggests for Lower Sarmatskiy (Volynskiy) age of sediments, and developed in this complex *Cerastoderma plicatum (Eichw.), Mactra eichwaldi crassa Sid., Paphia tricuspia (Eichw.)* are characteristic for Zbruchski Layers of Lower Sarmatskiy Sub-Regio-Stage [17]. Thickness of Zbruchski Layers attains 15 m.

M i d d l e   S a r m a t s k i y   S u b - R e g i o - S t a g e

The Pile of limestones and marls (N_1*vm*) is composed of marine shallow-water sediments and is developed in Shyrokivska LTZ (Fig. 2.8).

At the base of Pile there lie clayey sands and clays. The clays are grey, greenish-grey, montmorillonite-hydromica, marleous higher in the column. The sands are quartz, diverse-grained, grey to greenish-grey, clayey in various extents, in places calcareous with shells of *Mactra pallassi Baily, Cerastoderma fittoni (Orb.)*. The sands and clays are observed in lenses and interbeds that pinch out over short distances.

The limestones and marls normally comprise the upper portion of the column. These are light-grey, in places with yellow-brown shade, hard rocks, often cavernous, sandy in places, sometimes are being replaced by sandy-clayey sediments. The oolite, detritus and shell varieties of limestones are distinguished. Maximum thickness of the rocks is 10 m. Limestones throughout contain Middle Sarmatska fauna including principal forms like *Mactra fabreana (Orb.), Cerastoderma fittoni fittoni (Orb.), Cardium fittoni (Orb.)* [30, 42].

The total thickness of the Pile is 15 m.

The *Pile of sands* (N_1*p*) is developed in Vilnogirska LTZ (Fig. 2.8) and is composed of the coastal and shallow-water marine facies: fine-grained quartz sands, rarely, mainly at the base – medium- and coarse-grained varieties. The sands are "parti-coloured" and include grey, light-grey, greenish-grey, brownish-yellow varieties, often with pale-pink and raspberry-red spots and stains. In sands in places are found thin interbeds and lenses of greenish-grey clays with brownish-yellow or brick-red spots and stains. The sands contain (sometimes in economic amounts) ilmenite, rutile and zircon which in Samotkanske deposit are being mined by Vilnogirskiy MBP. Ore minerals in sands are distributed over entire Pile column.

In the upper part of Pile fairly often occur 0.2-1.3 m thick sandstone interbeds and lenses. The total thickness of the Pile is 12-18 m; the hanging-wall altitudes vary from +90 to +140 m.

In the north-eastern part of area at the base of column there lies 2-4 m thick layer of grey and brown clays, in places coaliferous, which by strike are sometimes replaced by quartz sands with up to 1.1 m thick interbeds of lignite brown coal.

The sands and clays do not contain fauna thus in case of lacking the clays at the base of layer the boundary with underlaying Novopetrivska Suite sediments is being put conventionally by indirect evidences, particularly, by interbeds of "parti-coloured" sands or clays.

Upper Sarmatskiy Sub-Regio-Stage

Geliksovi Layers (N_1gl) in the northern pert of area are composed of sandy-clayey rocks (Vilnogirska LTZ), and in the south – of limestones and marls (Shyrokivska LTZ). The facial transition between the two and change of thickness are being put by the line Khrystoforivka-Gleyuvatka-Sofiivka villages (Fig. 2.8).

Geliksovi Layers in Vilnogirska LTZ comprise the uniform sandy-clayey pile. They lie over Middle Sarmatskiy and Paleogene sediments, and in places of their lacking – over crystalline rocks. The rocks are mainly sands, light-yellow, light-grey, normally clayey. In places they contain bunches of limestone material, especially in the upper part of column. By composition the sands are quartz, fine-grained, rarely medium-grained, with clay interbeds. There are observed both marleous and carbonateless varieties.

Toward the northern slope of Ukrainian Shield the clay content in sands increases and the sands are being gradually replaced by sandy-clayey rocks with limestone and marl interbeds and lenses.

In Shyrokivska LTZ Geliksovi Layers comprise limestones and marls with subordinate clays and sands. The rocks are developed almost throughout in the map sheet L-36-IV and also some their "tongues" are extended over south-western part of the map sheet M-36-XXXIV.

Geliksovi Layers lie over the Middle Sarmatska Pile of limestones and marls or over crystalline rocks. The rocks include two facies: shallow-water and deeper-water. Shallow-water facies comprises limestones, in places at the column top – with clay and sand interbeds. In clays brown stains and limestone inclusions are often observed. In places clays completely replace limestones and comprise calcareous varieties.

The deepest-water sediments are developed in the southern part of L-36-IV map sheet and include pelitemorphic limestones, dolomites, marls and clays. Alternations of light-grey marls with limestones or clayey dolomites with dolomite marls are often observed. In places at the base of column there are developed grey, diverse-grained, carbonate sands. The Layers are characterized by abundant fauna: *Mactra caspia Eichw., Mactra podolica Eichw.* suggesting for Upper Sarmatskiy (Khersonskiy) age [30].

Meotychniy Regio-Stage

Bagerivski Layers (N_1bg) are only developed in the map sheet L-36-IV (Shyrokivska LTZ). The northern boundary of their distribution is limited by the line Shyroke-Kamyanka villages. The rocks lei over Upper Sarmatski Geliksovi Layers and are overlain by Pontychna limestone pile. Thickness of Bagerivski Layers is low – 0.5-7 m, in places attains 12 m. The hanging-wall altitude varies from +28 to +60 m.

Bagerivski Layers comprise sandy-clayey sediments, rarely – marls and limestones. The sandy-clayey sediments are fairly widespread. The sands are grey, white, with sandstone lenses and fauna and fragments of fish bones. The clays are greenish-grey, greyish-green, irregularly-sandy, often with iron-manganese films and beans. The sands and clays are connected by gradual transitions, in places they contain concretions of friable limestone. At the base in places the old rock pebbles are observed which are partly cemented. The sands and clays contain fauna of molluscs: *Ervilia pussila minuta Sinz., Dosinia maeotica Andrus*. This mollusc complex does correspond to that of Meotychni Bagerivski Layers in the south of Ukraine [17].

The limestone-marl rocks are developed over the area along Ingulets River only and comprise light-grey marls with abundant ostracoda, *Dosinia* shells and others.

Undivided sediments of Meotychniy and Pontychniy Regio-Stages

The *Pile of parti-coloured clays* (N_1sg) lies over Geliksovi Layers, and in case of their lacking – over the Pile of sands and older rocks. Normally these rocks are overlain by the Pile of red-brown clays. Parti-coloured clays are fairly distributed in the northern and central parts of M-36-XXXIV map sheet (Vilnogirska LTZ) and are mainly confined to the watershed relief sites.

The clays are fairly uniform in composition, montmorillonite with minor kaolinite material, mainly grey, greenish-grey, rarely yellow with greenish shade. Development of brown, ochre-yellow, cherry-red spots and stains is characteristic for the clays, as well as inclusion of carbonate concretions, iron-manganese beans, gypsum crystals and druses. Thickness of the clays varies from 2 to 18 m. By their nature the clays belong to the continental sediments of closed basins (lagoons) remained upon removal of Sarmatske sea.

The age position of parti-coloured clays requires further studies because of lacking in sediments the fauna remnants while their inclusion into Meotychniy and Pontychni units is based on their stratigraphic position between underlaying Sarmatski sediments and overlaying Pliocene rocks.

With regard to the age, the rocks can be correlated with marine sediments of Meotychniy and Pontychniy Regio-Stages within Shyrokivska LTZ.

P o n t y c h n i y R e g i o - S t a g e

The *Pile of limestones* (N_1v) includes oolite and shell limestone types, clays and minor marls and sands. It is developed over the territory of map sheet L-36-IV and in limited amount – in south-eastern part of map sheet M-36-XXXIV. The Pile unconformably overlies Bagerivski and Geliksovi layers and older rocks including crystalline ones, and is overlain by younger rocks.

The Pile is composed of shallow-water marine sediments. The coastal-marine facies – sandy-clayey sediments – is mainly developed close to the northern distribution limit of these rocks. In the north-western part of map sheet L-36-IV there are developed quartz sands, greenish-grey, grey, fine-grained, with sandstone and clay lenses. The sands often contain inclusions of manganese hydroxides and are up to 5 m thick.

In the southern direction the sands are being gradually changed by shallow-water facies limestones which are subdivided into two batches: lower one – yellow oolite limestones with imprints and cores of *Dreidensia*, rarely – *Cardid*; upper one – yellow, chre-yellow shell (cardide) limestones. Commonly limestones are highly re-crystallized losing down their primary features. Cardide limestones of various thicknesses lie over oolite limestones and often are leached.

At the bottom of the Pile column there lie clays and sands. The sands are quartz, grey, variable in clay content, in places with interbeds of greyish-green clays, are locally developed. Thickness does not exceed 1 m. The clays are greenish-grey, in places sandy, thickness up to 2 m.

The marls are developed in subordinate amounts; their thickness is 0.8-1.8 m.

The total thickness of limestone pile does not exceed 18 m.

Kosivski Layers (N_1ks) lie over Pontychni limestones providing well expressed layer of uniform grey, greenish-grey, dark-grey, dirty-grey clays, in places spotty with characteristic limestone concretions, iron-manganese beans and gypsum crystals. Often at the base of clays and in places in their mid portion there are observed light-grey sands, often with brownish shade, fine-grained, quartz, clayey; thickness from tens of centimetres up to some metres. At the column base the sands often contain pebbles of limestones, in places of crystalline rocks. Thickness of Kosivski Layers is 8 m.

Lower Pliocene

The *Pile of alluvial sands* (N_2ap). Alluvial sands are developed in the bands along Ingulets, Saksagan and Bokova river valleys. Width of these bands in the studied area attains 4-5 km. In most cases they are elongated along the left valley slopes. The sands are overlain by red-brown clays and underlain by Geliksovi Layers and sediments of Kyivska Suite and Buchatska Series. In places the sands lie over Precambrian rocks. In the southern part of L-36-IV map sheet the sands overlie Pontychni limestone Pile. The sands are mainly brick-red, rarely grey or yellowish-grey. In the column upper part the sands are fine-grained, clayey, in places with thin clay interbeds. Lower column portions comprise coarse-grained varieties. Normally the sands are horizontally-layered, rarely oblique layering occurs; thickness varies from 0 to 9 m. Their irregular thickness and shape over development area could be explained by deposition in ancient river reservoirs and deltas that joined bays of open sea.

Lower and Upper Pliocene

The *Pile of red-brown clays* (N_2cb) is fairly widespread over entire studied area and is only absent in the site of its present erosion. The Pile lies much higher modern erosion basis and often is exposed on the slopes of river and big gully valleys. Maximum thickness of the Pile is 32 m.

The clays are very dense, viscous, rather ductile, non-layered, calcareous, contain gypsum druses and iron-manganese films. In the upper column part red-brown clays predominate whereas in the lower part – yellow- or dark-brown ones.

The clays were deposited under continental conditions of eluvial, eluvial-deluvial and deluvil soil-forming processes.

Quaternary System

Quaternary sediments of the studies area comprise continental formations. They are developed throughout except erosion sites along rivers and big gullies as well as iron-ore open pit operations.

Subdivision of these sediments and their general grouping is presented in accordance with the "Stratigraphic scheme of Quaternary sediments in Ukraine" (Kyiv, 1993).

Detailed grouping of Quaternary sediments is performed by authors on the ground of their geology study results.

Two sub-areas are distinguished in the studies area – Northern-Inguletskiy and Southern-Inguletskiy which belong to the Central-Ukrainian and South-Ukrainian (loess) regions. The border between the two sub-areas is set in the northern part of L-36-IV map sheet. With regard to Quaternary geology Northern-Inguletskiy and Sourthern-Inguletskiy sub-areas differ one from another. For instance, in Northern-Inguletskiy sub-area thickness of loess stratons is considerably increased. In contrast, in Sourthern-Inguletskiy sub-area loess piles are often pinched out from the column. Besides that, in the latter sub-area are developed some additional types of sediments related to the distinct environments – lake-eluvial (le) and lake-aeolian-deluvial (lvd).

Normally, Quaternary sediments include complex of stratons essentially different in facial and lithological terms. Significant lithology-facial inhomogeneity causes requirements for separate description of the mapped stratigraphic complexes both in general and in respects of specific climatoliths. Each climatolith does correspond to certain paleo-geographic phase. Of 20 Anthropogenic paleo-geographic phases established, 10 ones represent sediments of warm periods and 10 – of cold periods. Over the warm period not a single soil but set of various soils can be formed, that is, soil suite.

Sub-aerial sediments, which are widespread over the map sheet area, are studied in more details, with description of specific stratons. Sub-aqueous rocks are described mainly on the branch level with adjustment to the river terraces.

Eo-Pleistocene (E)

Within Eo-Pleistocene sediments there are distinguished both sub-aerial and sub-aqueous units.

Alluvial sediments (aE) constitute lower column part of the high IX (Nogaiska) and X (Kyzyldzharska) over-flood terraces of Ingulets River and its branches. Alluvial comprises grey and light-grey sands, fine-grained, quartz, with clay interbeds, layered. At the alluvium column base the sands are diverse-grained, gravelous. Alluvium thickness is 1-9 m.

Eluvial and *aeolian sediments* (e, vE) include former soils and loess-like rocks, heavy-loam and clayey by granulometry. These sediments are especially widespread over watersheds in the southern part of studied area. Their depth varies from 10 to 20 m, thickness – 1-5 m. From underlaying Pliocene sediments these rocks differ in weaker mechanic composition, lighter colour, lack of large silica-carbonate concretions. On slopes there are observed eluvial and aeolian-deluvial (e, vd) sediments comprised of heavy loams, dirty, brown-pale, rarely of clays, which replace eluvial and aeolian sediments (e, vE) by strike.

In some places Eo-Pleistocene is represented by eluvial sediments only which belong to Upper Eo-Pleistocene (eE_{II}). They include former soils of mainly brown type, clayey and heavy-loam, up to 3 m thick. On the gully slopes eluvial sediments are changed by eluvial-deluvial rocks (eE_{III}) which are lighter in granulometric respect and consist of soil sediments that differ in lacking of some soils in the pedo-horizon of complete soil profile.

The principal features of Quaternary sediments in the column of branch or unit are defined by specific geological features of involved climatoliths. By these reasons below is given the brief climatolith description that form Eo-Pleistocene column. There are distinguished Berezanskiy (br), Kryzhanivskiy (kr) and Illichivskiy (il) climatoliths in Eo-Pleistocene column.

Lower Eo-Pleistocene (E_I)

Berezanskiy Climatolith (br). Straton includes aeolien and aeolian-deluvial rocks. The clays are greenish-grey, brownish-pale, dusty, carbonate; sandy loams are yellowish-grey. Straton was formed under conditions of moderate steppe climate [42]. It is developed within terraces older than IX, and at the watersheds. Maximum thickness of straton is 1 m, normally 0.3-0.5 m.

Upper Eo-Pleistocene (E_{II})

Kryzhanivskiy Climatolith (kr) includes two or three former soils, mainly brown, red-brown, in places hydromorphic. In some cases it is included into slightly differentiated Beregivsko-Kryzhanivskiy soil complex. Pedo-horizon is composed of heavy loams (up to clays), dense, coarse-lumpy with carbonate concretions, manganese (rarely iron) hydroxide particles and films; rarely sandy, with ochre and bluish spots. The former soils were formed in sub-tropic climate evidenced by spore-pollen spectrum [42]. Kryzhanivskiy pedo-horizon is a marker horizon of Eo-Pleistocene. It essentially differs from other paleo-soils in colour, occurrence of pseudo-sandy fraction and chemical composition (relatively high content of SiO_2 and Al_2O_3). And it is widely developed within terraces, older than IX, and at the watersheds. Thickness of pedo-horizon varies from 0.5 to 3.9 m, normally 2.0-2.5 m.

Illichivskiy Climatolith (il). This is cold-period straton composed of aeolian and aeolian-deluvial rocks. The loams are heavy, yellowish-brown, brownish-pale, carbonate, in places sandy with manganese hydroxide stains. Straton was formed under conditions of moderate climate of the steppe landscapes. It is locally developed within terraces, older than IX, and at the watersheds, re-worked during Shyrokinskiy soil-forming period. Thickness of climatolith is 0.8-1.0 m.

Neo-Pleistocene (P)

Lower Neo-Pleistocene (P_I)

Within Lower Neo-Pleistocene sediments sub-aqueous and sub-aerial facies rocks are distinguished.

Alluvial sediments (aP_I) are developed within VI-VIII terraces (Krukenytska, Donetska and Budatska) of Ingulets River and its branches where alluvium constitute lower part of terrace columns. The rocks include grey, yellowish-grey, ochreous sands, quartz, feldspar-quartz, fine-grained, often medium-coarse-grained to gravelous, wavy-oblique-cross-layered, as well as loams and sandy loams of oxbow and flood-land facies. Thickness of alluvium is 3-12 m.

Eluvial and *aeolian sediments* (e, vP_I) include former soils with interbeds of loess and loess-like loams variable in granulometric composition. The rocks are developed over the flat watershed areas and occur at the depth 6-15 m. Thickness is 6-12 m. From Eo-Pleistocene eluvial and aeolian sediments (e, vE) they differ mainly by loamy composition, both loess and soil ones. At the slope sites there are known eluvial and aeolian-deluvial (e, vd) sediments which column also include loess-like rocks composed of heavy loams, dusty, brownish-pale.

In those cases when Lower Neo-Pleistocene column consists of the former soils only, there are distinguished eluvial sediments (eP_I) which at the flat gully slopes are being changed by eluvial-deluvial rocks (edP_I) composed of soil sediments.

Complete description of variable-facies Lower Neo-Pleistocene sediments depends on specific features of involved Antropogene climatoliths. There are distinguished Shyrokivskiy (sh), Pryzaovskiy (pr), Martonoskiy (mr), Sulskiy (sl), Lubenskiy (lb) and Tyligulskiy (tl) climatoliths which are briefly described below.

Shyrokivskiy Climatolith (sh). Normally comprises former soil, brown, or the group of 2-4 soils of which the lower is often meadow one. In Sourthern-Inguletskiy sub-area somewhere are known hydromorphic soils. The former soils were formed in sub-tropic climate close to the modern Mediterranean one which is evidenced by composition of plant pollen including Pliocene forms *Myrica, Castanea, Cupressaceae* [42]. It is composed of heavy loams (up to clays), dense, often carbonate, fine-lumpy, with manganese hydroxide films. Climatolith is developed throughout within terraces older than VIII, and at the watersheds. Maximum thickness of climatolith is 3.5 m, normally 2-3 m.

Pryazovskiy Climatolith (pr). It is represented by aeolian-deluvial sediments. The loams are heavy, medium, greenish-pale, brownish-grey, micro-porous with spot manganese hydroxide inclusions, often cut by soil wedges, carbonate. In Pryazovskiy time the paleo-landscape was close to peri-glacial and climate was moderate evidenced by spore-pollen spectrum and analytical data [42]. It is developed within terraces older than VIII, and at the watersheds. Thickness of this straton is 0.2-0.4 m.

Martonoskiy Climatolith (mr). It comprises brown or red-brown former soils, rarely group of 2-3 soils or hydromorphic soil. Climatolith is often included into Shyrokivskiy-Martonoskiy (ePIsh-mr) soil complex which in the southern part of L-36-IV is related to the rock formation (lePIsh-mr). It is composed of heavy loams, dense, dusty, carbonate. Former soils were formed in sub-tropic climate close to the modern Mediterranean one which is evidenced analytical data and spore-pollen spectrum [42]. It is developed throughout within terraces older than VII, and at the watersheds. Thickness varies from 0.3 to 2.1 m, normally 0.9-1.2 m.

Sulskiy Climatolith (sl). It comprises aeolian, aeolian-deluvial and lake-aeolian-deluvial sediments – pale, olive, yellowish, brown-pale, bluish-grey, bluish-pale loams, dusty, often porous, dense, carbonate. The paleo-landscapes were similar to the cold peri-glacial. It is developed throughout within terraces older than VI, and at the watersheds. Thickness varies from 0.2 to 2.5 m, normally 0.2-0.8 m.

Lubenskiy Climatolith (lb). It is represented by former soil, mainly yellow-brown, brown, black, turf, often – by group (up to 3) of soils, hydromorphic, leached in places. It is composed of heavy loams, dense, dusty in places, with carbonate overprints. The soils were formed in the wood-steppe zone with moderate warm climate, wide development of broad-leaved plants of which there are found such heat-loving forms as *Tilia cardata Mill* and *Iugans* [42]. This Climatolith is being used as marker pedo-horizon of Lower Neo-Pleistocene due to distinct soil colour and relatively high Al_2O_3 content. It is developed throughout over terraces older than VI, and at the watersheds. Thickness of straton is normally 1-2 m, in places 3-4 m.

Tyligulskiy Horizon (tl). This one comprises aeolian and aeolian-deluvial sediments – brown-pale, pale loams, light, medium, carbonate, rarely – pinkish-white-pale sandy loams, often carbonate, porous. Paleo-landscapes were close to peri-glacial ones. It is developed in the Northern-Inguletskiy sub-area within terraces older than VI, and at the watersheds. In the Southern-Inguletskiy sub-area the later soil-forming processes (Zavadivskiy time) completely reworked Tyligulskiy loess. Thickness of straton varies from 0.3 to 1.2 m, normally 1.0 m.

Lower and Middle Neo-Pleistocene (P_{I-II})

Among Lower and Middle Neo-Pleistocene sediments sub-aqueous and sub-aerial facies are distinguished.

Alluvial sediments (aP_{I-II}) comprise the lower column portion of VIII, VII, VI, V terraces. Alluvium includes diverse-grained quartz sands, in the lower column part – coarse-grained and gravelous. Thickness of alluvium is 2-6 m. Grouping of alluvium from 4 over-flood terraces is caused by small scale of terrace range in the Ingulets valleys, in its upper course and in its branches.

Eluvial and *aeolian sediments* (e, vP_{I-II}) are developed on the flat watersheds. They are composed of Lower Neo-Pleistocene buried soil complex with interbeds of loess and loess loams described above, as well as soil suite of Zavadivskiy climatolith. Thickness of sediments is 7-13 m.

On the flat gully slopes and adjacent sites there are distinguished eluvial and aeolian-deluvial sediments (e, vdP_{I-II}) which replace by strike above eluvial and aeolian sediments and differ from them in lighter granulometric composition, as well as higher column discontinuity. In cases when loess climatoliths predominate in column over soils ones (northern part of M-36-XXXIV map sheet) there are distinguished aeolian-deluvial and eluvial sediments (vd, eP_{I-II}).

Eluvial sediments of Lubenskiy and Zavadivskiy pedo-horizons ($eP_I lb$-$P_{II} zv$) are known in some places of the studies area. The loess rocks of Tyligulskiy Climatolith lack in column. The sediments include suite of black, yellow-brown, brown soils, mainly heavy-loam, 2-4 m of total thickness. Description of Lubenskiy pedo-horizon is given above, and Zavadivskiy one – in description below of Middle Neo-Pleistocene sediments.

Middle Neo-Pleistocene (P_{II})

Within Middle Neo-Pleistocene there are distinguished sediments in sub-aqueous and sub-aerial facies.

Sub-aqueous facies (aP_{II}) include alluvial sediments: grey, yellowish-grey sands, fine-grained (with inclusions of pebble and gravel), quartz, feldspar-quartz, with horizontal or oblique layering, and with interbeds of loams and sandy loams. Alluvial sediments constitute lower column part of IV and V over-flood terraces. Thickness of alluvium is 2-5 m.

Among sub-aerial sediments (e,vP_{II}) most widespread are eluvial and aeolian ones developed over flat watersheds. The sediments include mainly heavy-medium-loamy former soils with a layer of loess or loess-like loam. Thickness of eluvial and aeolian sediments is 3-6 m.

From Lower Neo-Pleistocene sediments this complex differs in other soil types and lighter granulometric composition. In cases when Middle Neo-Pleistocene sub-aerial column contains paleo-soils only, there is distinguished eluvium (eP_{II}) of 2-3 m thickness.

At the plateau margins as well as on the flat slopes there is developed complex of eluvial and aeolian-deluvial sediments (e,vdP_{II}) composed of soils with separating loess-like loams. In cases when in the column loess climatoliths predominate over soil ones (northern part of M-36-XXXIV map sheet) there are distinguished aeolian-deluvial and eluvial sediments (vd,eP_{II}). Granulometric composition of the rocks is mainly medium-loamy. Thickness of sediments is 2.5-7 m. From plateau sediments they differ in lighter granulometric composition and brighter colour.

Within Middle Neo-Pleistocene there are distinguished Zavadivskiy (zv), Dniprovskiy (dn), Kaydatskiy (kd), and Tyasminskiy (ts) climatoliths. Their description is given below.

Zavadivskiy Climatolith (zv). It includes brown, hydromorphic former soil, leached, often group of 2-5 soils, in places with interbeds of loess-like loam. Often it is included into Lubensko-Zavadisvskiy soil complex ($eP_Ilb-P_{II}zv$) which is related to the rock formation ($leP_Ilb- P_{II}zv$) in southern part of M-36-IV map sheet. It is composed of medium and heavy loams, brown, brown-grey, bluish-olive-grey, dense, carbonate, often cut by overlaying loess wedges, with gypsum crystals and newly-formed manganese hydroxides. The soils formed in the wood-steppe zone of dry climate close to sub-tropic which is evidenced by rapidly increased role of plant group that belong to xerophites [42]. Pedo-horizon is fairly widespread over terraces older than V, and at the watersheds. Thickness of straton attains 2.9 m, normally 1-1.5 m.

Dniprovskiy Climatolith (dn). It comprises aeolian, aeolian-deluvial and lake-aeolian-deluvial sediments, in places with embryonic soil in the lower part. The loams are light and medium, olive-brown, light-, yellow-pale, pale, bluish-greenish-grey, loess-like, often carbonate, dusty, with mole-holes. Paleo-landscape was peri-glacial with cold climate as it is evidenced in depletion of thermophile plant pollen [42]. It is absent within I-IV terraces and is fairly widespread over terraces older than V, and at the watersheds. Thickness varies from 0.5 to 2.7 m, normally 1.2-2.5 m.

Kaydatskiy Climatolith (kd). It includes former soil, brown, black-earth, alkali-black-earth (somewhere leached), in places – group of two soils (black at the top and brown loess at the bottom). The soils were formed in the wood-steppe and meadow-steppe zones of moderate climate. They are composed of medium and light loams, often carbonate, dusty, rarely with fine gypsum crystals and carbonate aggregates. This climatolith is a marker of Middle Neo-Pleistocene. Kaydatskiy horizon strongly differs from other stratons by paleo-soil colour and relatively low content of Al_2O_3 and high potassium content (in the same sample) [42]. It is developed within IV-VI terraces as well as at watersheds. Thickness of pedo-horizon attains 1.8 m, normally 05.-0.7 m.

Tyasminskiy Climatolith (ts). It comprises aeolian and aeolian-deluvial sediments. The loams are medium, greyish-pale, bluish-grey, loess-like, dusty, sometimes compressed, essentially re-worked by soil-forming processes of the subsequent stage. Paleo-landscape was mainly pre-glacial as it is evidenced in depletion of thermophile plant pollen spectrum [42]. It is fairly widespread within IV-VI terraces while at the watersheds is normally absent. Thickness is 0.1-0.2 m.

Middle and Upper Neo-Pleistocene (P_{II-III})

These sediments include alluvial, eluvial and eluvial-deluvial units.

Alluvial sediments (aP_{II-III}) comprise the lower part of column in IV, III, II and I terraces of Ingulets River branches. They are composed of grey sands, diverse-grained, quartz, sometimes with gruss and pebble of crystalline rocks, with interbeds of loams and sandy loams. Thickness is 4-5 m.

On the gully slopes as well as at the watershed margins there are developed eluvial-deluvial sediments (edP_{II-III}) mainly composed of soil units. Their thickness is 1.5-5 m.

Upper Neo-Pleistocene (P_{III})

Upper Neo-Pleistocene units comprise sub-aqueous and sub-aerial sediments.

Alluvial sediments (aP_{III}) are developed at the column base in II and III terraces and most of the 1st over-flood terrace of Ingulets River. These include grey,yellowish-grey sands, diverse-grained, quartz, in places with gruss and pebble of crystalline rocks, with loam interbeds, fauna of *Unionides, Vivipartd* etc. Thickness of alluvium is 2-4 m.

Eluvial and aeolian sediments (e,vP_{III}) are known at the flat watersheds, mainly in the map sheet L-36-IV. They include former soils with loess interbeds. Granulometric composition – medium and light loams. Thickness is from 1 to 5 m. When loess stratons pinch out from the column and soil ones only remain, 1-3 m thick eluvial sediments (eP_{III}) are distinguished.

At the plateau margins as well as on flat slopes there is developed complex of eluvial and aeolian-deluvial sediments (e,vdP_{III}) which includes soils with separating loess-like loams. When loess climatoliths predominate in column over soil ones (northern part of M-36-XXXIV map sheet and south-eastern part of L-36-IV map sheet) there are distinguished aeolian-deluvial and eluvial sediments (vd,eP_{III}) within 2-3 terraces ($e,vdP_{III}bz-pc$).

On the gully slopes as well as at watershed margins there are developed eluvial-deluvial sediments (edP_{III}) comprised mainly of soil units. Their thickness is 1.5-3 m. From eluvial and aeolian sediments they differ in lighter composition.

In the southern part of Southern-Inguletskiy aub-area there are developed genetic varieties related to rock formations – lake-eluvial (leP_{III}pl-vt) and lake-aeolian-deluvial (lvdP_{III}).

Alluvial sediments of Desnyanskiy Branch (a1P_{III}ds) are developed in the valley of Ingulets River, within low first over-flood terrace. Alluvium comprises yellowish-grey sands, fine-grained, quartz, up to 10 m thick.

The following climatoliths defining features of mapped stratons are included in Upper Neo-Pleistocene soil-loess units: Prylutskiy (pl), Udayskiy (ud), Vytachivskiy (vt), Buzkiy (bg), Dophinivskiy (df), Prychornomorskiy (pc), which are decribed below.

Prylutskiy Climatolith (pl). It comprises brown former soils, the group of two brown soils or is included into differentiated soil complex of Prylutsko-Vytachivskiy (eP_{III}pl-vt) phase which in the southern part of L-36-IV map sheet is related to rock formation (leP_{III}pl-vt). It is composed of medium and heavy loams, often with fine gypsum crystals, carbonate, dusty. Prylutski soils were formed in wetter and warmer that modern climate of the wood-steppe zone as it is evidenced by analytical data [42]. It is fairly distributed within Quaternary terraces except I-III ones, and at the watersheds. Thickness varies from 0.2 to 1 m, normally is 0.3-0.5 m.

Udayskiy Climatolith (ud). It includes aeolian, aeolian-deluvial and lake-aeolian-deluvial sediments. The loams are brown-pale, bluish-pale, yellowish-pale, medium, carbonate with carbonate concretions and gypsum crystals. In Udayskiy time peri-glacial landscapes predominated with rapid ceasing of ancient plants and expansion of open territories [42]. It is fairly widespread within III-IV terraces and is locally known at the watersheds. Thickness is 0.1-1.2 m.

Vytachivskiy Climatolith (vt). It is composed of former soils and group of two soils (upper – brown-earth-like, lower – brown) or is included into slightly differentiated soil complex of Prylutsko-Vytachivskiy (eP_{III}pl-vt) phase. The soils were formed in the wood-steppe zone. Include medium and heavy loams, carbonate, dense. These are often cut by wedges filled with loess material, sometimes with gypsum druses and fine solid carbonate aggregates. It is fairly widespread over terraces older than II, and at the watersheds. Thickness normally is 0.3-1.3 m, in places up to 2 m.

Buzkiy Climatolith (bg). It comprises aeolian, aeolian-deluvial and deluvial-aeolian sediments. The loams are light to medium, brown-pale, often porous with the worm signs, with carbonate concretions. The paleo-landscape was mainly loess, of moderate cold, dry, peri-glacial climate. Thickness is normally 0.3 m. Thermo-luminescent dating yield straton age of 74$\pm$5 thousand years [42].

Dophinivskiy Climatolith (df). This is a horizon of warm forming stage. Includes soil or group of soils composed of loams, medium, brown, fine-lumpy, macro-porous with manganese hydroxide balls, often hydromorphic, lighter to the bottom, yellowish-brown. The soils were formed in colder than modern climate in the landscapes of dry steppe zone. Climatolith is widespread in Southern-Inguletskiy sub-area, within II-IV terraces, and normally is absent at the watersheds. Thickness is 0.4 m. Thermo-luminescent dating yield straton age of 40$\pm$5 thousand years [42].

Prychornomorskiy Climatolith (pc). Comprises aeolian and aeolian-deluvial sediments. The loams are light to medium, brownish- or greyish-pale, fine-lumpy with carbonate concretions, modified by Holocene soil-forming processes. As it is evidenced by spore-pollen spectrum, the paleo-landscape was mainlt peri-glacial under conditions of moderately cold dry climate [42]. The straton is known to be separate in Southern-Inguletskiy sub-area, within II-IV terraces. At the watersheds it is included into Buzko-Prychornomorskiy loess complex (vP_{III}bg-pc), and (vdP_{III}bg-pc) on the flat slopes which in the southern part of L-36-IV map sheet is related to rock formation (vdP_{III}bg-pc). Thickness is 0.3-0.6 m.

Upper Neo-Pleistocene and Holocene (P_{III}-H)

Alluvial-deluvial sediments (adP_{III-H}) constitute bottom gully parts in the map sheets M-36-XXXIV and L-36-IV. These units include 1-3 m thick sandy loams and fine-grained sands.

Prychornomorskiy Climatolith of Upper Neo-Pleistocene and Holocene (aP_{III}pc-H) are developed in the studied area within small river flooded lands where separate definition of the Ist over-flooded terrace is impossible in view of small scale and morphologic expression. Alluvium is composed of fine-grained sands with interbeds of sandy loams. Thickness of alluvium is 3-10 m. At the bottom of big gullies there are developed alluvial-deluvial sediments (adP_{III}pc-H) of mainly sandy loam composition and 1-5 m thickness.

Holocene (H)

Holocene sediments comprise sub-aqueous and sub-aerial facies. There are widely developed alluvial sediments (aH) which include alluvial oxbow-flooded facies. River-course alluvium is composed of sands and sandy loams, in places of light-grey, grey and brownish-grey shades. Oxbow-flooded facies include dark-bluish-grey loams, often with interbeds of light-bluish or ochre-grey sands. The rocks are mainly developed in the river-course flooded lands. Thickness attains 8 m. Sub-aerial facies (modern soils) are not indicated in the map, but since Holocene soils are being considered as same-order as the oldest Quaternary sediments, these are described below. These sediments are known at the watersheds being composed of black-earth soils, alkaline-black-earth, rarely salty. On the slopes genetic varieties are well expressed: humus (H) and transitional (HP). The unit is developed throughout in the area except water basins. Thickness varies from 0.3 to 3.3 m, normally 0.6-0.8 m.

Technogenic sediments are subdivided into the piled and washed. The piled sediments (tH) do form the dumps, embankments and dams composed of sedimentary and crystalline rocks, as well as industrial wastes. Thickness of piled sediments attains tens of metres.

Washed sediments (taH) were formed mainly through beneficiation of ferruginous quartzites and other technological processes. They are mainly composed of dusty-clayey material of grey and red-grey shades. Thickness attains 10 m and more.

3. ULTRA-METAMORPHIC, INTRUSIVE AND METASOMATIC UNITS

Ultra-metamorphic, intrusive and metasomatic units are distinguished in accordance with "Correlation stratigraphic scheme of Precambrian rocks in Ukrainian Shield" (Kyiv, 2000). Of these, ultra-metamorphic rocks predominate (over both map sheet areas), intrusive rocks are developed in subordinate amounts, and metasomatic rocks are locally known mainly being confined to the weakened tectonic zones.

Ultra-metamorphic rocks belong to three, and intrusive rocks – to five age groups. The oldest one is Meso-Archean group which in the Middle-Dniprean area includes small mafic-ultramafic intrusions of Oleksandrivskiy Complex and tonalites of ultra-metamorphic Dnipropetrovskiy Complex.

Fairly widespread is Neo-Archean age group which includes some ultra-metamorphic complexes developed mainly in the Middle-Dniprean area and partly in the Ingulo-Inguletskiy area: Saksaganskiy and Inguletskiy plagiogranitoid complexes, and Demurinskiy and Tokivskiy two-feldspar complexes. To the same group in these areas also belong some intrusive complexes: Verkhivtsivskiy mafic-ultramafic, Devladivskiy ultramafic, and Dyke Complex of mafic rocks.

The third, less widespread over the area Paleo-Proterozoic group is mainly developed in the Ingulo-Inguletskiy region and includes intrusive Novoukrainskiy Complex of mixed composition (from hornblendites to sub-alkaline granites) and ultra-metamorphic Kirovogradskiy Complex of potassium granitoids. The latter in this area are mainly developed after plagiogranitoids of another – Neo-Archean group.

Two remaining age group of intrusive rocks include Neo-Proterozoic gabbro-diabase dyke complex (developed mainly in the Ingulo-Inguletskiy region) and the locally developed Permian-Triassic sub-volcanic rocks of andesite-trachyandesite composition which are related to the platform stage of Ukrainian Shield history.

PRECAMBRIAN

ARCHEAN

Meso-Archean

Oleksandrivskiy Complex (AR_2ok) of the oldest intrusive rocks is developed in the Middle-Dniprean area (over map sheet L-36-IV) within volcanics of Bazavlutska Sequence. They form large (first meters – tens of meters) lens-shaped intrusions composed of mafic and ultramafic rocks [24]. There is observed their tight spatial association with the sequence of massive amphibolites and both rocks associations are together deformed, migmatized and metamorphosed under amphibolite facies [42].

Ultramafic rocks mainly comprise actinolitites which in places contain relicts of hornblendites, rarely – pyroxenites (DH 23612). More rarely within amphibolites are known gabbros which are always metamorphosed. Their primary-magmatic nature is evidenced by blasto-gabbro textures and relicts of primary pyroxenes. Granitized varieties normally contain (up to 20%) metatectite and, frequently, fine dust of accessory magnetite (up to 5-10%). By these reasons despite of considerable modifications the rocks are being reliably mapped through linear magnetic anomalies of various magnitudes.

By petrochemical characteristics, both metagabbroids of the Complex and their host volcanics of Bazavlutska Sequence are derived from the single tholeiite-basalt magma [42]. Ultramafic rocks are close to pyroxenite komatiites of Bazavlutska Sequence and apparently comprise their intrusive analogues. This allows conclusion the mafic-ultramafic rocks of Oleksandrivskiy Complex together with Bazavlutska Sequence rocks belong to the single volcano-plutonic association that formed oldest greenstone belts in the Middle-Dniprean granite-greenstone terrain, that is, the rocks of the Complex and the Suite are thought to be comagmatic.

Dnipropetrovskiy Complex (AR_2dn) of ultra-metamorphic plagiogranitoids is developed in the Middle-Dniprean area in between the rivers Bazavluchok-Kamyanka (map sheet L-36-IV). There plagiogranitoids, being developed after metavolcanics of Bazavlutska Sequence, do form semi-oval Bazavlutske arc uplift which is essentially re-worked in marginal parts by the later (Saksaganski) ultra-metamorphic granitoids. The contacts between these rocks are gradual and the boundary is set conventionally (taking into account geophysical data) by sharp drop in magnitude of increased gravity field, characteristic for Dnipropetrovski plagiogranitoids which contain abundant amphibolite remnants [47].

Two rock varieties are distinguished in the Complex: biotite and biotite-amphibole plagiogranites and plagiomigmatites with predomination of amphibole-bearing varieties. In contrast to the later plagiogranitoids of Surskiy and Saksaganskiy complexes, in the given Complex plagiogranitoids gneissosity and coarse banding are throughout developed and plagioclase is essentially calcium. Average chemical composition of the rocks does correspond to tonalites [42]. More detailed description of these plagiogranitoids is given elsewhere [19, 31, 32, 33, 42].

Distribution patterns of REE (low Rb/Sr ratio and Sr^{87}/Sr^{86} = 0.709 as well as homogenous spectrum of all HREE) suggest for the deep mantle origin of the Complex plagiogranitoids [1, 8]. Occurrence of numerous unbroken substratum relicts, lack of clear contacts and texture inheritance, as well as mineral and chemical composition suggest for mainly metasomatic nature of these oldest plagiogranitoids. Their formation was completed at about 3200 Ma in relation to formation of tonalite (proto-continental) crust [15]. Single determinations of Dnipropetrovski plagiogranitoids radiogenic age with values below 3150 Ma are explained by their age lowering under influence of extensive Neo-Archean ultra-metamorphism. The latter almost everywhere displays signs of co-genetic relations to the mentioned tonalite base.

Neo-Archean

Verkhivtskivskiy Complex (AR_3vr) of intrusive rocks is developed over both map sheets in the Middle-Dniprean area, mainly in volcano-tectonic structures, and in places within linear synclines filled with metavolcanics of Surska Suite [42]. In the first case mafic-ultramafic rocks constitute diverse-shaped intrusions which within volcanic structures belong to two depth facies – hypabyssal and sub-volcanic with predominate development of the latter one.

Intrusive rocks of hypabyssal facies mainly comprise differentiated massifs and stocks (up to 6 km^2 in size) normally composed of non-altered gabbro, rarely gabbro-peridotite. Among sub-volcanic facies are developed both differentiated sills (up to 30 m thick) composed of altered gabbroids (gabbro-amphibolites) and dyke bodies composed of variously-altered peridotites, pyroxenites and their metamorphosed analogues (actinolitites, tremolitites, serpentinites and talc schists). The sill and dyke bodies apparently are confined to the middle portions of volcano-tectonic structures (to the widely developed ring faults) whereas stocks and massifs – to their central portions (inferred necks).

Relationships of intrusive rocks with volcanics of Surska Suite are normally conformable, in places of cutting type. Rock colour and grain size changes as well as slight hornfels are commonly observed in the contact zones.

Described intrusive rocks together with the stratified lava units do form two magmatic belts – Yavdotivsko-Oleksandrivskiy and Komisarivskiy confined to the boundaries of large plagiogranitoid diapiric domes. In different parts of these belts relations between intrusive and extrusive rocks can vary depending probably on the depth of erosion cut and other factors. More detailed description of these intrusive units is given elsewhere in report on EGSF-200 [42].

In the linear greenstone synclines (Vysokopilska, Zhovtovodska and others) the rocks of this Complex comprise mainly dyke-like bodies confined to the longitudinal tectonic breaks. Commonly they include actinolitites, tremolitites, talc and talc-carbonate schists which are similar in composition to pyroxenite komatiites of Surska Suite and differ from the latter in coarser grain size, development of distinct intrusive textures, as well as contact alteration of the host rocks.

Aforementioned intrusive rocks, having high density (2.98-3.28 g/cm^3) and, in places, enhanced magnetization ($I = 1750\text{-}2450 \cdot 10^{-3}$ A/m), are normally clear expressed in the physical fields within the host volcanics or granitoids, forming oval-ring-shaped and linear gravity, and rarely magnetic anomalies.

Petrochemical features of gabbro, gabbro-amphibolites and ultramafic rocks of this Complex are almost identical to those of basalts, dolerites and pyroxenite komatiites of Surska Suite. Obviously, intrusive rocks are their comagmates [42].

By REE patterns mafic-ultramafic rocks from volcano-depressions are normally HREE and LREE enriched (especially peridotites – by a factor of 25) that is characteristic for the mantle melts [1]. This is also supported by low isotopic composition of oxygen in plagioclase from gabbro (δO^{18} = 6.5-7‰) and low isotopic ratio Sr^{87}/Sr^{86} = 0.7036 [42].

According to Rb-Sr studies, the age of Complex rocks is estimated to 3060 Ma [42]. Metallogenic specialization is copper-nickel, which is typical for these rocks.

Surskiy Complex (AR_3sr) in the map sheet M-36-XXXIV, in the Middle-Dniprean area, comprises a group of small intrusions (up to 10-15 m^2 in size) confined either to the tectonic junction zones of greenstone belts and plagiogranitoid domes or to the central portions of greenstone belts being observed in hypabyssal stocks and dyke bodies [32, 33]. In the studied area these rocks are developed in limited amounts and are much more widespread in the territory adjacent from the east.

Relationships of intrusive rocks to the host units are irregular, often with the tongues into volcanic rocks of Konkska Series. In the intrusions endo-contacts with metabasalts often contaminated rocks of granodiorite and diorite composition are observed, and in the exo-contact – reaction rims of micaceous rocks or slight hornfels development [33].

Among the Complex rocks there are fairly widespread medium-coarse-grained blue-quartz biotite-amphibole plagiogranites. Their detailed description (with definition of emplacement phases from rhyodacites to plagiogranites) is given elsewhere [31, 32, 33].

Results of reconnaissance works [8, 16, 28], REE patterns and thermobarometry studies suggest for their crystallization from high-temperature felsic melts co-magmatic to rhyolites and dacites of Konkska Series.

As it is evidenced by radiological dating of syn-genetic zircons from plagiogranites of the Complex, the age of these rocks is 3105-3114 Ma [33, 54]. Marking isotopic dating from the neighbouring territory provide expanded period of Complex formation – from 3171 (first phase) to 3050 (third phase) Ma [27].

Metallogenic specialization of this Complex is molybdenum-tungsten, gold and gold-silver as it is defined in Verkhivtsivska, Surska and Chortomlytska greenstone structures [31, 33].

Saksaganskiy Complex (AR_3sk) of ultra-metamorphic plagiogranitoids is most widespread over both map sheets, in the Middle-Dniprean area: it constitutes all major domes (Pyatykhatskiy, Saksaganskiy and others) which separate greenstone belts and impose their margin granitization. By these reasons the contacts of plagiogranitoids with volcanics are tongue-shaped, often with formation of hybrid rocks (diorites, granodiorites and migmatites of the same composition) in boundary zones [42].

Physical properties of plagiogranites essentially differ from those of greenstone rocks (density – 2.6-2.7 g/cm^3, magnetization - 15-45·10^{-3} A/m), and by these reasons they are being reliable mapped in magnetic and especially gravity fields.

According to recent studies [42, 53], two rock associations are distinguished in Saksaganskiy Complex which differ in composition, texture and genetic features. The first association includes major rock volume of the Complex and comprises biotite and amphibole-biotite plagiogranites and migmatites together with locally developed hybrid rocks (diorites, granodiorites and migmatites of the same composition). The latter are mainly confined to the peripheral zones of domes whereas biotite plagiogranites and plagiomigmatites are located in the central and transitional zones. The rocks display all signs of substratum metasomatic replacement.

The second rock association (much less voluminous) includes granitoids with evidences for selective melting. Particularly, it includes homogenous Saksaganski plagiogranites in the eastern margin of Kryvorizka structure, microcline-plagioclase granites and migmatites developed inside and in the rim of greenstone volcano-plutonic structures, as well as aplite-pegmatoid granites [42]. Their petrochemical features, K-Rb relations and Kenigsberger number [47] differ from those of the first association rocks suggesting for another mechanism of their formation. More detailed description of the Complex is given elsewhere [8, 16, 19, 31, 34, 42, 53].

Differentiated REE patterns in the first association plagiogranites (LREE – 10 times higher of chondrites, HREE – similar to chondrites, positive europium anomaly, etc.) suggest for Complex rock formation at shallow depth during re-working of both sialic rocks (tonalites of Dnipropetrovskiy Complex) and basaltoids of Surska Suite. Contamination of the latter (with their radiogenic strontium) in course of diorite formation is evidenced by high isotopic ratio Sr^{87}/Sr^{86} = 0.7075.

Taken together, aforementioned data suggest for autochthonous nature of most Complex plagiogranites (first rock association) whereas remaining part (second rock association) is of allochthonous or reomorphic origin. Occurrence of the latter (high-mobile) material apparently facilitated upward movement of granitoids masses under diapiric mechanism [8].

By isotope dating of syn-genetic zircons from various rocks the age of plagiogranitoids is estimated to 3010-2952 Ma [27]. Similar data are obtained also by U-Pb isochrones – 3041 and 2971 Ma (DH 23221, 23606).

Most of plagiogranitoids do not contain economic mineralization and in hybrid diorites only copper-molybdenum mineralization is encountered [46].

Inguletskiy Complex (AR_3in) of ultra-metamorphic plagiogranitoids over map sheet territory is developed in the Ingulo-Inguletskiy area. There Archean plagiogranitoids constitute some of dome-shaped blocks (Zelenivskiy, Zhovtyanskiy, Inguletskiy and others) which in Kirovogradska LTZ were remobilized over Paleo-Proterozoic [42].

Detailed studies of Inguletski plagiogranitoids during Kryvorizka SD-8 drilling [53] had revealed their considerable similarity to Saksaganski plagiogranites and plagiomigmatites. Likewise, there are also distinguished two rock associations: first one (major volume of Complex) includes biotite and amphibole-biotite plagiogranites and plagiomigmatites, and second one – microcline-plagioclase granites and migmatites, as well as aplite-pegmatoid granites. In the first association corrosion textures are mainly developed whereas in the second one – grano-blastic textures. Inguletski plagiogranitoids are similar to Saksaganski rocks by chemical composition, minor and trace element geochemistry, lead isotopes and accessory mineral assemblages [53]. Their petrophysical parameters also are actually identical. Inguletski plagiogranitoids are being much better mapped in physical fields by their reduced (in comparison to host gneisses and schists) density (2.66-2.70 g/cm^3) and locally higher magnetization (I = 58-110·10^{-3} A/m) [47].

Comparative analysis of REE patterns of Inguletski plagiogranitoids had revealed their complete identity with Saksaganski plagiogranitoids [42, 53]. Taking into account Rb-Sr index (equal 0.2) it can be assumed their formation under similar conditions and the same moderate depth.

Radiogenic age of the Complex plagiogranitoids (of both associations) along the column of SD-8 varies in the range 2810-3074 Ma [53]. These results suggest for coeval development of Saksaganskiy and Inguletskiy ultra-metamorphic complexes in different areas.

Demurinskiy Complex (AR$_3$dm) of ultra-metamorphic granitoids is developed in the Middle-Dniprean area of map sheet M-36-XXXIV where the rocks constitute the same-named dome of complex structure. In the core of this dome are known relicts of old substratum (plagiogranites, amphibolites, gneisses), and in the marginal parts – the zoned relations of newly-formed granitoids and metasomatites. Of these granitoids two-feldspar varieties strongly predominate with development of porphyry-blastic textures (mainly with microcline, rarely plagioclase). The late nature of porphyry-blastesis, especially microcline-type, is clearly indicated.

Magnetic field over granitoids is elevated (I = 205-260·10^{-3} A/m) and extremely irregular. Residual gravity field (2.63-2.65 g/cm^3) is reduced and flat. By these features and geological records these rocks differ from Saksaganski plagiogranitoids [47].

Two main varieties of granites and migmatites are distinguished in the Complex: meso- and melanocratic porphyry-blastic, and gneiss-like leucocratic uniform-grained. The first-type rocks are known mainly at the margins of the dome whereas second-type rocks are mainly confined to the central parts often being associated with granodiorites derived through re-working of mafic source. Transitions between all rock varieties are gradual.

Schlieren, often elongated bodies of aplite-pegmatoid granites are widespread at the dome margins and along fault zones in association with microcline-albite metasomatites. The latter, especially in Myloradivska fault zone, are observed in the system of up to 100 m thick vein bodies confined to tectonic breaks [42]. Detailed description of the rocks including their petrochemical features is given elsewhere [61]. It should be noted increased alkali content in granitoids (up to 6.71%). From these data it can be assumed that potassium metasomatism played key role in formation of two-feldspar granitoids through palingenic-metasomatic re-working of apparently Saksaganski plagiogranitoids. Aplite-pegmatoid granites presumably had been formed under crystallization of palingenic melt. Thus, most of Demurinskiy Complex granitoids are of para-autochthonous nature.

The age of two-feldspar granitoids is determined by U-Pb method by syn-genetic zircons to 2750-2850 Ma [8, 2, 61].

The oldest dates (up to 3000 Ma) known from the Complex rocks are provided by relic zircons residual from plagiogranitoids of Saksaganskiy Complex [61]. High values of Rb-Sr and K-Rb ratios suggest for shallow depth of porphyry-blastic granitoids formation. The records available suggest for similarity of these rocks to granitoids of Tokivskiy Complex. Likewise the latter, increased molybdenum and REE contents are determined in Demurinski granitoids. Semi-economic molybdenum grades are estimated in aplite-pegmatoid granites [58, 61].

Tokivskiy Complex (AR$_3$tk) of ultra-metamorphic granitoids, likewise Demurinskiy one, does form same-named dome-shaped massif in the Middle-Dniprean area of map sheet L-36-IV. The dome structure is confirmed by occurrence of non-displaced relicts of oldest volcano-plutonic rocks in the core portion, their separate development, and more active granite formation by periphery of massif [42].

Relationships of the Complex granitoids with plagiogranites and plagiomigmatites of the host Saksaganskiy Complex are active (tongue-wavy and layer-injection) with formation of up to some kilometers wide microclinization aureole in around the massif. Relicts of Saksaganski plagiogranitoids within newly-formed Tokivski granitoids are found in the massif endo-contact zone. And composition of Tokivski granitoids is essentially microcline throughout with common development of microcline porphyry-blasts.

Internal structure of Tokivskiy Massif is complicated. The central part (about 30%) is composed of hybrid rocks from diorites to granites which are clearly expressed in gravity and magnetic fields with high density (2.74-2.88 g/cm^3) and magnetization (I = 4062-8979·10^{-3} A/m). At the margins, in places of extensive basement breaking, there are developed mainly porphyry-blastic meso- and melanocratic granites (up to 20% by square) expresses in reduced gravity (2.63-2.67 g/cm^3) and magnetic (I = 340-650·10^{-3} A/m) fields. Above rocks are cemented by homogenized leucocratic granites (about 50% of the Massif) which are characterized by complex magnetic and flat (often reduced) gravity fields. Geology is further complicated by wide development of veined aplite-pegmatoid granites and fault-side metasomatites located mainly in the central part of the Massif.

According to results of DGM-50 [46] and EGSF-200 [42], in Tokivskiy Complex there are distinguished: amphibole diorites and migmatites of diorite composition; two-feldspar porphyry-blastic, meso- and melanocratic granites; aplite-pegmatoid granites; syenites; metasomatites (albitites, epidosites). Their detailed description is given in mentioned works.

Petrochemical features of granitoids are irregular, their general specifics comprises sub-alkaline affinity and significant dependence on the source rock composition [42]. The latter is evidenced by REE spectrum [46] suggesting for distribution patterns inherited from the host plagiogranitoids.

Analysis of data available allows reliable conclusion that the Complex granitoids are of polygenic origin including high-temperature potassium metasomatism and selective melting with magmatic replacement of host rocks through palingenic-metasomatic granitization. More active role of metasomatism is evidenced by high enough apatite mineralization in hybrid rocks and increased degree of triclinic structure in microcline from hybrid rocks to leucocratic granites [46]. Granite melt generation apparently occurred at shallow depth in view of increased Rb-Sr and K-Rb ratios [42] similar to those if granitoids of Demurinskiy Complex. Metallogenic specialization of Tokivskiy Complex granitoids is defined as molybdenum and apatite-REE.

The age of granitoids determined by U-Pb method on zircons is 2760-2860 Ma [46] and it is also similar to the age of Demurinskiy Complex granitoids. Both these complexes of potassium granitoids display a range of similar features allowing their consideration to be a single granite-migmatite formation. Although the rock volume of these complexes is relatively low (in comparison to plagiogranitoids) they are thought to be fairly important for continental crust formation in granite-greenstone terrain at about 2800 Ma [8, 27].

Devladivskiy Complex (AR_3dv) of ultramafic intrusive rocks is only defined in the Middle-Dniprean area (map sheet M-36-XXXIV) within latitudinal Devladivska Fault Zone. The rocks are observed over the distance up to 50 km in a series of discontinuous dyke bodies confined to the northern and southern branches of the Fault. In contrast to the similar ultramafic rocks of Verkhivtsivskiy Complex developed at the marginal parts of the Fault, the dyke bodies of Devladivskiy Complex are linearly-shaped, elongated in latitudinal direction and do have tectonic contacts with host rocks including ultramafic rocks of Verkhivtsivskiy Complex. Length of dyke bodies varies in the range 100-9000 m, thickness – from 80 to 300 m. The internal structure of the dykes is uniform and in some large bodies only slight differentiation is observed.

As revealed from geophysics, the dyke bodies are vertical or sub-vertical [47], the rocks are of high density (2.75-2.78 g/cm^3) and increased magnetization (I = 7400-11700·10^{-3} A/m).

The Complex mainly includes peridotites and gabbro-peridotites, rarely pyroxenites. In some dykes (close to Kryvorizka structure) these rocks are almost completely serpentinized. Their composition and petrochemical features are described elsewhere [24, 42, 63]. According to these results, the rocks belong to the deep hyperbasite (nickel-bearing) formation. It is confirmed by increased nickel content (up to 0.75%) in the rocks which is contained both in silicate and sulphide forms. It is reported high background content of chromium and copper. In weathering crust after these ultramafic rocks the nickel content attains economic values [57, 58].

The time of rocks emplacement is not defined precisely but since they cut the older Demurinski granitoids (2800 Ma) and, in turn, is cut by the younger diabase dyke swarm (aged to 2600-2700 Ma) it can be assumed the age of Devladivskiy Complex rocks falls into the time interval 2700-2750 Ma.

Dyke Complex (βAR_3) of intrusive rocks in both map sheets is mainly developed in the Middle-Dniprean area and locally in the Ingulo-Inguletskiy area where the rocks form the dyke swarms within Pyatykhatska, Demurinska, Inguletska and other dome-shaped structures at their core parts. The dyke rocks are mainly confined to sub-longitudinal fractures and breaks in granites and migmatites, rarely they are concentrated in fault zones (Lykhivskiy, Myloradivskiy and others) of the same direction. In the southern part of L-36-IV map sheet these rocks are observed in the zone of latitudinal fault [62].

By density (2.91 g/cm^3) and magnetic properties (I = 760·10^{-3} A/m) the dykes strongly differ from the host granitoids. Thickness varies from 0.5 to 50 m and in the fault zones they can swell up to 150 m and more. Length of dykes varies from some tens of metres up to first kilometers, dipping normally is steep (80-85^o) westward or vertical [54].

The contacts with granitoids are sharp. Rarely evidences for host rock quenching, more often grain size enlargement from centre to periphery is observed. In fault zones the contacts may be wavy with tongues and internal structure – slightly differentiated.

By composition in Dyke Complex diabases and rarely gabbro-diabases predominate. The latter are mainly developed in Lykhivska, rarely in Myloradivska fault zones. There dykes contain syn-genetic vanadium-bearing titanium-magnetite mineralization up to economic grades. The dyke composition and their petrochemical features are given elsewhere [31, 33, 46, 54, 60, 61, 62]. Metamorphic modification of diabases is expressed in various amphibolization. Granitization signs are not identified.

Radiological age of diabase determined by K-Ar method on hornblendes is 2600-2700 Ma [60, 61], and gabbro-diabases from Lykhivska fault zone, determined by U-Pb method on zircons – 2750 Ma [54].

Formation of the rocks apparently occurred over fracturing of consolidated dome uplifts and initial faults development in continental crust. This indicates beginning of stabilization in granite-greenstone terrain of the Middle-Dniprean area and the border zones in around [15].

PROTEROZOIC

Paleo-Proterozoic

Novoukrainskiy Intrusive Complex (PR_1nu) is located in the Ingulo-Inguletskiy area (within Kirovogradska LTZ) where these rocks constitute a range of massifs – Grafskiy, Novovolodymyrivskiy, Bokovyanskiy, Verblyuzhskiy and others of which some extends westward outside the area to adjacent territories. The massifs are composed of differentiated rocks – from ultramafic to felsic and sub-alkaline. Despite of difference in rock composition between the massifs they are similar in their tectonic setting (in Zakhidno-Inguletska Fault zone), age and petrology. The rocks were formed prior to Paleo-Proterozoic ultra-metamorphism. Apart from this, emplacement of the Complex intrusions besides primary differentiation of magmatic melt was accompanied by contamination and hybridism resulted in complicated geology of certain massifs [42, 45, 60].

In the paragenetic range of Novoukrainskiy Complex rocks there are clearly defined initial and final members of magmatic processes comprised respectively of gabbro-monzonite and charnockite-granite rock associations [8, 28, 42].

The first rock association comprises Kaluzka, Verbivska, Grafska, Novovolodymyrivska, Kudashivska and some other smaller intrusions in the map sheet L-36-IV territory. All these ones are rounded or oval-shaped and 2 to 20 km^2 in size. According to geophysical data [47], these intrusions are columnar bodies which are clearly expressed in the main magnetic ($I = 870\text{-}2350 \cdot 10^{-3}$ A/m), rarely in gravity (2.80-2.97 g/cm^3) fields by the ring or semi-ring anomalies. The contacts of intrusions with host amphibole-pyroxene gneisses of Spasivska Suite and Archean plagiogranitoids are both cutting and conformable. The contact modifications are completely obscured by later extensive Paleo-Proterozoic granitization.

Almost all intrusions composed of gabbro-monzonite association underwent later Paleo-Proterozoic ultra-metamorphic granitization but had preserved some patterns of primary zonation expressed in the chain-semi-ring distribution of the rocks. In the central zone small relic bodies of hornblendites and gabbro-amphibolites predominate, in the middle zone – larger bodies of gabbro-monzonites, monzonites and quartz-monzonites; in the marginal zone as well as in cementing material of previous zones there are mainly developed diorites, granodiorites and porphyry-blastic granites and migmatites of the same composition. The rocks of latter zone, as revealed from detailed mapping [42, 45, 60], belong to Kirovogradskiy Complex and were formed through ultra-metamorphic re-working of Novoukrainskiy Complex rocks as well as their host gneisses of Ingulo-Inguletska Series.

Charnockite-granite rock association of Novoukrainskiy Complex constitutes larger massifs (up to 200 km^2 in size) in the map sheet M-36-XXXIV – Verblyuzhskiy and Bokovyanskiy. In the latter locally are developed monzonites and quartz monzonites which are thought to be relicts of initial Complex members formerly developed there [8, 28].

Verblyuzhskiy and Bokovyanskiy charnockite-granite massifs, in contrast to gabbro-monzonite intrusives, are elongated in the north-western direction (in accordance with host-rock tectonics) and in their marginal parts contain abundant xenoliths of the host rocks, mainly pyroxene gneisses of Spasivska Suite. Their contacts with gneisses are smoothed (injection). These massifs also display zonation patterns of another type. The central parts are composed of coarse-grained or porphyry charnockite-granite varieties whereas marginal parts – of medium- and fine-grained varieties of charnockite-granites and, in lesser extent, granodiorites.

By physical properties the rocks of both massifs are characterized by high density (2.74-2.76 g/cm^3) and weak magnetization ($I = 153\text{-}440 \cdot 10^{-3}$ A/m) providing their good expression in gravity and magnetic fields [47].

The massifs are mainly composed of: charnockites and pyroxene, rarely amphibole and biotite porphyry granites – Verblyuzhskiy; biotite, rarely amphibole and pyroxene porphyry granites with minor porphyry granodiorites – Bokovyanskiy. In marginal parts of both massifs along tectonic breaks microcline-albite metasomatites are widely developed. Detailed description of the Complex rocks is given elsewhere [8, 16, 28, 41, 42, 45, 51, 59, 60].

By petrochemical features, some members of gabbro-monzonite association and almost all ones of charnockite-granite association belong to sub-alkaline range of intrusive rocks. The second association predominates suggesting by some evidences [8, 28] for crust-mantle source of the Complex rocks. Apparently, formation of this poly-facies Complex commenced with emplacement of basaltoid magma with further active syntectic substratum melting under conditions of extensive tension in the eastern part of Ingulo-Inguletskiy area (mega-block).

Age of hornblendites (Novovysunskiy Massif in adjacent area) determined by U-Pb method on zircons is 2110 Ma [45], and Bokovyanski granitoids – 2080-2330 Ma [41] that confirms ideas on multi-phase and durable formation of both associations in the Complex.

The leading metallogenic specialization of the Complex gabbro-monzonite rock association is apatite-ilmenite [45], and the charnockite-granite association – rare-metal [41, 60].

Kirovogradskiy Complex (PR_1kg) of ultra-metamorphic granitoids is widely developed over both map sheets in the Ingulo-Inguletskiy area, especially in Kirovogradska LTZ. Locally these rocks are also known in Inguletsko-Kryvorizka LTZ and at the boundary between two geological areas in the zone of Kryvorizko-Kremenchutskiy Deep-Seated Fault (at the margins of Skhidnogannivska Syncline and other sites).

Previous studies [41, 42, 51, 52, 53, 54] had revealed that granitoids of the Complex are involved in two modification groups: the first one includes dome-shaped uplifts (Olympiadivske, Gurivske and others) which comprise almost completely remobilized blocks of Archean plagiogranitoids or the zones of linear (along faults) reworking within Inguletskiy Complex plagiogranitoids; the second group – dome-shaped massifs (Zelenogayskiy, Volodymyrivskiy and others) and inter-layer bodies formed under ultra-metamorphic reworking pf Paleo-Proterozoic Ingulo-Inguletska Series and Novoukrainskiy Complex rocks.

The first group is confined to the marginal parts of Ingulo-Inguletskiy area but outside the map sheet areas reverse relations are observed.

Almost in all mentioned tectonic units the Complex granitoids are related to the host rocks by gradual transitions and contain relicts of the latter, especially in contact zones. In some massifs only (Zelenogayskiy etc.) and in the vein bodies of aplite-pegmatoid granites their contacts are sharp-cutting and the rocks are discordant to the host rocks.

Among granitoids formed through reworking of Archean basement are more abundant fine- and medium-grained, rarely porphyry-blastic banded and shadowed plagio-microcline granites and migmatites which are being considered by many authors [12, 34, 41, 53] as poly-migmatites. They normally differ in pink colouring caused by increased microcline content and occurrence of schlieren enclaves of aplite-pegmatoid granites. And only in places of Archean amphibolite reworking, besides amphibole-bearing granites also are developed diorites and granodiorites as well as migmatites of the same composition. In geophysical fields these granitoids are expressed by negative gravity anomalies (2.59-2.65 g/cm^3) and slightly increased mosaic magnetic field ($I = 7\text{-}99 \cdot 10^{-3}$ A/m) thus their contours are being mapped by geophysical methods.

By opaque minerals content biotite and amphibole-biotite varieties are distinguished in these granitoids. They normally contain corrosion-metasomatic textures and bi-metasomatic reactions at the contacts with chemically active rocks. Thus we can agree with previous authors [41, 42, 51, 53] concerning conclusion on formation of these granitoids mainly through metasomatic granitization.

In granitoids formed during ultra-metamorphic reworking of Paleo-Proterozoic rocks porphyry-blastic rocks predominate of which also two groups of granites and migmatites are distinguished – biotite and amphibole-biotite ones, as well as granodiorites and diorites where often is observed trachytoid texture and wide development of blastic, mirmekite and corrosion textures [11]. Regular association of these granitoids with pyroxene gneisses of Spasivska Suite and gabbroids of Novoukrainskiy Complex (with their frequent relicts) [42], anchieutectic composition [41] and petrochemical dependence on source rocks [53] suggest for complex metasomatic-anatectic origin of porphyry-blastic granitoids. Their distinct feature comprises considerable matter migration (including ore components) with development of vein phase of aplite-pegmatoid granites and metasomatites providing evidences for the ore-bearing potential [42, 53].

Less developed uniform-grained granites and migmatites (with inter-layer bodies within rocks of Ingulo-Inguletska Series) are characterized by homogenous composition, grano-blastic textures and occurrence of injections and side-contact modifications in the marginal facies allow consideration these rocks formed from crystallization of anatectic melt [11, 16].

Both groups of Kirovogradskiy Complex granitoids are related to metasomatic rocks of albite-microcline composition widely developed in the zones of various orientation coupled with the rocks skarnation, greisenization and silicification (often with ore mineralization). Their description as well as granitoids of the Complex is given elsewhere [41, 42, 45, 516 52, 53, 60, 62 etc.].

REE distribution patterns [42] and high values of K-Rb and Rb-Sr ratios in granitoids of the Complex suggest for shallow and moderate depths of these autochthonous and para- autochthonous rocks formation apparently related to the final stage of regional metamorphism in the Ingulo-Inguletskiy area (mega-block). It is supported by numerous isotopic age determinations of granitoids falling within interval 2100-1850 Ma [8, 27, 42, 53]. Thus, formation of Kirovogradskiy Complex granitoids occurred on the background of final crust consolidation in the Ingulo-Inguletskiy area.

Neo-Proterozoic

Precambrian magmatism is finished with Neo-Proterozoic Dyke Complex (βPR_3) that suggests for beginning of the platform regime. The rocks are mainly observed in linear dyke belts confined to the latitudinal breaks in the Ingulo-Inguletskiy area and adjacent marginal parts of the Middle-Dniprean area. There dykes cut all units described above, mainly the rocks of Ingulo-Inguletska and Kryvorizka series. The dykes are being clearly mapped by geophysical methods due to their high magnetization (I = 1950-2100$\cdot 10^{-3}$ A/m).

Dyke thickness varies from 1 to 30 m, length (by geophysical data) – up to 3-5 km, dipping is vertical. Contacts with host rocks are sharp often though thin (first centimeters) zones of contact alteration.

By composition dykes are mainly composed of diabases, rarely gabbro-diabases and gabbro (in Dobronadiivska and Verblyuzhska fault zones). Their detailed petrographic description is given elsewhere in geological mapping reports [12, 41, 51, 59, 60, 62]. Related ore mineralization (mainly titanium-magnetite) is not economic and is of mineragenic interest only. By chemical composition the dykes belong to derivates of low differentiated tholeiite-basalt magma [16, 24].

Isotopic age of diabases by K-Ar determinations varies from 1200 to 1600 Ma [60].

PHANEROZOIC

PALEOZOIC-MESOZOIC

Permian-Triassic

Sub-volcanic rocks (αP-T) of andesite-trachyandesite composition are encountered in Kryvorizka structure at the cross-junction of Kryvorizko-Kremenchutskiy Deep-Seated Fault and Devladivskiy Fault (V.A.Tykhonov, 1968; L.F.Mordovets, 1977). In Kryvorizka Series rocks (in the northern part of flexure-like Pershotravneva structure) there is observed bifurcation of tectonic zones and Ternivska crypto-volcanic structure is encountered. On the surface it is 800x500 m in size and to the depth (about 1000 m) it conically expands to 2500x700 m and more.

Volcanic structure is composed of lavas, often bubbly, which are andesitic at the margins and trachyandesitic, in places basalts in the central part. From the marginal parts of volcanic unit, along tectonic zones, some branches are observed where lava-breccias and explosive breccias together with tectonic breccias are developed.

Andesites comprise crypto-crystalline rocks, often porous and with vesicles. In the rocks, together with volcanic glass (often replaced by chlorite or montmorillonite) garnet, spinel, muassanite, pigeonite and high-pressure minerals (coesite, stishovite) are also observed. Detailed description of these rocks is given elsewhere [21].

In explosive breccias, besides blocks of Kryvorizka Series rocks (graphite schists, ferruginous quartzites, amphibolites) and underlaying plagiogranites are also found fragments of bubble lavas. Occurrence of the latter, as well as some layers of vesicular-textured volcanics, suggest for pulsing type of volcanic eruptions. At the same time, occurrence of high-pressure minerals and planar elements (in magnetite and quartz) suggest for explosive nature of volcanic activity.

Isotopic age of volcanics determined by K-Ar method is 250$\pm$10 Ma that corresponds to the end of Permian – beginning of Triassic [21]. In view of age and composition of the rocks described sub-volcanic units apparently comprise the tongues of Mesozoic basalt-andesite volcanic arc located to the south (in Kakhovskiy area) and formed during collision of Chornomorska Plate with southern part of Eastern-European Platform (V.M.Rybakov, 2000).

4. WEATHERING CRUST OF CRYSTALLINE ROCKS

Metamorphosed (Precambrian) and unmetamorphosed weathering crusts of crystalline rocks are developed in the studied areas. Metamorphosed weathering crusts are described above in the section “Stratified units”.

Over the most area underlain by crystalline rock there is developed unmetamorphosed weathering crust of planar type formed after overall rocks of crystalline basement (Fig. 4.1). Weathering crust is normally overlain by Paleogene and Neogene sediments. Numerous records described in the works of Yu.B.Bass, M.B.Slavutskiy, M.D.Elyanov and others suggest for crust formation over Paleozoic-Mesozoic time.

By forming conditions two types of weathering crust are distinguished – planar and linear. The first one is fairly widespread and displays normal zoning. Thickness of this crust type over most territory is 5-30 m, in places it raises up to 50-70 m. Linear crust type is locally developed and is controlled by fault structures and certain rock varieties susceptible to weathering. Thickness of this crust type attains 150-200 m (excluding deep hypergenic zones occurred in Kryvorizka structure). Among planar weathering crusts the units developed after granitoid rocks are most widespread providing complete three zones (upward):

1. Zone of initial weathering products (disintegration zone) where disintegration degree increases upward up to formation of gruss-gravel material. Thickness of the zone varies from 1 to 10 m.

2. Transitional weathering product zone (hydro-mica-kaoline) from 1 to 10 m thick. In this zone partial kaolinization of the feldspar rocks occurs without breaking their primary texture and structure features.

3. Zone of complete kaolinization (kaoline) which corresponds to the stage of the final weathering products and is composed of hydro-micas, kaolinite, quartz, as well as aggregates of montmorillonite and hydro-chlorite. Thickness of this zone varies from 10 to 25 m.

Transitions between the zones are gradual, smoothed.

Vertical section of weathering crust after gneisses is similar to that of granitoids: there are distinguished all three aforementioned zones although due to increased amount of opaque minerals the hydro-mica zone is more expressed and its thickness rises up to 10-15 m.

Weathering crusts after mafic rocks are characterized by the following (upward):

1. In the first zone (disintegration) the rocks underwent incipient disintegration and their rock-forming minerals are weakly altered.

2. In the second zone (hydro-mica) the rocks underwent more weathering and are composed of montmorillonite, hydro-micas, hydro-chlorite, and kaolinite.

3. The third zone (final products) is most complex and by mineral content there are distinguished two sub-zones:

- montmorillonite-hydro-chlorite (rarely nontronite) parti-coloured – from greenish-grey to red-brown and even violet colours;
- hydro-goethite-gibbsite, bauxite-like, where two horizons in turn are distinguished: i) ochres and brown iron-stones and ii) bauxites and bauxite-like rocks.

The total thickness of weathering crust after mafic rocks varies from 5-15 m to 30-40 m attaining 60-70 m in places.

Weathering crust after ultramafic rocks of Verkhivtsivskiy and Devladivskiy complexes also displays zoned patterns and differs in well-expressed iron-enrichment. Directly upon serpentinites is being formed nontronite zone which is further changed by the zone of ochreous iron hydroxides with minor gibbsite and kaolinite. Upper portions of the section comprise brown iron-stones.

Weathering crust after ironiferous rocks of Saksaganska and Artemivska suites includes two zones:

1. Disintegration zone composed of oxidized quartzite gravels. Primary texture of the rocks is well-preserved.

2. Zone of transitional products is normally thin and comprises brown iron-stone masses. Both iron-ore minerals and silicates are broken and replaced by iron hydroxides.

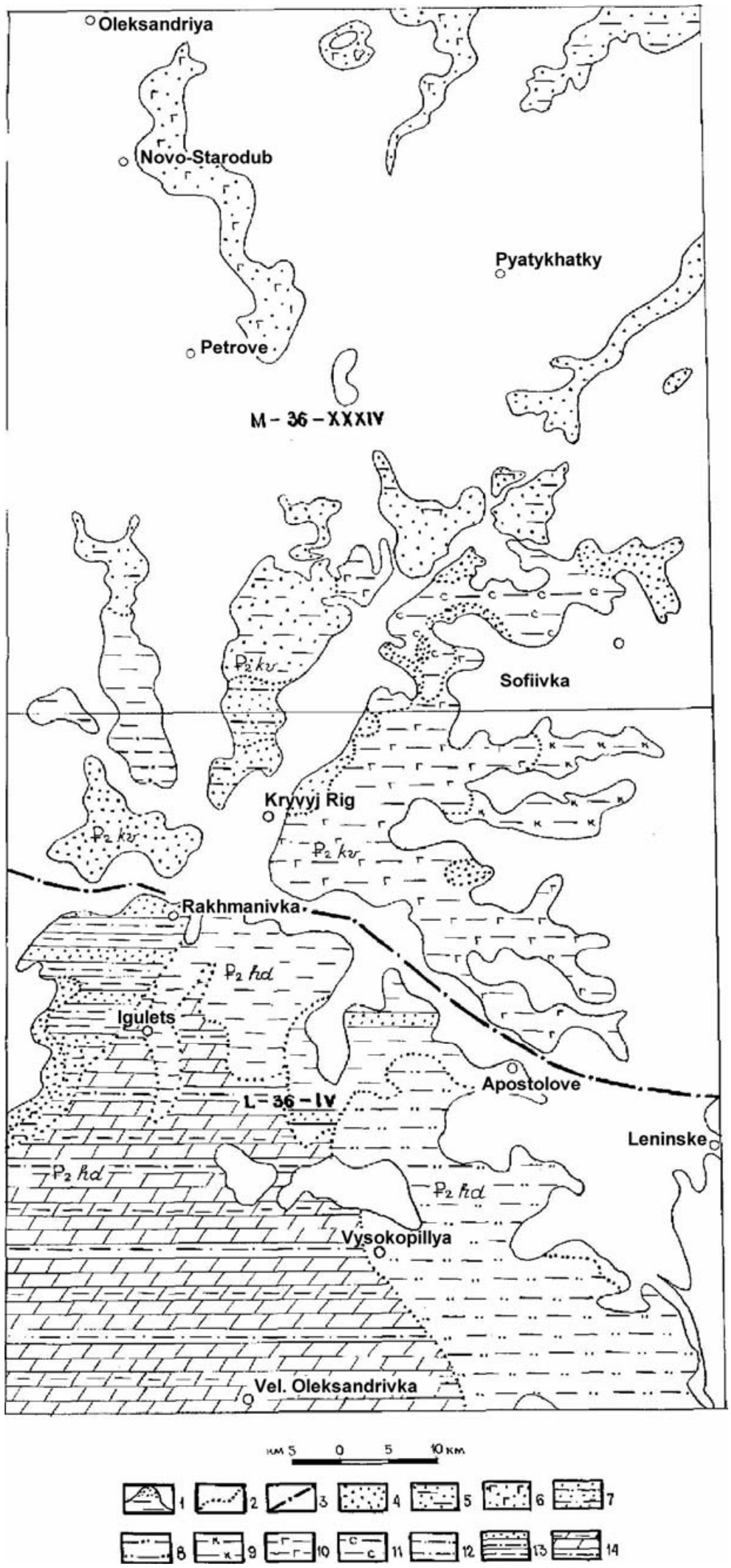
Non-ore quartzites are normally resistant in hypergenic zone and commonly they form thin weathering crust composed of disintegrated rocks only.

More detailed description of weathering crust after crystalline rocks over territory of map sheets M-36-XXXIV and L-36-IV is given elsewhere [12, 19, 42, 52, 60 etc.].

Weathering crusts in the studied areas contain deposits and occurrences of brown iron-stones, nickel, cobalt, aluminum, kaoline [45, 57, 58]. Stream-sediment sampling of weathering crust had revealed the points of increased ilmenite, zircon and gold content [29, 33, 41, 46, 51] but no economic deposits are found yet.

Fig. 4.1. Schematic geological map of crystalline basement weathering crust.

1 – area of weathering crust development; 2 – places of lacking weathering crust; 3-6 – zones of planar-type weathering crust: 3 – zone of the final stable weathering products (laterite), 4 - zone of the final stable weathering products (kaolines), 5 – zone of transitional weathering products (hydro-mica), 6 – zone of initial weathering products (disintegration); 7 – linear-type weathering crust zones; 8-13 – deposits (a) and occurrences (b) with numbers in the list to the left of symbols: 8 – nickel, 9 – aluminum, 10 – titanium, 11 – zirconium, 12 – kaoline, 13 – bauxite-prospective site; 14 – boundaries of weathering crust.



5. TECTONICS

Tectonic zonation

According to the description of geological units given above there are clearly distinguished two tectonic levels: Lower Level – crystalline basement of complex structure, and Upper Level – Mesozoic-Cenozoic platform cover.

Precambrian units of the Lower Tectonic Level, in accordance with "Correlation stratigraphic scheme of Precambrian rocks in Ukrainian Shield" (Kyiv, 2000), are located in two geological areas – Middle-Dniprean and Ingulo-Inguletskiy ones, which strongly differ not only in the rock composition and age but also in the patterns of geophysical fields, tectonic elements and thickness of earth crust.

The major tectonic elements in the Middle-Dniprean area comprise Archean granite-migmatite domes and inter-dome greenstone syncline structures. The latter are well-expressed in gravity fields by considerable gravity anomalies – up to 6-8 mGl. They do correspond to the complex and discontinuous magnetic fields with numerous local anomalies up to 10-30 thousand nTl of magnitude. In between the greenstone anomalies the gravity fields are normally flat (above plagiogranitoid domes) and discontinuous (above two-feldspar granitoid domes). Combination of two mentioned types of Archean structures allowed most authors [5, 8, 9, 15, 27, 42 etc.] consideration the Middle-Dniprean area to be Archean granite-greenstone terrain (mega-block) with leading role of igneous processes. It is supported by occurrence of volcanic rocks in riftogenic greenstone structures where micro-plate extension environments are preserved. Thickness of earth crust in the granite-greenstone terrain is reduced to about 30 km [5].

The marker rocks in granite-greenstone terrain (mega-block) comprise volcanics of Konkska Series that are mostly developed in Verkhivtsivska and Chortomlytska structures which marginal parts enter into both map sheets. Actually Zhovtovodska and Vysokopilska synclines comprise extensions of mentioned structures. These are volcanic rocks with distinct geology and composition which provide the territory zonation and allow definition of Verkhivtskivsko- Chortomlytska LTZ in the western part of granite-greenstone terrain. Greenstone rocks of this zone together their hosting granitoids constitute the Lower (Archean) Tectonic Floor within Precambrian Tectonic Level.

In the Ingulo-Inguletskiy area the major tectonic units include Paleo-Proterozoic graben-syncline structures (mainly sub-longitudinal tending) which to the west of Inguletskiy Fault getting together into the single (Ingulo-Inguletskiy) synclinorium of the same strike [6]. Mentioned structures are clearly expressed in gravity fields with high gravity values and occurrence of numerous magnetic anomalies up to 5000 nTl magnitude. Joining each other in space by various directions, these anomalies reflect the principal features of graben-syncline structures in the Ingulo-Inguletskiy area. The synform structures are mainly composed of sedimentary rocks (flysch-like and terrigenous formations) transformed (under metamorphism) mainly into gneisses. From these records, most authors [8, 13, 15, 42] believe that territory of Ingulo-Inguletskiy area belongs to Paleo-Proterozoic para-gneiss belt (mega-block) where geology is dominated by tectonic deformations. Particularly, it is evidenced by huge sedimentation, extensive folding, metamorphism and magmatism, as well as development of abundant longitudinal (along the belt) deep-seated faults. All the units were formed under conditions of micro-plate (block) extension-collision. Thickness of earth crust in the para-gneiss belt varies from 40 to 48 km [5].

Kirovogradska LTZ comprises principal units of the Ingulo-Inguletskiy para-gneiss belt (mega-block). Zonation of this unit is derived from distribution patterns of Spasivska and Checheliivska suites sedimentary rocks, as well as intrusive rocks of Novoukrainskiy Complex and ultra-metamorphic rocks of Kirovogradskiy Complex (on approach of Inguletskiy Fault).

In the east of this belt (between Inguletskiy Fault and Kryvorizko-Kremenchutskiy Deep-Seated Fault, KKDSF) there is distinguished Inguletsko-Kryvorizka LTZ where mainly meta-sedimentary rocks of Zelenorichenska, Artemivska and Rodionivska suites fill up sutures between the blocks of Archean plagiogranitoids (Lower Floor). This zone displays extensive linear folding (both in synclines and in Archean blocks) and development of banded iron formation. In view of these main features the Inguletsko-Kryvorizka LTZ is considered to be transitional (buffer) zone between para-gneiss belt and granite-greenstone terrain. Specifically, the rocks of this zone along the central axis of KKDSF (Tarapakivskiy Fault in Kryvbas) are thrusted by 2.5-3 km over the rocks of Kryvorizko-Kremenchutska LTZ at the marginal parts of granite-greenstone terrain [53].

Kryvorizko-Kremenchutska LTZ is confined to the marginal (eastern) part of the same-named deep-seated fault which separates two major Precambrian mega-blocks – stable and mobile ones. In the syncline structures of this zone (Saksaganska and others) there are preserved both extensive compression records and some elements of subduction beneath Ingulo-Inguletskiy para-gneiss belt [42, 53]. Thickness of earth crust in Kryvorizko-Kremenchutska LTZ is highest in the area – 55 km. Paleo-Proterozoic meta-sedimentary rocks of this belt together with stratigraphic analogues of Kryvorizko-Kremenchutska LTZ constitute the Upper (Proterozoic) Tectonic Floor within Precambrian Tectonic Level. The boundary between Archean and Proterozoic tectonic floors is mainly marked by the ancient metamorphosed weathering crust. In the map this contact line is quite curvilinear and is observed over both sides (but just nearby) the zone of KKDSF.

Mesozoic-Cenozoic sediments of the Upper Tectonic Level, according to the "Legend for geological maps of Ukraine in the scale 1:200,000" (Kyiv, 1996), are developed in two geological areas of Ukrainian Shield – the Central and Southern ones. The Central area does correspond to the elevated (axial) part of the Shield. There, mainly in depression structures, are developed Paleogene sediments whose laying forms strongly depend on the relief of crystalline basement. Conversely, the Southern area encompasses southern slope of Ukrainian Shield (as far as Prychornomorska Depression) where Paleogene sediments lie with slight southern inclination (often along benches split by series of latitudinal breaks). Neogene sediments lie almost horizontally in both areas. The boundary between the Central and Southern areas in Paleogene is positioned in the central part of map sheet L-36-IV, and in Neogene – approximately along the border between the sheets.

In compliance with the mentioned tectonic and paleo-geographic environments, more detailed zonation is completed within areas. In the central area there are distinguished Oleksandriysko-Apostolivska and Vilnogirska LTZs, and in the Southern area – Vysokopilska and Shyrokivska LTZs. Substantiation for their definition and their facial features is given elsewhere in the section "Stratified Units".

Structures of Archean Floor

Tectonic layout of Archean Floor is defined by combination of greenstone syncline and granitoid dome-shaped structures.

Greenstone structures comprise principal units in granite-greenstone terrain. These include linear-type syncline structures and central-type volcano-tectonic depressions.

The linear-type syncline structures include major synclines (up to 5-6 km wide) – Vysokopilska, Zhovtovodska and Alferivska, as well as some minor synclines (up to 1-2 km wide) – Mykolaivska, Novopavlivska and others. All these ones are linear-shaped over the distance of first tens of kilometers highlighting their key role in fault formation. In the plane, some of mentioned structures (Novopavlivska) are bifurcated, other ones are swelled (Vysokopilska) or discontinued by strike (Alferivska). At the same time, all these structures are steeply-dipped (55-75^o) and often are complicated by secondary folds [42].

In gravity maps these structures are expressed with high-magnitude positive anomalies. By geophysical data, syncline structures are extended to the depth 5-7 km, the minor ones – to the depth 1-2 km [47]. Their lower portions are composed of basalt-tholeiite and komatiite formation rocks which underwent essential granitization. Upper portions of large synclines are filled with andesite-basalt formation, and Alferivska syncline also with rhyodacite formation; taken together these formations define homodrome volcanic trend in the linear-type greenstone structures.

Central-type volcano-tectonic depressions form some linearly-arranged chains of volcanic units up to first tens of kilometers in size. Of these, Yavdotivskiy, Dovgyntsivskiy and Oleksandriyskiy volcano-tectonic depression chains are rather continuous being formed of 3-5 individual central-type volcanic units; together with mafic-ultramafic rocks of Verkhivtsivskiy Complex these units do form Yavdotivsko-Oleksandriyskiy igneous belt [42].

All central-type volcano-tectonic structures are characterized by the following features:

- brachy-syncline (funnel-like) shape with fairly steep (up to 60-70^o) dip angles;
- ring or semi-ring (in the plane) arrangement of lava flows, sill and dyke bodies, well-expressed in gravity and rarely magnetic fields by isometric anomalies;
- regular distribution of igneous rocks within the units: volcanic rocks over periphery, sub-volcanic rocks in marginal and transitional zones, and intrusive rocks in the central parts of structures;
- ring and semi-ring faults that separate the core, transitional and marginal zones, and radial faults that split structures into the blocks. The faults are often "sealed" with dyke rocks;
- the size of Archean units being comparable with Phanerozoic volcano-tectonic structures (from 5-6 km to 10-12 km across).

The limbs of most volcano-tectonic structures are deformed and structures themselves are often flattened both in sub-latitudinal (Oleksandrivski paleo-volcanoes) and in sub-longitudinal (group of Yavdotivski and Dovgyntsivski paleo-volcanoes) directions. Depth of these structures (derived from gravity anomalies) does not exceed 2.5 km (Fig. 5.1).

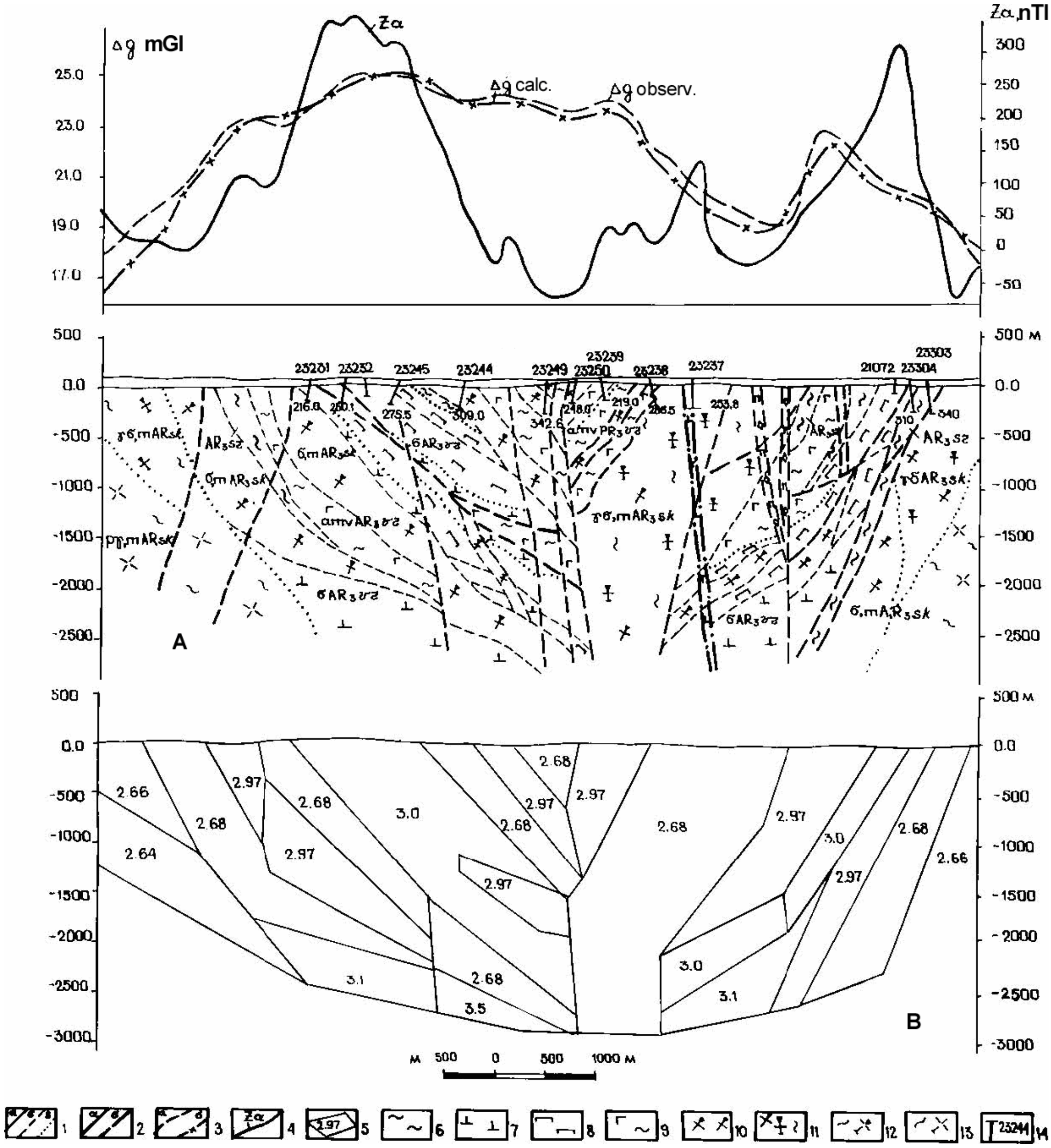


Fig. 5.1. Geological section (A) along interpretation fence (B) through Oleksandrivska volcano-tectonic structure.

1 – geological boundaries: proven (a), probable (b), facial (c); 2 – faults: proven (a), probable (b); 3 – gravity field curves: Δg – observed (a), calculated for given section (b); 4 – Za curve; 5 – blocks selected by Δg curve; Konkska Series: Surska Suite – AR_3sr (6 – amphibolites); Verkhivtsivskiy Complex – AR_3vr (7 – pyroxenites, peridotites; 8 – actinolitites, tremolitites; 9 – gabbro-amphibolites); Saksaganskiy Complex – AR_3sk (10 – amphibole diorites, 11 – granodiorites, granites and migmatites: 12 – amphibole-biotite, 13 – biotite); 14 – drill-holes and their numbers.

Volcano-tectonic depressions are composed of basalt-tholeiite and komatiite formations together with gabbro-peridotites of Verkhivtsivskiy Complex. In the southern group of volcanic units in Yavdotivsko-Oleksandriyskiy igneous belt, gabbro intrusions and gabbro-dolerite sills predominate over metabasalt lava rocks, whereas in the northern group reverse relations are observed. Marginal parts of volcanic units and especially their internal zones (inferred neck places) are considerably granitized and transformed into migmatites of diorite and granodiorite composition. Some fragments only of such the units are preserved from extensive granitization within Komisarivska Fault Zone and in Tokivskiy Massif.

Formation of these structures is apparently related to the local (or one-side) extension of micro-plate-blocks resulted first in formation (along breaks) of volcanic units and then, upon deposition of thick lava piles, the unit subsidence by ring faults with formation of depressions. The sill and dyke rocks of Verkhivtsivskiy Complex were emplaced first into the weakened fault zones followed by granite magma emplacement in association with growth of adjacent plagiogranitoid diapiric domes. Due to subsequent tectonic motions the units were deformed and eroded, while hypabyssal gabbroid stocks from magma chambers were brought to the surface.

Granitoid dome-shaped structures (Pyatykhatska, Saksaganska, Shyrokivska, Arkhangelska and others) comprise another structure type in granite-greenstone terrain. Their dome shape, mapped mainly by geophysical data [47], is generally highlighted by periclinal laying of linear-planar textures in migmatites. It is revealed from recent studied [8, 42, 53] that shape of domes is often broken both at formation stage and subsequent deformation phases and this is why the shape is highly variable and normally depends on morphology of surrounding greenstone synclines.

Analysis of dome-shaped structures allows definition of their three main features [8, 15, 16, 42]:

- occurrence of rough (and not always equally prominent) zonation: biotite plagiogranitoids predominate in the core and transitional zones, whereas marginal zone is mainly composed of amphibole-bearing granites, grnodiorites, rarely diorites and migmatites of the same composition, formed through re-working of greenstone rocks. This suggests for plagiogranitoid domes formation mainly after older substratum – tonalite proto-crust;
- overall conformity of greenstone structures to the tectonic plane of plagiogranitoid domes suggesting for their synchronous or joined formation;
- tight association of two genetic groups of plagiogranitoids in the domes: metasomatic and anatectic (rheomorphic) ones. Occurrence of the latter, susceptible to flow and move, obviously facilitated upward penetration of granitizing components and dome formation.

Mentioned geological features of Archean dome-shaped structures allow supposing their diapiric formation during crustal extension in greenstone rifts and crustal collision (with dome growth) in sialic blocks. At the final stages (due to felsic magmatism evolution under conditions of progressive tectonic stabilization) some plagiogranite domes underwent extensive microclinization (Demurinskiy Dome) up to formation of potassium granitoid massifs (Tokivskiy Massif).

Structures of Proterozoic Floor

Tectonic layout of Proterozoic Floor within Ingulo-Inguletskiy para-gneiss belt is fairly complex because in the studied area there is observed the marginal part of the belt which is transitional from granite-greenstone terrain. This transition is gradual and is expressed in westward decreasing the size and number of Archean structures (mainly block-dome) and increasing the number of Paleo-Proterozoic tectonic elements (graben-synclines and tectono-magmatic structures).

Graben-syncline structures (Zelenivska, Zhovtyanska, Artemivska, Petrivska, Main Kryvorizka, Rodionivska and others) comprise major tectonic elements in para-gneiss belt of Proterozoic Floor. Some of them contain numerous large iron deposits. All these structures undoubtedly formed through faulting the Archean basement blocks and their extension with formation of graben units. It is evidenced, particularly, by suture or fault-side kind of most synclines, linearity of their strike (mainly sun-longitudinal), and predominate linear folding resulted from compression of micro-plate-blocks.

By size, the graben-synclines are not large, their length does not exceed 30-35 km and width varies from 2 to 8 km. The folds elongated along the belt in Ingulo-Kryvorizka LTZ often join the same-sized latitudinal folds where tectonic inheritance from Archean greenstone structures is recognized [9, 15]. Conversely, such variously-oriented fold joining within Kirovogradska LTZ is probably caused by several phases of tectonic structure formation in the mobile belt [10].

Two types of syncline structures are distinguished in these two litho-tectonic zones. Specifically, in the Ingulo-Kryvorizka LTZ rock dipping in syncline limbs is normally steep (60-80^o) whereas in Kirovogradska LTZ it is less steep (30-50^o). In the first zone synclines are linearly-elongated (in the plane) and keel-shaped (in cross-section) with steep western dipping of their axial planes. In the second zone synclines are mainly oval (in the plane) and trough-shaped (in cross-section) with symmetric limbs [42]. The depth of the latter structures (derived from computer calculations) does not normally exceed 2.5 km [41] whereas depth of keel-shaped structures may attain 4-4.5 km [12].

Keel-shaped synclines in the Ingulo-Kryvorizka LTZ are normally asymmetric with reduced western limbs, apparently, caused by non-uniform development in different parts of grabens along the faults (subsidence-uplift with further tension). Specifically, it is evidenced in some graben-synclines by occurrence of the second-order anticlines (horsts) with cores composed of Archean granitoids (Zelenivska, Zhovtyanska), or Rodionivska Suite quartzites (Balakhivska, Bereznevatska) which constitute most of the syncline.

Hinges of both syncline types are often variable by strike. In the limbs there are abundant high-order folds and flexure-like bends which often are played as ore-traps [41, 51, 53].

In the zone of KKDSF geology of graben-syncline structures is much more complex due to higher horizontal tension over their formation. As it revealed from recent data [53] tectonics in the central part of Kryvbas is defined by two syncline folds (Main and Saksaganska) which essentially differ each other by morphology and internal composition. The units are separated by the axial (central) branch of KKDSF (Tarapakivskiy in this place) where distinct paragenesis of tectonic forms is developed – keel-shaped nappe-folds and faults [42].

The Main Syncline displays all features of mentioned keel-shaped units in the Ingulo-Kryvorizka LTZ of Ingulo-Inguletskiy para-gneiss belt. At the same time, being displaced along the deep-seated fault zone (its western part), this syncline is essentially deformed by the fault systems of Zakhidniy (Western) and especially Tarapakivskiy faults. Over the latter fault system the Main Syncline is thrusted onto Saksaganska Syncline with vertical displacement amplitude 2.5-3 km, that is supported by differences in metamorphic degree of syncline-forming rocks (at present erosion surface PT-conditions in the first syncline are as follows: temperature 500-530^{o}C, pressure 4.5-5 Kbar, in the second syncline – 400-430^{o}C and 2.7-3 Kbar respectively) [53].

Saksaganska Syncline, which belongs to the eastern part of KKDSF, comprises very tight (with deformed hanging-wall), westward-inclined nappe-fold. By strike and depth Syncline is bounded by Skhidniy (Eastern), Saksaganskiy and Tarapakivskiy faults. Together with these faults Syncline changes its steep dipping at surface (up to 75^{o}) to more flat (up to 40^{o}) at the depth 6-7 km where it is pinched out [53]. The same faults split the Syncline into series of sheets (nappes) and underthrust them mainly by Tarapakivskiy Fault (perhaps, by others too) beneath the Main Syncline [42]. It is supported by wide development of flowing and squeezing textures, described in details by G.V.Tokhtuev and other authors [4, 19, 39], in the rocks of all nappes (including ferruginous quartzites). At the same time, it is thought the underthrust may not be essential in view of remnants of normal stratigraphic succession in Kryvorizka Series rocks observed in Syncline nappes [42].

In Kryvbas, the similar tectonics is displayed by Skhidnogannivska Nappe – the syncline where in its western, extensively deformed limb, by Tarapakivskiy Fault (between given syncline and the Main Syncline), there is uplifted to the surface the sheet of Archean plagiogranitoids [1], partially regenerated in Paleo-Proterozoic. These two major ore-controlling structures of Kryvbas (Saksaganska and Skhidnogannivska) are separated by Pershotravneva Flexure (with steep western dipping of ironiferous rocks) of fold-block type. Its detailed description is given elsewhere in [53].

The regular development of two main groups of geological formations comprises the distinct feature of all mentioned syncline structures of Proterozoic Floor.

The first group includes mainly rocks of banded iron formation and carbonate-carbonaceous formation (often together with basalt formation at the base) metamorphosed from greenschist to amphibolite facies. This group constitutes all linear-keel synclines and nappe-synclines in the Ingulo-Kryvorizka and Kryvorizko-Kremenchutska LTZs. The second group comprises mainly flyschoid (carbonate-terrigenous and terrigenous) formations metamorphosed under amphibolite and granulite facies. The rocks are mainly developed in the oval-trough synclines of Kirovogradska LTZ. Such combination of lithological and tectonic units in different parts of para-gneiss belt confirms previous assumption on some (with simplification) inheritance of Archean greenstone troughs by the syncline structures at the edge of the belt. The best example provides Inguletska (in Kryvbas), Zhovtovodska and some other Paleo-Proterozoic synclines inserted into Archean structures. However, most of Paleo-Proterozoic synclines (mainly sub-longitudinal) are newly-formed, developed under conditions of multi-phase extension-compression of Archean basement blocks.

Granitoid dome-shaped structures comprise the second major tectonic type in para-gneiss belt. At the belt margins, these ones include the ledges of Archean plagiogranitoids in consolidated blocks, and granite-migmatite (poly-migmatite) dome-shaped uplifts, which actually comprise the same Archean plagiogranitoid ledges but almost completely re-mobilized in Paleo-Proterozoic.

The two first forms of tectonic units (ledges and uplifts) most authors [5, 8, 15, 41, 42, 51] are considered to be the block-dome structures. Their distribution and patterns in the Ingulo-Inguletskiy para-gneiss belt are thought to be regular.

Specifically, in the Ingulo-Kryvorizka LTZ plagiogranitoid blocks are much bigger than in Kirovogradska LTZ, and their erosion cut is higher [42]. It is supported by better arrangement of plagiogranitoid textures, less abundant substratum remnants in the core parts, geochemical records, and overthrusting of the belt marginal portion onto granite-greenstone terrain [41, 51, 53]. These Archean plagiogranitoids are only in part regenerated by Paleo-Proterozoic ultra-metamorphic processes but are highly re-worked by Paleo-Proterozoic tectonic deformations in comparison to Kirovogradska LTZ where these rocks in the blocks are almost completely re-mobilized and transformed into poly-migmatites. Thus, the block-dome structures in both zones belong to the Upper (Paleo-Proterozoic) Floor. Their block nature is evidenced by the following records [42]:

- occurrence of stratigraphic unconformity relicts in around of some domes (Inguletskiy, Zelenivskiy);
- occurrence of the faults, which completely or partly surround some domes (Petrivskiy, Gurivskiy etc.);
- occurrence of the older granitoids in the dome cores in comparison to the periphery;
- lack of zonation characteristic for diapiric domes in granite-greenstone terrain;
- tectonic independence of core regions in some domes (with preserved tectonic trends of substratum relicts).

Presented data suggest for apparent major factors of Paleo-Proterozoic block granitoid dome formation in the belt marginal part to be conditions of micro-plate-block tension coupled with folding and metamorphism in synclines.

Dome-shaped massifs (Pishchanobridskiy, Starodubskiy, Volodymyrivskiy and others) formed during metamorphogenic granitization of mainly pyroxene and biotite gneisses of Ingulo-Inguletska Series, rarely gabbroids of Novoukrainskiy Complex, are less developed in the studied area. These are most characteristic for adjacent western areas [11, 16].

These massifs, mainly in Kirovogradska LTZ, do form elongated, rarely isometric, comparatively small domes (up to 10-12 km^2 in size). Evidently, these dome-shaped units are superimposed or secondary ones since they are developed after other, previously-formed anticline structures composed of metamorphic rocks or the rounded intrusive massifs. It is evidenced by the internal features of the dome-shaped massifs where normally is distinguished the external zone (up to first tens of meters thick) with wide development of substratum rock textures, often tight vertically compressed, and the internal zone composed of the body of anatectic-metasomatic granitoids with relict elements of primary anticline structure. More detailed description of these massifs is given elsewhere in the reports on DGM-50 [41, 51, 54].

The growth and development of mentioned massifs had normally occurred in the high-grade metamorphic rocks and apparently took place under tension conditions accompanied by upward heat flows. In case of thermodynamic regime increase these rocks may be transformed into intrusive ones similar to the rocks of Bokovyanskiy and other massifs.

Tectono-magmatogenic structures had been formed at the final stage of the Ingulo-Inguletskiy para-gneiss belt development and provided modifying influence over the belt tectonics [8, 16, 28, 42]. These induced structures caused by interaction of tectonic and igneous processes, particularly, fault-side granitoid massifs and mafic-ultramafic intrusions of Novoukrainskiy Complex.

The most prominent features of these rocks of intrusive origin include:

- clear relation mainly to longitudinal ZakhidnoInguletskiy and Inguletskiy faults, which separate two litho-tectonic zones of the mobile para-gneiss belt;
- development of the massifs (Bokovyanskiy, Verblyuzhskiy) and some intrusions (Volodymirivska, Grafska) at the junctions with north-west-trending faults resulted in their shape elongation in both directions;
- complication of the fold structures in around of the massifs and intrusions suggesting for their breakthrough the bedrock structure;
- development of numerous tectonites and metasomatites in the marginal parts of the massifs and intrusions suggesting for active tectonic environment after formation of these bodies;
- occurrence of early rock association (gabbro-monzonite) remnants in granitoid massifs suggesting for multi-phase history of their formation (allowed by active tectonic environment).

Formation of mentioned tectono-magmatic structures occurred under tension conditions of two major mega-blocks and some underthrusting of the greenstone terrain margin beneath the edge of para-gneiss belt [5].

The fault structures essentially define the spatial distribution and probably forming conditions of most mentioned units. By the scale of their influence on geological processes the faults are clearly subdivided into three categories: I – trans-regional KKDSF, II – regional faults (Devladivskiy, Komisarivskiy, Lykhivsko-Myloradivskiy, Konkskiy, Inguletskiy, ZakhidnoInguletskiy, Dobronadiivskiy, Verblyuzhskiy), III – local breaks.

The first two fault groups (trans-regional and regional) define the principal morphology of tectonic structures in Proterozoic Floor (Ingulo-Inguletskiy para-gness belt) and, in lesser extent, Archean Floor (Middle-Dniprean granite-greenstone terrain). Thus, their maximum development (or settlement) had occurred in Paleo-Proterozoic under emerging extension-compression geodynamic environments [5].

Degree of the fault expression in geophysical fields is variable [47]. Most of faults are clearly distinguished by complex of records (linear gravity-magnetic maximums, gravity gradients, etc.) and these faults are regularly arranged into the lengthy zones [41, 51, 54].

The first arc-shaped faults apparently emerged in the beginning of Neo-Archean during formation (under extension conditions) of rift structures in granite-greenstone terrain. These faults (in Vysokopilska, Zhovtovodska and other greenstone synclines) are normally sealed with numerous volcanic emplacements. Their fragments are mainly recognized by strike-following ultramafic dykes and products of hydrothermal activity [9].

The linear regional faults in the Middle-Dniprean granite-greenstone terrain (Devladivskiy, Komisarivskiy, Lykhivsko-Myloradivskiy and Konkskiy) apparently are emerged late in Neo-Archean during consolidation of Archean basement. It is evidenced by their association with mafic and ultramafic dykes of this age. By geological-genetic features, these faults are thought to be resulted from block extension in cases of Archean basement breaking [42].

During further breaking of Archean consolidated basement into the blocks and formation of side-fault grabens in Paleo-Proterozoic, there commenced formation of sub-longitudinal and then sub-latitudinal faults of Ingulo-Inguletskiy mobile belt (Kryvorizko-Kremenchutskiy, Inguletskiy, Zakhidno-Inguletskiy, Dobronadiivskiy and Verblyuzhskiy). Apparently, by their nature these ones initially were con-sedimentation extension breaks or normal faults (like Inguletskiy Fault), of which later on (at the junction of two mega-blocks only) Kryvorizko-Kremenchutskiy Fault had been transformed into the thrust system. Over their formation these Paleo-Proterozoic faults, besides the newly-formed linear structures, had used (or inherited) the older fragments of the arc-shaped breaks in rift zones. It is, particularly, evidenced by features in some portions of Kryvorizko-Kremenchutskiy and Inguletskiy faults.

Almost all regional faults are normally composed of two-three contiguous parallel breaks, and trans-regional KKDSF (within Kryvbas) – of 3-4 breaks. Among these faults the main suture is often distinguished (in FFDSF this is Tarapakivskiy Fault with a batch of tight folds inside – the nappes and uplifted sheets of Archean plagiogranitoids) [53]. The minor faults are normally arranged in parallel to the major one, in places joining the latter at high angles, or bifurcating and pinching out [42].

Described faults are normally accompanied by all types of brittle deformations (brecciation, cataclasis, milonitization) in the zones from some meters (Komisarivskiy Fault) to hundreds of meters thick (Tarapakivskiy Fault). Besides these, in the fault zones are also found the wide development of viscous-ductile (deep) rocks – blastic, eye-gneissouse, boudinaged, as well as various metasomatites, retrograde-metamorphic rocks and dykes of diverse composition. In the faults of granite-greenstone terrain the dislocation-blastic rocks predominate and frequently mafic-ultramafic dykes are observed whereas in the faults of para-gneiss belt there are encountered more complex dislocation-blastic-metasomatic rocks while the mafic-ultramafic dykes are known in sub-latitudinal breaks only [42]. In the zones of sub-longitudinal faults the high-order folding is more frequently observed. Moreover, in the Tarapakivskit Fault tectonic mélange is encountered (composed of marble blocks cemented by graphite-mica mass), as well as the local high-grade metamorphism and granitization of Ingulo-Inguletska and Kryvorizka Series rocks [53]. More detailed description of mentioned faults is given elsewhere [5, 12, 19, 29, 31, 34, 39, 41, 42, 45, 51, 52, 53, 54, 60, 61, 62].

The major break in the territory of both map sheets is the trans-regional Kryvorizko-Kremenchutskiy Deep-Seated Fault, which attains the upper mantle and separates mega-blocks with different geology. According to recent studies [42, 53], within Kryvorizka structure this fault comprises three-branch system consisting of western branch – Zakhidniy (Western) Fault, central branch – Tarapakivskiy Fault, and eastern branch – Saksaganskiy and Skhidniy (Eastern) Faults. With depth, these faults sharply change their steep dipping (at the surface) to the flat one providing similar deformations in the folded units. The Zakhidniy (Western) Fault (at the border with the consistent plagiogranitoid block) displays arc-shaped bend further joining other faults (as it is evidenced by direction of seismic benches [53]) into the single deep-seated fault.

Of all three branches of deep-seated fault, Zakhidniy (Western) Fault and combined Saksaganskiy and Skhidniy (Eastern) Faults on their exit from Kryvorizka structure (in the north and south) are being separated from the common zone with arc-shaped tongues, bifurcated and pinched out. Tarapakivskiy Fault (central branch of deep-seated fault) is continuously traced over entire Kryvbas splitting the structure into two parts - western (Main Syncline) and eastern (Saksaganska and Skhidnogannivska synclines). Along the plane of this fault the western part of Kryvbas (being the part of para-gneiss belt) is thrusted over 2.5-3 km onto the eastern part, and up to recent it retains the tendency to uplift [42]. Tarapakivskit Thrust, taken as the boundary between two geological areas (Middle-Dniprean and Ingulo-Inguletskiy), comprises the tectonic contact between two series – Kryvorizka and Ingulo-Inguletska.

Besides described faults – trans-regional and regional ones, over the territory of both mega-blocks there are widely developed the local faults which normally cut the fold structures and are limited in length. In physical fields the local breaks are expressed by the chains of linear gravity and magnetic anomalies. Normally the faults are filled with breccias, cataclasites and milonites, often together with products of low-temperature metasomatism (silicified, chloritized, epidotized rocks). Diabase dykes and pegmatite veins are commonly observed in these faults. From these records it can be assumed that most of local faults comprise extension breaks (resulted from primary or secondary compression) and formed in the latest phases of both mega-blocks tectonic evolution.

Upon formation of Proterozoic Floor structures it had commenced period of long-term (Paleozoic-Mesozoic) aerial weathering crust formation.

6. HISTORY OF GEOLOGICAL DEVELOPMENT

Description of Precambrian geological units given above does not allow completely apply the geodynamic model for the territory development designed over last year, with definition of such the major tectonic regimes as spreading and subduction in Archean and Paleo-Proterozoic [5, 19, 45]. None of these regimes is supported by the known geology of Precambrian basement, and first of all in lacking of ophiolites, alkaline gabbroids and other rocks [42, 53]. Thus, it looks likely the plate tectonics with its Phanerozoic features did not operate in Archean and Paleo-Proterozoic. From the data of previous sections it seems more reasonable assumption on the region development in Early Precambrian under some embryonic form (getting more extended in time) of plate tectonics with predomination of extension (rifting) environments in Archean and combination of extension and compression (with incipient thrusting) in Paleo-Proterozoic on the ground of the small-block structure of the earth crust and occurrence of primitive horizontal motions within the blocks (micro-plates) [8, 10, 15].

The studied undertaken [9, 15, 42] had revealed that as yet Meso-Archean the tonalite proto-continental crust did exist which relicts are encountered in Bazavlutske arc-shaped uplift (plagiogranitoids of Dnipropetrovskiy Complex). Their formation was preceded by deposition of mafic volcanics (Bazavlutska Sequence) which apparently together with ultramafics of Oleksandrivskiy Complex had formed the first greenstone belts in the Middle-Dniprean granite-greenstone terrain. The regularities in these oldest rocks development as well as transition to the Neo-Archean stage with further regeneration of greenstone belts remain unclear.

In the Neo-Archean, as it is evidenced by geology of riftogenic greenstone structures and diapiroid domes in the Middle-Dniprean granite-greenstone terrain, predominated extension environments caused by convective motions in the mantle [15]. As a result, along the series of diverse-trending faults the rifts were formed and numerous small blocks of tonalite composition had appeared.

At the early stages of rift development mainly tholeiite and komatiite lavas were emplaced (Surska Suite) with minor siliceous sediments. At the sites of local (or one-side) extension the central-type volcanism had appeared. Significant thickness (more than 3-4 km) of komatiite-tholeiite lavas in the rift synclines suggests for the slow rift extension and fairly fast (apparently sub-marine) chilling of volcanics with formation of jointing fissures and subsidence fractures and emplacement of inter-layer intrusions of Verkhivstivskiy Complex.

At the late stage of the rifts development (recognized in Alferivska Syncline) more intermediate-felsic volcanics appeared as well as sedimentary rocks (Chortomlytska, Alferivska and Solenivska Suites). Felsic lava emerging in the rifts is obviously explained by beginning of tonalite crust melting in the inter-rift blocks caused by the mantle depletion [15]. It was the stage when felsic granitoid magmatism in the inter-rift blocks (together with felsic volcanism in the rifts) had commenced with formation in these blocks the concentric-zoned diapiroid domes composed of Saksaganskiy Complex granitoids and some (rheomorphic) intrusions of Surskiy Complex which, as revealed from high strontium isotopic ratios, were formed through remobilization of Dnipropetrovskiy Complex tonalites.

Potassium granitoids (Demurinskiy and Tokivskiy massifs) had been formed at the final stage of Neo-Archean diapirism, perhaps, simultaneously with moderate deformations (during diapiric growth) and slight metamorphism of greenstone rocks. Their appearance indicates maturity of continental crust in granite-greenstone terrain. Thus, at the end of Archean the Middle-Dniprean granite-greenstone terrain was involved in processes of stabilization stage. It is evidenced by formation of the first linear regional faults (Devladivskiy and others) filled with intrusions of mafic and ultramafic rocks, formation of the giant sub-longitudinal diabase dyke swarm, as well as by development of weathering crust after Archean rocks.

In the neighbouring Ingulo-Inguletskiy mega-block that time (in Archean) apparently had existed the mobile belt (para-gneiss) with granulite-gneiss rock association [8] which small remnants (pyroxene and biotite mafic gneisses) are often observed in the dome cores of Archean plagiogranitoids (almost completely remobilized in Paleo-Proterozoic) in Kirovogradska LTZ. In the buffer Ingulo-Kryvorizka LTZ, which probably existed as yet in Archean between the para-gneiss belt and granite-greenstone terrain, there were formed transition-type sedimentary-volcanogenic rocks of undivided Konkska Series, and plagiogranitoids of Inguletskiy Complex similar in composition to the ones of Saksaganskiy Complex.

Prior to the beginning of Paleo-Proterozoic, at the surface of Archean granite-greenstone terrain (and partly in the transitional Inguletsko-Kryvorizka LTZ) already existed the plains with weathering crusts, where in places paleo-volcano ridges (Yavdotivsko-Oleksandrivske and others) raised above. Tectonic processes had renewed within Ingulo-Inguletskiy mobile belt only and commenced with formation of sub-longitudinal regional faults (with their satellites), expansion or pull out the blocks of continental crust along these faults, and insufficient volcanic activity just in the transitional Inguletsko-Kryvorizka LTZ (Novokryvorizka Suite and Lower Sub-Suite of Zelenorichenska Suite).

Limited volcanism of Novokryvorizkiy time was probably caused by incipient extension of the blocks and their short-term compression. This break in tectonic motions is fixed in the stratigraphic unconformities: regional (between Novokryvorizka and Skelyuvatska suites in Kryvorizko-Kremenchutska LTZ) and local ones (in the Inguletsko-Kryvorizka LTZ between the sub-suites of Zelenorichenska Suite, and in case of its lacking – with overlaying suites). The general Paleo-Proterozoic geodynamics in the belt comprised Archean basement breaking into the minor blocks, which probably provided sedimentation basins in Kirovogradska LTZ, and formation of linear graben structures in transitional Inguletsko-Kryvorizka LTZ and marginal Kryvorizko-Kremenchutska LTZ. The shallow and stair-like relief in the grabens of these zones had primarily facilitated sedimentations of coarse-grained rocks (sand-gravel), and then, upon the bottom smoothing (and deepening) the clayey and high-magnesium carbonate rocks of Skelyuvatska Suite and Upper Sub-Suite of Zelenorichenska Suite were deposited [42].

Further active basin subsidence in the Inguletsko-Kryvorizka and Kryvorizko-Kremenchutska LTZs caused the change in sediment genetic types under conditions of humid climate. First, in distinct sedimentation environments the banded iron-formations of Saksaganska and Artemivska suites were deposited. Apparent source rocks included mafic volcanics from adjacent Yavdotivsko-Oleksandrivske paleo-volcano ridge [9, 42]. In both zones (with changes in paleo-geographic conditions of sedimentation), the graben formation was finished with siliceous-clayey and carbonaceous-carbonate sediments of Gdantsivska and Rodionivska suites and minor chemogenic banded iron-formation sediments.

Completion of linear graben formation in the Inguletsko-Kryvorizka and Kryvorizko-Kremenchutska LTZs apparently was accompanied by development of the wider grabens (merging in places) in Kirovogradska LTZ. In the latter zone this resulted in the aerial deposition of flyschoid marleous sediments (Spasivska Suite) and aleurite-clayey sediments (Checheliivska Suite) under paleo-conditions of arid climate [51, 52]. Simultaneously to the latter (or directly next of) in the marginal Kryvorizkiy graben the molassoid sediments of Gleyuvatska Suite were deposited [53].

The end of Paleo-Proterozoic in the para-gneiss belt is expressed in conditions of extensive tension, folding and metamorphism of sedimentary rocks with thrusting (along the central branch of KKDSF) of the belt eastern margin onto the granite-greenstone rocks and onto the rocks of Kryvorizka Series locally developed over the latter. Notably that Kryvorizka Series rocks are split by the thrusts into the series of tectonic sheets which underwent some flowing and squeezing (ductile underthrust) beneath the same-aged rocks of Ingulo-Inguletska Series [42]. Occurrence of such the underthrust is supported by the flowing textures in the footwall of deep-seated fault zone and almost twice increased thickness of earth crust, as well as development of gabbro-monzonite-charnockite-granite plutons of Novoukrainskiy Complex in the fault zone hanging-wall [42]. Further on, under conditions of progressive stabilization in para-gneiss belt, formation of Kirovogradskiy Complex granitoids commenced. Their spatial distribution was also essentially affected by compression zones (and faults) accompanied by upward heat flows. At the end of Paleo-Proterozoic, Ingulo-Inguletskiy para-gneiss belt was involved in stabilization which is supported by Neo-Proterozoic development of sub-latitudinal diabase dyke swarm.

The platform stage is characterized by only short-term activization of tectonic motions at the Paleozoic-Mesozoic boundary (at the time of Chornomorska Plate collision with southern margin of Eastern-European Platform) which had caused local development (at the junction of Kryvorizko-Kremenchutskiy and Devladivskiy faults) of explosive volcanic processes with formation of Ternivska crypto-volcanic structure [21]. Over Paleozoic and Mesozoic times the territory of the latter was the land where weathering crust were formed.

The end of Cretaceous – beginning of Paleogene is characterized by the territory irregular subsidence resulted in formation of elevated central (axial) part of Ukrainian Shield and its southern slope. Uplifted part of Ukrainian Shield in the relief of the end of Cretaceous – beginning of Paleogene times was expressed as elevated wavy plain slightly inclined to the north and south, and cut by river valleys, which prominent signs are preserved in the south of the basement surface (Zakhidnokryvorizka, Skhidnokryvorizka, Apostolivska and other depressions). Southern slope of the Shield was partly covered by the waters of Cretaceous transgression resulted in formation of Kodymska Suite coastal-marine sediments. At the end of Cretaceous time the sea had regressed and erosion processes encompassed whole territory until the Middle Eocene.

Over Cenozoic time marine and continental sediments were deposited which blanketed Precambrian crystalline rocks with the cover. Distribution of Paleogene sediments was mainly controlled by the relief of crystalline basement which depressions were filled with the sediments first of all. Paleogene sedimentation had commenced from the Middle Eocene when the southern slope of the Shield was covered by the sea basin waters whereas further water expansion to the north was limited by the central uplift of the Shield. The sediments were deposited in the coastal marine environments as it is evidenced by the column patterns of the coaliferous clays and sands pile. At the same time, the continental sedimentation regime existed in the elevated part of the Shield where the river-course and lake-swamp facies rocks of Buchatska Series were deposited in the central parts of depressions.

In the Middle and Late Eocene the paleo-geographic conditions over the studied areas had changed due to sea transgression from the sides of Dniprovsko-Donetska and Prychornomorska depressions with formation of shallow-water and deeper sediments of Kyivska, Khadzhybeyska and Alminska suites.

Sedimentation conditions in Oligocene, as compared to the Eocene ones, had essentially changed. Oligocene sediments are almost completely lime-free while the rock lithology differs in the northern and southern parts of the area suggesting for respective variability in deposition environments. In the north, under conditions of relatively shallow sea, mainly clastic material was deposited (sands of Kharkivska Series), whereas in the south – mainly clayey material and mobile manganese compounds (clays of Maykopska Series). Manganese material was removed from weathering crust of crystalline rocks in the sea bays where manganese-ore sediments were deposited in direct proximity to the source regions. In the end of Late Oligocene the sea had transgressed outside the studied map sheets. It was occurred the long break in sedimentation and from the Late Oligocene until Early Miocene the area comprised the elevated denudation plain.

Neogene period of the geological history is characterized by the wide aerial sedimentation over entire territory. Beginning of Miocene stage is expressed in Chokrakski sediments and in the continental rocks of Novopetrivska Suite. Column structure and composition of Chokrakski sediments suggest for shallow-water Middle Miocene transgressive basin in the south-eastern part of the L-36-IV map sheet.

The continental sediments were deposited in the north-eastern part of M-36-XXXIV map sheet. River-course and flood-land facies were deposited first. Then, as territory subsided, the large lake-type basins were formed to which clastic material was removed, in places together with ore minerals (rutile, zircon, ilmenite). The sediments formed in these basins are known as Novopetrivska Suite.

In the Lower Sarmathian time the area was involved in the sea transgression from the side of Prychornomorska Depression resulted in deposition of Zbruchski Layers. Sedimentation occurred in the sea coastal parts while erosion processes prevailed over other parts of the territory.

The Middle Sarmathian time differs in extensive sea transgression both from the south and the north, and apparently just a limited part of the studied area was the land. Conditions of sedimentation in the southern and northern parts were quite different. Essentially clastic material was deposited in the north (Pile of sands) whereas limestones and marls were formed in the south. Formation of the coastal-marine titanium-zirconium placers in the north-eastern part of M-36-XXXIV map sheet (Samotkanske deposit) is also related to the Middle Sarmathian sea transgression.

The sea transgression was considerably expanded in the Upper Sarmathian time as it is evidenced by widespread Geliksovi Layers. The sea had covered most of the territory except the sites of Precambrian basement maximum uplift.

In the end of Sarmathian time the sea changed to regress. In Meotychniy time marine basin gradual shortening and shallowing occurred as evidenced by Bagerivski Layers development in the central and southern parts of L-36-IV map sheet. Sedimentation took place in the shallow-water basin of closed type.

Transgression of Sarmathian sea was the last one in the northern part of studied area where at the end of Meotis in the beginning of Pontychniy time the Pile of parti-coloured clays was formed. In contrast, the southern part was involved into the new transgression at the end of Miocene resulted in formation of limestone pile of Pontychniy regio-stage. And the next sea transgression had caused formation of Kosivski Layers.

Starting from Pliocene sedimentation occurred in continental environments. At the same time, alluvial sands and red-brown clays were deposited. The latter are widely distributed and include eluvial, deluvial, eluvial-deluvial and aeolian-deluvial facies.

Quaternary sediments were formed in the back-glacier zone and their formation occurred both in warm and cold periods. Through the dust input the loess and loess-like loams were deposited, and the climate warming had resulted in the buried soil formation. Simultaneously the river courses got deeper and alluvial sedimentation occurred.

The modern period of territory development is characterized by deposition of eluvial, eluvial-deluvial and alluvial sediments everywhere in the studied area.

7. GEOMORPHOLOGY AND RELIEF-FORMING PROCESSES

The territory of map sheets M-36-XXXIV and L-36-IV is located within plain morpho-structures and includes various relief types. Northern and central parts of the territory are transected in sub-latitudinal direction by the complex of accumulative-denudation relief forms that constitute back-glacier zone of Pravoberezhne uplift and at the surface are composed of eluvial-deluvial loess rocks with extensive denudation processes development. The southern part is located within the relief form complex of Prychornomorska lowland plain composed at the surface by the thick pile of eluvial-deluvial loess rocks [42].

Prominent lineament-block structure of the area is reflected in the geology and modern relief. In particular, in the river network configuration the straight-line sections are observed of various orientations – sub-latitudinal, sub-longitudinal, and some sub-diagonal varieties. The highest places in the territory attain the altitude +200 m and are located in the north of the area whereas southward the altitudes gradually drop down to +70…+75 m.

According to the scheme of neo-tectonic zonation and average gradients of neo-tectonic motions (V.P.Palienko, 1992), the northern (larger) part of territory belongs to the sub-area of active discontinuous uplifts in the Eastern-European Platform and is subdivided into three areas: i) slight – less than 100 m (in the north-west of M-36-XXXIV map sheet), ii) moderate – 150-200 m (in the north-east of M-36-XXXIV map sheet), and iii) Miocene subsidings and relatively slight Anthropogenic uplifts – 0-100 m (southern part of M-36-XXXIV and northern part of M-36-IV map sheets). From the south, mentioned sub-area is joined by sub-area of slight Miocene depressions (up to 100 m) and post-Pontychni uplifts (less than 100 m) of Prychornomorska Depression. Geomorphologic features of the far northern areas, specifically, the water-flow terrace relief (the bench between pre- and post-Dniprovski terraces), suggest for tectonic glacio-isostatic motions of the earth crust.

In the studied area, within plain morpho-structures the following relief types are distinguished: accumulative-denudation elevated plain; denudation-accumulative plateau plain; accumulative-erosion valley-ravine-gully relief; subsidence relief; valley terrace relief.

Accumulative-denudation elevated plain in the central part of Ukrainian Shield is located in the northern part of M-36-XXXIV map sheet and comprises a range of elevated plain, hilly sites, extensively cut by valley-ravine-gully network. By type of underlaying rocks it belongs to the Quaternary accumulative-denudation flattening surface superimposed onto the Neogene accumulative mainly continental flattening surface. Further to north, outside M-36-XXXIV map sheet, accumulative-denudation elevated plain meets the loess water-glacier flattening surface superimposed onto the peneplained Shield surface.

Denudation-accumulative subsided plain in the southern part of Ukrainian Shield is located in the southern part of M-36-XXXIV map sheet and northern part of L-36-IV map sheet. It includes the sites slightly inclined toward the river valleys and cut by valley-ravine-gully network. By type of underlaying rocks it belongs to the Quaternary flattening surface over Sarmatska accumulative marine flattening surface.

Denudation-accumulative plateau plain in the northern margin of Prychornomorska Depression is located in the southern part of L-36-IV map sheet and comprises a range of plateau-like, flat-wavy, in places just flat sites with general inclination to the south, changed by subsequent exogenic processes. By type of underlaying rocks it belongs to the Quaternary flattening surface over Pontychna marine accumulative flattening surface.

Accumulative-erosion ravine-gully relief in the central and southern parts of Ukrainian Shield (northern margin of Prychornomorska Depression) comprises the network confined to the river valleys. Some gullies are fairly extended – up to 20 km and more; the permanent water-flow is often observed in these gullies. Ravines are developed almost everywhere on the inclined surfaces and often are extended outside the river valleys to the watersheds.

Subsidence relief is developed in the central and southern parts of L-36-IV map sheet. It includes pods formed through loess rock volume reduction due to over-wetting. The lower parts (pods) essentially differ in geomorphologic (expression in relief with closed dimples, location at watersheds) and geologic features (facial, paleo-pedologic) from other sites.

The valley terrace relief had formed within water-flows in accordance with the paleo-geographic stages reflected in "Stratigraphic scheme of Quaternary sediments". In the northern sites the Pliocene terrace relief is steeper toward the river valleys. There is also widely developed the strike-terrace relief formed through displacement of the water-flow junctions. In the southern lowland sites terrace relief is very slightly inclined and is expressed in wide (up to some kilometers) bands over the right- and left-side banks of Ingoulets River.

The following minor relief forms are distinguished in the plains: valleys of rivers and big gullies developed in relation to Ingoulets, Saksagan, Kamyanka, Zhovta, Zelena and other rivers; technogenic human-made relief forms including water reservoirs, water ponds, quarries, dumps, subsidings in relation to collapse zones, heaps and dams. They are mainly developed in the northern part of L-36-IV map sheet, and in the southern part of M-36-XXXIV map sheet, within Kryvorizkiy iron-ore basin.

In the territory are relatively widely developed exogenic processes, for instance, linear erosion, and in the north (in the upper course of Saksagan River) also planar erosion as well as coast abrasion in Kakhovske water reservoir.

The land-slides are observed in some valleys of rivers and large gullies and at the mouth of some gullies proluvial fans occur.

Geomorphology of the territory reflects essential changes of neo-tectonic regime at the boundary between Pliocene and Pleistocene. Pliocene stage is characterized by slight uplift which in the south attains zero values. In Eo-Pleistocene – Late Pliocene new tectonic regime was established – Pleistocene which comprised extensive territory uplift and probably was terminated in the mid of Late Pleistocene [42].

8. HYDROGEOLOGY

The territory of studied map sheets is located within two major tectonic-hydrogeological units: the northern part is confined to the hydrogeological province of Ukrainian Shield, and southern part – to the hydrogeological province of northern slope of Prychornomorskiy artesian basin (Fig. 8.1).

In comparison to the hydrogeological province of Ukrainian Shield, the province of Prychornomorskiy artesian basin is characterized by higher thickness and water content of the water-bearing horizons in sedimentary cover, as well as their wide distribution and key role in the water supplying. In the hydrogeological province of Ukrainian Shield the underground waters from crystalline rocks are being used for water supplying while water-bearing horizons of sedimentary rocks do not have considerable practical value.

In the studied territory the following water-bearing horizons are distinguished which are confined to: a) fractured Precambrian crystalline rocks; b) sediments of Buchatska Series and sequence of coaliferous sands; c) Upper Eocene and Oligocene sediments; d) Miocene sediments; e) Quaternary sediments.

Most water-bearing horizons are being fed mainly through infiltration of atmospheric precipitates and inflow of pressurized fracture waters.

The water-bearing horizon in fractured Precambrian crystalline rocks and products of their weathering is quite widely distributed in the hydrogeological province of Ukrainian Shield. The waters are confined to the tectonic breaks in crystalline rocks and to their upper fractured portion where they form the uniform hydraulically-linked system. Water depth varies in a wide range: from some meters to 110-115 m, and in the rocks of Kryvorizka Series – up to 250 m and more. The waters are mainly pressurized, the pressure height attains 60-96 m.

In the river valleys the pressure often drops down and disappears. Fractured water drill-hole yield varies from 0.002 to 4.7 l/sec. Fresh and slightly-salty waters predominate with mineralization from 0.6-1.0 g/dm^3 to 2.5-5.1 g/dm^3. By their composition the waters belong to sulphate-hydrocarbonate, sulphate, hydrocarbonate-sulphate.

Fractured zone in the rocks of Kryvorizka Series differs in high water content but high water mineralization (3-150 g/dm^3) precludes their use in water supplying. The water regime in the rocks of Kryvorizka Series is broken by trial-exploitation water depression and shaft water outflow resulted in formation of depression funnel. In the funnel centre, in the rocks of Saksaganska Suite, the level of underground waters is decreased to the depth 720-1200 m, and in the funnel limb (in the zone of shaft workings) – up to 450-600 m. The waters being pumped out from the shafts, quarries, drainage collectors, are being dropped to the tailings of mining-beneficiary plants and participate in the technological cycles in the course of iron-ore beneficiation.

Clayey products of crystalline rock weathering are water-bearing in places but their water content is normally low.

The waters of fractured zone in Precambrian crystalline rocks and products of their weathering are being exploited through some drill-holes and shaft wells for water supplying in rural areas and for small enterprises.

Water-bearing horizon in sediments of Buchatska Series and sequence of coaliferous clays and sands is developed in both hydrogeological provinces where it is distributed in local enclaves and lies directly over crystalline rocks. Water-bearing rocks include diverse-grained, in places gravelous sands which lie at the bottom of Buchatska Series or sequence of coaliferous clays and sands. The primary and secondary kaolines comprise the waterproof. Thickness of water-bearing horizon varies in the range 1-15 m, its depth varies from 7-8 to 75-85 m. The waters are pressurized, the pressure height varies from some metres to 32 m. Filtration coefficient of sands is 0.06$\pm$27 m/day, drill-hole yield varies from 0.01 to 3.8 l/sec, specific yield – 0.002-1.0 l/sec.

Water chemical composition is variable: in the northern part of studied area (hydrogeological province of Ukrainian Shield) these are mainly hydrocarbonate-sulphate and sulphate-carbonate of mixed cationic composition, and in the southern part (hydrogeological province of northern slope of Prychornomorskiy artesian basin) – sulphate-chloride, chloride-sulphate, sodium-calcium. The waters are hard and very hard, their mineralization varies from 0.4 to 3.0 g/dm^3. In view of local development the practical value of this horizon for water supplying is limited.

Water-bearing horizon in Upper Eocene and Paleogene sediments (Khadzhybeyska and Kyivska Suites, Maykopska and Kharkivska Series) is locally developed over the territory. Water-bearing rocks include sands with sandstone and friable marl interbeds and lenses. The waterproof rocks include clays, rarely brown coal or secondary kaolines of Buchatska Series. In places, where water-bearing sands and aleurites overlie the sands of Buchatska Series there is observed the mixed water-bearing horizon. The links with overlaying horizons is also observed in those places where Upper Eocene and Oligocene sands are overlain by Miocene sands and limestones.

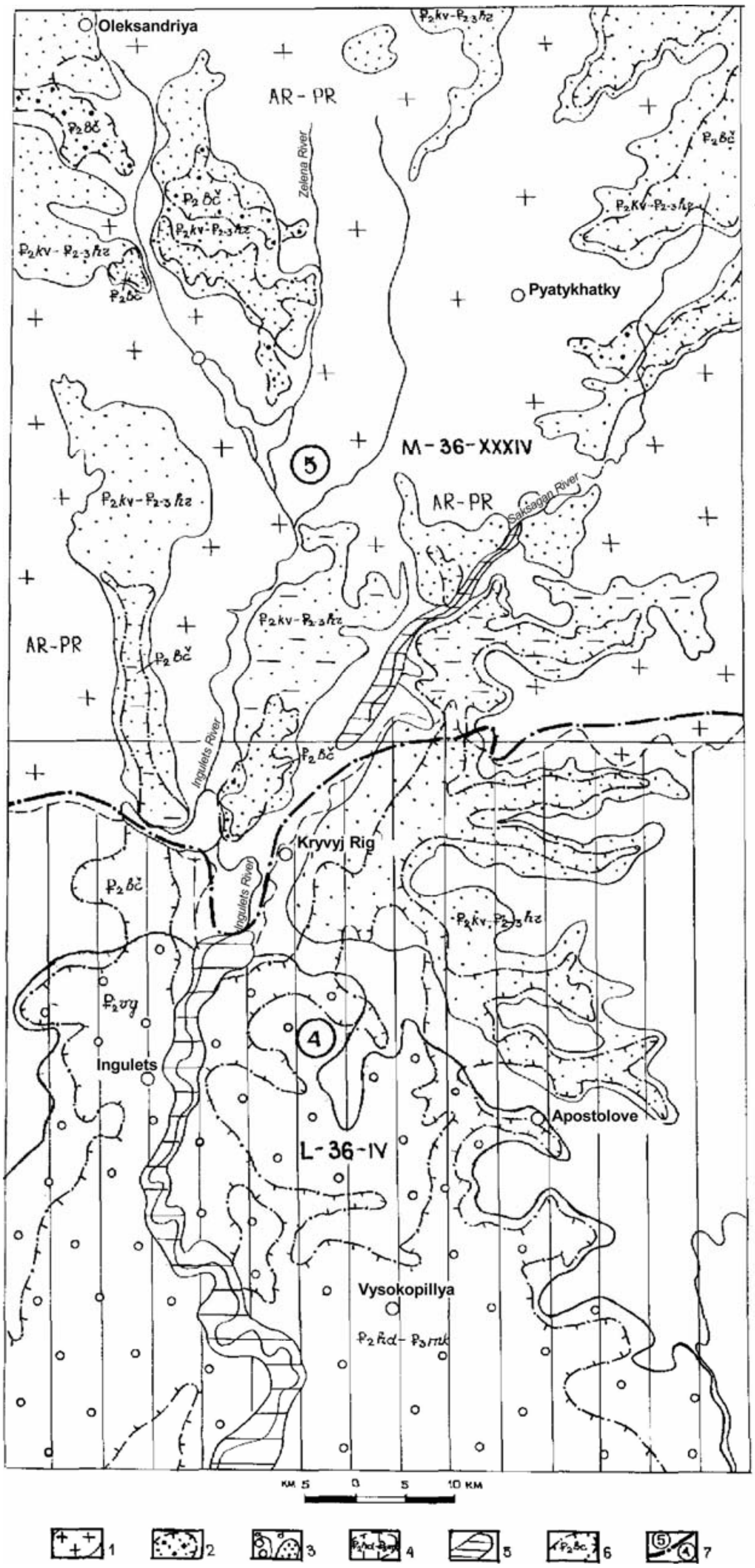


Fig. 8.1. Distribution scheme of major water-bearing horizons.

Distribution areas of water-bearing horizons: 1 – in Precambrian crystalline rocks (granites, migmatites, gneisses, amphibolites, quartzites) and products of their weathering (AR-PR); 2 – in sediments of Buchatska Series (Ᵽ$_2$*bu*) and sequence of coaliferous clays and sands (Ᵽ$_2$*vg*; diverse- and coarse-grained sands, in places gravelous); 3 – in Upper Eocene and Oligocene sediments: a – Khadzhybeyska Suite and Maykopska Series (Ᵽ$_2$*hd*-Ᵽ$_2$*mk*), b – Kyivska Suite and Kharkivska Series (Ᵽ$_2$*kv*-Ᵽ$_{2\text{-}3}$*hr*) (sands, sandstones, friable marls); 4 – in Miocene sediments (N_1; sands, limestones); 5 – in Quaternary deluvial-alluvial sediments (diverse-grained sands); 6 – overlain by younger sediments; 7 – boundaries of hydrogeological provinces: northern slope of Prychornomorskiy artesian basin (4), and Ukrainian Shield (5).

Water-bearing horizons are mainly non-pressurized. In case of waterproof sediments occurrence in the hanging-wall the waters are pressurized and pressure height is 5-25 m. Drill-hole yields varies from 0.017 to 2.2 l/sec.

The waters are mainly hydrocarbonate-sulphate calcium-magnesium and sulphate-carbonate sodium-magnesium with mineralization 0.5-1.4 g/dm^3.

The waters of Upper Eocene and Oligocene sediments are being used for water supplying of small enterprises and rural inhabited locations.

The water-bearing horizon in Miocene sediments is widely distributed over both hydrogeological provinces. In places adjacent to the river valleys this horizon is being drained. The water-bearing rocks include sands of Novopetrivska Suite as well as sands and limestones of Sarmatskiy and Pontychniy stages. From overlaying horizon of Quaternary sediments the given one is separated by waterproof red-brown and parti-coloured clays. Thickness of water-bearing horizon increases from north to south and varies from 1.8 to 30 m. Hanging-wall depth increases from 2.0-10.0 m in the north of M-36-XXXIV map sheet up to 36-50 m in the south of L-36-IV map sheet. Water-bearing horizon is mainly non-pressurized or slightly-pressurized with pressure height 2-17 m. Drill-hole yields vary from 0.01 to 2.5 l/sec, specific yields – 0.002-1.3 l/sec. The daily water scoop is 0.2-6 m^3 in average. By chemical composition the waters are mainly chloride-sulphate, sulphate-chloride with variable cationic composition. Water mineralization varies from 0.5 to 8 g/dm^3.

In the southern part of Kryvbas the underground waters of Sarmatski and Pontychni limestones are susceptible to contamination due to filtration losses from MBP tailings and the pond of Svystunova gully. Over long time the levels of underground waters in places had increased by 8-20 m and their mineralization grown from 0.5-1.5 g/dm^3 to 2.5-13.9 g/dm^3.

In places of shallow depth the water-bearing horizon is being fed from atmospheric precipitates and by pressurized waters from underlaying sediments. Somewhere this horizon is being used by local people for home needs and drinking purposes.

Water-bearing horizon in Quaternary sediments is related to the loams and alluvial rocks, it often comprises underground water top. The horizon is widely distributed and is absent at the highest river-valley sites. The waterproof rocks include dense loams and red-brown clays. The depth varies from 1.5 to 12 m, thickness – from parts of meter to 20 m, 2-5 m in average. Water saturation of the loams is low, drill-hole and shaft well yields vary from 0.002 to 0.3 l/sec. The daily water scoop from shaft wells is 0.2-20 m^3. By chemical composition the waters are chloride-sulphate-sodium with mineralization up to 12 g/l. The horizon is being fed through infiltration of atmospheric precipitates and various waters of technogenic origin. The horizon regime is essentially broken, water saturation and quality are quite variable but in spite of this the horizon is widely used by local population.

Water-bearing horizon of modern alluvial sediments in river flood-lands and gully bottoms is locally distributed and is known in the valleys of Ingoulets, Saksagan, Zhovta, Beshka, Bokova, Kamyanka and Omelnyk rivers. The water-bearing rocks include alluvial of the flood-land and over-flood terraces and comprise diverse-grained sands, sandy loams and muddy loams.

This water-bearing horizon is non-pressurized, the depth of soil waters varies from 0.5 to 5 m, water saturation – from 0.3 to 4 l/sec. The water is fresh, hydrocarbonate-sulphate-calcium and hydrocarbonate-sulphate-magnesium-calcium. Water mineralization varies from 0.5 to 3-4 g/dm^3, the waters are hard. The horizon is being used by local population, daily water scoop from shaft wells is 0.2-1.0 m^3.

9. MINERAL RESOURCES AND REGULARITIES IN THEIR DISTRIBUTION

Metallogenic zonation

In accordance with description of Precambrian units and tectonic zonation given above, and taking into account position of the studied area in metallogenic zonation of the territory of Ukraine (A.S.Voynovskiy, 1999), the Middle-Dniprean and Ingulo-Inguletska TMZs are distinguished in Precambrian basement (Fig. 9.1) which correspond to respective Archean granite-greenstone terrain (craton) and Paleo-Proterozoic (mobile) para-gneiss belt [8, 10].

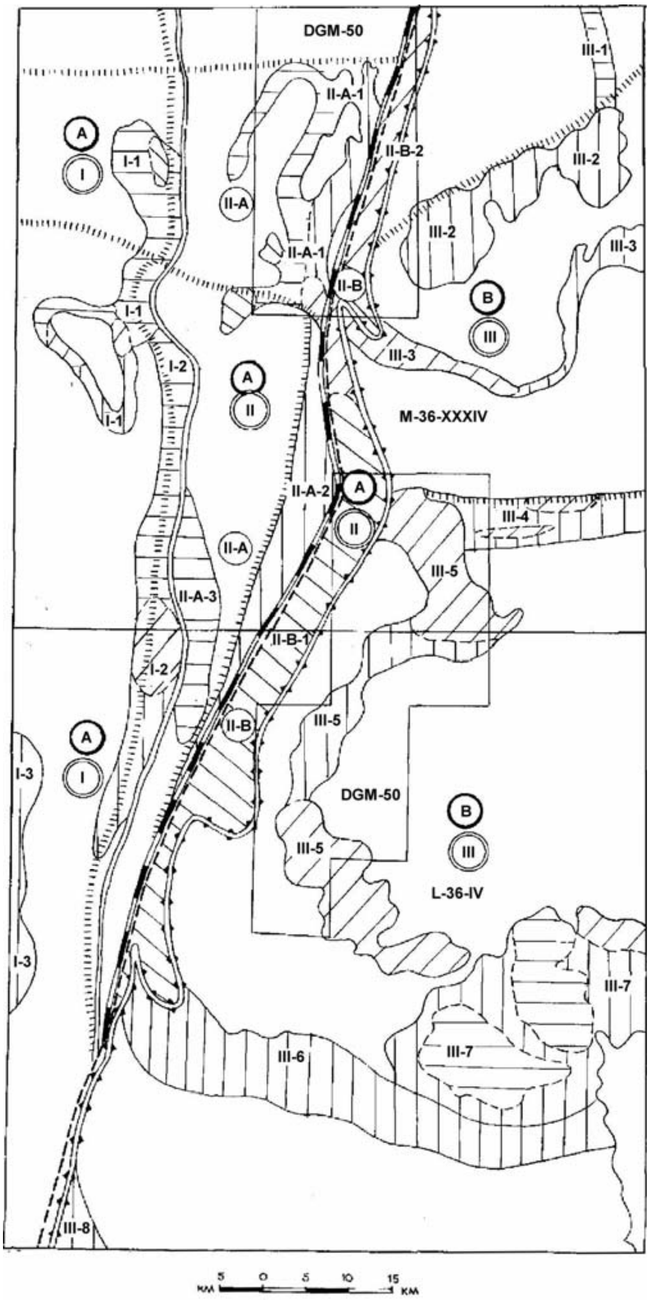


Fig. 9.1. Scheme of metallogenic zonation with elements of prospective evaluation the fields for mineral resources in crystalline basement.

Numbering and boundaries of metallogenic fields:

Tectono-mineragenic zones and areas

Metallogenic zones

Metallogenic sub-zones

Ore (ore-bearing) zones (camps)

Faults:

deep-seated

regional

Metallogenic fields:

A – Ingulo-Inguletska TMZ

I – Kirovogradska TMZ

I–1 - Balakhivsko-Varvarivska ore zone [Mo(REE), graphite]

I–2 - Chervonokostyantynivsko-Rodionivska ore zone [Pb, Zn (Au, Ag)]

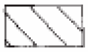
I–3 - Novovolodymyrivsko-Kaluzka ore-bearing zone [apatite, Ti]

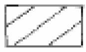
See next page for remaining captions.

Fig. 9.1. Continued.
A – Ingulo-Inguletska TMZ. Continued
II – Inguletsko-Kryvorizko-Kremenchutska metallogenic zone
II-A – Inguletsko-Kryvorizka metallogenic sub-zone (iron-ore)
II–A– 1 - Petrivsko-Zhovtyanska ore zone [Fe (Au)]
II–A– 2 - Zakhidnokryvorizka ore zone [Fe (Au, W, Mo, As)]
II–A– 3 - Karachunivsko-Lozuvatska ore-bearing zone [Fe, Cu (Au, Ag)]
II-B – Kryvorizko-Kremenchutska metallogenic sub-zone (iron-ore with gold)
II– B– 1 - Kryvorizka ore-zone [Fe (Au, Pb, Zn, Mo, W)]
II– B– 2 - Zhovtovodsko-Popelnastivska ore zone [Fe (Au, W, Sc)]

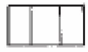
B – Middle-Dniprean metallogenic area
III – Verkhivtsivsko-Chortomlytska metallogenic zone
III–1 - Lykhivska ore-bearing zone [Ti, V]
III–2 - Komisarivska ore-bearing zone [Ni (Cu, Co)]
III–3 - Zhovtovodsko-Alferivska ore-bearing zone [Fe, Au (Ni, Co, Cu, Al)]
III–4 - Devladivska ore zone [(Ni, Co)]
III–5 - Avdotiivsko-Oleksandrivska ore-bearing zone [Ni, Cu, Co (Mo, Au, Pt, Al)]
III–6 - Vysokopilsko-Mykolaivska ore zone [Al (Au, Ni, Co)]
III–7 - Tokivskiy ore-bearing camp [Mo, REE (apatite, Ti)]
III–8 - Novopavlivska ore-bearing zone [Fe (Au)]

Prospectivity degree of the fields within ore (ore-bearing) zones and camps:

 - high

 - medium

 - low

 - unclear

Types and scales of the works suggested over prospective fields:

- Deep geological mapping

Depending on distribution of LTZ within mentioned units and metal potential of LTZ, the following major metallogenic subdivisions are distinguished in Precambrian basement: in the Middle-Dniprean metallogenic area (in its western part) – Verkhivtsivsko-Chortomlytska metallogenic zone (corresponding to respective tectonic zone), and in the Ingulo-Inguletska TMZ – Kirovogradska (corresponding to tectonic one) and Inguletsko-Kryvorizko-Kremenchutska metallogenic zones. The latter includes two LTZs – Inguletsko-Kryvorizka and Kryvorizko-Kremenchutska filled with the same-aged stratigraphic analogs with the same-type (iron-ore) mineralization.

Metallogenic features of Verkhivtsivsko-Chortomlytska metallogenic zone are defined by iron, aluminum and nickel deposits (non-economic so far) as well as occurrences of nickel, titanium, vanadium, molybdenum and rare earths formed mainly in Neo-Archean metallogenic epoch. Depending on specific position of this mineralization in particular structures and complexes, eight ore-bearing camps are distinguished in this metallogenic zone which differs in perspective degrees of prospecting for not only known minerals (iron, aluminum, nickel, titanium, etc.) but also new mineralization types (copper-nickel and gold).

Metallogenic features of Inguletsko-Kryvorizko-Kremenchutska metallogenic zone are traditionally defined by the largest iron deposits formed in Paleo-Proterozoic metallogenic epoch. Depending on described geological patterns and distribution of major economic types of iron ores, two metallogenic sub-zones are distinguished which correspond to the same-named Inguletsko-Kryvorizka and Kryvorizko-Kremenchutska LTZs.

Kryvorizko-Kremenchutska metallogenic sub-zone contains iron deposits with Saksaganskiy, Inguletskiy and Pershotravneviy types of iron ores. In the Inguletsko-Kryvorizka metallogenic sub-zone

Pravoberezhniy and Verkhivtsivskiy types of iron ores are developed which may form economic deposits in favourable environments. Depending on specific geology and iron-ore types two ore sub-zones are distinguished in both metallogenic sub-zones and in these sub-zones most prospective fields are defined.

Metallogenic features of Kirovogradska metallogenic zone are defined by graphite deposits (in places of high metamorphic degree) as well as occurrences of molybdenum, lead, zinc, titanium and apatite formed in Paleo-Proterozoic metallogenic epoch. Depending on specific geology and tectonic position three ore-bearing zones are distinguished with different perspective degree (see Fig. 9.1). Regularities in distribution of mineralization in each ore (ore-bearing) zone (of three mentioned metallogenic zone) are described below with respect to particular mineral types. In total, within crystalline basement of both map sheets there are defined 166 mineral deposits and occurrences (Annex 3) which by their genetic affinity belong mainly to metamorphic and rarely to magmatic, metasomatic and residual (weathering crust) groups.

In Meso-Cenozoic platform cover over both map sheets territory there are defined typical sedimentary deposits and occurrences in total amount of 145 (Annexes 1 and 2). Of these, most important for the local economy are brown coal, titanium-zirconium placers, manganese ores as well as various construction materials. Description of their ore-bearing facies and regularities of their distribution in the platform cover rocks are given below for particular mineral types.

COMBUSTIBLE MINERALS

Solid combustible minerals

Brown coal

Brown coal is confined to Buchatski continental sediments which fill up depressions in crystalline basement [29, 40, 49, 56, 59, 110].

Over the map sheets territory there are known 12 explored deposits and 18 occurrences located within 15 brown-coal fields 2.5-15 km long and 1-4 km wide each. The bodies are sheet-like and lens-like, horizontal or flat-wavy laying. Coal does form a single layer, rarely two layers from 0.5 to 10-145 m thick, 4.8 m in average, mainly of high quality, low-ash (19-21%), high-volatile content (45-52%), heating value up to 5060-5500 calories. It is being used mainly for the local fuel-energy needs. For the time being most of brown coal deposits are exhausted.

METALLIC MINERAL RESOURCES

Ferrous metals

Iron

Iron deposits and prospects are located in the Inguletsko-Kryvorizka and Kryvorizko-Kremenchutska metallogenic sub-zones. In the latter sub-zone the distinct unit comprises Kryvorizka ore zone or Kryvorizkiy Iron-Ore Basin (KIOB) where major iron-ore reserves are explored.

By iron content two economic-technological ore types are distinguished: 1) high-grade ores which are being directly used by metallurgy without beneficiation; 2) low-grade ores – ferruginous quartzites which require beneficiation.

High-grade iron ores in KIOB comprise layers, lenses, thick hinge lodes and pillars, and are confined to the folded and folded-faulted structures.

Low-grade iron ores constitute most deposits in KIOB and some deposits and occurrences in the Inguletsko-Kryvorizka metallogenic sub-zone. All these objects provide the source base for MBPs. Most valuable are non-oxidized magnetite and silicate-magnetite quartzites. In parallel, in all deposits oxidized ferruginous quartzites are being mined which at present are separately stock-piled without beneficiation and will be further processed by new plant for oxide ores presently under construction.

All iron-ore deposits display strong stratigraphic control. In Kryvorizko-Kremenchutska metallogenic sub-zone all iron-ore bodies are located within Saksaganska (rarely Gdantsivska) Suite of Kryvorizka Series; in Inguletsko-Kryvorizka metallogenic sub-zone – within Artemivska and Rodionivska Suites of Ingulo-Inguletska Series; in Verkhivtsivsko-Cortomlytska zone – within Surska Suite of Konkska Series.

By age and forming conditions, mineral composition, morphology of ore bodies, quality, technological properties and industry use the iron ores are subdivided into some geological-industrial types: Saksaganskiy, Inguletskiy, Pershotravneviy, Skelyuvatskiy, Pravoberezhniy, Verkhivtsivskiy and Bilgorodskiy. First three ore types comprise high-grade ores and four remaining – low-grade ones.

Saksaganskiy geological-industrial type includes high-grade ores of KIOB with iron content 46-70% which in genetic respect are residual-metamorphic formed in deep oxidation zones under conditions of greenschist and epidote-amphibolite facies. The ores are confined to Saksaganska syncline structure and are located within fifth and sixth ferruginous horizons of Upper Sub-Suite of Saksaganska Suite. The ore bodies are sheet-, pillar- and bunch-like and are confined to the high-order folds, cross-fold flexure bends and boudinage units. Their dipping angle is 30-80^{o}, thickness does not exceed 40-50 m, length varies from 50-100 m to 300-500 m. By composition martite and martite-hematite ores predominate.

This type ores prevail in KIOB comprising 85% of all explored high-grade ore reserves and are concentrated in eight large deposits: Im. Frunze, Im. R.Luksemburg, Im. K.Libknekhta, Im. Kirova and others where reserves are estimated to the depth 1500 m. Established regularities in localization of these ores allow predictions of their distribution in Saksaganska structure to the depth 3000 m and more that was confirmed by more than 50 drill-holes which intersected high-grade ores at the depth 2000-3000 m.

Typical representative of high-grade iron-ore deposits is one within shaft fields “Gigant” and “Saksagan” (I-2-259) of the former mine “Im. Dzerzhynskogo”.

Deposit is located within southern closure of Saksaganska syncline which is tightly compressed and overturned to the east. Syncline limbs dip under the angles 40-60^{o}. Western limb is partly cut by Saksaganskiy fault. Fold hinge plunges to the north under the angles 15-20^{o}; maximum fold width is 450 m.

Deposit country rocks include Skelyuvatska and Saksaganska suites of Kryvorizka Series. High-grade iron ores are mainly confined to the ferruginous and in lesser extent schist horizons of Saksaganska Suite and are developed to the depth 800 m. The fourth-sixth ferruginous and fourth-fifth schist horizons are ore-bearing. In the hinge portion the rocks are almost completely mineralized and form pillar-like ore bodies about some hundred meters long. High-grade iron ores include mainly goethite-hematite-martite, goethite-hematite and martite varieties formed through deep oxidation and further late metamorphogenic transformations of oxidation products [4].

Goethite-hematite ores are confined to the fourth ferruginous and fourth-fifth schist horizons. Iron content in ores is 46-54%.

Martite and hematite-martite ores with iron content 46-56% are developed mainly in the fifth ferruginous horizon.

Transition of high-grade ores into the host rocks is gradual and is expressed in iron content decreasing and silica content increasing.

Deposit is in production through underground mining.

Inguletskiy geological-industrial type includes high-grade ores inside the ferruginous horizons of Saksaganska Suite as well as those located at the contact and inside Gdantsivska Suite within Kryvorizka ore zone.

The ores of this type are specularite-martite, hematite-martite and chlorite-magnetite in composition. The ores are modified by carbonate metasomatism and in the linear weathering crusts are oxidized to the depth 600-800 m.

Ore bodies (lens-shaped or discontinuous-sheeted) are observed at the contact zone between Saksaganska and Gdantsivska suites and are traced in KIOB along this contact over the distance about 50 km in the narrow discontinuous chain. The ore depth is limited by depth of Gdantsivska Suite rocks. Thickness of ore bodies is 1-100 m and their length varies from 100-200 m to 1000-1500 m.

Within KIOB ores of this type are concentrated in 14 deposits (deposits in Lykhmanivska syncline, “Valyavko-Pivnichna” shaft field etc.). Established regularities in ore localization (prominent stratigraphic control, sheeted ore bodies and their conformity with host rocks) allow prediction their distribution to the depth along the contact between Saksaganska and Gdantsivska suites.

Pershotravneviy geological-industrial type in Kryvorizka and Zhovtovodsko-Popelnastivska ore zones includes high-grade iron ores modified in various extents by alkaline metasomatism. The ores are located in the non-oxidized ferruginous quartzites and are amphibole-magnetite and amphibole-hematite-magnetite in composition (Pershotravneve, Zhovtorichenske deposits).

The ores are massive with total iron content 46-68%. Ore bodies are sheet-like, lens-like, pillar-like, their thickness varies from 8 to 60 m and length – from 10 to 250-350 m. Up to now, the high-grade ores are completely mined to the depth 1300-1400 m. This ore type is characterized by lack of oxidation processes, which defines their magnetite composition and morphology of rich iron-ore bodies; the latter inherit the composition and morphology of ferruginous beds. Besides that, iron ores of Pershotravneviy type in places of superimposed carbonate-sodium metasomatism contain economic uranium mineralization described below.

Relatively persistent parameters of ore fields and stable ore quality allow this ore type prediction to the depth of major banded iron-formation (over 2 km). In high-grade ores and ferruginous quartzites germanium comprises the principal accompanying element and is contained in magnetite, hematite, goethite, aegirine and other minerals; germanium content varies from 3-4 to 15 g/t attaining 80 g/t.

Skelyuvatskiy, Pravoberezhniy and Verkhivtsivskiy types comprise the low-grade ores – ferruginous quartzites which constitute majority of ores in KIOB and in area of Pravoberezhni anomalies.

Ferruginous quartzites of Skelyuvatskiy type are confined to weakly-metamorphosed banded iron-formation of Saksaganska Suite. They comprise the major portion of iron ores in KIOB which require beneficiation. By mineral composition the following ore varieties are distinguished: non-oxidized - silicate-magnetite, magnetite; oxidized – martite, hematite-martite. Average content of magnetite iron is 23.8-34.5%. Prevailed sheet-like ore bodies are from 500-650 m to 2200-2400 m long and from 10-20 m to 300-350 m thick. Ferruginous quartzites are oxidized in more or less extent from the surface to the depth 1500 m.

By their tectonic setting deposits of Skelyuvatskiy type are subdivided into three groups: a) deposits located in the core portions of folded structures; their length by strike attains 2-2.5 km, horizontal thickness varies from 50 to 400 m in the fold limbs and to 1000 m in the core parts (Southern MBP); b) deposits confined to the fold limbs; they are monoclinal, normally steeply-dipping and high length extending in places over some tens of kilometers at the horizontal thickness from 30 to 400 m (Central MBP); c) deposits located at the cross-strike deformation sites of folded structures, complicated by faults and provided nappe-thrust internal structure; variable rocks dipping and alternating quartzite and schist blocks are characteristic (Northern MBP, Pershotravneve deposit).

Perspectives of this ore type are defined by distribution of Saksaganska Suite ferruginous quartzites along strike and depth as well as consistent ore composition. Of most economic value are ferruginous quartzites of Inguletske, Skelyuvatsko-Magnetytove, Novokryvorizke, Pershotravneve and Gannivske deposits. Major MBP (Inguletskiy, Central, Southern, Northern, Novokryvorizkiy) do mine non-oxidized quartzites from seven open pits.

The typical representative of ferruginous quartzite objects which require beneficiation of ores is Skelyuvatsko-Magnetytove deposit (II-2-285).

Deposit is located in the southern closure of the Main (Kryvorizka) structure, within asymmetric second-order syncline composed of Novokryvorizka, Skelyuvatska and Saksaganska suites rocks of Kryvorizka Series. Fold limbs dipping is 25-40^o, its hinge plunges to the north under the angles 10-25^o. In the central part fold width attains 1400 m, plunging depth exceeds 1000 m; fold is complicated by sub-longitudinal breaks. Rock metamorphic degree is about upper zone of greenschist facies.

Magnetite and silicate-magnetite quartzites of the fourth and, much less, fifth ferruginous horizons of Saksaganska Suite are of economic value. Horizontal thickness of the ferruginous quartzites in fourth horizon is up to 500 m, and their true thickness is 240 m. The difference in thickness is caused by extensive folding. Ferruginous quartzites are fine-grained (magnetite grains in ore beds are 0.07-0.20 mm in size). In the ore body iron content is 30-45% of total iron and 21-35% of magnetite iron. Iron content in concentrate upon beneficiation – 64.5-65.2%.

Deposit is being mined by open pit; expected depth is 490 m, actually achieved by 01.01.2000 – 350 m.

Pravoberezhniy geological-industrial type comprises relatively easy-beneficiating ferruginous quartzites confined to Artemivska and Rodionivska suites of Ingulo-Inguletska Series within Petrivsko-Zhovtyanska and Zakhidnokryvorizka ore zones. Ore bodies include steeply-dipping relatively short beds composed of highly-metamorphosed (amphibolite facies) amphibole-magnetite, pyroxene-amphibole-magnetite quartzites within gneisses and carbonate rocks. Thickness varies from 30-50 m to 150-200 m (Petrivske, Artemivske and other deposits).

Perspectives of this ore type are defined by the depth of Artemivska and Rodionivska suites (700-1000 m and more) which contain the layers of highly-metamorphosed silicate-magnetite quartzites.

Verkhivtsivskiy geological-industrial type comprises lens-shaped and sheeted bodies of ferruginous quartzites related to the Surska Suite banded iron-formations of Konkska Series within Karachunivsko-Lozuvatska and Zhovtovodsko-Alferivska ore-bearing zones. Ore bodies of low thickness and extension are located both within amphibolite remnants (Chkalivskiy massif) and amphibolites and chlorite-amphibole schists (Alferivske deposit).

Bilgorodskiy type includes residual ores in weathering crust. The distinct features of these deposits are their age (Meso-Cenozoic) and predominating location in the fault zones.

The bodies of brown iron-stones and goethite-hydro-goethite ores are related to the ferruginous layers of Artemivska and Saksaganska suites.

The ores are locally developed and are of limited economic value (Pivnichniy Tarapak, Ingulets deposits).

Manganese

Manganese ores (within platform cover) are confined to quartz-glauconite sandy-clayey rocks of Oligocene Borysfenska Suite. Ore-bearing sediments lie almost horizontally with slight inclination to the south toward Prychornomorska Depression.

Ore-bearing field is observed in the band 60 km long and 10-16 km wide (Fig. 2.8). In the plane, manganese ore bodies are preserved in the separate enclaves confined to the depressions in crystalline basement (Novovorontsivska, Fedorivska, Vysokopilska, Inguletska and others, Fig. 2.8).

Fedorivske (III-3-93) and Pivdenno-Inguletske (III-1-91) deposits as well as other manganese occurrences comprise small-scale layers at the depth from 12-30 m to 65-75 m. Thickness of the layers 0.5-3.45 m, manganese content in ores varies from 8.01 to 35.7% [42, 46, 56].

Magnanese ores include three types: oxide, oxide-carbonate and carbonate. Oxide ores are mainly composed of manganite, rarely pyrolusite; carbonate ores – manganocalcite; oxide-carbonate ores – of manganese oxides and carbonates.

Manganese ores had formed under conditions of slow sea transgression with some stabilization periods resulted in regular distribution of sediments and ore facies changes along the layer dipping.

Analysis of paleo-geographic situation allow supposing the manganese ores were deposited in the shallow-water portions of Oligocene sea and normally followed coastal line of sedimentation basin (see Fig. 2.8). Manganese-bearing sediments were deposited in small depressions and basement erosion sites pinching out toward basement uplifts.

On the ground of established ore-controlling factors of manganese mineralization (stratigraphic, lithological-facial, tectonic, paleo-geographic) and taking into account direct evidences (occurrence of manganese ores) some perspective sites with evaluated prognostic resources are defined in the studied map sheets [42, 46].

Non-ferrous and base metals

Aluminum

In the territory of map sheet L-36-IV there are known Vysokopilske deposit (III-2-305) and more than ten aluminum occurrences.

Aluminum ores comprise bauxite-like rocks and bauxites divided into two groups by their forming conditions: i) bauxites related to lateritic weathering crusts of crystalline rocks, and ii) re-deposited bauxites (in association with sedimentary rocks).

Sedimentary bauxites, which lie within the rocks of Buchatska Series and sequence of coaliferous clays and sands, are not economic due to low quality, thickness and reserves.

Of practical interest could be bauxites related to lateritic weathering crust after ultramafic rocks, amphibolites and silicate schists which constitute Vysokopilska greenstone structure and Oleksandrivsko-Yavdotiivskiy igneous belt. Bauxites are located in the upper portions of weathering crust and are confined to the elevated relief sites or to the slopes of depressions.

Vysokopilske deposit consists of 10 small bodies of bauxite ores extended in discontinuous band over 30 km long, 2 km wide and 0.5-7 m thick. Three horizons are distinguished in the ore body columns. Upper one, 0.5-1.5 m thick, is composed of brown iron-stones with gibbsite; middle horizon is essentially gibbsite in composition and 1.-2.5 m thick containing (%): Al_2O_3 – 38.05, SiO_2 – 8.55, Fe_2O_3 – 35.0; lower horizon, 1-2 m thick, is composed of gibbsite-kaolinite-goethite rocks with Al_2O_3 – 35.0%.

In general, by mineral composition gibbsite-hydrogoethite, gibbsite and gibbsite-kaolinite bauxites are distinguished. Deposit is explored, out of production.

Bauxite occurrences are weakly studied but the data available suggest for limited perspectives in the area to discover new economic aluminum objects. The only interesting exception could provide bauxites of Soldatskiy occurrence (II-2-294) with high vanadium content (V_2O_5 – 0.112-0.29%).

Titanium

Titanium mineralization comprises several genetic types: i) magmatogenic in gabbro-diabases; ii) eluvial (residual) in weathering crusts after crystalline rocks; iii) Neogene coastal-marine placers of complex composition in the platform cover. The latter type is most perspective being located in the north-eastern part of M-36-XXXIV map sheet. Here Neogene sands are enriched in ilmenite, rutile, zircon, monazite and other minerals which amount in places becomes economic (Samotkanske deposit, I-4-22). The sites with economic mineral grades look like the bands consisting of elongated or rounded lens-shaped bodies. Placers are fairly large in size and are related to the fine-grained sands in upper part of Novopetrivska Suite (lower ore horizon) and to the sands in the middle and lower parts of Middle Sarmatski sediments (upper ore horizon). Mineral accumulation in the lower ore horizon is resulted from the regressive, and in the upper horizon – transgressive sedimentation cycles. Middle Sarmatski sands are more enriched with heavy minerals than sands of Novopetrivska Suite.

Major ore minerals include ilmenite, leucoxene, rutile, zircon; minor ones – disthene (kyanite), sillimanite, staurolite, monazite.

Titanium-zirconium placers were formed along the coastlines located close enough to the hard rocks containing titanium minerals (gabbro-diabase dykes with titanomagnetite-ilmenite mineralization – Lykhivskiy occurrence (I-4-159). Here ore mineral content attains 20-30% [54] hence these rocks could provide source region for placer formation.

In Samotkanske deposit ore minerals content attains (kg/t): ilmenite – 5-25, rutile – 2-5, zircon – 1-7. Concentrate yield (minerals with specific gravity higher 2.9) varies from 0.5 to 300 kg/m^3 and more. Besides mentioned objects, titanium occurrences are also found in weathering crust after pyroxene gneisses (II-1-166), charnockites (II-1-164), gabbro-diabases (IV-4-240). Thickness of weathering crust does not exceed 10 m, ilmenite content is not consistent and varies from 4 to 17.1 kg/m^3. These small-scale sites are low-perspective for economic deposits of titanium ores of the given genetic type. Ilmenite, rutile and zircon placers are also developed in Quaternary sediments. Thickness of titanium-bearing alluvial sands is 0.5-4 m, mineral content – 9-45 kg/t. These occurrences are low-perspective.

Nickel, copper, cobalt

By forming conditions and localization the known nickel deposits and occurrences are divided in two types: i) magmatic sulphide copper-nickel within Yavdotivsko-Oleksandrivska ore-bearing zone, and ii) silicate nickel ores in weathering crusts, mainly within Devladivska ore zone.

Magmatic occurrences of copper-nickel ores – Volodymyrivske (II-3-298) and Oleksandrivske (II-3-293) – are encountered within Yavdotivsko-Oleksandrivskiy igneous belt. Their specific feature is association with gabbro-peridotites of Verkhivtsivskiy Complex which rocks by some petrochemical parameters are thought to be favourable for concentration of copper-nickel sulphide mineralization [46].

By texture features and mineral composition three types of copper-nickel ores are distinguished: disseminated, vein-disseminated and massive. Ore major minerals include pyrrhotite, pentlandite, chalcopyrite, and minor ones – pyrite, magnetite, bravoite. Petlandite permanently contains cobalt admixture and in places also copper. Thickness of ore bodies is quite variable – from 0.3-1 m to 12.5-14 m. Their shape is complex and is inherited from the hosting ultramafic rocks. Metal content in ores varies: nickel – from 0.18 to 0.36%, cobalt – from 0.028 to 0.037%, gold – from 0.004 to 0.888 g/t [46]. The base of ore bodies is composed of minerals developed at the bottom of intrusions which are funnel-like in the cross-section (Fig. 4.1) allowing prediction for higher-grade copper-nickel ores in the lower parts of such the funnels.

Distribution of precious metals in the ores and rocks of these occurrences is weakly studied. It is determined (in g/t): gold – 0.052, platinum – 0.012, palladium – 0.015 [46]. Gold distribution is fairly irregular, often with low grade at about 0.3-0.5 g/t, in some samples up to 3-5 g/t.

The favourable regional and local factors controlling copper-nickel mineralization as well as occurrence of direct evidences for copper-nickel ores allow definition of perspective nickel-bearing zone (together with gold) confined to Yavdotivsko-Oleksandrivskiy igneous belt where economic deposits could be expected.

In the map sheet M-36-XXXIV, within Devladivska ore zone, there are known three silicate nickel deposits – Ternivske (IV-3-234), Chervoniy Yar (IV-4-241), Devladivske (IV-4-243), and eight occurrences confined to weathering crust after ultramafic rocks. Ore bodies are sheet-like, their length by strike varies from 100 to 1200 m, width – from 20 to 250 m, thickness – from 1.0 to 17.6 m. The ores include the nickel ores themselves, iron ores alloyed with nickel, iron ores slightly alloyed with nickel, and cobalt ores.

Nickel ores are composed of nontronite, jefferisite, halloysite, gibbsite, montmorillonite and carbonate; nickel content is 0.7-2.5%. Iron ores consist of limonite and goethite with admixture of nickel-bearing minerals. Metal content in the ores (%): iron – 20-30, nickel – 0.7-2.5 (nickel-alloyed ores); iron – 30, nickel – 0.1-0.3 (slightly nickel-alloyed ores). Cobalt ores consist of asbolan, cobalt content – 0.048%.

Aforementioned deposits are explored but are not exploited due to insufficient size of mineralization.

Copper

Three copper occurrences are encountered in the three major ore-bearing zones (see Fig. 8.1): Chervonoshakhtarskiy (I-2-255), Oleksandrivskiy (II-3-295) and Alferivskiy (II-4-187); all these ones belong to the sulphide type. Most known is Chervonoshakhtarskiy occurrence located within Karachunivsko-Lozuvatska fault zone. Host rocks include Archean amphibolites, ferruginous quartzites and plagiogranites of Inguletskiy Complex. Ore bodies are lens- and bunch-shaped, thickness varies from 0.3-1.0 m to 12.3 m, length up to 60-80 m. Mineralization is of vein-disseminated type, ore minerals include chalcopyrite, pyrite and pyrrhotite; copper content varies in the range 0.45-0.5%. Minor elements include nickel, zinc, lead, gold and silver.

Chervonoshakhtarskiy occurrence is low-perspective due to limited host rock distribution by strike and depth (in addition, considerable part of host rocks are flooded by Karachunivske water reservoir) and low magnitude of ore-forming process.

Lead, zinc

This type of mineralization comprises some occurrences in Kryvorizka (Rudnychniy 1 and 2 (II-2-287, II-2-286)) and Chervonokostyantynivsko-Rodionivska (Rodionivskiy (I-1-244)) ore zones.

Rudnychniy occurrence is confined to the zones of fracturing and shearing within graphite-bearing schists of Gdantsivska Suite, and to the contact of Novokryvorizka Suite amphibolites and Skelyuvatska Suite conglomerates. Individual ore intercepts 0.6-5.0 m thick in drill-holes comprise vein-disseminated mineralization of galena and sphalerite with content (spectral analysis) of lead 0.2-1.0% and zinc 0.7-1.0%. Perspectives of this occurrence are unclear due to weak study.

Rodionivskiy occurrence is located in the western limb of the same-named syncline complicated by higher-order folds and breaks to be satellite of Zakhidno-Inguletskiy Fault. It is confined to the contact zone of Archean plagiogranitoids with calcite-dolomite marbles of Rodionivska Suite. The ore formation is poly-metallic, genetic type – hydrothermal, ore type – disseminated and massive. Ore minerals include pyrite, melnikovite, galena, sphalerite, chalcopyrite, pyrrhotite. Thickness of lens-like ore bodies varies from 0.2 to 3.4 m (1 m in average). Metal content (in %): lead – 0.21-8.07, zinc – 0.15-6.94, copper – 0.05-0.4, cadmium – 0.01; and silver – 0.5-2 g/t, gold – 0.012-0.5 g/t. Weighted-average lead content – 0.51%, zinc – 1.45%, sum of two metals – 1.96% (conditional content – 1.5%).

Rodionivskiy occurrence is thought to be prospective and requires further studies.

Molybdenum

Mineralization includes three genetic types: skarn, hydrothermal and greisen ones.

Skarn occurrences (II-1-165, III-1-189, IV-1-211) are known in Zakhidno-Inguletska fault zone and are confined to the contact of Rodionivska Suite calciphyres with plagioclase-microcline granitoids of Kirovogradskiy Complex. Carbonate and associated rocks are arranged into high-order folds and underwent hydrothermal-pneumatolic processes with formation of molybdenite dissemination and minerals containing fluids (ripidolite, axinite, clinohumite etc.). Ore bodies are 0.1-4.0 m thick, sheet-, lens- and bunch-shaped, and variable by strike and depth. Molybdenum content varies from thousandth to 0.05% in places attaining 0.5%. Low thickness of ore bodies and molybdenum grade as well as variability of spatial parameters preclude consideration this occurrence as prospective.

Hydrothermal Tokivskiy occurrence (II-4-300) of vein-disseminated copper-molybdenum ores is genetically linked with plagioclase-microcline granitoids of Tokivskiy Complex within same-named ore-bearing camp. Ore mineralization is resulted from hydrothermal-metasomatic alteration of amphibolites within north-west-trending zones of extensive fracturing accompanied by silicification and sericitization. Molybdenum content varies from 0.01 to 0.255% (0.019% in average), thickness of ore bodies – 0.1-0.4 m. Chalcopyrite, galena and sphalerite are observed in association with molybdenum. By the scale of ore mineralization this occurrence is thought to be not prospective.

Greisen occurrences (II-1-162, III-3-205, II-2-240) are related to granitoids of mainly Kirovogradskiy Complex in Kryvorizka and Balakhivsko-Varvarivska ore zones and Saksaganskiy Complex – in Yavdotivsko-Oleksandrivska ore-bearing zone.

Most perspective is Gannivskiy occurrence (III-3-205) with tungsten-molybdenum mineralization in the northern part of Kryvorizka ore zone. Molybdenum is observed in the zones of sulphide mineralization which in dissemination is developed along the contact between amphibolites of Surska Suite and aplite-pegmatoid and potassium granites of Kirovogradskiy Complex in the eastern limb of Gannivska Syncline. These are the contact zones where the rocks are greisenized and silicified. Occurrence is located in the zones of extensive fracturing where ore mineralization is related to quartz and quartz-feldspar veinlets. By chemical analysis results, molybdenum content is 0.01-0.18%, tungsten – 0.001-0.7%, copper – 0.001-0.1%. Minor elements include lead (0.1-0.2%, zinc (0.25-1.0%) and arsenic (0.02%).

Mineral composition of ore bodies is as follows: molybdenite, scheelite, chalcopyrite, arsenopyrite, sphalerite, quartz, sericite, biotite, carbonate, chlorite; multi-phase nature of ore-forming processes is clearly expressed. Total length of ore zone is 3 km, width – 100-300 m. In molybdenite rhenium content is up to 0.019%, cesium – 0.0019%, rubidium – 0.046%.

Gannivskiy occurrence is most perspective for discovery of molybdenum deposit. This conclusion is supported both by established favourable ore-controlling factors and direct evidences for economic mineralization [42, 57].

Arsenic

Arsenic occurrences (II-4-184) are encountered within Alferivska structure [33]. Arsenopyrite-pyrrhotite-pyrite mineralization is observed in thin veinlets and as dissemination in crushed ferruginous quartzites of Surska Suite. Arsenic content varies from .038 to 6.3%, gold content – 0.8 g/t. Mineralization is not studied and perspectives are not clear.

Rare metals, trace and rare-earth elements

Tungsten

Tungsten occurrences (I-1-146, I-1-147, II-3-175, IV-2-213) are confined to metamorphic (often high-calcium) rocks of Ingulo-Inguletska and Kryvorizka series within Balakhivsko-Varvarivska, Kryvorizka and Zakhidnokryvorizka ore zones. Most of these sites with increased tungsten content are related to skarnation of diopside-bearing gneisses [42, 51]. The sites are not studied and their perspectives are not clear.

Of mentioned ones, Zhovtyanskiy tungsten occurrence (II-3-175) is confined to the schists and ferruginous quartzites of Kryvorizka Series at their contact with microcline granites of Kirovogradskiy Complex. Here, in the zone of Kryvorizko-Kremenchutskiy fault, fractured and crushed rocks underwent extensive metasomatism which probably caused deposition of ore elements. Ore minerals include scheelite, arsenopyrite, chalcopyrite, pyrrhotite and pyrite; WO_3 content is 0.07-0.5%. Thickness of mineralized zones is 10.0-19.3 m.

To the south, in the same fault zone, drilling of Kryvorizka super-deep bore-hole [53] had revealed that similar scheelite mineralization is related to bi-metasomatism in migmatites of granodiorite composition, and to magnesium-carbon-dioxide metasomatism of the retrograde metamorphism in the rocks of Gleyuvatska and Gdantsivska suites. From these records it can be supposed that genetic type of Zhovtyanskiy tungsten occurrence is sedimentary-metamorphic-hydrothermal.

Favourable geological factors and direct evidences of tungsten mineralization suggest for possible discovery here the object of apparent economic value.

Rubidium

Rubidium occurrences (III-1-194, IV-4-210) within Chervonokostyantynivsko-Rodionivska ore zone belong to the formation of rare-metal oligoclase-microcline pegmatites. Ore-hosting rocks include microcline-plagioclase-biotite pegmatoid granites with relicts of gneisses extensively biotitized in the zone of Inguletskiy fault. Rubidium content is 0.06-0.211%, cesium – 0.002-0.009%. Ore mineralization is not studied and its perspectives are not clear.

Scandium

Scandium occurrences (I-4-160, II-3-180) are confined to amphibolites of Surska Suite and metasomatites of Kirovogradskiy Complex. It is established [57] that scandium in increased amounts is contained in the rock-forming minerals (hornblende, biotite, diopside) of none economic value.

Increased scandium content is also established in brown coal of Buchatska Series where (by spectral analysis) it varies in the range 20-50 g/t (Dmytrivskiy occurrence – I-4-21). Scandium enrichment is also determined in talc schists (up to 50 g/t), alkaline metasomatites (up to 100 g/t), and in minerals-concentrators – aegirine, riebeckite. Occurrences are not studied.

Rare earths

In places increased rare earths content is observed in albitites and albitized granites of Tokivskiy Massif [47]. REE content is 0.34-0.55% (Maryanskiy occurrence – III-4-308).

Rare earth mineralization is found within Balakhivsko-Varvarivska ore zone. Occurrences are confined to the vein granites with apatite mineralization (Starodubske – I-1-149), skarn rocks (Kodatske – III-1-190), and plagioclase-microcline granites (Novolozuvatske – IV-1-209). Occurrences are not studied and their perspectives are not defined.

Increased REE content in brown coal (occurrences I-1-3, 7, 8, 9, 10 (0.1-0.22%); II-1-26; III-1-46 [59]) could provide some interest.

Zirconium

Zirconium occurrences – Balakhivskiy (II-1-163) and Novovolodymyrivskiy (II-1-279) are confined to albitites and pegmatites located within Inguletskiy and Zakhidno-Inguletskiy faults.

The major mineral-concentrator is zircon, accompanied minerals – apatite and monazite. Maximum grade is 0.6-0.7%, thickness of intervals with zirconium mineralization is 2-6 m. Besides zirconium, rare earths are frequently observed, specifically, in Novovolodymyrivske occurrence their content rises up to 0.25%. Occurrences are not studied and their perspectives are not clear. Zirconium mineralization in the banded iron-formation rocks of Skhidnogannivska structure could be of practical interest where it is confined to magnetite-riebeckite-aegirine rocks and comprises malacon (Gannivskiy occurrence III-3-204).

Increased zircon content (up to 6 kg/m^3) is encountered [200] in weathering crusts after granitoids of Pivnichnogannivskiy occurrence with thickness 6.0 m. Occurrence is not studied.

Precious metals

Gold

Geological setting of known gold occurrences is fairly variable. Gold mineralization, similar to economic, is normally known in zones of silicification and sulphidization within greenstone, banded-iron and black-shale formations. In the latter case two occurrences are encountered – Petrivskiy (III-2-197) and

Grafitivskiy (III-2-198) – where vein quartz-sulphide with gold mineralization is confined to graphite gneisses and schists of Upper Sub-Suite of Rodionivska Suite. Gold is fine-dispersed and is mainly related to pyrite. Gold grade is low and rarely attains 3-5 g/t; mineralization is confined to the zones of silicification and sulphidization located within satellite breaks of Inguletskiy fault. Perspectives for discovery of economic mineralization are estimated to be low [42].

More prospective are thought to be zones of sulphide vein-disseminated mineralization in greenstone structures of linear and central types filled with mafic metavolcanics. This type of mineralization is exemplified by Novochygyrynskiy occurrence (III-3-201) where gold grade is 0.282-3.82 g/t. Here within fault zone mineralization is confined to sulphidized, chloritized and carbonatized amphibolites of Surska Suite. Host rocks are metamorphosed under epidote-amphibolite facies. These data as well as gold records on mafic-ultramafic rocks from volcano-tectonic structures in Yavdotivsko-Oleksandrivska ore-bearing zone suggest for the needs of further studies.

The most prospective (according to recent data) is gold mineralization confined to the zones of extensive tectonic and metasomatic re-working and banded-iron and black-shale rocks within Kryvorizko-Kremenchutskiy fault. In similar geological setting Zhovtyanskiy occurrence is located (II-3-176) where the rocks are extensively milonotized, silicified, carbonatized and include abundant sulphide dissemination with gold grade 0.2-4.4 g/t, in places 12 g/t. Gold is free with grain size up to 0.06-0.08 mm. At present occurrence is involved in prospecting-evaluation studies. According to prognostic results [42], similar sites, prospective for gold mineralization, can be found elsewhere in Kryvorizko-Kremenchutska metallogenic (iron-ore) sub-zone.

Silver

Silver is observed as concomitant element mainly in occurrences of nickel, copper and gold. Silver distribution in Precambrian rocks is irregular: it is established that high silver content is found in graphite gneisses where it attains 30 g/t (Starodubskiy occurrence – I-1-148) and in sulphide copper-nickel ores (5-7 g/t). The highest silver grades determined in some samples are 30-133 g/t (polymetallic ores of Rodionivskiy occurrence).

Radioactive metals

Uranium

Four uranium deposits are known in the studied area – three Precambrian ones in crystalline basement and one Paleogene deposit in the platform cover.

In crystalline basement, the largest are deposits of hydrothermal-metasomatic origin – Zhovtorichenske (II-3-179) and Pershotravneve (IV-3-229) with identical composition of uranium-ferruginous ores. Uranium mineralization is related to carbonate-sodium metasomatic processes, superimposed over iron ores, and comprises uraninite and pitchblende, rarely coffinite, nenadkevite and brannerite. Uranium-bearing ore bodies are sheet-like and lens-like, rarely pillar-like; their thickness varies from 1 to 15 m (rarely up to 50 m) and length to first hundreds of meters. Ore body depth does not exceed 1500 m. Uranium content in ores varies from 0.07 to 0.47%, rarely to 1-3%.

Isotopic age of uranium ores in both deposits is 1800 MA [27]. Pershotravneve uranium-iron deposit is conserved, and Zhovtorichenske deposit is under exploitation by Eastern MBP.

In Mykolokozelske deposit (III-1-302) uranium mineralization of sedimentary-metamorphosed type is located in conglomerates, rarely in sandstones of Skelyuvatska Suite of Kryvorizka Series. Mineralization comprises dissemination of uraninite, coffinite, brannerite, uranium-bearing bitumen, peachblende, uranium black in cement of conglomerates and sandstones. Uranium grade is 0.01-0.09%, rarely 0.16-0.22%. Ore body thickness is 0.15-12.8 m. Isotopic age of uranium mineralization is 2310-2680 Ma [27]. Nowadays ores of this type are not economic.

Devladivske uranium deposit (IV-3-64) is confined to the continental sediments of Buchatska Series. Uranium mineralization is located in coaliferous sands, rarely in brown coal and coaliferous clays, with distinct ore composition. Uranium is absorbed onto coaliferous and clayey matter in uranium black, rarely radio-barite and uranium-bearing ozokerite.

Uranium content varies in the range 0.01-0.3%, in place up to 1%. Thickness of ore bodies is 0.2-15 m, rarely 0.5-6.5 m. Ore bodies are sheet-like and are extended over hundreds of meters.

Deposit is exhaustive mined through underground leaching.

NON-METALLIC MINERAL RESOURCES

Agro-chemical raw materials

Apatite

Gannivskiy apatite occurrence (III-3-206) is encountered in Skhidnogannivska Syncline in amphibole-magnetite quartzites of Saksaganska Suite, at the contact with quartz-mica schists of Skelyuvatska Suite. Apatite is observed in dissemination and thin veinlets. The latter, being grouped in mineralization zones, are extended over the distance from first metres to some tens of metres, and are confined to the zones of alkaline metasomatism. This occurrence is prospective but weakly studied.

Tokivskiy apatite occurrence (III-4-307) is encountered within Tokivskiy granite massif [46]. Mineralization is confined to the zones of metasomatism and is superimposed onto gabbroid rocks of total width 0.1-0.5 km and length 0.5-1.5 km. The ores are disseminated, P_2O_5 content varies from 2.0 to 4.5%. In view of small size of metasomatites, at present occurrence is thought to be of little importance.

Non-metallic raw materials for metallurgy

Flux dolomites

Dolomite marbles can be used as refractory materials in metallurgy and in fluxing of iron-ore pellets.

Velyka Gleyuvatka deposit (IV-2-226) is located in the central part of Saksaganska structure and is composed of dolomite marbles of Gdantsivska Suite, Kryvorizka Series. Productive marble sequence is from 120-170 m to 300-350 m thick and up to 5 km long. Overburden thickness in the eastern part of deposit is 16-20 m, in the western part – 50 m. Detailed description of deposit is given elsewhere [42].

Refractory clays

In the map sheet areas there are located four deposits of refractory clays with economic reserves (Pyatykhatske – II-3-39, Chervonoivanivske – II-3-40, Veseloternivske – IV-3-63, Devladivske – IV-4-662). Clays are observed in 5.0-13.0 m thick lenses in Paleogene and Neogene sediments.

Secondary kaolin

Secondary kaolines are mined as by-product with refractory clays in Pyatykhatske deposit (II-3-41). White and grey kaolines do have refractory properties.

Occurrences of refractory kaolines comprise white and grey kaolinite clays of Kyivska Suite and are observed in 1.5 m thick lenses and interbeds; they have refractory properties.

Foundry sands

There are known four deposits (Artemivske – II-2-34, Chervonoivanivske – II-3-43, Gannivske – III-2-50, Pavlivske – I-1-68) of Lower and Middle Pliocene sands which can be used as counterpart of the foundry charge.

Chervonoivanivske (II-3-43) and Pavlivske (I-1-68) deposits are explored, do have economic reserves, but are not mined.

Non-ore (technological) raw materials

Graphite

Four graphite deposits and four occurrences are known in the studied area [35, 42].

Within Balakhivsko-Varvarivska ore zone most perspective are Balakhivske (II-1-161), Varvarivske (III-1-192) and Kodatske (III-1-191) deposits. Graphite bodies are sheet-like and are confined to syncline fold structures. Graphite bodies are from 30 to 60 m thick and up to 5.5 km long, composed of coarse-flaky graphite and belong to the economic type of crystalline graphite ores. Graphite carbon content in ores is 5-8%; it is obtained concentrate with graphite carbon content 93.74-94.60% and ash content 5.4-6.66%. In Balakhivske deposit graphic ore reserves are approved by categories B, C_1 and C_2.

Strong litho-stratigraphic control of mineralization is characteristic: all economic ore bodies are confined to the Upper Sub-Suite of Rodionivska Suite and are located in graphite-biotite gneisses and sillimanite-graphite-two-mica mafic gneisses.

Besides others, metamorphism of graphite ores comprises important factor of graphite quality. Economic ores (coarse-flaky graphite) are formed under amphibolite and granulite facies metamorphism. Under retrograde metamorphism close to fault zones ore texture rearrangement may appear with additional ore enrichment and formation of high-quality graphite ores (Balakhivske deposit). Under greenschist facies crypto-crystalline graphite ores are formed which are encountered in Kryvorizka structure (Gdantsivskiy occurrence – I-2-263).

Recent geological mapping, prospecting-evaluation and exploration works had allowed re-evaluation the perspectives of Balakhivsko-Varvarivska ore zone and recommendation of this area as major graphite-bearing province in Ukrainian Shield [42].

Talc

Talc deposits Osychky (I-2-271) and Inguletske (III-1-301) are confined to the talc horizon in Skelyuvatska Suite of Kryvorizka Series. Talc horizon is mainly composed of chlorite-talc schists and is traced over the distance of 2250 m at thickness 100-250 m and 15-33 m depth. Deposits are not being mined.

Amphibole asbestos

Occurrences of amphibole asbestos (Tarapakivskiy – I-2-257 and Gleyuvatskiy – IV-2-224) are located in Saksaganska structure and confined to the rocks of Upper Sub-Suite in Saksaganska Suite of Kryvorizka Series. In this structure the zone of amphibole-asbestos mineralization is extended by strike over 8 km and is 600-800 m wide. In the zone, quartz veins with amphibole-asbestos are observed over the distance about 60 m by strike and 20 m by dip at thickness from 5 to 50 cm.

Amphibole-asbestos mineralization is not economic due to low quality and small quantity of amphibole-asbestos fibres.

Primary kaolin

Primary kaolines are used as raw material for ceramic and refractory wares.

In the prospected and explored deposits (I-2-151, III-2-196, IV-2-212, I-1-245, I-1-246) the productive sheet-like sequence is from 9.0 to 25.0 m thick and composed of primary kaolines – white and light-grey, greasy, with quartz grains. Melting temperature exceeds 1500°C. Overburden thickness varies from 8.0 to 29.5 m. Deposits are not being exploited.

Mineral pigments

This type of minerals is known in the biggest in Ukraine deposit of iron-oxide mineral pigments (shaft Gigant, I-2-258). The ores provide the major raw material for varnish-pigment industry in chemical processing cycle.

Deposit is confined to the rocks of Saksaganska Suite of Kryvorizka Series and is composed of chlorite and hornblende schists intercalating with goethite-hematite and kaolinite-hematite ores.

Goethite-hematite ore ("mummy" – mineral pigment) of dark-red colour is composed of water-free iron oxide which content in the ore is 58-70%.

Kaolinite-hematite ore ("red lead" – mineral pigment) comprises non-layered hematite variety which is easily being crushed to the blood-red powder. Content of Fe_2O_3 in the ore is 41.9%.

Deposit is in production since 1962.

Mineral pigments are known in Zhovte village (II-3-36) where they comprise ochre that is observed in separate bunches within Miocene sands. Ochre thickness varies from 0.4 to 1.5 m. Deposit is not being mined.

Construction raw materials

In construction purposes there are widely used Precambrian crystalline rocks (aggregate and crushed stone materials), as well as Sarmatski and Pontychni sediments (cement raw material), Neogene sediments (construction sands and limestones), and Quaternary loess-like loams (brick-tale raw materials).

Construction stones

Construction stones (aggregate and crushed stones) are being obtained from granitoids of Tokivskiy, Demurinskiy and Inguletskiy massifs. From there Savrivske (III-2-202), Devladivske (III-3-208), Kolomoytsevske (IV-3-236), Karachunivske (I-2-262) and Tokivske (II-4-299) deposits are in production. Of these deposits Tokivske one should be noted since its granites are used not only in construction purposes but also as outstanding facing and ornamental stones.

Besides explored deposits there are encountered numerous exposures of granitoid rocks in the valleys of Ingulets, Saksagan, Zelena, Zhovta and Kamyanka rivers. Reserves of these sites are thought to be actually indefinite but are not studied for specific purposes.

Cement raw materials

In the map sheet L-36-IV there are known some deposits (Zhovtokamyanske – II-4-88, Matyanske – III-4-95) of limestones and clays which are suitable as major raw material for cement production. Limestones and clays of Sarmatskiy and Pontychniy age are from 5.0 to 10.0 m thick; overburden thickness – from 0.2 to 18.0 m.

Zhovtokamyanske deposit is mined by Kryvorizkiy cement plant.

Construction limestones

Limestones and dolomitized limestones of Sarmatskiy and Pontychniy age are widely used in construction purposes (wall stone, slack lime etc.). Deposits in production (Zhovtokamyanske – II-4-85, Arkhangelske – IV-2-99, Osokorivske – IV-4-101 and others) are located along river valleys where their exploitation is economically reasonable.

Construction sands

In the both map sheets there are known numerous deposits (IV-2-61; I-2-69,70; II-2-82; IV-2-98) of various-age sands – Upper Miocene, Middle Pliocene, Quaternary which can be used as natural construction materials for aggregates, construction liquids, inert admixture to concrete and reinforced concrete, as well as for silicate brick manufacturing.

Brick-tile raw materials

The most widespread and accessible for brick-tile raw materials mining are Quaternary loams and clays laying in solid sheet beneath the soil-plant layer.

There are known numerous deposits of these raw materials over both map sheets (Lozuvatske – IV-2-60, Oleksandriyske – I-1-102 and others). They comprise pale-brown, light-yellow, brownish-yellow and brown loess-like loams from 3.1 m to 13.0-15.0 m of total thickness.

MINERAL WATERS

The known deposits of mineral waters with approved reserves are located in the map sheet L-36-IV. These include deposits of medical-potable fresh waters (Vesela Dacha – I-2-256) and neo-radon waters (Southern MBP – I-2-276).

In addition, there are known explored but currently not producing radon waters at the sites Valove, Khrystoforivka, Ingulets, and mineral waters fee of specific components – the sites Karachuny and Chervoniy Shakhtar.

Vesela Dacha deposit is confined to the extensively fractured granites of Inguletskiy Complex. The depth of fracturing zone is up to 90-120 m. The waters are sulphate-chloride and chloride-sulphate with complex cationic composition, mineralization – 2.5 g/l.

Southern MBP deposit is confined to arkose-conglomerate-quartzite sequence of Skelyuvatska Suite, Kryvorizka Series. The waters are chloride-sulphate-sodium-calcium, mineralization – 5.7 g/l. Occurrence of thorium-uranium mineralization in the rocks facilitates formation of medical (healing) radon waters. Radon content is 57-78 nCn/l.

10. EVALUATION OF THE TERRITORY PERSPECTIVES

Evaluation of the territory perspectives is based on the integrated knowledge on mineral deposits and occurrences as well as regularities in their distribution. And perspective evaluation is resulted in recommendations for further geological exploration works.

By degree of prospective potential the following fields are distinguished (see Fig. 9.1):

- high-perspective, which include the sites of producing iron-ore deposits in Kryvbas and explored Balakhivske graphite deposit;
- medium-perspective (under-explored), where are located iron-ore and graphite deposits with economic reserves out of production, as well as occurrences of molybdenum, gold and nickel with prognostic resources [42];
- low-perspective (weakly explored), where some occurrences without evaluated prognostic resources are located. These also include the fields with favourable ore-controlling factors and available highly-contrasted geochemical anomalies [42];
- unclear-perspective sites with favourable geological setting and development of hydrothermal-metasomatic processes, which are weakly studied and require further works.

The major perspectives of the area are related to the iron-ores and are defined by:

i) in Kryvorizka and Zakhidnokryvorizka ore zones:

- increasing the depth of high-grade iron-ores to be mined;
- implication the magnetite quartzites within operating shaft fields and in between them;
- bringing into production the oxidized ferruginous quartzites;

ii) in Petrivsko-Zhovtyanska ore zone – extended exploration over known deposits;

iii) in Zhovtovodsko-Popelnastivska ore zone – evaluation of deposits over new fields.

Major perspectives for iron-ores are confined to Kryvbas and are related to ferruginous quartzites. Expanded prognostic evaluation of iron-ores by specific sites is given elsewhere [42].

The perspectives in prognosis for new in the area copper-nickel sulphide mineralization are defined. It is recommended Yavdotivsko-Oleksandrivska ore zone to be the principally new field perspective for nickel and copper where copper-nickel ore and molybdenum occurrences (II-3-293, II-3-298) with evaluated prognostic resources [46], as well as nickel, copper, cobalt, gold and molybdenum mineralization points and geochemical anomalies [42] are encountered. Application the complex of regional and local ore-controlling factors as well as direct mineralization records had allowed conclusion Yavdotivsko-Oleksandrivska ore zone is highly perspective in term of economic concentrations of nickel, copper and probably precious metals – gold and platinoides.

Among the findings to be prospective for gold mineralization in crystalline basement two ones are distinguished by complex of prognostic-evaluation criteria:

- Zhovtyanskiy (II-3-176), where geological structures and the rocks involved are proven to be extensively broken and therefore economic gold mineralization is most probable to be found there. Specifically, it is evidenced by favourable ore-controlling factors, occurrence of ore finding with economic gold grade as well as mineralization points and anomalies of gold and associated metals by strike of mineralized zone [36]. At present prospecting-evaluation works are underway at this occurrence;
- Novochygyrynskiy (III-3-201), with evaluated prognostic gold and copper resources where prospecting-evaluation works are recommended [61].

Two occurrences are thought to be prospective for stockwork-type molybdenum ores – Gannivskiy (III-3-205) and Oleksandrivskiy (II-2-290). Most interesting is greisen mineralization of Gannivskiy occurrence with complex tungsten-molybdenum ores. Taking into account the ore-controlling factors established as well as occurrence of ore mineralization with prognostic resources, the small-scale molybdenum deposit can be expected [45, 57].

In Oleksandrivskiy occurrence the molybdenum mineralization, which by complex of evidences is thought to be of re-generated type [46], is located in volcanic units. Since the major part of this mineralization is confined to the lower portions of these units, it can be supposed economic mineralization at the depth [42, 58].

Large- and medium-scale graphite deposits are being predicted in Balakhivsko-Varvarivskiy ore camp. Evaluated total graphite ore reserves and resources allow entitlement of this camp as the biggest graphite-bearing area in Ukraine [35, 42].

Besides mentioned leading mineral types some new perspectives for tungsten mineralization are established in Precambrian rocks within Central-Kryvorizkiy deep-seated fault [53]. The tungsten occurrences (II-3-275, IV-2-213) are accompanied by extensive hydrothermal-metasomatic processes resulted in ore-element re-distribution and allowing prognosis of tungsten-ore objects, apparently of sedimentary-metamorphogenic-hydrothermal type.

Long-term weathering processes over studied area in Paleozoic-Mesozoic had led to the abundant productive weathering crusts after ultramafic rocks and formation of silicate nickel occurrences within the new Yavdotivsko-Oleksandrivskiy igneous belt [42, 46]. Laterite bauxite occurrences with complex vanadium mineralization are already encountered there. This suggests for the opportunity of small-scale silicate nickel and aluminum deposits to be found coupled with associated cobalt in the first case and vanadium in the second one.

In the platform cover sediments over the studied area, by complex of prospecting-evaluation evidences, there are distinguished the fields prospective for manganese deposits [42]. The new working direction comprises study, besides the oxidized ores, the mixed oxide-carbonate and carbonate manganese ores, which prognostic contours are shown in Fig. 2.8.

Based on aforementioned features of prospective fields and occurrences, the following directions for their further studies are recommended.

In the high- and medium-perspective fields and objects with perspective ore types and evaluated prognostic resources there are recommended.

1. Various-stage geological exploration (by applicant requests):

- for iron, graphite and manganese ores as well as brown coal.

2. Prospecting-evaluation works for:

- gold in Zhovtyanskiy and Novochygyrynskiy occurrences;
- molybdenum in Gannivskiy and Oleksandrivskiy occurrences;
- nickel, copper and cobalt in Oleksandrivskiy occurrence;

3. Deep geological mapping in the scale 1:50 000 (DGM-50) (see Fig. 9.1):

- within prospective but weakly studied Yavdotivsko-Oleksandrivska ore-bearing zone specialized for copper-nickel and molybdenum mineralization, silicate nickel, and bauxites. The purposes of these works include the study of potentially ore-bearing structures (Yavdotivska, Dovgyntsivska, Pivnichnooleksandrivska); prospecting and establishing the regularities in location of copper-nickel ores and precious metals; studies of weathering crusts.
- in the northern part of Kryvorizkiy Deep-Seated Fault within prospective and ore-bearing structures (Popelnastivska, Zhovtyanska) where iron-ore deposits, gold and tungsten occurrences as well as numerous geochemical anomalies are encountered [12, 42, 43].

11. ECOLOGICAL-GEOLOGICAL ENVIRONMENT

Technogenic loading over the geological environment, mainly due to abundant mining and metallurgical activities, is high over the most of studied area. It is mainly caused by big open pits and numerous small quarries (from first tens to hundred meters deep), enormous dumps, ponds, tailings, as well as collapse zones nearby many shafts of Kryvorizkiy basin. In around the latter there are also formed huge depression funnels up to 2 km deep and up to 6 km wide, which had activated processes of rock tension and subsidence, suffusion etc. These sites, occupying up to 10% of the territory, are so hardly broken that are actually excluded from the human activities (Fig. 11.1). Particular description of these fields is given elsewhere in report of EGSF-200 [42].

Contamination of geological environment over most part of the area is mainly resulted from aforementioned technogenic loading as well as extensive agricultural land use. The latter had caused input of chemical elements and pesticides in soils and bottom sediments as well as chemical contamination of surface and underground waters. The soil chemical contamination over entire territory is evaluated by the bulk concentration coefficient (BCC) of chemical elements (see Fig. 11.1). The highest BCC values (exceeding admissible ones by the factor of 20) are encountered in the southern part of Kryvyj Rig city, where metallurgical plant, coke-chemical plant and two biggest MBP (Southern and Novokryvorizkiy) are located. This technogenic anomaly is dominated by lead, zinc and copper.

Over about half an area (mainly in the central and southern parts) the soil technogenic contamination varies from 6 to 20 BCC and is clearly related to the local contamination sources (mining enterprises, industrial objects, animal-farm complexes, waste dumps, fertilizer and pesticide storages etc.) under specific wind rose, landscape and relief. In these anomalies, within Kryvorizkiy mining complex, lead, zinc, chromium, and tin predominate whereas beryllium, niobium, arsenic, strontium, phosphorus – over remaining territory; these are mainly elements of the first and second danger groups. Their more detailed features are given elsewhere [42].

Chemical contamination of bottom sediments had allowed delineation of contamination paths through water streams marking the contamination origins, and in this way provided the explanation for these elements appearance in the soils (see Fig. 11.1). It can be exemplified by the Ingulets River basin which crosses over entire territory from the north to south and where bottom sediments contain high concentrations of lead, zinc and chromium just in and down-stream the Kryvyj Rig city. Expanded description of chemical element accumulation in bottom sediments is given in report of EGSF-200 [42].

Pesticide soil contamination in the agricultural areas is mainly caused by insecticides. Most of identified varieties belong to high-stable, stable and moderate-stable by their preservation (mainly chlorine-organic). The highest BCC anomalies are encountered at Shyrochany, Yavdotivka, Kamyanka and other villages in the eastern part of the area (see Fig. 11.1).

Radioactive soil contamination is encountered in the area of Terny and Zhovti Vody towns where enterprises are located which mine and process uranium ores; their wastes had contaminated the local environment in mechanical way. Besides that, in the tailing to the south from Zhovti Vody town increased radioactivity is also identified being originated through residual elements of uranium ore beneficiation (see Fig. 11.1). Since the radioactivity in mentioned places is several times (sometimes by the factor of ten) higher the admissible norms, these sites belong to the high danger zones.

Most extensive surface water contamination is identified within Kryvbas. Particularly, in the streams of Ingulets and Saksagan rivers, just within Kryvyj Rig city and down-course, there are determined increased concentrations of bromine – 3-25 times of top admissible concentration (TAC), iron – 10 TAC, selenium – 1-6 TAC, manganese – 3 TAC. Water mineralization attains 2 g/dm^3. The situation is better in the rivers to the north of Kryvorizkiy basin where TAC of mentioned elements does not exceed 2 and water mineralization – 1 g/dm^3.

Contamination of underground waters in Quaternary water-bearing horizon is almost aerial (see Fig. 8.1). It was established through some trials the following rank of underground water contamination degree: less than 10 BCC – low-contaminated, 10-30 BCC – high-contaminated, and more than 30 BCC – extremely high-contaminated. The widest and most extensively contaminated areas are characteristic for the sites of mining and large industrial enterprises. In these cases high concentrations of bromine (up to 29 TAC), strontium (up to 22 TAC), iron (up to 478 TAC), selenium (up to 9 TAC) and barium (up to 10.5 TAC) are determined; mineralization varies from 1.2 to 20.4 g/dm^3.

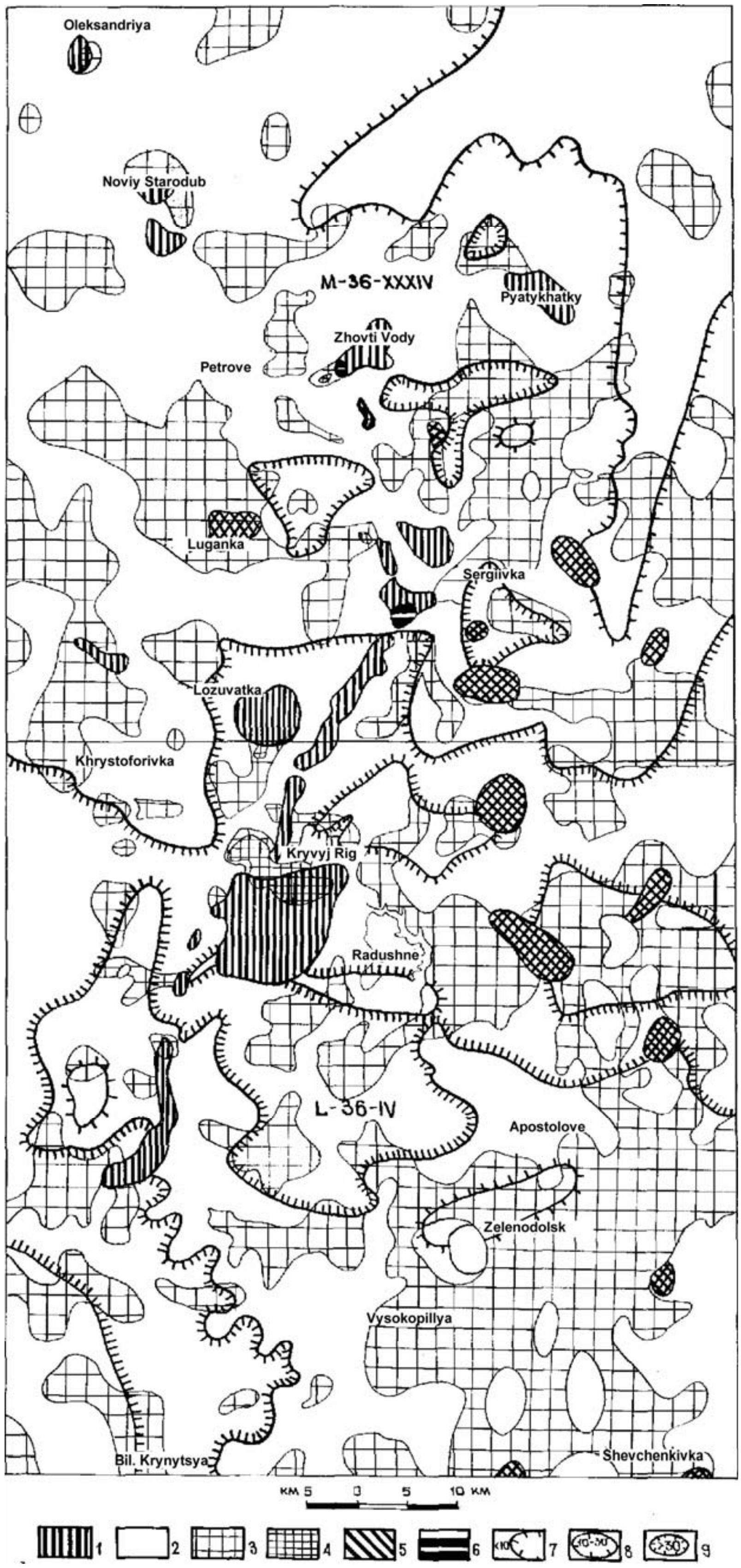


Fig. 11.1. Ecological-geological sketch map.

Technogenic loading: 1 – estrangement zones (big quarries, tailing, shaft collapse zones). Contamination of geological environment: 1) in soils – a) chemical in BCC (2 – less than 6, 3 – from 6 to 20, 4 – higher than 20); b) pesticide in BCC (5 – from 3 to 10); c) radioactive (6 – occurrence of radioactive wastes of Southern MBP); 2) in underground waters in BCC (7 – less than 10, 8 – from 10 to 30, 9 – higher than 30).

In the agricultural land areas the underground waters are more contaminated at the sites of irrigated farming where their mineralization varies from 1.3 to 19 g/dm^3. The toxic element distribution is as follows: bromine – from 1.2 to 47 TAC, strontium – from 1.2 to 33 TAC, iron – from 1.2 to 38 TAC; increased (up to 2-3 TAC) content of barium, aluminum, fluorine, selenium and mercury are also determined.

Based on distribution and magnitude of technogenic loading and contamination of geological environment the territory zonation is performed by two major parameters – the living comfort and suitability degree of engineering-geological development. In this respect, the worst zone encompasses entire Kryvorizkiy mining-industrial complex [42]. It is also evidenced by the air contamination analysis in Kryvyj Rig city.

The studies carried out had revealed the major changes of geological environment occurred mainly in the soils as well as surface and underground waters; at present yet a number of these changes are irreversible. Due to lacking of necessary funding in the environment protection as well as strong ecological control the situation most probably will get worse and this may cause catastrophic consequences. In line of ecological state stabilization it is recommended:

- in course of construction the new and re-construction the former industrial enterprises it is compulsory to use environmentally-safe technologies which preclude geological environment contamination with harmful components;
- to make strong preference of the underground iron-ore mining comprising less ecologically dangerous process;
- to process the enormous reserves of stock-piled iron-ores in the dumps, and in case of non-processing dumps to undertake their reclamation;
- to continue development of technologies for utilization of toxic wastes and high-mineralized shaft waters;
- to perform monitoring of geological environment over the major contaminator - Kryvorizkiy mining-industrial complex;
- to improve medical activities in reduction the impact of unsuitable ecological environment over population in Kryvorizkiy mining-industrial complex.

CONCLUSIONS

Prepared second-edition set of geological maps over the map sheets M-36-XXXIV and L-36-IV in the scale 1:200 000 provides the chiefly new ideas on geology and mineral resources of Kryvorizkiy iron-ore area. These principally new results of practical value include:

in crystalline basement:

- establishment the new specific boundary between the Middle-Dniprean and Ingulo-Inguletskiy areas in Kryvbas along Tarapakivskiy thrust with definition of transitional Inguletsko-Kryvorizka LTZ in the latter;
- establishment the iso-facial patterns of lower part of Ingulo-Inguletska Series in the area of Pravoberezhni magnetic anomalies and in the Main (Kryvorizka) syncline with definition the stratigraphic analogs of Skelyuvatska Suite in the upper part of Zelenorichenska Suite;
- definition and mapping the new volcano-tectonic structures within Yavdotivsko-Oleksandrivskiy igneous belt and fault-side zoned plutons of Novoukrainskiy Complex;
- the new tectonic concept of: main iron-ore Saksaganska nappe-syncline (by depth too) in Kryvorizko-Kremenchutska LTZ; graben-synclines and block-dome structures in Kirovodragska and Inguletsko-Kryvorizka LTZ; linear greenstone synclines, diapiroid domes and Tokivskiy Massif in Verkhivtsivsko-Chortomlytska LTZ; zone of Kryvorizko-Kremenchutskiy Deep-Seated Fault at the boundary between Archean greenstone terrain and Paleo-Proterozoic para-gneiss belt;

in platform cover:

- adjusted zonation of Paleogene and Neogene sediments in the Central and Southern regions of Ukrainian Shield;
- definition of two Paleogene and Neogene column types in mentioned regions with their development in two LTZ in both regions;
- definition and mapping in the Southern region the new stratified subdivisions – coaliferous clay pile, Khadzhybeyska Suite, Chokrakski, Zbruchski, Geliksovi and Bagerivski layers;
- definition and mapping the sub-aerial facies in Quaternary sediments and their subdivision (for the first time) into climatoliths.

Presented new features of geology had allowed another metallogenic zonation of the territory and its perspective evaluation making prediction not only mineral types traditional for the area – iron, manganese, titanium-zirconium, graphite ores and brown coal, but also new types of mineralization: sulphide copper-nickel, tungsten-molybdenum and gold in the new perspective fields including major Yavdotivsko-Oleksandrivska ore-bearing and Zhovtyansko-Popelnastivska ore zones. It is suggested large-scale deep geological mapping in these fields.

For the first time over both map sheets there is characterized ecological-geological situation with definition the technogenic landscapes and description of contaminating element distribution over them. On this ground, there are distinguished the fields with high contamination figures and the fields of negative technogenic processes development, and for the first time prediction is made for geo-ecological situation in Kryvorizkiy iron-ore region with practical recommendations.

Despite of high information background and precision of prepared maps, some geological issues remain unsolved yet. These disputable points mainly concern weakly-studied and geologically complex Precambrian units. The most important ones include:

- the forming conditions and age of the oldest greenstone rocks (Bazavlutska Sequence) and their metal-bearing;
- occurrence and distribution of Kirovogradskiy Complex granitoids within Neo-Archean granitoids of Demurinskiy Complex and their impact on evolution of the latter, Skhidnogannivska Syncline and formation of molybdenum and tungsten mineralization in its eastern limb;
- lack of U-Pb (Sm-Nd) isotopic dating of metasedimentary rocks of Ingulo-Inguletska and Kryvorizka Series making vulnerable their correlation in stratigraphic scheme of Precambrian units;
- occurrence of plagiogranitoid bodies with age about 3.0 Ga (outside the studied areas in the western limb of Ingulo-Inguletskiy synclinorium) which cut biotite gneisses of Checheliivska Suite making doubtful the age of upper part of Ingulo-Inguletska Series.

Solution of mentioned problems is possible through further geological mapping which can be grounded on the prepared maps of the given map sheets.

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Annex 1. List of deposits and occurrences indicated in the geological map and map of mineral resources in pre-Quaternary units

Square index and object number in the map	**Mineral type, object name**	**Reference**
	Map sheet M-36-XXXIV (Zhovti Vody)	
	Combustible minerals	
	Solid combustible minerals	
	Brown coal	
	Deposits	
I-1-1	Semenivsko-Oleksandriyske	7, 42, 59
	Krasnopilske	
I-1-4	Krasnopilska site	42, 59
I-1-5	Krynychuvatska site	7, 42, 59
	Balakhivsko-Mykhaylivske	
II-1-25	Maryanivska site	7, 59
II-1-27	Mykhailivska site	7, 59
II-1-28	Balakhivska site	7, 59
IV-1-52	Gurivske	7, 60
IV-3-62	Veseloternivske	42, 49
IV-3-65	Pichuginske	42, 49
	Occurrences	
I-1-2	Shumylivskiy	59
I-1-6	Izmaylivskiy	59
I-2-15	Maloovnyankivskiy	29
I-3-17	Popelnastivskiy	29
I-4-20	Lykhivskiy	38, 54
I-4-24	Maryanivskiy	38, 54
II-2-29	Zelenivskiy	29
II-2-30	Zhuganskiy	29
II-2-31	Zelenivskiy-2	29
II-2-32	Ivanivskiy-2	29
II-2-33	Ivanivskiy-1	29
III-1-45	Varvarivskiy	59
III-2-49	Oleksandro-Maryvskiy	60
IV-1-53	Gruzskiy	60
IV-1-57	Ivanivskiy	60
IV-1-59	Novolozuvatskiy	60
	Metallic mineral resources	
	Non-ferrous metals	
	Titanium	
	Deposits	
I-4-22	Malyshevske (Samotkanske)*	
	Occurrences	
I-3-16	Popelnastivskiy	12, 29
I-3-18	Veselopodilskiy	12, 29
I-3-19	Grygorivskiy	12, 29

Square index and object number in the map	**Mineral type, object name**	**Reference**
	Rare metals, rare-earth and trace elements	
	Zirconium	
	Occurrences	
I-2-13	Ovnyankivskiy-1 (DH 23844)	29
I-2-14	Ovnyankivskiy-2 (DH 23730)	29
	Rare earths	
	Occurrences	
I-1-3	Golovkivskiy (DH 4583)	59
I-1-7	Krasnopilskiy (DH 4571)	59
I-1-8	Mykhaylivskiy-1 (DH 4683)	59
I-1-9	Novostarodubskiy (DH 4656)	59
I-1-10	Mykhaylivskiy-2 (DH 4609)	59
II-1-26	Balakhivskiy (DH 4653, 4663)	59
III-1-46	Varvarivskiy (DH 4449)	59
	Scandium	
	Occurrences	
I-4-21	Dmytrivskiy	54
	Radioactive metals	
	Uranium	
	Deposits	
IV-3-64	Devladivske	49
	Non-metallic mineral resources	
	Raw materials for metallurgy	
	Foundry sands	
	Deposits	
II-2-34	Artemivske	12, 42
II-3-43	Chervonoivanivske	29
III-2-50	Gannivske	42
	Refractory clays	
	Deposits	
II-3-39	Pyatykhatske	29
II-3-40	Chervonoivanivske	29
IV-3-63	Veseloternivske	49
IV-4-66	Devladivske	49
	Secondary kaoline	
	Deposits	
II-2-35	Pivnichnoartemivske	29, 59
II-3-41	Pyatykhatske	12, 29
	Occurrences	
II-3-38	Kulturne Village	29
III-1-47	Bashtynskiy	60
III-1-48	Kirovskiy	60
	Non-metal ore (technological) raw materials	
	Mineral pigments	
	Deposits	
II-3-36	Zhovtyanske	7, 29
II-4-44	Saksaganske	7, 38
	Construction materials	
	Construction sands	
	Deposits	
I-2-11	Gubarivske	29

Square index and object number in the map	Mineral type, object name	Reference
I-2-12	Chervonokamyanske	29
I-4-23	Lozuvatske	38
II-3-37	Novoluzke	29
II-3-42	Erastivske	42, 44
III-2-51	Gannivske	42, 44
IV-1-54	Gruzke-1	42, 60
IV-1-55	Sofie-Geykivske	60
IV-1-56	Novolozuvatske	42, 60
IV-1-58	Ivanivske	42, 60
IV-2-61	Maryanivske	20
	Brick-tile raw materials	
	Deposits	
IV-2-60	Lozuvatske-3	20
	Map sheet L-36-IV (Kryviy Rig)	
	Combustible minerals	
	Solid combustible minerals	
	Brown coal	
	Deposits	
I-1-67	Khrystoforivske	40
I-3-71	Pivdennopichuginske	2, 49
II-1-77	Zelenivske	2
II-3-84	Apostolivske	45, 50
	Occurrences	
II-1-79	Zakhidnoingouletskiy	56
II-1-80	Skhidnoingouletskiy	56
	Metallic mineral resources	
	Ferrous metals	
	Manganese	
	Deposits	
III-1-91	Pivdennoingouletske	56
III-3-93	Fedorivske	45
	Occurrences	
II-1-74	Lativskiy	56
II-1-76	Novoselivskiy	56
II-1-78	Zelenkivskiy	56
II-1-81	Ingouletskiy	56
III-2-92	Vysokopilskiy	46
III-4-94	Kostromskiy	46
IV-4-100	Novovorontskivskiy	46
	Non-metallic mineral resources	
	Raw materials for metallurgy	
	Foundry sands	
	Deposits	
I-1-68	Pavlivske	40, 42
	Construction raw materials	
	Construction sands	
	Deposits	
I-2-69	Anastasivske	20
I-2-70	Ionivske	42
II-2-82	Shyrokivske	42, 56
IV-2-98	Bratske	61

Square index and object number in the map	**Mineral type, object name**	**Reference**
	Construction limestones	
	Deposits	
II-1-72	Zelene	42, 62
II-1-73	Lativske	42, 56
II-1-75	Zelena Balka	42, 56
II-3-83	Mykhaylivske	56
II-4-85	Zhovtokamyanske-2	56, 20
II-4-86	Zhovtokamyanske-3	50
II-4-87	Zhovtokamyanske-4	50
III-1-89	Mykolokozelske	56
III-1-90	Mykolaivske	56
III-4-96	Maryanske	46, 50
IV-1-97	Bilokrynytske	62
IV-2-99	Arkhangelske	62
IV-4-101	Osokorivske: site-1	46
IV-4-101	Osokorivske: site-2	46
	Cement raw materials	
	Limestones	
	Deposits	
II-4-88	Zhovtokamyanske-1	20, 42
III-4-95	Maryanske	20, 42
	Clays	
II-4-88	Zhovtokamyanske-1 (site 3)	20, 42
III-4-95	Maryanske	20, 42

Annex 2. List of deposits and occurrences indicated in the geological map and map of mineral resources in Quaternary units

Square index and object number in the map	Mineral type, object name	Reference
Map sheet M-36-XXXIV (Zhovti Vody)		
Metallic mineral resources		
Non-ferrous metals		
Occurrences		
Titanium		
II-1-108	Chechelievka Village	7, 42
II-4-113	Balka Khalvina	7, 42
III-2-115	Sokolivka Village	7, 42
IV-2-118	Nedayvoda Village	7, 42
IV-3-126	Balka Skotovata	45, 49
Non-metallic mineral resources		
Construction raw materials		
Deposits		
Construction sands		
I-1-103	Zvenigorodske	7, 42
I-1-104	Oleksandro-Stepanivske	7, 42
I-1-105	Novostarodubske	7, 42
IV-2-124	Maryanivske	20
Loams		
I-1-102	Oleksandriyske	7, 42
I-2-106	Dobronadiivske	7, 42
I-4-107	Lykhivske	20
II-2-109	Artemivske	48
II-2-110	Petrivske	7, 42
II-3-111	Pyatykhatske	20
II-3-112	Osynivske	20
III-3-114	Petrivske-2	48
III-3-116	Gannivske	48
IV-2-117	Nedayvodske-1	48
IV-2-119	Nedayvodske-2	48
IV-2-120	Oleksiivske	48
II-2-121	Lozuvatske-2	20
IV-2-122	Lozuvatske-1	20
IV-2-123	Chervonogvardiyske	20
IV-2-125	Maryanivske	42
IV-3-127	Veseloternivske	48
IV-4-129	Sofiivske	20
Map sheet L-36-IV		
Non-ferrous metals		
Occurrences		
Titanium		
I-1-130	Khrystoforivka Village	2

Square index and object number in the map	**Mineral type, object name**	**Reference**
Non-metallic mineral resources		
Construction raw materials		
Deposits		
Construction sands		
II-1-132	Maryanivske	2, 20
II-2-140	Shyrokivske	20
IV-2-145	Arkhangelske	42
Loams		
I-1-131	Chapaevske	48
I-2-133	Ingouletske	20
I-2-134	Balka Glyboka	48
I-2-135	Karnavatske	20
I-2-136	Karachunivske	48
I-2-137	Valyavko	48
I-2-138	Pytomnyk	48
I-3-139	Dovgyntsivske	48
II-2-141	Shyrokivske	20
III-3-142	Apostolivske-1	20
III-3-143	Apostolivske-2	20
III-4-144	Maryanske	20

Annex 3. List of deposits and occurrences indicated in the geological map and map of mineral resources in crystalline basement

Square index and object number in the map	Mineral type, object name	Reference
Map sheet M-36-XXXIV (Zhovti Vody)		
Metallic mineral resources		
Ferrous metals		
Iron		
Deposits		
I-3-155	Popelnastivske	43, 45
I-3-156	Zhovtyanske	36, 43, 45
I-3-157	Zhovtyanske (western)	36, 43, 45
II-2-167	Leninske	45
II-2-170	Zakhidnozelenorichenske	36, 45
II-2-173	Artemivske (quarry # 4)	45
II-3-177	Zhovtyanske (eastern)	45
II-3-181	Kulynivske and Netesivska site	45
II-4-188	Alferivske	45
III-2-195	Petrivske (quarry # 3)	45
III-2-199	Skhidnogannivske	19, 45
III-3-203	Pivnichnogannivske	19, 45
III-3-207	Gannivske	19, 45
IV-2-217	Low-ore quartzites	19, 45
IV-2-219	Site # 4	19, 45
IV-2-220	Gleyuvatske extension (ore bodies 7, 8)	45
IV-2-221	Former RU R.Luksemburg (Gvardiyska Shaft)	45
IV-2-222	Site # 5	45
IV-2-223	Yuvileyna Shaft, OJS „Sukha Balka“	45
IV-2-227	Im. Frunze Shaft, OJS „Sukha Balka“	45
IV-3-231	Pershotravneve, OJS „Northern MBP“	45
IV-3-233	Site # 3	45
IV-3-235	Im. Ordzhonikidze and Im. Lenina shaft fields	45
Iron-uranium		
II-3-179	Zhovtorichenske	45
IV-3-229	Pershotravneva-Drenazhna Shaft	45
Occurrences		
I-2-170	Pivnichnozelenivskiy	45
IV-2-215	Novomykhaylivskiy	45
IV-2-216	Far western bands	45
IV-2-225	Chkalivskiy	45
Non-ferrous metals		
Occurrences		
Titanium		
I-4-159	Lykhivskiy (southern)	54
Copper		
II-4-187	Alferivskiy	33
Lead		
II-4-185	Baykivskiy	33

Square index and object number in the map	Mineral type, object name	Reference
	Molybdenum	
II-1-162	Fedorivskiy	51
II-1-165	Vodyanskiy	51
III-1-189	Kodatskiy	41
IV-1-211	Zakhidnogurivskiy	41
	Molybdenum-tungsten	
III-3-205	Gannivskiy	45, 57
	Arsenic	
II-4-184	Baykivskiy	33
	Rare metals, trace and rare-earth elements	
	Occurrences	
	Tungsten	
I-1-146	Golovkivskiy (DH 19566)	51
I-1-147	Balakhivskiy (DH 19911)	51
II-3-175	Zhovtyanskiy	36, 42
IV-2-213	Zoryaniy (DH 19926)	42
	Rubidium	
III-1-194	Chervonokostyantynivskiy (DH 17158)	41
IV-1-210	Novolozuvatskiy (DH 17132)	41
	Zirconium	
II-1-163	Balakhivskiy	51
III-3-204	Gannivskiy	45
	Rare earths	
I-1-149	Novostarodubskiy	51
III-1-190	Kodatskiy	41
IV-1-209	Novolozuvatskiy	41
	Scandium	
I-4-160	Dmytrivskiy	54
II-3-180	Zhovtorichenskiy	45
	Precious metals	
	Occurrences	
	Gold	
II-3-176	Zhovtyanskiy	36, 42
III-2-197	Petrivskiy	57, 42
III-2-198	Grafitivskiy	57, 42
III-3-201	Novochygyrynivskiy	57
IV-2-218	Leninskiy	57
	Silver	
I-1-148	Starodubskiy	51
	Non-metallic mineral resources	
	Ore-chemical and agrochemical raw materials	
	Occurrences	
	Apatite	
III-3-206	Gannivskiy	57
	Raw materials for metallurgy	
	Flux dolomites	
	Deposits	
IV-2-226	Velyka Gleyuvatka	45
	Technological raw materials	
	Graphite	
	Deposits	
II-1-161	Balakhivske	35, 42
III-1-191	Kodatske	35, 41

Square index and object number in the map	Mineral type, object name	Reference
III-1-192	Varvarivske	35, 45
III-1-193	Petrivske	41, 45
	Occurrences	
I-2-153	Ovnyankivske	57
II-2-172	Zelenivskiy	57
II-3-178	Zhovtyanskiy	57
	Asbestos	
	Occurrences	
IV-2-224	Gleyuvatskiy	57
	Construction raw materials	
	Granites, migmatites	
	Deposits	
I-2-150	Fedorivske	29
I-4-158	Kholodievske	54
II-4-182	Lozuvatske	33, 42
II-4-183	Baykivske	33, 42
III-3-202	Savrivske	20
III-3-208	Devladivske	20
IV-2-214	Nedayvodivske	20
IV-3-236	Kolomoytsivske	20
IV-2-228	Zhovtneve	20
	Weathering crust	
	Metallic mineral resources	
	Ferrous metals	
	Iron	
	Occurrences	
I-2-154	Leninskiy	45
II-2-168	Pivnichnozelenivskiy	45
II-2-169	Zelenivskiy	45
II-2-171	Skhidnozelenivskiy	45
	Non-ferrous metals	
	Occurrences	
	Aluminum	
II-2-174	Bayrakivskiy	57
IV-3-232	Veseloternivskiy	57
IV-3-242	Devladivskiy	57
	Titanium	
II-1-164	Spasivskiy	57
II-1-166	Vodyanskiy	57
IV-4-240	Krasnoorlikivskiy	57
	Nickel-cobalt	
	Deposits	
IV-3-234	Ternivske	57
IV-4-241	Chervoniy Yar	57
IV-4-243	Devladivske	57
	Occurrences	
IV-3-230	Kamyane Pole	57
IV-3-237	Balka Pryvorotna	57
IV-3-238	Vodyanskiy	57
IV-3-239	Vesele Pole	57

Square index and object number in the map	Mineral type, object name	Reference
	Rare metals, trace and rare-earth elements	
	Zirconium	
	Occurrences	
II-4-186	Baykivskiy	33
	Non-metallic mineral resources	
	Non-metal ore (technological) raw materials	
	Primary kaoline	
	Deposits	
I-2-151	Oleksandriyske	57
III-2-196	Petrivske	57, 61
IV-2-212	Nedayvodivske	42
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	Metallic mineral resources	
	Ferrous metals	
	Deposits	
I-2-247	Velyka Gleyuvatka, quarry # 1	45
I-2-249	Former RU Im. Kominternu (together with site # 7)	45
I-2-250	Former RU Im. K.Libknekhta (Batkivshchyna Shafy)	45
I-2-253	Former RU Im. Kirova	45
I-2-252	Pivnichniy Tarapak	45
I-2-259	Gigant-Glyboka and Saksagan shaft fields	45
I-2-260	Misto	45
I-2-261	Pivdenniy Tarapak	45
I-2-264	Pivdenna Shaft	45
I-2-265	GPU shaft field together with site northward	45
I-2-266	Gdantsivka	45
I-2-267	Antonivka	45
I-2-268	Valyavko-Pivnichna shaft field	45
I-2-269	Ingouletska Antycline	45
I-2-270	Lykhmanivska Syncline (Osychky, Vesela Dacha sites)	45
I-2-273	Valyavkinske (together with quarry # 3 and Skhidnovalyavkinske	45
I-2-274	Novokryvorizke (NK MBP)	45
I-2-275	Skelyuvatske Skhidne	45
I-2-277	Zakhidne	45
II-1-280	Ingoulets	45
II-1-283	Ingouletske, In MBP (together with sites 12 and 12p)	45
II-2-284	Shymanivske	45
II-2-285	Skelyuvatske Magnetytove (Southern MBP)	45
II-2-288	Lykhmanivske extension (Zelenivska site, Nova shaft field)	45
	Occurrences	
I-2-251	Chervoniy Shakhtar	45
IV-1-309	Novopavlivskiy	45
	Non-ferrous metals	
	Occurrences	
	Nickel-copper	
II-3-293	Oleksandrivskiy	46
II-3-298	Volodymyrivskiy	46

Square index and object number in the map	**Mineral type, object name**	**Reference**
	Copper	
I-2-255	Chervoniy Shakhtar	52, 57
II-3-295	Soldatskiy-1	46
II-3-296	Soldatskiy-2	46
	Lead-zinc	
I-1-244	Rodionivskiy	45
	Lead-zinc-copper	
II-2-287	Rudnychniy-1	45
	Zinc	
II-2-286	Rudnychniy-2	45
	Molybdenum	
II-2-290	Oleksandrivskiy	45
II-4-300	Tokivskiy	45, 46
	Rare metals, rare earth and trace elements	
	Occurrences	
	Zirconium, rare earths	
II-1-279	Novovolodymyrivskiy	45
	Rare earths	
III-4-308	Maryanskiy	45, 46
	Precious metals	
	Gold	
	Occurrences	
I-2-254	Artem-2 Shaft	57
II-1-281	Ingouletskiy	57
	Radioactive metals	
	Uranium	
	Deposits	
III-1-302	Mykolokozelske	56
	Non-metallic mineral resources	
	Ore-chemical and agrochemical raw materials	
	Apatite	
	Occurrences	
III-4-307	Tokivskiy	46
	Non-metal ore (technological) raw materials	
	Graphite	
	Occurrences	
I-2-263	Gdantsivskiy	45
	Talc	
	Deposits	
I-2-271	Osychky	45
III-1-301	Ingouletske	45
	Asbestos	
I-2-257	Tarapakivske	57
	Mineral pigments	
	Deposits	
I-2-258	Gigant-Glyboka Shaft	19

Square index and object number in the map	Mineral type, object name	Reference
	Construction raw materials	
	Granites and migmatites	
	Deposits	
I-2-248	Maryanivske	20
I-2-262	Karachunivske	20
II-4-299	Tokivske	46
	Mineral waters	
	Deposits	
I-2-256	Vesela Dacha	19, 42
I-2-276	Radon waters of Southern MBP	19, 42
III-1-303	Ingouletske	42
	Weathering crust	
	Metallic mineral resources	
	Non-ferrous metals	
	Aluminum	
	Deposits	
III-2-305	Vysokopilske	42, 46
	Occurrences	
I-2-278	Zelenogorodskiy	57
II-2-289	Grushevatskiy	57
II-2-291	Nyzivskiy	57
II-2-292	Trudolyubivskiy	57
II-2-294	Soldatskiy	46
IV-2-310	Ivanivskiy	57
IV-2-311	Mykolaivskiy	57
	Nickel-cobalt	
	Occurrences	
II-3-297	Soldatskiy	46, 50
III-2-304	Vysokopilskiy	57
III-3-306	Apostolivskiy	46, 50
	Precious metals	
	Gold	
	Occurrences	
II-1-282	Ingouletskiy	45
	Non-metallic mineral resources	
	Non-metal ore (technological) raw materials	
	Primary kaoline	
Deposits		
I-1-245	Khrystophorivske	2, 57
I-1-246	Sofie-Geykivske	2, 57

STATE GEOLOGICAL MAP OF UKRAINE

Scale 1:200 000

Central-Ukrainian Series
Map sheets M-36-XXXIV (Zhovti Vody), L-36-IV (Kryvyj Rig)

EXPLANATORY NOTES

Authors:

V.V.Zakharov, A.V.Martynyuk, Yu.M.Tokar

Editors:
M.S.Kurlov, B.D.Vozgrin

Expert of Scientific-Editorial Council:
B.Z.Berzenin

Published according to the decision of Scientific-Editorial Council
of the Department of Geology and Subsurface Use of the Ministry of Ecology and Natural Resources of Ukraine
on November 29, 2000 (Protocol No. 108)

Chief of Publishing Center	S.O.Nekrasova
Editor	G.G.Golubeva
Technical Editor	K.N.Koliychuk
Computer arrangement	S.I.Vyshnytska, A.V.Volkogon

English translation and computer arrangement B.I.Malyuk (2009)

Published by UkrSGRI.
Registration Certificate Series DK No. 182 of 18.09.2000

Address: UkrSGRI Publishing Centre, 04114, Kyiv-114, Autozavodska Str., 78A
Tel.: 206-35-18; tel./fax: 430-41-76